Institution: Liverpool Hope University (LHU)

Unit of Assessment: Sport and Exercise Sciences, Leisure and Tourism (C24)

1. Unit context and structure, research and impact strategy

The UoA24 at Liverpool Hope University is composed of 10 colleagues and sits within the School of Health Sciences alongside Human Biology, Applied Biomedical Health and (Clinical) Nutrition, which affords excellent networks for collaborative and multidisciplinary science research.

Since the Unit made its first REF submission in 2014, the University's, School's and Unit's Research strategies have been instrumental in enabling the continued evolution and development of a vibrant, established research culture in Sport and Exercise Science. In the context of this Unit, high-quality research outputs (publications) of national and international excellence were recognised as a key objective across the research groups for the 2014 REF. This was achieved, as measured by the quality of the outputs in the REF2014 submission, in which the Unit demonstrated international excellence in selective areas of research output and ranked 2nd in the Northwest for research intensity. However, the Unit noted an evidently restricted scope of research returns (primarily physiology) and insufficiencies in focus on research impact (i.e. informing end users and policy-makers).

Addressing these entities necessitated an evaluation and reformulation of the research environment strategy. Thus a strategic restructuring of research groups within the Unit was undertaken in 2014, in order to provide an infrastructure that would advance and support the research of colleagues with shared and cognate areas of expertise, enabling the realisation of the Unit's future aims. Supported by the appointment of new staff, internal equipment funding and new laboratory facilities, the 3 Research Groups became: Musculoskeletal Sports Medicine, Exercise Performance and Health Physiology, and Psychology of Action and Learning of Movement, with each group led by a senior academic. The restructuring considerably widened the scope of the Unit from a sole focus on physiology whilst permitting overlap for multi- and interdisciplinary approaches to research.

Musculoskeletal Sports Medicine Group

Led by Professor Omid Khaiyat (strategic recruitment from the University of Liverpool). Members: Dr Coyles, Dr Jackson, Associate Professor Roche. This research group is supported by membership of staff from other Units based within the School, PhD Scholarships, on-site physiotherapy/rehabilitation clinicians, visiting professors (Professor Simon Frostick and Dr Chris Wong), and strategic external research advisors/collaborators e.g. Dr Ian Horsley from the English Institute of Sport (EIS), Mrs Jo Gibson and Mr Rish Parmer from Liverpool University Hospitals NHS Foundation Trust. Colleagues from the Musculoskeletal Sports Medicine Group have two primary areas of research focus namely: *Upper Limb/Shoulder Research* with a remit to understand the pathophysiology of upper limb/shoulder injury and efficacious means by which to promote healing and rehabilitation (see *Internationally Recognised Research Excellence)*; and *Musculoskeletal Health in Older Adults With/Without Clinical Conditions*, with a remit to investigate interventions that mitigate declines in musculoskeletal health that accompany the ageing process. This latter research strand has included interdisciplinary projects such as the musculoskeletal health benefits of tennis, interventions for healthy ageing and age-related sarcopenia (RCT-NCT02912130), and musculoskeletal health and function in older adults with iron deficiency anaemia (RCT - ISRCTN13325706).

Exercise Performance and Health Physiology Group

Led by Dr Angell. Members: Associate Professor Marwood, Associate Professor Roche, Dr Malone, Dr Dagger, and Dr Jackson. Colleagues in the Exercise Performance and Health Physiology Group have research interests in *Cardiovascular & Metabolic Health* and *Sports Performance*. Within *Cardiovascular and Metabolic Health*, a wide-range of techniques (cardiac imaging, peripheral vascular ultrasound, flow mediated dilation, pulse wave velocity, laser Doppler, VO_2 kinetics, near infrared spectroscopy) are utilised to investigate fundamental and applied/interventional aspects of human health. Sports Performance colleagues examine effective workload monitoring and application in sport, and the modelling of sports performance.

Psychology of Action and Learning of Movement Group

Led by Associate Professor Wakefield. Members: Dr Koehn and [Drs Wood & Roberts - both now external at Manchester Metropolitan University and Liverpool John Moores University, respectively]. Colleagues in this group have research interests incorporating areas surrounding *Human Movement Science*, *Sport and Exercise Psychology*, and *Sport Coaching and Pedagogy*. Research projects include the exploration of the mechanisms and learning efficacy of motor imagery, examining the equivalence between imagery and execution, the effect of action observation and motor imagery combinations on upper limb kinematics and EMG, and simultaneous and alternate action observation and motor imagery combinations improve aiming performance.

