Institution: King's College London
Unit of Assessment: 24
1. Unit context and structure, research and impact strategy

Unit Context and Structure

The Centre for Human and Applied (formerly "Aerospace") Physiological Sciences (CHAPS) at King's College London (KCL) was formed in 2010. It is a research department within the School of Basic and Medical Biosciences (BMBS), one of 7 schools making up the Faculty of Life Sciences & Medicine (FoLSM). The research undertaken is complementary to, and collaborative with, the other departments within BMBS. CHAPS is based on the Guy's Campus, and has research groups at the Waterloo, King's College Hospital (KCH) and St Thomas' Hospital campuses. Thus, it is well positioned to pursue interdisciplinary and translational research within the framework of King's Health Partners (KHP); one of eight UK accredited Academic Health Sciences Centres which links KCL to the local NHS Foundation Trusts.

The overarching strategic research theme of CHAPS has been to increase insight and understanding into the *Functioning and Adaptation of the Human Body in Health and Disease.* This mission is specific to the contexts of exercise and diet, performance in sport, ageing and age-related diseases, the clinical respiratory environment, and understanding the unique challenges faced by the human body in the aerospace environment. Our ongoing mechanistic investigations of the tissues central to human physical performance, coupled with our strengths in integrative physiology, resulted in CHAPS being returned to the Sport, Exercise, Leisure & Tourism UoA Panel C in 2014 and 2021.

Research Strategy

Our research strategy aligns closely with King's Strategic Vision 2029 and the 4 underpinnings of the university's research strategy outlined in KCL REF5a. Our environment also aligns strongly with KCL's commitment to Equality, Diversity and Inclusion (EDI), which is embedded in all that we do.

Over the past 7 years our centre has grown substantially. With both replacements for retirees and with university investment we have 8 new members of academic staff (3 female/5 male). We have seen a rise in the number and value of research grants awarded (particularly from UKRI sources), expanded and enhanced our laboratory facilities and also developed new national and international research collaborations and partnerships.

In 2014 our research strategy was underpinned by three overlapping research groupings: *Muscle Form & Function, Aerospace Medicine & Physiology, and Movement, Function & Behaviour*. Each of these has evolved, grown and been added to with the formation of our *Respiratory Physiology & Medicine Group* (Figure 1). These new research groupings emerged through the restructuring of FoLSM in 2017/8, targeted academic appointments and affiliation (through formal honorary contracts) of consultant respiratory physicians, intensivists and anaesthetists within KHP with aligned research interests.

The strengths of our research environment and strategy are closely aligned with our research-informed teaching to inspire and develop the next generation of scientists, supporting our future team and the wider research base. To share our passion and expertise in exercise-related research, a new undergraduate programme, the **BSc in Sport & Exercise Medical Sciences** was launched in 2018 and adds to our portfolio of specialist post-graduate programmes in **Human & Applied Physiology (MSc), Space Physiology & Health (MSc until 2020)** and **Aerospace Medicine (PGDip and MSc).**

In 2014 we stated that our unique portfolio of expertise in the physiological sciences placed us at the nexus of mechanistic, applied and translational research in human physiology. We thus planned to focus on providing further insight, understanding and impact with a combination of mechanistic investigations into the biology of the key tissues central to exercise and health (e.g. skeletal and cardiac muscle) and

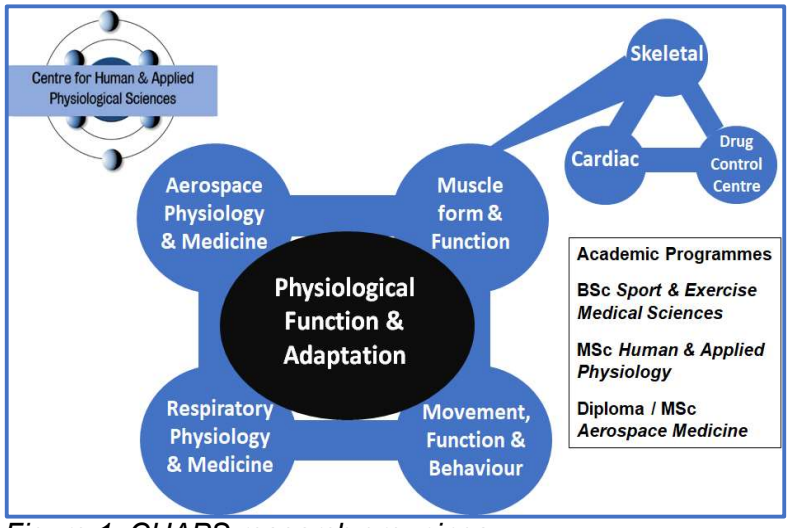

Figure 1. CHAPS research groupings

integrative physiological studies. The success of our diverse and thriving research environment is evidenced by the total number of publications (>370) and citations (>6000, Scopus) and by the fact that we have published in the world's leading journals across basic, physiological and clinical sciences e.g. Nature, New England Journal of Medicine, Nature Communications, PNAS, Circulation, Journal of Physiology, Lancet Respiratory Medicine, European Heart Journal. With EDI embedded in our strategy, our research has been undertaken with a clear aim, wherever possible, of including equal numbers of males and female participants while encouraging the participation of a wide diversity of individuals. Our research partnership with St John's Research Institute in Bangalore involving exercise, metabolism and muscle function in patients with type 2 diabetes in the Indian population, demonstrates our commitment to tackling both global health questions and the challenges faced by specific ethnic groups.

Below briefly summarises the strategy and achievements of our four research themes that demonstrate how our research environment has enabled both outstanding research and impact.

