Institution: Liverpool John Moores University

Unit of Assessment: Sport and Exercise Sciences, Leisure & Tourism (UoA24)

Unit Context

The Research Institute for Sport and Exercise Sciences (RISES) at Liverpool John Moores University (LJMU) was established in 1997 and we recently celebrated the RISES 20th anniversary, a major landmark in our history ('RISES 1997-2017: 20 Years of Excellent Research with Impact'). The Institute is the vibrant home of research activity within the School of Sport and Exercise Sciences at LJMU, the first institution in the world to establish a single-honours Sport Science degree in 1975. Our research environment was awarded 100% 4* in REF2014 and this world-leading position was strengthened further with a strategic decision by the University to front-load the QR funding, the second largest in our UoA. This foresight and early distribution of QR allocations accelerated growth immediately after REF2014 with major investment that enhanced infrastructure and enabled the development of innovative approaches. We have thus launched major research programmes that concluded successfully during this cycle and led to high-quality, paradigm-shifting research exploring global issues using state-of-the-art techniques as described in the following sections. RISES continues to drive the cutting edge of developments through pioneering work interrogating the human exercise response "from the cell to the community" to target 21st century challenges, societal issues and major questions related to sport, exercise, physical activity and health and well-being.

Unit Structure & Governance

RISES has five Research Groups spanning natural to behavioural sciences in sport and exercise led by experienced, internationally renowned scientists: Biomechanics (**Maganaris**), Brain and Behaviour (**Bennett**), Cardiovascular Health Sciences (**Thijssen**), Exercise Metabolism and Adaptation (**Wagenmakers**) and Psychology and Development (**Tod**). Our two "Exchanges" draw expertise from different Research Groups but are externally oriented with a focus on end-user engagement and developing mutually beneficial partnerships with stakeholder to capitalise on key alliances. The Football Exchange (**Littlewood**) delivers real-world solutions to football and the Physical Activity Exchange (**Boddy**) delivers applied solutions for better health and well-being based on world-class research. The Exchanges are unique and were recognised as examples of good practice in the sector by the REF2014 sub-panel. We have strengthened and supported their development and reach during this cycle to generate significant societal impact on a global level (**ICS4, ICS5**).

All academic staff in the School belong to the Research Institute as primary or associate members of the Research Groups and/or the Exchanges. This inclusive approach is one of the major strengths of RISES that, currently, includes 66 academic staff members, 13 post-doctoral researchers, 137 PGRs, 5 technical staff, 2 research officers, 2 administrative staff, 6 Honorary Visiting Professors/Researchers and 1 Emeritus Professor, all working together in a research-intensive environment. Our dynamic academic culture empowers staff, facilitates exchange of expertise and enables training of postgraduate researchers in a world-class environment. This structure and organisation allows RISES to shape the forefront of developments in our subject area and act as a global hub through high-quality research and truly global societal impact.

During this REF cycle, the reorganisation of Faculties in the University enabled the expansion and restructuring of both the School and RISES. Our psychology and development research was formerly associated with staff primarily based in the two Exchanges with an applied focus on physical activity, football and sport, in particular around athlete and practitioner welfare and identity across the lifespan. The growth of activity and its importance led to targeted recruitment of staff with an interest in the area and the establishment of Psychology and Development as the fifth Research Group in RISES. Furthermore, as the Exercise Metabolism and Adaptation Research Group (EMARG) expanded, we created two sub-groups within EMARG to focus strategically on Integrative, Cellular and Molecular Physiology of Lifelong Health coordinated by **Burniston**, **Jarvis, Stewart and Wagenmakers** and Applied Sport and Exercise Physiology, Nutrition and Metabolism coordinated by **Close**, **Morton** and **Walsh.** This group's 'Paper-to-Podium' strategy is informed by the Vision to be recognised as "the world's leading group for generating and translating research that delivers winning performances"**.**

The University Estates Strategy gave the opportunity to reorganise the Faculty of Education, Health and Community and the School of Sport, Leisure and Nutrition merged with the School of Sport and Exercise Sciences in 2019 and moved to the Faculty of Science from the historic I.M. Marsh campus. The expanded School of Sport and Exercise Sciences now has 91 academic staff with expertise and interests in sport and exercise sciences ranging from the natural to social sciences and psychology, coaching and physical education/pedagogy. As a result, some School staff now engage with additional University research institutes, the Centre for Educational Research (CERES) in the Faculty of Arts, Professional and Social Studies and the Institute for Health Research (IHR), a cross-Faculty home for health research across LJMU. Primary alignment of staff and membership of Research Institutes/Centres is based on their status regarding significant responsibility for independent research (SRIR) determined according to the institutional Code of Practice. Overall, 78 of the 91 staff (86%) in the School of Sport and Exercise Sciences have SRIR status, with tailored support packages offered to the remaining staff for developing their research profiles. The majority of School staff are primary members of RISES (N=66, 63.2 FTE) and are submitted to UoA24, nine are aligned with CERES and are submitted to UoA23/UoA34, and three are aligned with IHR and submitted to UoA3. This RISES submission to UoA24 with 63.2 FTEs represents an increase of 82% over the 34.75 FTEs submitted to UoA26 in REF2014.

The management and governance structure facilitates communication and interaction and is headed by the RISES Board, chaired by the Head of RISES (**Baltzopoulos**). It includes all the Research Group and Exchange leaders, a Deputy Head with responsibility for PGRs (**Hollands**) and a Deputy Head for Research Strategy (**Stewart**). The RISES Board coordinates and oversees the strategic research direction of the Institute, communicating with the Research Groups and Exchanges and the School and Faculty Management Teams and meets quarterly to review progress against strategic aims, manage overall direction and allocate research resources. It supports setting and reviewing milestones for quality of outputs, postgraduate recruitment and completions, income generation and impact. The Head of RISES is a core member of the School Management Team and **Baltzopoulos** also chairs the Faculty Research, Scholarship and Knowledge Transfer Committee in his role as Associate Dean Research in the Faculty of Science and member of the University Research and Knowledge Exchange Committee (URKEC). These key positions and direct lines of communication allow effective management and alignment of research strategies.

Achievement of Research & Impact Strategy Aims 2014-2020

Our three strategic **AIMS** outlined in the REF2014 submission were:

1) To further enhance the significance, quality and impact of our research OUTPUTS by using mechanistic and applied approaches to investigate real-world issues in the areas of human performance and health,
2) To increase the translational IMPACT of our work by building the activity and profile of our "Exchanges" regionally, nationally and internationally to sustain current collaborations and develop new partnerships with key external stake holders,
3) To continue to develop and extend our excellent research ENVIRONMENT through alignment with current LJMU Estates Strategy whose mission is to promote local and regional civic partnerships including activities related to sports performance and health in our communities.

To achieve these **AIMS**, four different **Activities** were planned to a) promote, retain and recruit high quality staff across the range, b) increase UK, European and International grant funding with a specific strategic target of "Big Science" priorities and initiatives across our portfolio of work, c) Extend recruitment of high quality PGRs through Dual/International PhD awards with high-profile partners, and d) provide all staff and students with high quality support, training, development and communication opportunities with key national and international partners through conferences and training programmes.

The combination of expert personnel and world-class facilities enabled all our groups to develop innovative mechanistic and applied approaches to enhance the significance, quality and impact of our research outputs (**AIM 1**). The 66 RISES staff submitted to UoA24 published 1178 outputs in the period 2014-2020 (168/year) with 376 (34%) in the top 10% journals by CiteScore and 202 (17%) in the top 10% most cited publications worldwide (SciVal). Importantly, nearly two thirds or 760 outputs (64.5%) are co-authored with international collaborators from institutions in 103 countries around the world (Figure 1).

International collaborations enhanced the quality, significance and impact of our outputs (**AIM 1**). For example, the Physical Activity Exchange (PAEx) work on children and exercise led by **Boddy** contributed knowledge and data to the global collaborative NCD-RisC programme generating outputs in *Nature* and *The Lancet* (e.g., **REF2#764, REF2#826, REF2#838**). These are highly significant and internationally influential publications linking rising BMI in rural areas with the global obesity epidemic after pooling data from millions of participants (19.2M-128.9M) and include our two highest cited outputs with 2079 (**REF2#838**) and 1876 (**REF2#826**) citations.

Figure 1. Global map showing country affiliations of collaborators for all LJMU UoA24 outputs (N=1178) between 2014-2020. The size of the bubble is proportional to the number of collaborative outputs with researchers in that country, with most collaborators outside the UK based in Australia (N=344).

Wagenmakers, Strauss, Cocks and **Shepherd** generated previously inaccessible information on molecular mechanisms that cause functional differences in muscle metabolism and exercise performance between sedentary vs trained, young vs old, lean vs obese, and insulin resistant vs insulin sensitive individuals. They developed novel confocal immuno-fluorescence microscopy methods (**REF2#1417**, **REF2#775, REF2#717**) to visualise subcellular localisation and density of lipid droplets, mitochondria and capillaries on cross-sections of skeletal muscle. In biopsies taken and analysed before and during exercise in our labs, these methods demonstrate translocation of hormone-sensitive lipase into lipid droplets during exercise (**REF2#1416**) and redistribution of GLUT-4 from intracellular stores into the sarcolemma (**REF2#830**). Because of the novelty of this information, the above outputs are published in high impact scientific journals (**AIM 1**) and supported significant additional funding (**Activity b**). **Wagenmakers** (PI) and **Shepherd** (Co-I) were awarded a Diabetes UK grant (DUK-17/0005744) to examine the inhibition of adipose tissue lipolysis to enhance a walking programme for improving insulin sensitivity in pre-diabetics. **Wagenmakers** is LJMU lead (Co-PI) and **Cocks** Co-I on an MRC grant to investigate Mechanisms of Insulin Resistance in South Asians (MIRSA) and the roles of skeletal muscle microvasculature and mitochondrial metabolism led by the University of Glasgow (MR/R023247/1).

Other highlighted examples of **AIM 1** achievements include the work of **Burniston** who pioneered new proteomic methods using stable isotope labelling to provide the first insight into the synthesis, abundance and degradation of individual proteins in human muscle, as well as in non-human animal models and cell cultures. We (**REF2#645**) were the first to report that in response to exercise, proteins in human muscle exhibit a broad spectrum of dynamic responses linked to synthesis rate, abundance and degradation rate. These new insights differ from expectation and challenge the widely held assumption that all gains in protein abundance are driven by increased synthetic rate (**REF2#2020**). Further work on the mechanisms of adaptation examined the impact of ageing on the biochemical cross-talk between immune cells and muscle (**REF2#773**) and the impact of age and nutrition on endocrine influencers of adaptation *in vivo*

(**REF2#853**, **REF2#1415**, **REF2#1419**). **Jarvis, Owens** and **Stewart** showed that epigenetic changes accompany muscle atrophy and remodelling (**REF2#772, REF2#839, REF2#836**), and human adaptation to exercise training, detraining and retraining. Such changes may constitute a 'muscle memory' modifying the impact of previous exercise bouts on subsequent responses to exercise or disuse both at a physiological and molecular level (**REF2#700**, **REF2#724**). These were the first studies of their kind, relating to exercise, to be carried out in healthy human participants. Genotype profiling (**Erskine, Akhmetov**) has revealed important genetic predispositions in responses to resistance training (**REF2#582**), risk of soft tissue injury, elite status in rugby (**REF2#635**) and power/speed in elite youth sport (**REF2#2118**), with implications for talent identification and player recruitment in elite sport.

The links of **Close** and **Morton** to elite sport have allowed access to unique field and track-side research environments resulting in ground-breaking applied research and innovation published in high-quality journals (**AIM 1**), changing applied sport nutrition practice and attracting significant, sustained funding **(Activity b)** also linked to **ICS2**. This work involved pre- and post-race muscle biopsies and blood samples taken on-site, for the first time, during a track marathon (**REF2#683**), and from professional rugby league players during a scheduled match fixture to measure the energetic cost of the sport and assess the effects of nutrition on post-game recovery. These data informed England Rugby current nutrition strategies and were implemented in the 2019 World Cup tournament in Japan. Over the past 5 years **Close** and **Morton** also used the Doubly Labelled Water (DLW) method to measure accurately the energetic costs of many professional sports including rugby, football and horse-racing and have transformed nutritional advisory strategies (**REF2#1433**). The DLW studies on jockeys have revolutionised jockey nutrition (**ICS2**), and the work on academy football players highlighted the extremely high energetic demands of youth footballers and resulted in major changes to how these players are fed (**ICS5**). This work was also covered in a recent UEFA expert statement in BJSM that will have significant impact across the globe. **Walsh**'s team has shown the benefits of preventing vitamin D insufficiency for health and physical performance in military recruits (**REF2#440**). Based on these large, multicentre observational and randomised controlled trials, the UK Ministry of Defence has implemented daily vitamin D supplementation for all recruits as part of the Covid-19 Force Health Protection measures. Walsh's team also developed non-invasive tools to assess immunity using delayed type hypersensitivity skin tests (**REF2#438, REF2#437**) and tear fluid antibody measurements for field application (**REF2#439**).

The Cardiovascular Health Sciences (CHS) Research Group has world-leading experience in introducing and validating novel non-invasive ultrasound technology to assess vascular and cardiac function, published in the most influential, highest-profile journals including *JACC, Circ, JAMA Cardiol* (**AIM 1**). **Thijssen** introduced the carotid artery test as a simple, predictive measure of coronary artery health (**REF2#645**) and **Oxborough** introduced cardiac strain-volume loops as a non-invasive alternative to pressure-volume loops which improve diagnosis of cardiac pathology (**REF2#677)** and independently predict clinical outcomes **(REF2#2050**). Both non-invasive measures have been used extensively to measure the impact of exercise training on cardiovascular health (**REF2#632, ICS1).** The CHS group has brought challenging new scientific concepts to exercise cardiology, including the importance of cardiac screening in soccer players recently published in *New Engl J Med* (**REF2#735**) and published the first study to examine the independent predictive value, and hence the clinical relevance, of exercise-associated elevations in cardiac troponins **(REF2#1288**). These concepts have received significant attention, and changed widely adopted dogma in exercise cardiology.

The Brain and Behaviour Research Group adopted a mechanistic approach to understand the neural mechanisms underpinning sensorimotor adaptation (**AIM 1**, **REF2#2087**). This was also linked to **Activity b** as it was supported by a BBSRC grant (25/2/13-27/11/16) with collaborators at Bradford and St Andrews, and a commercial contract with Nike Inc. and Manchester United FC (1/10/12-31/3/14) to investigate the visuomotor processes influencing elite sports performance (**Bennett)**.

In Biomechanics, the Research to Improve Stair Climbing Safety (RISCS) is a multidisciplinary cross-Faculty team with external stakeholders formed in 2015 to examine factors compromising stair safety for older people and develop effective tools to detect stair fall risk and exercise interventions to prevent falls. The RISCS group have discovered and published evidence for factors contributing to stair fall risk in the real world including inconsistencies in stair dimensions, lighting, and the visual appearance of steps affecting stepping biomechanics and safety (**REF2#2096, REF2#827, REF2#2099**). They also developed

prevention methods and a novel stepping profiling tool for the assessment of stair fall risk in older people (**REF2#11, REF2#2098**).

The translational impact of our research was further enhanced through the work of our Exchanges by strengthening and expanding existing collaborations and developing new partnerships with key external stakeholders (**AIM 2**). In the area of physical activity, our PAEx has developed impactful international collaborations with The Association for International Sport for All (TAFISA), via the Triple Active City work and **Global Active City** (**GAC**) projects (**ICS4**, **Boddy, Knowles, George**) supported by the International Olympic Committee, and involving 7 cities around the world. They also hosted international delegates at two workshops at LJMU as part of the GAC project in 2018 and 2019 funded through Global Challenges Research Fund (GCRF) grants (**AIM 2 & Activity b**). The PAEx also has long-standing local and regional collaborations and civic partnerships (**AIM 3**) including the City Council and the Liverpool Clinical Commissioning Group, with examples included within **ICS4**. PAEx members also work collaboratively with a range of other regional partners such as the NIHR North West Coast Applied Research Collaboration (**Boddy**, Contributing Lead, Improving Population Health Theme), Blackburn with Darwen Council (**Watson**) and are active members of the Liverpool Centre for Cardiovascular Science (**Sprung, Watson**).

The Football Exchange (FEx) further developed engagement with the football industry including top clubs such as Liverpool FC through the collaborative research of **Morton, Erskine and Clark** to capture the team's nutritional requirements and to implement new training protocols and recovery strategies. Similarly, **Close and Morton** implemented systemic changes based on their nutrition research at Everton FC (see also **ICS5)**. Applied relationships have developed at other Premiership clubs including Leicester City and Arsenal through the work of **Andrew, Littlewood and Richardson** from a training load, coaching and psychological perspective reflecting the breadth and diversity of expertise within the FEx to serve end-users. These applied research and civic partnerships and activities of our Exchanges in our communities and with key stakeholders and end-users of our research enhance further the quality and impact of our research environment **(AIM 2 & 3)**.