1) MUSCLE, FORM & FUNCTION comprises three interlinking sub-groups with exercise, ageing and health as cross-cutting themes. **(a) Skeletal Muscle; exercise and ageing**. This group has utilised primary cell culture, animal models, as well as healthy (young and old) humans and patient populations, extending to critical medicine and muscle diseases. We have used combinations of state-of-the-art techniques ranging from single-cell RNAseq and molecular biophysics through to whole-body magnetic resonance imaging, which have produced novel scientific insights into muscle function, adaptation, repair and understanding muscle disease. **(b) Cardiac muscle.** This group has generated new knowledge in fundamental cardiac physiology and cell biology regarding mechanisms of adaptation, disease, regeneration and repair. This work has involved the application of fundamental physiological, cellular and molecular techniques and has advanced our understanding of the myocardial responses to ischaemia, reperfusion, ageing, exercise, damage and hypertrophy. **(c) Drug Control Centre (DCC).** This research has continued to explore cutting edge approaches for the detection of performance enhancing agents in athletes. These include: i) the novel use of supercritical fluid chromatography-mass spectrometry, ii) strategies for cost reduction in anti-doping such as dried blood analysis and iii) continuing the world-leading work on detecting human growth hormone misuse (**Impact Case 1**).

2) RESPIRATORY PHYSIOLOGY & MEDICINE is now our fastest growing group, enhanced by the close collaboration with our clinical partners within KHP. Research has focused on broad aspects of human respiratory physiology from developing new tools to understand mechanisms of oxygen sensing, through to physiological studies of gas exchange in health, and disease as well as extreme environments. We have increased our understanding of respiratory control in exercise and breathlessness in both health and disease and from infancy to old age.

3) AEROSPACE PHYSIOLOGY & MEDICINE interacts closely with the work of the other three groups and includes collaborations with the Royal Air Force Centre of Aviation Medicine (RAF CAM), the European Space Agency (ESA) and industry (QinetiQ) as well as with unique expeditions in extreme environments e.g. Xtreme Everest and White Mars. Our research has resulted in several important discoveries relating to human performance in the aerospace environment particularly relating to hypoxia and acceleration (+Gz). With RAF CAM we have evaluated the incidence of G-induced loss of consciousness (G-LOC) in fast-jet aircrew and designed and evaluated a new aircrew conditioning programme targeted at improving G tolerance and reducing the risk of neck injury **(Impact Case 2).**

4) MOVEMENT, FUNCTION AND BEHAVIOUR focuses on a bidirectional Body and Mind approach to investigating and understanding the relationship between physiological function and human behaviour. Research themes are organised around the global public health issues of long-term conditions, multimorbidity and frailty, including Parkinson's disease and vestibular conditions. We have facilitated interdisciplinary collaborations and applied innovative research methods to identify physiological / biomechanical mechanisms and processes underlying functional, behavioural and emotional responses. Our research has aimed to identify effective, evidence-based assessment methods to predict clinical outcome and management strategies.

Research Integrity

KCL provides clear guidance on best practice led by a dedicated Research Integrity Team working to RCUK Policy and Guidelines on Governance of Good Research Conduct. A range of activities including university-wide training for all researchers is provided. At a departmental level, research integrity is part of our standard working practice. All participant/patient research is rigorously assessed ethically through the local KCL Research Ethics Committee (REC), the NHS Integrated Research Application System (IRAS) or with the Ministry of Defence Research Ethics Committee. One of our staff sits on the KCL REC, whilst another sits on the ESA Medical Board which considers the medical risk of all research proposals involving ESA astronauts. Our animal studies are undertaken under stringent UK Home Office Licences and one of our staff is a member of KCL's three Animal Welfare and Ethical Review Bodies (AWERBs), Chairperson of the London AWERB hub and a member of the national Hub Chairs' network, set up by the government's advisory Animals in Science committee to spread good practice between establishments. In addition, we have our own local Person Designate, responsible for all work that comes under the auspices of the Human Tissue Act. In all of this we offer bespoke support to staff beginning their research careers.

The Future

Our strategy for the next 7 years is to capitalise on the strengths of our research environment, to build on our multi-disciplinary approaches and continue to generate new knowledge and further insight, whilst enabling outstanding impact across our 4 research domains. We will further develop international partnerships, including in lower- and middle-income countries. Our success in delivering on this vision will be facilitated by the prospering research environment that we work hard to cultivate and evidenced by sustained and collaborative grant funding, publication of outputs in the leading journals and real-world impact. The world faces the challenges of an ageing population and one where lifestyle/inactivity related diseases remain prevalent. "Exercise is medicine", is being increasingly recognised as a means of health maintenance, disease prevention and as a treatment modality. This concept is a fundamental driver of our research strategy. Our combined expertise and thriving research environment put us in a prime position to progress investigations into the mechanisms which determine the functioning, adaptation and repair of the skeletal muscle, cardiac muscle, and respiratory systems. We will move these fields forward by exploiting new and innovative technologies. These range from single-cell RNAseq and ATACseq, metabolomics, new imaging technologies which can combine with whole body-integrative physiology, through to the use of machine learning and virtual reality technologies for understanding movement disorders. We will build on our military and industrial collaborations including research on the new state-of-the-art human centrifuge at RAF Cranwell, which opened in 2018. Our growing aerospace medicine group will be at the forefront of physiological and medical research as the country generates its next generation of fast-jet aircraft. The prospect of space tourism is becoming ever more realistic, and a clear understanding of the physiological and medical factors associated with suborbital flight in people who previously would not have made "astronaut grade" (space tourists) is essential. We will target research in these areas and develop further collaborations with key stakeholders and relevant commercial organisations.