The achievements of our AIMS were also underpinned by recruiting high quality staff and recognising research achievements through promotions (**Activity a**). Nine staff were promoted to Professor, another nine staff promoted to Reader and three new Professors and 15 other staff were recruited during this cycle (details in Section 2). Excellent post-doctoral fellows were appointed through funding from prestigious sources (**Activity b**) such as **H2020 'Societal Challenges'** programme (Britzman, OACTIVE project on musculoskeletal modelling for the prevention of Osteoarthritis, **Baltzopoulos, Maganaris**) and **Marie Skłodowska-Curie Actions** (MSCA) from the **H2020 'Excellent Science'** Programme (Eijsvogels, MSCA Fellowship CARDI-ACHE: The cardiovascular consequences of endurance exercise on cardiac health in athletes, **George**). This resulted in multiple publications in leading journals (**AIM 1**), including *Circulation* **(REF2#1288)** and YIA award at ACSM (2017). Buckley and Leo currently hold post-doctoral positions to strengthen the collaborative network of the Liverpool Centre for Cardiovascular Science (LCCS) led by Prof. Lip from the University of Liverpool. The LCCS is a cross-university centre focused on understanding the role of exercise in atrial fibrillation and in adult and paediatric congenital heart disease.

Internationally, a long and fruitful collaboration continues with Green at the University of Western Australia (UWA), generating >150 co-authored outputs (81 in this REF2021 cycle) in leading journals including *J Physiol, Obesity Reviews, Physiol Reviews, Hypertension*. In 2019, we obtained a **Research England International Investment Initiative** award (i-CARDIO) that was built on and formally underpinned this extensive, successful and long-standing collaboration with UWA, leading to a new (UK-wide) framework for training, registration, accreditation and recognition of 'Clinical Exercise Physiologists' in the health and social care sector (**Activity b & d**). Another main outcome of i-CARDIO is a dual PhD-studentship agreement with UWA (**Activity c)**, funding 4 jointly supervised PhDs and 1 post-doctoral fellow. We have a long and successful record and tradition of providing high quality training and support to our students and staff and our sector as a whole to develop research-related skills (**Activity d**). For example, since 2008 we have hosted an annual **Cardiovascular Ultrasound Summer School** that teaches best practice and practical skills in early detection of cardiovascular disease. This workshop has also been hosted three times in Australia (University of Canberra 2015; Australian Catholic University, 2016; UWA, 2018), twice in Canada (University of British Columbia, 2010, 2015) once in Brazil (University of Sao Paulo, 2019) and has attracted ~400 delegates from >30 countries.

The aim of translating our world-class research into actions of significant societal benefits is also reflected in the ICSs presented in REF3 that are aligned with some key themes of our work (improving sport performance, physical activity and health). They are embedded in and span the work of Research Groups on cardiovascular screening (**ICS1**), nutrition and metabolism (**ICS2**) and biomechanics and cell biology (**ICS3**) and our two Exchanges on global physical activity (**ICS4**) and applied football solutions (**ICS5**).

Research and Impact Strategy 2021-2027

Our vision is to maintain RISES as a world-leading institute at the forefront of international research and a global hub in sport & exercise sciences conducting cutting-edge research with significant impacts for individuals and society. We have a focused research and impact strategy to develop and implement innovative and state-of-the-art approaches to target 21st century challenges and major issues in sport, physical activity, health and well-being. Towards 2027, which will mark the 30th anniversary of RISES, we have refined our 2021-27 strategic AIMS given recent key sector and scientific developments:

1. Increase the quality of our research OUTPUTS by developing innovative, state-of-the-art and inter-sectoral approaches,
2. Improve the reach and significance of our IMPACT by designing and translating our research to target 21st century global challenges, societal issues and major problems in sport and physical activity across the lifespan,
3. Expand our excellent research ENVIRONMENT through increased funding by addressing key priorities, fostering international collaborations and further promotion of Open-Access.

To achieve these AIMS, our research and impact strategy is based on six strong pillars (▪) with specific ACTIONS (➢) in each:

- Staff Development, Support and Mentoring
  - ➢ Support all academic staff to develop international or world-leading profiles
  - ➢ Develop aligned individual and group research plans that target future priorities
- Research Capacity & Collaborations
  - ➢ Increase research capacity by targeted recruitment of academics with world-class profiles and talented young researchers and students
  - ➢ Increase funding by addressing key local, regional and global priorities and developing international collaborations.
- Research Culture and a Vibrant & Dynamic Environment
  - ➢ Foster a culture of exploration & discovery based on stimulating scientific debate
  - ➢ Promote research challenges, scientific frontier meetings and interactions with world authorities
- Research Impact, Knowledge Exchange and Public Engagement,
  - ➢ Engage with external stakeholders guided by the Exchanges and impact plans,
  - ➢ Take a strategic approach to leadership, targeting sector positions that shape the translational research and impact agenda
- Inspirational Leadership, Inclusive Governance and monitoring of progress
  - ➢ Appoint strategic and supportive leadership, providing clarity and strong inclusive governance
  - ➢ Monitor progress against targets
- State-of-the-Art Research Environment, Infrastructure & Facilities enabling innovative approaches
  - ➢ Develop further inter-disciplinary and inter-sectoral techniques
  - ➢ Enhance state-of-the-art infrastructure and facilities and innovative technological approaches

Delivering Our Research and Impact Strategy 2021-2027

We continually strive for research excellence at an international level. Given the development of our field, especially in the last few years and the emergence of promising new advances across different scientific fields and technological sectors, our future vision for research will focus on key innovation avenues for development. These have the potential to revolutionise research approaches in the sport and exercise sciences and help us lead the advancement of our field globally by harnessing innovations and methods developed across a wide range of technological and research fields. Research and Impact strategy delivery is based on a 'Support-Coordination-Monitoring' process for continuous assessment of progress and any

amendments of ACTIONS in each pillar of our strategy that are considered necessary for achieving our key strategic AIMS. We have agreed specific performance indicators for the monitoring and achievement of these ACTIONS and all Research Group and Exchanges have developed 7-year Research Strategy maps and appropriate Action Plans monitored by the RISES Board that provides strategic guidance and support through QR distribution. Our approach to impact comprises nurturing existing links and building future long-term, trusting, two-way relationships with stakeholders and research end-users based on specific Impact Plans. These are based on the framework of the UKRI-ESRC Impact Toolkit and grounded on the 'RISES Impact Journey' pathway to Identify-Inform-Influence-Involve-Impact stakeholders and research users.

2. People

Staffing Strategy

The RISES staffing strategy is focused on recruitment of internationally renowned academics with a proven record of accomplishment in high-quality outputs, research leadership and funding and exceptional ECRs with significant potential. This provided strategic direction and critical mass across all research areas promoting effective team building, vitality and sustainability. New members of staff recruited in professorial positions include **Baltzopoulos** in Biomechanics (2016) appointed as Head of RISES, **Walsh** in Exercise Immunology (2019) and **Butt** in Psychology (2020). Other new appointments include: **Andrew** (2015)**, Louis** (2015), **Bradley** (2016), **Foster** (2016), **Foweather** (2016), **Clark** (2017), **Owens** (2017), **Areta** (2018), **Brennan** (2018), **Sprung** (2018), **Thomas** (2018), **Akhmetov** (2019), **Roberts** (2019), **Champ** (2020) and **Olthof** (2020). The RISES membership has thus grown from 53 in 2014, (with 39 submitted to REF2014) to 66 and includes 22 Professors, 9 Readers, and 8 ECRs with a high retention of staff and two thirds of staff submitted to REF2014 still active across the RISES Research Groups and Exchanges. The new members of staff were all strategic appointments to support research in new or growth areas. For example, appointments to support the new Psychology and Development Research Group included **Thomas** (Senior Lecturer, 2018), **Champ** (Senior Lecturer, 2020), **Butt** (Professor, 2020). There were also targeted appointments for succession planning e.g. **Baltzopoulos** appointed as Head of RISES to succeed **George** following his appointment as Associate Dean and then Pro-Vice Chancellor Research.