Research Impact Strategy

Our research is both multi- and inter-disciplinary. We work with a variety of partners; internally, nationally and internationally and our research has had notable impact over the past 7 years. We actively support our group in a number of diverse organisational roles outside of KCL that extends our influence and enables impact well beyond the institution. Beneficiaries have included health

service providers and users, policy makers, industry, the military, the aerospace and sporting communities. Our research will continue to have a wide impact on individuals whether they be members of the public (particularly older people), patients, elite athletes and those striving to push forward the frontiers of human endeavour. We have four main pathways to impact which are outlined below.

i) Impact on drug testing and athlete health (DCC): We continue to have a major global impact in the field of anti-doping science and have played a significant role in maintaining the integrity of competitive sports. The rise in tests performed by the DCC (from 8,800 in 2015 to 12,587 in 2018) has resulted in more athletes taking prohibited substances being caught thus increasing the confidence of both clean athletes and the public in the fairness of sporting competition. In addition, the DCC has delivered the anti-doping analysis for major sporting events e.g. Rugby and Cricket World Cups, and its scientists have worked as international experts at major games around the globe e.g. The 2019 World Swimming Championships (Moscow), 2016 Olympics (Rio de Janeiro), 2018 Winter Olympics (PyeongChang), 2018 Asian Games (Doha). Due to its standing the DCC was chosen to manage and deliver the forensic evidence underpinning the WADA Independent Commission/Report into state-endorsed doping in Russian sport **(Impact Case 1)**.

ii) Impact in the aerospace medicine and science communities: Aviation and space environments are highly challenging, putting unique stressors on the human body. Aerospace Medicine is an evolving field with rapidly advancing technologies linked to enhanced performance capabilities of new fast-jet aircraft and ambitions to take astronauts further into space, along with the advent of space tourism. Therefore, the importance of understanding the physiological and medical challenges to the body in space has never been greater. Ongoing studies with RAF CAM and QinetiQ are evaluating the physiological challenges provided by the increased manoeuvrability of the UK's Typhoon, F35B Lightning and future Tempest aircraft. Our collaborative research into the development of an aircrew conditioning programme has led to an important change in RAF policy, with the programme now being mandated for all new aircrew entering the training pathway and has had impact worldwide (**Impact Case Study 2**). Our research-informed Diploma and MSc in Aerospace Medicine is responsible for training specialist clinicians in aerospace medicine who work for military (UK and international) and civilian organisations or privately. This includes training those taking clinical responsibility for aircrew aboard the Royal Navy's new aircraft carriers. Our Professor of Aerospace Medicine (to 2019), David Gradwell, edited the leading textbook in the field (*Ernsting's Aviation Space Medicine*, 5th Edition) and took the lead in establishing "Aviation and Space Medicine" as a new clinical specialty in the UK. This was added to the General and Specialist Medical Practice Order in April 2016 and the curriculum subsequently approved by the GMC in 2016. Our recently appointed Clinical Senior Lecturer (Dr Hodkinson) is the first Consultant in this specialty to be added to the GMC specialist register. We have pioneered the first clinics in Aerospace Medicine within the NHS at St Thomas' Hospital. We are working closely with the UK Civil Aviation Authority (CAA) to research the impact of members of the public taking commercial suborbital spaceflights (e.g. Virgin Galactica), to inform the development of CAA policy and regulations governing these flights.

iii) Impact on clinical practice: We work closely with clinicians, patients and members of the general public across different sectors. Numerous research projects have been collaborative ventures between our academics and clinical partners as co-applicants on grants and co-authors on publications. Our interdisciplinary translational research programmes apply expertise in physiological measurement to the major public health challenges posed by long-term health conditions, multimorbidity and frailty. We have pioneered the use of respiratory muscle electromyography as an index of neural respiratory drive, respiratory disease severity and exertional breathlessness, establishing reference benchmarks for use in clinical and research studies cited in European Respiratory Society guidelines. Our respiratory muscle laboratory at KCH receives tertiary NHS referrals for diagnostic tests from across the UK.

Work in collaboration with critical care explores the clinical effectiveness of novel modes of respiratory support including Neurally Adjusted Ventilatory Assist and transcutaneous electrical stimulation of upper airway dilator muscles in obstructive sleep apnoea and has informed development of novel biomarkers of clinical deterioration and readmission risk (Myotrace technology, Philips Respironics). Our NIHR-funded research demonstrated the benefits of early

integration of respiratory medicine and palliative care to refractory breathlessness in advanced disease, informing the Global Initiative for Chronic Obstructive Lung Disease (GOLD) Report and the American Society of Clinical Oncology Clinical Practice Guideline (2017 update). Insights gained through a unique programme of work exploring the physiology of heroin overdose inform UK guidelines on clinical management of drug misuse and dependence, the National Expert Working Group to investigate drug-related deaths in England, and Dame Carol Black's Independent Review of Drugs (2020).

Research from the Movement, Function and Behaviour group has developed a validated screening tool for vestibular disorders in children and a separate tool for identifying visual-induced dizziness symptoms. These are being used in paediatric clinics in the UK and USA and have been recommended in several publications for use as part of the screening protocol for childhood vestibular disorders and have been translated for use in multiple countries. Guidelines for dual-task exercises in older adults have also been developed and are being adopted by AGILE (the Professional Network of the Chartered Society of Physiotherapy).

Impact on the Covid-19 pandemic: KCL/KHP was at the epicentre of the UK COVID-19 pandemic. Our departmental respiratory physiology research laboratories were redeployed to KCH for clinical use. In response to the pandemic CHAPS staff have made important clinical (being redeployed fulltime to the NHS) and research contributions with direct patient impact. i) Dr Jolley and colleagues developed, designed and delivered a holistic post-COVID respiratory clinic at KCH, embedding routine assessment of symptoms and physiology of every patient seen. These findings are now embedded in routine clinical care and referenced in the NICE COVID-19 rapid guideline "Managing the long-term effects of COVID-19". Dr Jolley is also a local Co-I of the UKRI-funded PHOSP-COVID post-hospitalisation study. ii) Dr Smith and colleagues at GSTT developed mobile emergency rapid intubation teams (MERIT) and became the first UK centre to develop combined MERIT/surgeon tracheostomy teams and publish COVID-19 tracheostomy guidelines. iii) Dr Formenti co-led an interdisciplinary team of engineers and clinicians from KCL and Oxford University which pioneered the development of new low-cost ventilators (OxVent). iv) Prof. Ellison-Hughes and colleagues in China were the first to show intravenously transplanted mesenchymal stem cells into COVID-19-pneumonia patients to be safe and effective, decreasing hospitalisation and recovery time. v) Prof. Harridge was an expert panel member/co-author for the Physiological Society's report "A National Covid-19 Resilience Programme: Improving the health and wellbeing of older people during the pandemic".