Encouraging, supporting and rewarding staff for excellent research achievements are central elements of our staffing strategy aligning with the University Strategy (2017-2022) that includes research as an integral part of academic staff recruitment, induction, development and reward. Internal recognition through University awards include the VC Research Excellence Award 2015 (**George**) and the LJMU Spotlight research award for radical ideas and ground-breaking research and **Knowles** receiving two VC Awards for Socio Economic Engagement (2014 & 2016). Internal recognition is also reflected in promotions to Professor: **Richardson** (2014), **Barton** (2015), **Burniston** (2015), **Close** (2015), **Gregson** (2015), **Morton** (2015), **Jones** (2016), **Knowles** (2017), **Hollands** (2018); and Reader: **Erskine** (2015), **Low** (2017), **Boddy** (2015), **Bradley** (2018), **Littlewood** (2018); **O'Brien** (2018), **Causer** (2019), **McRobert** (2019), **Foweather** (2020). This diverse staffing base and the demographic profile of our staff allow an energising mixture of ECRs and more established researchers working together and managing future research activities effectively.

Staff Development

Staff Development, Support and Mentoring is one of the pillars of our Research Strategy (Section 1), framed in the context of the University's staff strategy with LJMU becoming a signatory (2020) to the Revised Concordat to Support the Career Development of Researchers whilst holding an HR Excellence in Research Award since 2012. We aim to support all staff to develop international or world-leading profiles. Individual and group research plans target future priorities and we provide pump-priming funding and team support to enable success. Research achievements and future research plans are considered annually as part of the University's appraisal process and inform the dedicated research time allocated through the LJMU Workload Allocation Model that has a three-tier research allowance to encourage research activity. All new staff receive a protected full research allowance during the first three years of employment to facilitate research at the start of their careers. Staff development requirements (training, research collaborations and networking, pilot studies and pump-priming, conferences, CPD) are provided through RISES and funded strategically from QR funds.

New staff and ECRs are assigned a Line Manager and/or academic mentor and are embedded in the RISES Groups/Exchanges where they are encouraged to work collaboratively alongside established researchers to develop research plans aligned with the group's strategy. ECRs are eligible to compete for Faculty-funded PhD studentships (25 awarded since 2014), and the University runs a matched-funding PhD programme that is targeted at new staff and ECRs with 25 matched-funding PhDs awarded since 2014. These were jointly funded in cooperation with a range of external partners translating to ~£750K contribution by the University and an equal amount by the external organisations that include Sport Governing Bodies (e.g., FA, EIS, England Rugby, British Gymnastics, Talented Athlete Scholarship Scheme), Sport Clubs/Teams (e.g., Everton FC), industry and healthcare (e.g., GSK, Alder Hey Hospital Trust) but also leisure (Mersey Forest) and arts organisations (e.g., Royal Liverpool Philharmonic).

The Faculty supports ECRs through funding for research development that includes collaboration visits covering international travel, subsistence and consumable costs, to develop research networks and enhance research capacity. For example, **Watson** received funding to visit York and Brock University, Canada and **Graves** made a funded research visit to Dr Genevieve Healy, University of Queensland. Post-doctoral ECRs appointed on specific projects rather than staff establishment posts have staff development needs addressed by the Researcher Development Concordat (2019) and the resulting principles set out by our institutional steering group are implemented by RISES to ensure we provide an inclusive, supportive and fulfilling work environment. Three of our post-doctoral researchers achieved independent researcher status determined via the SRIR process and are submitted as Category A staff (**Langan-Evans**, **Martin, Wilson**).

The annual RISES Away Day every January is the focal point of our strategic research reflection, planning and support. All Groups and Exchanges outline their research achievements and plans and there are also opportunities to discuss research quality issues, inter- or multidisciplinary approaches and for horizon scanning in sport and exercise science and related fields. Recognising, communicating and celebrating successes are key elements of a vibrant and thriving research culture and the RISES Newsletter that is published quarterly includes achievements, awards, and news of staff and PGRs. We organise a RISES Seminars Series that provides opportunities for networking and communicating research findings, developments and plans and includes invitations to world-leading experts to present their work. There are also dedicated sessions in the series for PGR research progress reports and preparation for conference and awards presentations.

There is also a comprehensive range of university-based research development activities for staff, ECRs and PGRs provided by the Doctoral Academy and the Research and Innovation Services (RIS) who also offer REF upskilling support. This is for new staff and ECRs who require additional mentoring and research pump-priming to develop their academic profile; two of our staff benefitted from REF upskilling awards (£2000), and both are submitted (**Clark** mentored by **Close** and **Burniston; Edwards** mentored by **Burniston**). Impact support is comprehensive, structured and provided through a dedicated RIS Impact Officer and other RIS support/library staff and includes workshops covering all stages of the Impact Journey pathways including knowledge transfer and impact generation (e.g. Building Blocks of Impact; Influencing Government Policy Through Research; Exploring Stakeholder Engagement). Impact is planned and captured through VV Impact Tracker (all our 5 ICS developed using Impact Tracker) with the Impact Officer providing training and 1-2-1 meetings to support the development of impact from specific projects. There is also central support to develop ICSs (REF ICS Fund) and three of our ICSs benefitted from this award (**ICS2**, **Close**, £3000; **ICS3**, **Barton**, £1000; **ICS4**, **Boddy & Knowles**, £17288).

Postgraduate Researchers

RISES has a thriving and vibrant postgraduate research community (137 PGRs enrolled July 2020) that are crucial to our research culture and the vitality of our research environment. There was a large increase in enrolments and completions with 128 PhDs awarded in this cycle compared to 60 in the REF2014 period, with our 2019/20 graduation cohort of 32 PhDs our largest ever. There are also two Professional Doctorate programmes in Sport and Exercise Psychology and Applied Sport and Exercise Science with 8 graduations in the last two years. This phenomenal growth (see Table below) was achieved with strategic management of recruitment avenues providing a dynamic and multicultural environment with diverse funding resources underpinning the PhD programmes and 11% funded internationally. This included national authorities

(Ministry of Education Malaysia, Commonwealth Scholarships), university sponsorships, and Dual PhD programs with Mahidol (Thailand), the University of Malaya, Radboud University in the Netherlands and UWA in Australia (i-CARDIO project). These avenues enable the recruitment of motivated and excellent international PhD students and make a significant contribution to the University's Internationalisation Strategy.

	PhD Headcount (FT & PT enrolled)	Professional Doctorates (enrolled)	PhDs Awarded	Professional Doctorates Awarded
2013/14	57 FT 42 PT	N/A	8	N/A
2014/15	74 FT 50 PT	N/A	17	N/A
2015/16	97 FT 51 PT	8	8	0
2016/17	122 FT 47 PT	17	15	0
2017/18	128 FT 47 PT	15	17	0
2018/19	135 FT 48 PT	11	31	3
2019/20	118 FT 54 PT	7	32	5
TOTALS			128	8

The record of achievements and contributions of our graduates were showcased in the RISES 20th anniversary celebrations. These included a series of high impact scientific events, a dedicated website with the history of the Research Institute and the achievements since the inauguration of RISES in 1997, alongside a celebration of all the ~250 PhD students that graduated between 1997-2017 with a special feature entitled '20 Years, 20 Stories'. These were the stories of 20 selected PhD students, one for each of the 20 years of the Research Institute, illustrating how RISES shaped the thinking of generations of researchers and influenced sport and exercise science research since its inception.

PGR Support and Monitoring Mechanisms

Support for PGRs is multi-level and overseen by the URKE Committee and the Doctoral Academy through its comprehensive Researcher Development Programme (RDP), which aligns fully with the Vitae Researcher Development Framework supporting PGRs throughout the doctoral journey. The Faculty Research Degrees Committee (FRDC) and administration teams provide induction, support, annual monitoring and mentoring at Faculty level. The FRDC is chaired by **Hollands** who is also RISES Deputy Head with responsibility for PGRs so there is effective and coordinated support for our PGRs. Local support is provided by the RISES office and supervisory teams. Monitoring and support of PGRs during their studies is managed though a new online system (e-Doc) where training activities, progress reports and supervisory meetings (10/year minimum) are recorded and approved.