iv) Public involvement, engagement and outreach: We are passionate about sharing our research findings and use our work in a variety of approaches to increase public understanding of science and inspire the next generation about STEM fields; helping to build access, diversity and inclusivity in science. In addition to our research being heavily featured by major national and international broadcasters (BBC, Sky, CNN, CBS,) and newspapers (Washington Post, New York Times), our staff have contributed to television and radio programmes, made high profile web media contributions (e.g. "Can exercise reverse the ageing process?", BBC News) and given public lectures (TEDx). In collaboration with the International Space School Educational Trust (ISSET) and Pint of Science we have organised and hosted numerous public events aimed at promoting our science and aerospace medical science and featured former NASA astronauts. One particular highlight in 2015 was the organisation of a live link-up to the International Space Station (ISS) and a Q&A session with astronaut Scott Kelly where over 500 members of the public attended. For the past 9 years we have worked closely with ISSET in hosting "Mission Discovery" (MD) at KCL. This is a week-long international summer school for ~250 pupils who work in small teams to design a scientific experiment to be undertaken on the ISS. MD works in parallel with several scientific learning opportunities as well as with NASA confidence and team-building activities. All participants are mentored by current KCL postgraduate students providing development opportunity for our students, as well as attendees. Under the direction of Dr Keeble (CHAPS researcher and ISSET Chief Scientist), the best experiment from every programme is launched to the ISS with 11 experiments launched to date. A further 20 experiments have been prepared for launch from MD events held internationally e.g. Australia, India, USA, which have grown out of the success of the KCL model, demonstrating global impact. We have organised and hosted lectures to children in our partner schools, as well as supporting several Mission X activities targeted at schools and the general public. As part of our new BSc in Sport & Exercise Medical

Sciences, we hosted "Connecting Science and Performance: Fuelling for Athletes" (in 2019), our first annual public event, where coaches and athletes interact with our researchers and leading experts to discuss scientific findings that are pertinent to sports performance.

2. People

Staffing strategy and staff development

CHAPS (headed by Professor Stephen Harridge) comprise a tenured staff of 3 Professors, 3 Readers, 2 Clinical Senior lecturers, 5 Senior Lecturers and 3 Lecturers, eight of whom were appointed since 2014, a 15% increase in staff numbers since 2013. Staff come from a variety of backgrounds including physiology, sport and exercise science, medicine, physiotherapy, cell biology and bioengineering and two who are from the School of Cardiovascular Medicine and Sciences. In addition to the HEFCE funded staff returned here, our research has benefitted from the work of Visiting and Emeritus Professors and colleagues in collaborating institutions who hold visiting appointments from RAF CAM, QinetiQ, ESA and 10 clinical colleagues from within KHP who have honorary KCL contracts that enhance our impact and contribution to the wider research base. We currently have 7 externally funded Post-doctoral Research Associates (3 female/4 male,1 BAME) in CHAPS who are fully supported by the department throughout their time at KCL.

New academic staff are appointed based on their fit within our 4 research groupings and have a designated affiliation to an academic teaching department in a matrix management structure. New staff actively engage with our mentoring programme, being assigned an experienced senior colleague who advises and guides them on all aspects of academic development and career progression and through the 3-year probationary period. We introduced a career pathway framework to CHAPS, which clarifies career development and key transition points all the way from MSc student to Professor, and what milestones should be completed at each career stage. This allows an individual to identify where they fit within this framework and what is needed to progress to the next stage. This framework was introduced as a guide in the performance development review (PDR) process. This occurs annually for all staff and is designed to help steer individuals on their career path and, for academics, is conducted with the heads of the relevant research and teaching departments, ensuring a balance of workload regarding research and education. Through *Skills Forge* the University provides multiple support and training opportunities for investigators in a range of areas from post-graduate research (PGR) student supervision to developing leadership skills.

Post-graduate Research students

As with for our PDRAs, the development of the next generation of scientists from PhD level is a top priority and enabled by the inclusive and positive environment we foster. We average ~22 FTE PhD students registered at any one time, with a good gender and ethnic balance (Table 1). All PGR students have graduated within 4 years or part-time equivalent (unless an extension is granted following a formal review of mitigating circumstances).

	2014	2015	2016	2017	2018	2019	2020
Total	27.25	22.25	21.5	23.5	21	17.75	18.25
# Female	16.25	13.75	12	11	11.75	9.25	9
# BAME	6.5	4.25	4.25	4	4.5	8.25	8

Table 1. Postgraduate research students (FTE) enrolled on doctoral programmes per calendar year

Each student has a first (lead) and second supervisor and our post-graduate co-ordinator (PGC) has overall responsibility for student welfare in collaboration with the BMBS PGR officer. Students are monitored and supported through the Faculty's Thesis Progression Committee (TPC) system, whereby an independent chair and two independent experts meet with the student and supervisors every 6 months to review progress and offer guidance and support. This is in addition to individual meetings and an online system of quarterly progress reports, agreed by students, supervisors and the PGC. The upgrade from MPhil to PhD registration, normally occurs at 9 months FTE, involves a written report and formal approval by the TPC. A collaborative and supportive culture is promoted by having students and researchers located in designated shared offices within the department.

Supported by the department, students and PDRAs run their own journal club and interact closely with other journal clubs, laboratory meetings and peers from other departments within BMBS and beyond. Annually, all the students present their work to the Department as an oral presentation and

at the BMBS PhD symposium; 1st and 2nd year students present a poster and final year students deliver an oral presentation. All research staff and students are actively encouraged and supported, wherever possible, to attend and present at national and international meetings and conferences. At departmental level, training is further facilitated by interaction with our MSc students, whose projects offer the chance to work alongside and be partly supervised by PDRAs and PGR students, providing valuable experiences for all. Further training opportunities are provided with PGR students acting as demonstrators for BSc and MSc practical classes and giving tutorials.