PGR Environment, Culture and Supervision

The recruitment of exceptional and highly motivated postgraduate students was always central to the RISES Research Strategy as a key element of a world-class, vibrant research environment. Our PGRs are active in all Research Groups and Exchanges, working and networking collaboratively across the full spectrum of our research portfolio and are fully integrated in the RISES environment. Each PGR has access to Symplectic at enrolment and receives training and support at induction to build a profile in the system that is directly linked to the RISES website where they are listed alongside RISES staff (https://www.ljmu.ac.uk/research/centres-and-institutes/research-institute-for-sport-and-exercise-sciences/people). All RISES postgraduate researchers have access to open plan PG office space in the Tom Reilly Building (TRB), the Life Sciences Building (LSB) and the Exchanges buildings so their offices are co-located in the laboratory buildings where their research is being conducted. All students are supervised by a team of experienced and ECR staff (n=3-4/student) to allow a range of experience in supervisory teams and multi-disciplinary approaches to research projects and doctoral training.

PGR Training and Development

RISES PhD vacancies are advertised on the LJMU vacancies page and FindAPhD.com. Shortlisting and interviews are conducted according to LJMU policies. There is a comprehensive induction programme with activities and information covering University, Faculty and RISES support that includes Health & Safety. The University's decision to move to three specific enrolment dates has further enhanced induction

effectiveness and cohort cohesion because PGRs benefit from development provision as part of a broader peer group in line with the UKRI Statement of Expectations for Postgraduate Training (2016).

The Doctoral Academy's RDP supports PGRs to get started and then enhancing personal effectiveness, engaging with others and successfully communicating research (e.g. Café Scientifique, poster, infographic and research story competitions, monthly community writing days and residential "Thesis Boot Camps" writing retreats). The RDP comprises ~80 events annually, including a Summer School. The "3i's" initial academic teaching training program is offered to PhD students alongside their research work and supporting programme to enhance skills in teaching, assessment and administration. We led the development of this programme within RISES that is now compulsory for all PhD students wishing to contribute to teaching or supervision in undergraduate programmes (up to the maximum hours allowed by UKRI) and 151 of our students have completed the 3is programme.

In addition to central Doctoral Academy support, at RISES all Research Groups and Exchanges have regular meetings to present current research progress, trouble shoot experimental methods, discuss new papers and practice conference and pre-viva presentations. All PGRs are also invited to attend the RISES Seminar Series taking part in discussions and broadening their horizons by networking with researchers from different fields. Specific dates in the Seminar Series are ring-fenced for International student progress presentations and conference/awards rehearsal and preparation receiving feedback and advice on their presentations. There are further opportunities to gain confidence in presenting at University events such as the Faculty of Science Research Day, University Research Day and 3 Minute Thesis competition with several finalists/winners from RISES for outstanding oral and poster presentations at these internal events but also external conferences. Other enhancement and enrichment events include the hosting of student-organised conferences. For example, PGRs Hesketh and Viggars raising £30K from the Physiological Society to organise and chair the Future Physiology Conference at LJMU (December 2019) with the main conference theme on 'Translating Cellular Mechanisms into Lifelong Health Strategies'. The Society's Future Physiology conferences provide ECRs with experience and networking opportunities to enhance their careers. We also provide competitive QR funding to support PhD student participation in conferences where they compete for awards and, for example, between 2014-2019 we supported 28 PGRs with a total of £15888 to attend ECSS Congresses and take part in competitions with several winners (e.g., YIA: Owens 2015; Scott 2017, 2018; GSSI: Hammond 2016; Morehen 2018; Fell 2019).

Equality & Diversity

EDI Strategy and Athena SWAN Bronze Award

Sport & Exercise Sciences was awarded the first Athena SWAN Bronze Charter at LJMU in December 2019, reflecting our commitment to equality and diversity (EDI) and continued investment in enhanced practices and systems to drive equality of opportunity for all. This involved a thorough self-assessment of practices within RISES including recruitment and support of staff and PGRs, to enable a wider cross-section of society to engage in research and to enhance diversity in terms of all protected characteristics. Since then, **Sprung** was appointed as Strategic Lead for EDI (February 2020), sitting at Senior Management level to increase momentum and broaden the EDI agenda to address other areas of inequality (intersectionality), not limited to gender. Selection of staff for submission to REF through the SRIR process in accordance with the institutional Code of Practice considers fully all EDI issues. There are currently 4 women (3.93 FTE) Professors in RISES (20% of all Professors) and 23.6% of all staff submitted are women; this is higher than the proportion of women submitted in REF2014 (18%) and RAE2008 (9%). There are 8 ECRs (12% of the 66 staff submitted) 2 of whom are women (25% of ECRs). The proportion of women in the staff base is also reflected in the number of outputs selected from female staff (N=31 or 20% of the total number of 158 outputs submitted).

EDI considerations in Recruitment, Flexible Working and Career Development Support

By means of positive action, all employment advertisements for staff and postgraduate researchers now contain the following text: "RISES is proud of its commitment to equity, diversity & inclusion and endeavours to cultivate a staff base that is representative of society. We therefore encourage applications from all individuals who meet the advertised criteria, but would particularly encourage females, BAME, LGBTQ+, non-binary and individuals with a disability to apply". We have 60 full-time, 5 part-time and 1 flexible working, term-time only staff. No academic staff are on zero-hours contracts. Maternity cover is provided for the whole leave period, and in the past 18 months there were extensions of maternity cover posts by

~3 months to allow for handover periods and two 12 months unpaid leave periods (**Hopkins, Graves**). All benefits remain and staff on maternity/paternity/shared parental leave are invited to social events, meetings and Away Days. Before return, staff meet with their Line Manager to discuss support and review working patterns. Staff can request flexible working for fixed periods to support an effective work life balance; they may then return to their previous working pattern or make a further flexible working request. Mandatory modules (including EDI, bias and bribery) are completed annually/biannually and monitored during annual appraisal. Female staff can apply to the Aurora personal development-training programme to enhance career development and promotion to Reader/Professor. Three members of staff have benefitted (**Boddy, Dawson, Sprung**) and **Boddy** has already been promoted to Reader. **Knowles** mentored on this programme and she co-founded (2015) and Chairs the University-wide Women's Academic Network to support applicants for promotion. **Knowles** also Chairs the LJMU Women's Professors Network.

We are committed to EDI and we will form an EDI panel with staff and PGR representation and the Athena SWAN self-assessment team. This group will have terms of reference for an annual cycle of business to review and monitor the EDI Action Plan, update internal data and work on new reports and recommendations for action.

3. Income, infrastructure and facilities

Income

Total external research income generation reached £6.5M, with the largest contributions from UK Industry and Commerce (£1.8M, 27% of total income), UK-based Charities (£1.3M, 20%) and UK Central Government Bodies/Local Authorities, Health and Hospital authorities (£1M, 16%). Although the total income was slightly (~5%) lower than the total in REF2014 (£6.9M), there is now a more diverse portfolio of sources compared to the REF2014 period income that was primarily obtained (£3.7M or 54% of REF2014 total) from UK Central Government Bodies/Local Authorities, Health and Hospital authorities. Importantly, we achieved a targeted increase of income from UKRI Research Councils that quadrupled to £476K (7% of total) from £102K (1.5% of total) in REF2014. Contributions from International sources increased to £802K (12% of total) from £200K (3% of total) in REF2014. The income from UK Industry reported above is more than double that in REF2014 (£678, 10%) and the income from UK-based charities more than triple compared to REF2014 (£407, 6%). Income from EU sources (£826K, 13% of total) remained similar (15% in REF2014). The increased diversity of income sources and the targeted growth of income from UKRI Research Councils, UK Industry, UK Charities and International sources reflect our strategic approach to increase our income from a variety of UK, EU and International sources with a specific strategic target of "Big Science" priorities and initiatives.

We have strategically targeted UK, EU and international funding streams with large collaborative projects addressing key priorities in sport and major societal problems related to physical activity and health. These include funding from **EU H2020 'Societal Challenges'** (OACTIVE project on Osteoarthritis, H2020-SC1-PM-17-2017: #777159), **H2020 'Excellent Science', Marie Skłodowska-Curie Actions** (MSCA Fellowship CARDI-ACHE), **BBSRC** (Perception to Action in Sport, BB/J018163/1), **MRC** (Mechanisms of insulin resistance in South Asians, MR/R023247/1) and **Diabetes UK** (A walking programme to improve insulin sensitivity in people with prediabetes, DUK-17/0005744). Other prestigious funding sources include international research organisations (CIHR, NSERC), charities (Sparks and Great Ormond Street Hospital Charity, Help Musicians UK, Dunhill Trust), sports clubs (Liverpool FC, LFC Foundation, Everton FC, Manchester United FC), national and international sports bodies (English FA, EIS), industry (Nike Inc., New Balance, GlaxoSmithKline, Danone Waters, MINERVA Research Labs, Globus Italia), and Government (MOD, Defence Science and Technology Laboratory).