Supporting the PGC at departmental level, and the BMBS PGR officer at school level, is the Centre for Doctoral Studies at University level. This has responsibility for the student experience across KCL and provides multiple layers of support ranging from careers advice, access to Royal Literary Fund Writing Fellows, e-learning support and one-to-one coaching. The Researcher Development Unit provides a programme of >300 free workshops annually. Training for new PhD supervisors is compulsory and is provided by half-day sessions that run several times each year. All experienced supervisors in CHAPS are required to refresh their knowledge and skills at least every 5 years via a refresher training session.

Promotion of Equality, Diversity and Inclusion (EDI)

Our commitment to EDI is embedded in our practice through FoLSM governance, operations and culture. In 2014 CHAPS secured its own Athena Swan Bronze Award and in 2018 we contributed to securing a Faculty Athena SWAN Silver Award. We are passionate about the role and importance of leadership in visibly championing our commitment to EDI principles and to ensuring EDI principles feed into all decision-making and operations. The Diversity & Inclusion (DDI) Team & Committee oversee implementation of the Faculty Inclusion Action Plan. Prof. Ellison-Hughes from CHAPS is the academic lead for DDI for BMBS, chairs the School DDI committee and is responsible for implementing the EDI action plan across the five centres within BMBS. Having one of our staff in this senior role further helps ensure that an inclusive environment is fostered.

Awareness of commitment to EDI is high across our Faculty. The 2017 King's Staff Survey showed 96% of FoLSM staff were aware of our commitment to EDI; 91% agreed we were committed to an inclusive environment; and 92% agreed we acted fairly, regardless of protected characteristics. Meanwhile, our BMBS Staff Survey in 2019 showed that 99% were aware of Athena SWAN and 76% aware of Race Equality Charter Mark. Since 2014, the proportion of staff who are aware and attend EDI training has increased annually. 81% are aware of Diversity Matters Training, and 62% had attended unconscious bias or Diversity Matters training. From 2020, it is mandatory for everyone in BMBS to undertake Diversity Matters training, which includes unconscious bias, bullying and harassment guidance, and this must be refreshed every 4 years. Our survey showed 76% agreed that there is a supportive culture within the School/Department. Central to our approach of mainstreaming an inclusive environment has been the improvement of key transition points for all employees e.g. reviewing induction content, probation and promotion processes, ensuring that career progression/promotion are more constructively discussed in the PDR process, and improving awareness and access to flexible working. Our survey shows an increased proportion of staff taking up informal flexible working (67%).

Career progression for academics

In the 2019 BMBS staff survey, 62% were aware of career development training, 64% said their line manager encouraged them to attend and 81% agreed that there are visible female role models of senior staff in the School/Department. Alongside removing structural barriers, our programme of activity includes initiatives aimed at promoting career progression for women, particularly within the academic community. These include mentoring, promotions workshops; opportunities to deputise on decision-making committees; funds to support return from career breaks and to cover childcare costs when attending conferences/training, leadership development programmes, and bespoke training. The accumulated impact from these initiatives is an increase in the proportion of women across the academic pipeline, with the most notable increase at the Reader level (from 37% in 2013-14 to 44% in 2016-17). Furthermore, we introduced thematic leadership positions e.g. Academic Lead for Research & Impact, across our Schools in 2017, as part of our strategy to diversify leadership. As a result, 52% of these positions are held by women and we will target support for these individuals to equip them for Faculty leadership positions. Since 2014 CHAPS staff have seen 1 promotion from

Reader to Professor (female), 3 promotions from Senior Lecturer to Reader (3 male) and 1 promotion from Lecturer to Senior Lecturer (female). For the appointment of new academic staff all shortlisting and interview panels comprise at least one member of staff from each gender.

Career progression for research staff

In our FoLSM Executive DDI Pledge, we committed explicitly to "taking collective responsibility and accountability for the development and inclusion of research staff", and both Vice-Deans for DDI and Research & Impact have specific responsibility for supporting research staff. BMBS has a research staff network and runs a successful PDRA mentoring scheme. CHAPS developed and implemented a bespoke post-doctoral career development model, which provides clear goals with objective-setting and training opportunities. The model was part of our original departmental Athena Swan Bronze award action plan and has demonstrated fruition as our post-docs have gone on to obtain university Lectureships (1 female/2 male, 1 BAME), Senior Scientist positions at the Francis Crick Institute (1 female), independent Fellowships (1 female) as well as forming their own companies in the biomedicine field (1 male, BAME). This model has been rolled out across BMBS, and together with the Centre for Research Staff Development has been included in the College-wide research staff PDR process. PDRAs are represented on School decision-making committees i.e. School DDI committee. Annually, the PDRAs together with the PhD students organise a career's day, involving talks and networking with a diverse range of scientific careers.

Culture

We are committed to embedding inclusivity across our broader working environment and have implemented a number of new initiatives, which include incorporating EDI as a standing item on the CHAPS, BMBS and FoLSM Executive Committees; aligning meeting times within core hours (10.00-16.00) and running regular staff consultations e.g., surveys and focus groups, to encourage feedback on all aspects of our culture and operations. As part of our zero-tolerance policy towards bullying and harassment, we run a Confidential Advisors Service for staff and PhD students experiencing bullying and harassment. FoLSM are in the process of implementing a Cultural Change Initiative, which has used qualitative evidence to improve confidence and capability in role modelling, best practice and inclusion and inform a coaching and training programme for Leadership. CHAPS has been the driving force behind the implementation of School Holiday Activity Camps, where children of KCL staff, aged between 5 and 12 years, can participate in a host of activities, including sports, science, arts and crafts. These camps are planned to be held on campus, be affordable and to run over the Easter and Summer holidays. These were to be introduced in 2020 but were postponed due to the Covid-19 pandemic.