Infrastructure and Facilities

Experienced and influential leadership over the years has facilitated a strategic approach to growth and innovation in research. Successful planning has underpinned excellence that has been recognised through the University's investment in staffing and infrastructure enhancing the quality and sustainability of the research environment. The RISES Research Groups facilities and laboratories are all housed over 2 floors (~2000m^2) in TRB and the adjoining three-storey LSB in an environment that provides all the essential resources to investigate the impact of exercise, activity and disuse on molecules, proteins, cells, systems

and organisms in an integrated fashion. The co-location of human-based and other animal laboratories allows interrogation of the exercise response within a comprehensive world-class infrastructure. This provides an exciting platform from which to investigate emerging research questions in exercise and health and thereby sustain future world-leading scholarship. The two Exchanges are in a separate building designed for applied work on the same campus and comprise of a Human Performance Unit and exercise rooms, physical activity analysis labs, physiotherapy suite, match analysis room and meeting spaces. This enables translational activity with high performance athletes and exercise and health interventions for the community. These activities will be significantly enhanced since the reorganisation of Faculties in 2019 included an Estates Strategy to replace the IM Marsh campus sports facilities with a new £22.6M Sports Building at the neighbouring Copperas Hill site in the City campus (February 2021). This includes a two-storey sports building with an eight-court sports hall, two multi-purpose studios and a state-of-the-art gym that will enable an escalation of applied sport and exercise science, physical activity, PE and sport coaching research activities, in addition to teaching and university sports.

Following on from the REF2014 QR funding allocation increase, the University also took the strategic decision to front-load the distributed QR income and this allowed major infrastructure investment at the start of the current REF period (2015-2016) that included an allocation of £750K for research equipment. We invested in state-of-the-art technologies early in the period so that research work could benefit immediately from enhanced infrastructure. For example, QR supported a high-resolution LC-MS/MS system (Waters nano Acquity UPLC and QToF Premier Mass spectrometer) that was crucial for establishing new methods for the analysis of stable isotope-labelled samples. We subsequently became world-leaders in muscle proteome dynamics and the only Sport Sciences unit to have such proteomics/mass-spectrometry capacity in-house (**REF2#654, REF2#2112**). To date, we are the only institution able to report the three constituent components of protein turnover (synthesis rate, abundance and degradation rate) on a protein-by-protein basis in human muscle, as well as non-human animal models and cell cultures. This strategy and foresight at LJMU accelerated research and has led to a 3-fold increase in capacity to make functional outcome measures in humans and new analytical capacity for blood and muscle samples in the dedicated TRB and LSB laboratories. Our discoveries in this area pave the way for new mechanistic investigations of the regulatory role of protein degradation in muscle adaptation. Our latest method “Absolute Dynamic Profiling Technique for Proteomics (Proteo-ADPT)” (**REF2#2112)** is unique to LJMU and offers unparalleled analyses of the dynamic responses of muscle to exercise and lifestyle interventions.

Bespoke laboratories in TRB provide integrated space to investigate a wide range of acute exercise and training interventions in health and disease with adjoining muscle biopsy suites. The state-of-the-art environmental chambers allow exercise interventions in a wide range of environmental conditions controlling temperature, humidity and atmospheric gas content (-20 to 50°C with normobaric hypoxia capability to simulate an altitude of up to 4500 m). State-of-the-art equipment is also available to measure functional indices that include VO_2max, time-trial performance, muscle strength (isometric and isokinetic dynamometers), and body and muscle morphology (DEXA and high-resolution ultrasound).

Physiology, Biochemistry and Molecular and Cell Biology Laboratories:

We have the latest Randox Daytona+ clinical chemistry analyser to measure blood and tissue metabolites, hormones and cytokines and MALDI-ToF, LC-MS/MS and GC-MS mass spectrometers to measure the plasma and muscle proteome (see details above). The adjacent LSB provides world-class research suites and analytical facilities. These include excellent rodent facilities with individually ventilated cages and surgical theatres, recording rigs for electromyogram, electroneurogram and muscle force, and electroporation for transfection of muscle fibres in vivo. This facility allows RISES researchers to complement their strength in human muscle metabolism research with studies in unique transgenic rodent models imported from world-leading rodent laboratories. Mechanistic, cellular and molecular physiology research is supported in LSB by i) an imaging suite (confocal and wide-field fluorescence microscopy with tile scanning and automated image analysis; inverted light microscopy; transmission and scanning electron microscopy) for visualisation of live cells and sections of muscle (heart and skeletal), tendon, bone, adipose tissue, vascular endothelium and smooth muscle cell layers; ii) a cell culture suite including muscle organ culture from commercial and primary human cells with exercise models such as cyclic mechanical stress and electrical stimulation, and circadian rhythm assessment to follow cell metabolism via fluorescent and luminescent markers in multi-well plates; iii) molecular biology and biochemistry laboratories for mRNA,

DNA and protein preparation and analysis (RT-PCR, DNA methylation and polymorphism analysis, Western blotting, ELISA and FLOW cytometric analysis); iv) an HTA-approved LJMU human tissue bank; v) an HPLC suite, and vi) a DNA/RNA suite with additional PCR and sequencing facilities. Successful joint projects also make use of the facilities overseen by the Technology Directorate at the University of Liverpool and allow us access to microCT and bioluminescence imaging, small animal MRI, and next generation sequencing including whole genome transcriptomics by RNA sequencing.

Cardiovascular Laboratories:

The cardiovascular TRB labs allow acquisition and analysis of real-time images related to blood vessel and cardiac structure and function, covering the entire cardiovascular tree (cardiac, vascular, cerebrovascular) at the level of conduit, resistance and micro vessels. Three state-of-the-art echocardiographic systems provide 2D, M-mode, Doppler, tissue-Doppler and strain imaging capacity (GE Ltd; Echopac) with additional software for coronary flow assessment and left ventricular opacification. A further 6 vascular ultrasound machines (Terason) provide 2D and Doppler imaging of intima media thickness, diameter, flow, shear stress and endothelium (in)dependent dilation in central and peripheral conduit arteries. Microvascular function (skin) is examined with 4 Laser Doppler set-ups (Perimed and Moor systems), which can be combined with microdialysis of vasoactive substances. Three dedicated rigs for trans-cranial Doppler (Spencer and DWL) provide state-of-the-art insight into cerebrovascular function, autoregulation and neurovascular coupling. Electrocardiography (ECG) and finometry allow assessment of heart and vascular function. Data are acquired in 3 temperature-controlled ultrasound laboratories complemented by an analysis room with dedicated, encrypted image and data server and workstations that include automated, validated and observer-independent vascular and cardiac analysis software. Customised software analysis, introduced and validated in our lab, allows for dynamic insight into cardiac and vascular function.

Biomechanics Laboratories:

The TRB biomechanics laboratories are equipped for the study of in-vivo fundamental, sport and clinical human biomechanics from the muscle-tendon level to whole-body locomotion. Two large research laboratories and a 70 m runway are equipped with optoelectronic motion capture systems (2 Qualisys Oqus with 8 & 10 cameras), 3 force platforms, plantar pressure measurement systems, wireless electromyography and Xsens inertial sensors to allow complex movement analysis. The mechanical and geometric properties of the human musculoskeletal system are examined using dynamometry and ultrasound imaging. A further laboratory houses a CAREN virtual reality system including a large display screen, a computer driven motion platform with integrated Kistler force plate, an M-gait instrumented double-belt treadmill, a Vicon MX system with 16 T-series cameras and a Vicon Vero with 12 cameras and EMG. This laboratory also has a unique custom-made staircase instrumented with 4 independent Kistler force plates, ultrasound scanners for in vivo muscle-tendon behaviour during locomotion, and was recently equipped with software for marker-less motion capture (4xMiqus Colour, synchronised cameras and Theia Markerless software. These tools are integrated to: i) study posture and balance and the prevention of stair falls in the elderly, ii) examine muscle-joint structure and function in patients with cerebral palsy to optimize treatment, iii) provide real-time feedback for gait modification strategies to reduce joint loading and pain during gait in pathological conditions.