3. Income, infrastructure and facilities

Research Income: The total value of the grants with CHAPS investigators as a Principal or Co-investigator totals ~£9m (Figure 2). We have received funding from a wide range of sources: Research Councils (EPSRC, BBSRC, MRC, NIHR, UK Space Agency), European (EU Horizon 2020) and International agencies (World Anti-Doping Agency, US Anti-Doping Agency/Partnership for Clean Competition). We have also received funding from Medical Research Charities including: Wellcome Trust, Nadace JetBrains Foundation, British Heart Foundation, Heart Research UK, Dunhill Medical Foundation and Guy's & St Thomas's Charitable Trust. Each year we have been awarded at least one of the competitive Each year we have been awarded at least one of the competitive PhD studentships funded by the MRC or BBSRC (LIDo) DTPs. We also regularly have a number of non-EU government funded PhD students. We have also received in-kind funding to support research projects namely RAF/MOD (~£250k), GSK (~£300k).

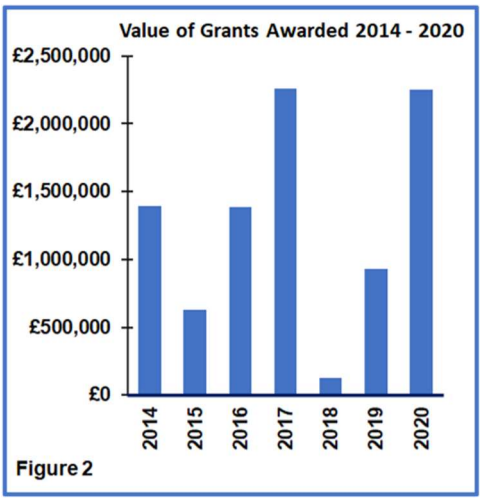

Figure 2

Infrastructure & Facilities: Our facilities on the Guy's campus provide excellent laboratories for human exercise and whole-body functional studies, as well as for cellular and molecular investigations as well as studies using animal models. Additional laboratories are located at King's College and St Thomas' Hospitals and on our Waterloo Campus.

Whole body human physiology and biomechanics: Our physiology and biomechanics laboratories have benefited from a £0.5m investment from the university, which along with research grant funding, has enabled investment in state-of-the-art cycle ergometers, metabolic carts, a DEXA scanner, as well as a new gait laboratory incorporating cutting-edge integrated force plate and opto-electronic camera systems. With EU funding we also have a new state-of-the-art augmented reality system (Holobalance). Our human physiology laboratories are equipped for a range of *in vivo* and *in vitro* studies: cardio-pulmonary exercise testing; motion analysis and motor control (3D motion analysis, force plates, accelerometers, EMG, double-probe ultrasound and eye-tracker) systems; cardiovascular function (Finometers, tilt tables, pulse oximetry, Near Infra-Red spectroscopy); neuromuscular function (isometric, isokinetic and inertial dynamometry); electrical, magnetic and direct current stimulation, various cognitive test batteries and ocular/visual function

Opening of our new exercise physiology and biomechanics facilities by Olympic Gold Medallist Dame Katherine Grainger in February 2019.

testing. We have a suite for human tissue sampling and our Centre is accredited by the Human Tissue Authority. Our environmental chamber allows for a range of temperatures and humidities, as well as a normobaric-hypoxic capability up to 17,000ft equivalents. At KCH we have a unique respiratory physiology research unit which is a comprehensive suite for respiratory assessments - including respiratory flow, volume and pressure. This is adjacent to the Chest Unit of the hospital providing a unique facility for physiological investigations in respiratory patient populations. For collaborative experimental work in aerospace physiology and medicine there is ready access to additional facilities with our partners including the short arm centrifuge at ESA, the new state-of-the-art long-arm centrifuge opened at RAF Cranwell in 2018, as well as hypobaric chambers at RAF Henlow and MOD Boscombe Down (QinetiQ).

Animal, cellular & molecular: Our laboratories house advanced analytical tools and equipment for research on the biology of cardiac and muscle tissue, stem cell biology and molecular physiology. These include new cell culture facilities, Thermo Scientific™ Shandon™ Cytospin®, nanodrop spectrophoto-meter, RNAscope *in situ* hybridization, fluorescence plate reader, immuno-magnetic bead cell sorting, qRT-PCR, Western Blotting, Chromatin immunoprecipitation (CHiP), bright field, fluorescence and confocal microscopy. We utilise analytical flow cytometers and cell sorters (BD FACS Aria II and CytomationMoFlo) and for small animal mechanistic studies have purpose-built procedure rooms with equipment for behavioural and conditioning studies. These include rodent exercise training systems; motorised treadmills coupled with metabolic analysis capabilities. There are two suites with surgical tables and dissecting microscopes, including induction of myocardial infarction and denervation for muscle damage-regeneration studies. These suites house high-resolution rodent ultrasound and Pressure Volume systems. Advanced experimental tools include retrograde perfusion/Langendorf systems for temperature and pressure-controlled retrograde perfusion of buffers and enzymes through the coronary tree of different animal models.

Mass Spectrometry and Proteomics: The DCC was key in establishing the Mass Spectrometry Facility (MSF) at King's which enables research and analysis, both qualitative and quantitative, of

small molecules and larger biomolecules. Instruments include liquid chromatography (LC) coupled tandem MS, LC coupled high resolution MS, LC coupled tandem high-resolution MS, gas chromatography coupled MS, Matrix Assisted Laser Desorption Ionisation - Time of Flight MS and Inductively Coupled Plasma MS. The small molecule applications include substance identification from complex matrices, profiling and metabolomics, metabolite identification and quantification. The proteomics platform provides services from the simplest protein identification to very complex large-scale biomarker discovery and verification studies in a wide range of biological matrices. The MSF is further underpinned by the facilities of the DCC, which has a wide array of gas chromatography and liquid chromatography coupled simple, high resolution and tandem mass spectrometers.

Laser microdissection (LMD: CHAPS PIs Ellison-Hughes and Ochala were part of a Wellcome Trust multi-user equipment grant awarded for a Zeiss PALM Laser Microdissection/Tweezers system. This state-of-the-art instrument enables high precision selection, manipulation and extraction of cells, sub-cellular structures and particles from tissue and cultures. The ability of LMD to select specific cells or sub-cellular structures is enhanced by using infrared laser-based optical trap and tweezers. These tools permit manipulation of skeletal muscle and cardiac cells or particles for extraction, in addition to moving cells, beads or particles in live tissues, without damage, for measuring tissue stiffness or flow. Extracted samples are processed for downstream quantification using genomics, transcriptomics, microarrays, next generation sequencing, biochips, or proteomics. This allows users to correlate precisely 'upstream' measurements such as imaging of cells or physiological readouts with molecular characterisation.

Other excellent KCL core research facilities utilised by CHAPS researchers include:

NIKON Microscopy Imaging Centre: This is one of only 8 worldwide centres and provides cutting edge microscopy and imaging equipment including: A1R Si Confocal, A1R Multiphoton, AZ100 Multizoom, Biostation IM-Q, Inverted Spinning Disk, N-SIM Super Resolution, N-STORM Super Resolution microscopes and two Eclipse Ti-E Live Cell Imaging Systems. ***Magnetic Resonance and PET Imaging:*** We have access to 1.5T and 3T GE Signa HDx Twin Speed MRI scanners. Within the Preclinical Imaging Unit there is an Agilent 7T horizontal MR scanner fully equipped to study various aspects of disease including anatomical, metabolic, functional and experimental models. The KCL Imaging Scanning facility also includes Bioscan Mediso nanoSPECT/CT and nanoPET/CT scanners as well as two prototype magnetic-field compatible single slice PET scanners (for both 9.4T and 3T MR systems), which enable simultaneous acquisition of PET scans and MRI images/spectra from either small animals or isolated perfused organs. ***NMR Facility:*** With support from the Wellcome Trust new 800MHz (18.8 T) and 600 MHz (14.1 T) spectrometers were added to the NMR Facility in 2017 for high-resolution and high-throughput applications. ***Genomic facilities:*** These comprise equipment and services to cover all aspects of genomics research, including transcriptomic and gene expression projects using microarray technology and SNP Genotyping, as well as NGS technology.

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

Research collaborations, networks and partnerships:

Local & Regional: CHAPS actively collaborates with local colleagues within other departments in BMBS (Randall Centre for Molecular Biophysics, Department of Medical & Molecular Genetics and the Centre for Stem Cell and Regenerative Medicine), with other schools within FoLSM (Cardiovascular Medicine & Sciences, Biomedical Engineering & Imaging Sciences, Immunology & Microbial Sciences) as well as other Faculties (Institute of Psychiatry, Psychology & Neuroscience). In 2016 Professor Harridge and Dr Siow (Cardiovascular Medicine & Sciences) formed a cross-faculty multidisciplinary consortium of investigators which brings together scholarship and research in ageing (Ageing Research at King's, ARK). With support from Unilever and King's Together funding, ARK was established to bring together scholarship, research activities and enhance academic and industry collaboration in ageing research. This research spans basic mechanisms of the biology of ageing, human and exercise physiology, through to clinical translation and the socio-economic impact of ageing. We have hosted numerous events to foster research networking and develop partnerships within King's, the Research Councils, research charities, other academic institutions and industrial partners and have held multiple

international keynote lectures that have been open to the public. ARK has 16 global academic partners and is a founding member of the UK All Party Parliamentary Group for Longevity, hosting the launch of their National Strategy for Healthier Longer Lives in February 2020 (Keynote address by Rt Hon Matt Hancock MP, Secretary of State for Health and Social Care). A further networking and strategic initiative has been the formation of a Respiratory Medicine and Science which brings together clinicians and basic scientists involved in respiratory research, hosting regular meetings to promote collaborative research. This has included activities relating to the recent merger of KHP with the Royal Brompton Hospital.

National: We have extensive and numerous collaborations with scientists within the fields of translational and basic mechanistic research, as well as exercise science, in the UK. These include Imperial College London, University College London, the Universities of Birmingham, Nottingham, Oxford and Cambridge. Our staff contribute to national esteemed bodies, particularly The Physiological Society, the Royal College of Physicians and the UK Space Life & Biomedical Sciences Association - we were a founding member of the latter. We have an ongoing partnership with the RAF Centre of Aviation Medicine, both in research and the delivery of academic programmes in aerospace medicine and research designed to tackle specific physiological/medical and operational requirements in the RAF. Military staff have undertaken PhDs within our Centre, as have staff from QinetiQ. With QinetiQ there is bilateral activity with many of our MSc and PhD students undertaking careers there. We have also had research activity in collaboration with industrial partners including GSK (BBSRC industrial partner award, GSK Human Performance Lab) and Smith & Nephew (ventilator manufacture). Our expertise is frequently called upon by the Physiological Society in numerous contributions to their scientific outreach and policy initiatives including Expert Group membership, and Scientific Advisors (e.g. “Growing Older, Better” policy document, “What is Sport and Exercise Science”? Animation, Covid-19 updates).

International: Our network of international research collaborations and partnerships is extensive. We have active joint research projects with scientists and institutions across the world. These include the Mayo Clinic; the Universities of California Davis, Pittsburgh and Pennsylvania, MIT (USA), McMaster University (Canada); University of Sydney (Australia); St John’s Medical College (India); University of Graz (Austria); Magna Graecia University, University of Campania Luigi Vanvitelli (Italy); Tokyo Women’s Medical University, Nagoya University (Japan); University Medical Center Utrecht (The Netherlands); Guangzhou Medical University (China); Uppsala University (Sweden). With ESA and the German Space Agency DLR (Cologne) we have had a number of collaborative projects with the Crew Medical Support Office in regard to novel exercise interventions for optimising astronaut health and safety. CHAPS staff are also members of the NASA GeneLab consortium and ESA’s Space-Omics Topical Team.

Our staff contribute substantially to the wider research base both nationally and internationally though editorships, invited high profile conference presentations, research committees, learned societies and organisation of prestigious scientific meetings and symposia as well as public outreach as summarised below.