Brain and Behaviour Laboratories:

Our sensorimotor neuroscience TRB laboratories now house apparatus for non-invasive brain imaging (near infrared spectroscopy and EEG) and neural navigation. In combination with existing apparatus for non-invasive brain stimulation (tDCS, TMS, EMG), video-oculography (EyeLink1000) and wireless motion analysis (Optotrak 3D Investigator), this unique laboratory enables world-class research on the neural mechanisms that underpin perceptual, cognitive and motor processes of human skill development, control and learning.

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

Research Collaborations, Networks & Partnerships

Research collaborations with other leading national and international institutions and world-leading scientists are among our key strengths and a main pillar of our world-class research environment with significant benefits for all staff and research students. The quality and significance of these collaborations are also reflected in the large number joint publications with international partners (64.5% of all our 1178 outputs in this period are co-authored with international collaborators from 107 countries). Some highlighted examples from this large number of excellent and fruitful collaborations (and resulting REF2 returns) are described below.

In the area of Sports Genomics **Akhmetov** and **Erskine** are members of the Athlome Project Consortium and the BASES Molecular Exercise Physiology Steering Group. Via these channels they have established collaborations leading to joint publications (**REF2#731, REF2#635, REF2#852)** with world renowned Sports Genomics researchers including Pitsiladis, Montgomery and Williams in the UK, Collins (University of Cape Town), Bouchard (Louisiana State University) and North (University of Melbourne). **Close** has a long-standing collaboration with Jackson and McArdle at the University of Liverpool resulting in numerous publications on exercise-induced redox signalling and redox-regulated exercise adaptive responses in aged human skeletal muscle **(REF2#1419, REF2#2109). Close** is also collaborating with Fraser at the UEA, a world leader in the assessment of vitamin D and its metabolites. The collaboration resulted in 11 co-authorships to date to include **REF2#415** and **REF2#744** and numerous presentations at international conferences. Research on optimal vitamin D strategies for athletes has attracted many citations and featured on international news channels. **Burniston** has international collaborations with Hawley (ACU) and Camera (Swinburne), Phillips (McMaster), van Loon (MU), Chen (Washington DC), Esser (Florida), Koch (Toledo) and Britton (Michigan) working on muscle proteomics and exercise responses (e.g., **REF2#640, REF2#654**). **Cocks, Shepherd** and **Wagenmakers** are members of the Exercise for Type 1 Diabetes (EXTOD) collaborative research group that brings together clinical researchers Andrews (Exeter) and Narendran (Birmingham), NHS organisations and academic researchers aiming to develop evidence-based exercise support for people with Type 1 diabetes (**REF2#602, REF2#680, REF2#698**). **Shepherd** also established a collaboration in 2016 with Ørtenblad and Nielsen (University of Southern Denmark). They are world leaders in quantitative analysis of lipid droplet and glycogen content in skeletal muscle fibres using TEM with the collaboration so far resulting in an output (**REF2#2119)** and a PhD project completion at LJMU. **Shepherd and Strauss also** collaborate with Chow (Minnesota) to investigate differential responses of lipid droplet dynamics in trained and sedentary individuals during a lipid infusion (**REF2#840). Jarvis** and **Stewart** collaborate with Sharples (Norwegian School of Sport Sciences, Oslo) on muscle memory investigating cellular responses to repeated episodes of training and disuse (**REF2#836**, **REF2#839**). In biomechanics, **O'Brien** collaborates with orthopaedic surgeons at Alder Hey Hospital, Desloovere (KULeuven) and Bar-On (VU Amsterdam) on musculoskeletal function of children with cerebral palsy (**REF2#237, REF2#847**) and **Robinson** collaborates with Pataky (Kyoto University) on time-series statistical analysis and specifically statistical parametric mapping (**REF2#824, REF2#849**).

There are numerous other collaborations linked to the work of our Exchanges, including physical activity, sedentary behaviour and cardiovascular health with Dunstan and Healy at the Baker Institute (**Hopkins**) and Geurts (Radboud University, **REF2#2055**), Welk at Iowa State and Saint-Maurice (NIH) on international Youth Physical Activity Profile studies (**Boddy**), Macefield (Baker Institute) and Taylor (Western Sydney University) on muscle sympathetic nerve activity (**Sprung** and **Low)**, and Hellsten in Copenhagen (**Thijssen, Jones, Cocks, REF2#858)**. The FEx through the work of **Gregson, Littlewood, Morton, Close & McRobert,** partnered with Isokinetic Medical Group since 2016 on four 'Football Performance' focused days at the Football Medicine Conferences in 2016 (London), 2017 (Barcelona), 2018 (Barcelona) and 2019 (London) as the only academic partner of the events. The partnership has gone from strength to strength, and there has been clear and demonstrable benefits for training, development and communication opportunities (see also **ICS5**).

Contributions to Research Base

The experience, reputation and standing of RISES staff in the academic community are reflected in their important professional roles and academic responsibilities and involvement across the world allowing outstanding contributions to the sector and the scientific community.

Editorships

Several staff are Editorial Board members in some of the most prestigious journals in our sector including the American Journal of Physiology - Section Endocrinology and Metabolism (**Wagenmakers**), Journal of

Cellular & Molecular Exercise Physiology (**Stewart)**, Physiological Genomics (**Burniston**), Proteomes (**Burniston**), Journal of Applied Physiology (**George**, **Thijssen**), Scientific Reports (**Jarvis**), Experimental Physiology (**Dawson, Thijssen**), Frontiers in Physiology (**Low**, **Owen**), Frontiers in Cardiovascular Medicine (**Thijssen**), Echo Research and Practice (**Oxborough**), Ultrasound Official Journal of the British Medical Ultrasound Society (**Oxborough**), Frontiers in Exercise Physiology (**Oxborough**), Frontiers in Paediatric Cardiology (**Oxborough, Jarvis**), European Journal of Applied Physiology (**Baltzopoulos, George, Low, Dawson**), European Journal of Sports Science (**Close, Morton**), International Journal Sport Nutrition Exercise and Metabolism (**Close, Morton**), Clinical Science (**Jones**), Journal of Biomechanics (**Baltzopoulos**), Sports Biomechanics (**Robinson**), Gait and Posture (**Hollands**), Journal of Sports Sciences (**Bennett**, **Bradley, Louis**), Journal of Sport and Exercise Sciences (**Robinson**), Biology of Sport (**Akhmetov**), Frontiers in Nutrition (**Areta**), International Review for Sport and Exercise Psychology (**Tod**), Journal of Sport Psychology in Action (**Butt)** and International Journal of Environmental Research and Public Health (**Boddy**).

Conference Keynotes and Scientific & Organising Committees

The selection of keynote and invited presentations below demonstrates the respected international reputation of our researchers and the influence and significance of their work.

There were keynote and invited presentations at ECSS (**George** 2014, 2016, **Jones** 2014, 2019; **Thijssen** 2017; **Oxborough** 2019), ACSM (**Close 2017**; **George** and **Thijssen** 2015), ISB (**Maganaris** 2019), ESSA **(George, Jones and Oxborough** 2016), ASCA (**Close** 2016) and ICCE (**Morton** 2017). **George** delivered keynote presentations on physical activity and the GAC initiative including the 15th Asiania Sport for All Association (ASFAA) Congress (2018), All China Sports Federation with TAFISA and ASFAA (2018), 26th TAFISA World Congress, Tokyo, (2019). **Low** delivered an invited lecture at the joint meeting of the International Society of Autonomic Neuroscience, the European Federation of Autonomic Societies and the American Autonomic Societies (2015). **Thijssen** delivered keynote lectures at the World Congress for Microcirculation (2018) and the EuroPrevent annual meeting of the European Society for Cardiology (2017). **Oxborough** also had invitations to EuroPrevent (2018) and the World Extreme Medicine Conference (2015, 2016). **Jarvis** delivered the keynote lecture on 'omic technologies at the International Vienna Workshop on Functional Electrical Stimulation Vienna 2016. **Tod** was keynote speaker at the International Society of Sport Psychology conference (2017) and **Butt** was keynote speaker at the Australia Performing under pressure: Developmental Perspectives (ModelAthlete) conference (2018)**.**

Our leadership position within Sport and Exercise Sciences means we continue to make unique and strategically important bids to host major national and international conferences and specialised meetings and courses. We organised the International Society of Biomechanics in Sports (ISBS) conference (2020), the first time hosted in the UK (**Robinson and Lake**), but the Covid-19 pandemic allowed online activities only; the ISBS conference will be hosted again at LJMU in July 2022. **Barton** organises the annual European Society for Movement Analysis in Adults and Children (ESMAC) Gait Course, and **Hollands** was co-host of the International Society of Posture and Gait Research (ISPGR) International Congress 2015, Chair of the scientific content committee in 2017 and as ISPGR President oversaw the planning for the 2019 meeting in Edinburgh. **Low** was a convenor and Co-Chair of the Experimental Biology Annual Meeting, (2014). **Oxborough** has been directly involved in organising and running the annual conference of the British Society of Echocardiography (BSE), the BSE Advanced Imaging Course and joint BSE/Irish Cardiac imaging Group conference throughout (2014-2020) and the FA Screening in Athletes course in 2016 and 2021. **Clark** is Organising Committee member for the UK Sports Science and Medicine Conference. **Knowles** was Co-Chair for the ICCE Global Coaching Conference 2017, held in Liverpool. **Jarvis** was on the scientific organising committee meeting for The Bone Research Society annual meeting Liverpool 2016 and organised the schools outreach programme for that conference.

Awards

Excellence has been recognised with a range of individual and group awards including Research Team of the Year 2015 at the inaugural 'Educate North' Awards for RISES led by **George** and the TAFISA Mission2030 Academic Partner Award 2019 for LJMU (**Boddy, Knowles, George,** PAEx). **Barton's** clinical biomechanics work was shortlisted for Best Research Project, Educate North 2016. **Thijssen** won the Acta Physiologica Rising Star Award 2017 and **Burniston** was nominated for the American Physiological Society (APS) "OMICS Distinguished Lecturer Award" 2020 (see also 'Proteo-ADPT' method in Infrastructure and Facilities).

Scientific Societies and Professional Associations

Our staff have key leadership and responsibility positions in several scientific and professional associations making significant contributions to the research base and our sector in general. For example, **Hollands** was ISPGR President until 2020, **Knowles** was BASES Chair for the Division of Psychology and Board member (2018-2020) and BASES CPD Lead 2014-2018 and influential in the development of SEPAR, the psychology accreditation route to HCPC registration of BASES members. **Knowles** is also the first woman elected Chair of BASES and is currently Chair Elect. **Stewart** is Chair of the British Society for Research on Ageing, British Endocrine Society Public Engagement Board Member and Training Group and Management Group Member (LJMU representative) in the University Alliance Doctoral Training Alliance for Health. **Wagenmakers** is on the International Physiology Committee (IPC) of APS and until July 2014 Chair of the Scientific Board followed by Membership of the Advisory Board of ECSS. **Close** is Deputy Chair of the Sport and Exercise Nutrition Register. **Jarvis** is Executive Board (Secretary) for the International Functional Electrical Stimulation Society and **Barton** is elected board member of ESMAC. **George** and **Burniston** are ECSS Scientific Committee members and **Baltzopoulos and Thijssen** are on the ECSS reviewing panel. **Oxborough** is Co-Chair for the Research and Audit Committee of the British Society of Echocardiography and representative to the British Heart Foundation Clinical Research Collaborative. **Chester** is BASES Clean Sport Interest Group steering committee member. **Louis** is Member of the UEFA Nutrition Expert panel. **Butt** is Deputy Chair and **Eubank** a member of the Training and Standards Partnership Committee in the Division of Sport and Exercise Psychology, of the British Psychological Society. The contributions of our staff are also recognised through Fellowships from various professional and scientific associations including ACSM (**George**), ECSS (**Burniston, Close** and **George**), BASES (**Baltzopoulos, Close, Knowles**) and the Physiological Society (**Wagenmakers,** Elected Fellow since 2018).

Consultancies

There are important contributions to various external organisations through consultancies and advisory roles including England Rugby and European Tour Golf (**Close**), Liverpool FC and Team Sky (**Morton,** Head of Nutrition), FC Barcelona and VizRT (**Bradley),** UK Anti-Doping (**Chester**), EIS acclimation review panel and Para-swimming Sports Science Support team for Tokyo 2020 (**Doran**), Team GB Rio Olympics and England Rugby coping strategies for travel and jet lag (**Edwards**), French Football Association (**Louis** Consultant Nutritionist of the World Cup French winning team), Liverpool FC (**Louis** 2015-2016) and Lille Football Club (**Louis** 2016-2018). **Butt** has had consultancies with the British Equestrian Federation and Sport England, McMillan Cancer, England Volleyball and Sport England. **Jarvis** was consultant to Prof. Sir Ian Kennedy for the commissioned review of the Alder Hey archive.

Contributions to UKRI & International Research Councils

Our experienced researchers make significant contributions as reviewers to UKRI, other UK & International Research Councils and funding bodies including BBSRC (**Baltzopoulos, Close, Jarvis, Stewart, Wagenmakers**), MRC (**Baltzopoulos, Boddy, George, Wagenmakers**), EPSRC (**Baltzopoulos,** member of EPSRC peer-review College), ESRC (**Boddy**), BHF (**Boddy, Dawson, Hopkins, Jarvis, Jones, George, Low, Oxborough, Wagenmakers**), NIHR (**Boddy, Cocks, Edwards, Jones, Watson**), Diabetes UK (**Jones, Wagenmakers**), Wellcome (**Jarvis, Thijssen, Wagenmakers**), Dunhill Medical Trust **(Jones, Wagenmakers)** and Action Medical Research (**Boddy, Jones**). **Wagenmakers** is an expert reviewer for the European Research Council (ERC) and **Stewart** is an external expert reviewer for South Africa's National Research Foundation (NRF) and Royal Society of Biology commentary provider.

Public Engagement Contributions to Impact, Economy & Society

Sport and Exercise Sciences has the first University Strategic Lead for External Engagement and NCCPE Public Engagement Professional (**Knowles**), establishing an internal promotion pathway to Professorship in Engagement. External Engagement is embedded within our mission and core activities and staff have a multi-award winning track-record of public engagement funding through Royal Society, NIHR, Learned Societies and Universities UK and delivery experience with museums, schools, hospitals, charities, art galleries, cultural events and community groups. We have developed innovative, inclusive and engaging learning opportunities acting as a sector beacon of excellence for public knowledge exchange to over 15,000 members of the public in 5 years. Since 2016 we are an inaugural learning partner with Eureka! to co-develop with children and young people their first sport and exercise science installation opening in 2022 aiming to inspire the scientists of the future. Our conference organisation bids contain a public engagement commitment to impact beyond that of delegates. For example, LJMU hosted the ICCE Global

Coach conference (2017) and supported local coaches, schools and the public through free engagement activities. Researchers are encouraged to include PPI and consider how this will be evidenced and implemented in an ethical and pragmatic way informed by UK Standards for Public Involvement and NCCPE training. **Close** is an expert in Sport Nutrition and recipient of the prestigious Sport and Exercise Nutrition register (SENr) Award for Innovation (Media and Industry, 2018). **Whyte** is formally recognised as one of the top 10 Science Council Communicators in the UK and since 2019 sits as an elected Director of UKActive. His high-profile public engagement with the Comic Relief Charity "Challenges" have led to >£30 million of charity fund raising. The Mission2030 Academia Award by TAFISA in 2019 commended our openness and readiness to share our expertise with the world, and train stakeholders, universities and cities worldwide to promote physical activity. Our commitment to encourage girls into a sector traditionally underrepresented by women through our annual 'Here Come the Girls – The Future of Sport and Exercise Scientists' events and support of The Girls Net (LJMU Corporate Charity) with staff mentoring/projects aligns with our EDI agenda priorities. This is very important for the future of our subject area and a fitting reflection of our own history and tradition. The IM Marsh College of Physical Education that was one of the founding institutions of LJMU, was established in 1900 by Irene Mabel Marsh who started a revolution in Physical Education and demonstrated that girls should receive instruction in PE. She devoted her life to enthusing generations of students about the importance of physical activity. Our public engagement initiatives are sustainable and underpinned by inspirational leadership, tradition, experience and strategy with movement towards embracing civic and place-based engagement to inform our practices.

In summary, through exceptional leadership, visionary thinking and strategic planning we remain at the forefront of originality and research quality having had a vital formative role in the birth of this discipline. Over almost half a century, since the early 70's, our School and Research Institute have continued to serve and expand our founding mission to engineer excellence in research and innovation and promote interdisciplinary work and research translation for the benefit of our region, country and the world. Our endeavours have created unique approaches, world-leading research and award-winning public engagement with a collective commitment and guided by the enduring strength of LJMU's vision to make a difference to the lives of all people through sport, exercise, physical activity and health.