Editorships

CHAPS staff have senior editing roles in journals pertinent to our wide-ranging research interests. Since 2012 Prof Harridge has served as the Editor-in-Chief of one of the leading journals in its field (Scandinavian Journal of Medicine and Science in Sports). Our staff serve and have served as senior/review or associate editors on many of the leading journals including: Journal of Physiology; Experimental Physiology; Extreme Physiology & Medicine; Frontiers in Physiology, BMC Molecular and Cell Biology, Frontiers Medical Technology, Scientific Reports; Stem Cells International.

Conferences

CHAPS researchers have international reputations in their field and are often invited, keynote/plenary speakers at national and international conferences, meetings and symposia. Notable lectures have included: European College of Sports Science, Malmö 2015 (Harridge); Biomedical Basic of Elite Performance II, Nottingham 2016 (Harridge). “John Lane Oration” at the Australasian Society of Aerospace Medicine, Australia 2019 (Smith); “Kevin Dolan Memorial Lecture”, Institute of Animal Technology's Annual Congress, UK 2017 (Keeble). “Sport science in the 100-year-old Finland” Finland 2017 (Harridge); “Doctors Updates”, *Val d'Isère* 2017 (Harridge);

Biology of Aging Symposium: Advances in therapeutic approaches to extend healthspan, USA 2017 (Ellison-Hughes); Dyspnea 2018, Montreal, Canada (Jolley); Barcelona FC Inaugural Sports Nutrition seminar series, on "Protein nutrition for recovery in professional football' 2018 (Witard); European Respiratory Society International Congress, Paris, 2018 (Jolley); Life at the Limits 2019, Physiological Society, Portsmouth 2019 (Clark); 2nd International Biomedical Health Annual Conference (UNESCO), China 2019 (Ellison-Hughes); International Sport and Exercise Nutrition Conference, Newcastle 2019 (Witard); Royal Society of Medicine, London 2020 (Witard); International Symposium on Geriatric Care, Taiwan 2019 (Harridge); 4th Guangzhou International Conference on Respiratory Disease, China 2019 (Jolley).

In addition, we are invited frequently to be session chairs and panel experts and have been on the organising committees for international meetings including the 63rd International Congress of Aviation and Space Medicine, Oxford: 2015 and "Muscles and movement: a memorial meeting to celebrate the life and work of Professor Roger Woledge", London 2016.

Contribution to grant awarding bodies, learned societies and policy

CHAPS researchers act as reviewers for all the major UK grant awarding bodies as well as internationally including the MRC, BBSRC, EPSRC, The Wellcome Trust, British Heart Foundation and the EU Framework 2020. Prof Shattock serves on the BHF Chairs and Programme Grants Committees.

Aside from being active members of learned societies involved in promoting and disseminating research findings, our staff have a number of key roles within different organisations. Professor Gradwell was President of the Aerospace Medical Association (ASMA, 2016-2018) and President-elect of the Scientific Committee of the International Academy of Aviation & Space Medicine (2019). Prof Ellison-Hughes is an Executive member of UNESCO's 'Anti-Aging and Disease Prevention' Committee (2019-). Dr Formenti has been Trustee & Director, Council member, of the Publications Committee and of the Education and Public Engagement and Policy committee of The Physiological Society (2016-2020) and member of the Board of the General Assembly of International Union of Physiological Sciences. Dr Pavlou was Vice-chair, Chair & Research Officer, Association of Chartered Physiotherapists Interested in Vestibular Rehabilitation and was a member of Advisory Group for the Department of Health publication "Provision of Adult Balance Services: a good practice guide". Dr Smith is a member of the Scientific Program Committee and Science and Technology Committees (Deputy Chair since 2018) of ASMA. Dr Rafferty serves as Chair for the Association for Respiratory Technology & Physiology Working Group on Respiratory Muscle and was a member of the American Thoracic Society workshop and co-author of the report "Evaluation of respiratory mechanics & function in the paediatric and neonatal ITU". Dr Witard co-authored the IAAF Consensus Statement 2019 on "Nutrition for Athletics". Prof Harridge represented the Royal Society of Biology and Physiological Society as a speaker at the Parliamentary Links Day in 2019 and was co-author of the Physiological Society's report "Growing Older, Better", highlighting physiology's role in meeting the UK Government's target of "at least five extra healthy, independent years of life by 2035".

Advisory Boards

CHAPS staff serve/have served on a number of advisory boards and trial steering committees including: Prof Ellison-Hughes: Project REMAIN; The Netherlands Heart Foundation, 2016-2020; Executive Board member of CARE-MI consortium EU FP7 (to 2015); MONACO clinical trial (Chair). Prof Harridge: MRC Arthritis Research UK Centre for Musculoskeletal Ageing Research (2018-).

National and International recognition

Our research contribution has been recognised both nationally and internationally through prestigious prizes and awards. These include recognition of the work done by the DCC who were awarded the Partnership for Clean Competition's Outstanding Scientific Contribution to Anti-Doping Research award in 2017 with former Director Prof. David Cowan winning the prestigious Larry D. Bowers award for his contribution to the advancement of anti-doping science over his career. Dr Tom Smith was winner of the 2019 Eric Liljencrantz Award from ASMA honouring research excellence in aerospace medicine and was elected as an Academician of the International Academy of Aviation and Space Medicine. Dr James Clark was awarded the Otto Hutter Prize by

the Physiological Society in 2019. Dr Federici Formenti and the OxVent team have been recognised with the "Small Idea, Big Impact: Global Challenge" award from the Institution of Engineering and Technology and the "Collaborate to Innovate 2020 COVID-19 response" award from the Engineer for their work on the development of a low-cost ventilator. "Ernsting's Aviation Space Medicine" (5th Edition), edited by Prof Gradwell won the British Medical Association's (BMA) Book of the Year award (Medicine Category) in 2017 and Dr Caroline Jolley was nominated as a BMA Role Model for Women in Academic Medicine in 2020.