The research groups provide a concentrated mass of colleagues with complementary research specialisms who meet regularly to share ideas, develop and undertake collaborative research projects and support one another in peer review (manuscripts, research proposals), external funding bids and postgraduate research supervision. The research group infrastructure aligns with the School Research Strategy which articulates that all staff are expected to contribute towards a productive research environment within the School. Staff readily contribute into more than one Research Group in accordance with the aims of the Unit and the Research Group.

Shortly after publication of the REF2014 report, the University emphasised the significant role of critical friends with broad REF-related knowledge and experience as a means by which to promote research excellence. Accordingly, an experienced external advisor was identified and appointed for the Unit. The Unit has benefited from this appointment over the past six years due to the vigorous and constructive feedback appraising our research environment enhancement strategies in addition to the quality of our research outputs, the efficient development of impactful research and our related case studies. The external advisor attended the Unit's Annual Research Day over the past 5 years, and this embedding facilitated a better understanding of ongoing activities and an efficient interaction with the Unit.

Research and Impact Strategy

Building on successes of 2014, our strategic aims were: (i) Interdisciplinarity & Multidisciplinarity for real-world impact; (ii) Internationally recognised research excellence; (iii) Enhancing the wider research environment to support aims (i) and (ii).

The focus of (i) resulted from the desire to undertake empirical research for the advancement of knowledge and understanding that can make an impact on real world issues, and thus promote translational research which bridges the gap between laboratory-based research and applied

practice. This strategic focus recognised the need for multidisciplinary and interdisciplinary research through which to achieve this. Given the Unit's size, operating in an increasingly collaborative manner was necessary to facilitate and enable rigorous and applied multi- and interdisciplinary research. Accordingly, and in line with aim (iii), members of the three research groups within the Unit are expected to establish wider academic networks with other researchers external to Hope. In addition, the research groups are expected to establish and maintain links with key beneficiaries and stakeholders such as sport governing bodies and local NHS trusts, in order that our research has a positive societal impact.

Evidence of activities and actions towards *'Interdisciplinarity & Multidisciplinarity for Real-World Impact'* include our large-scale study into the musculoskeletal, cardiometabolic, psychological and nutritional health benefits of tennis (ICS1: The Health Benefits of Tennis). This comprehensive research project was both interdisciplinary and multidisciplinary in order to gain a more coherent and enriched knowledge and understanding of the health benefits of the sport. It was led by the *Musculoskeletal Sports Medicine Research Group* with input from colleagues from other research groups (Associate Professor Roche, *Exercise Performance and Health Physiology Group*; Dr Koehn, *Psychology of Action and Learning of Movement Group*), plus other members of the School from outside of this Unit (Associate Professor Amirabdollahian, Nutritional Sciences). From the conception stage, the research was designed around generating an impactful outcome for a real-world problem: evaluating the efficacy of tennis, from a number of perspectives, as an ecologically valid solution to promote and secure the health benefits of physical activity in our growing sedentary population. The multi-dimensional data collection of this study with more than 90 participants was completed in 2018, supported by a HEIF allocation to recruit a post-doctoral research fellow.

The study findings (published in international peer-reviewed journals and presented at international conferences indicated a strong association between regular tennis and markedly lower risk of musculoskeletal and cardiometabolic disease, in combination Improved indicators of quality of life. including mental health. Translational value and the potential to make real-world impact occurred through establishing significant collaborations with key local tennis and health bodies and national level governing bodies (e.g. Lawn Tennis Association (LTA) (Section 4). A "Tennis and Health" symposium to communicate and widely disseminate findings, hosted by the Unit in 2018, brought together key stakeholders including representatives from the National Tennis Centre and the British LTA, the Director of Public Health for Liverpool, policy makers, health care professionals, local tennis club managers and members, study participants and the wider public. This project was included in the Parliamentary Report of the Physiological Society detailing the benefits of sport science research to the UK economy (https://bit.ly/35KjyQX; page 33).

This interdisciplinary research strategy with real-world focus underpinned the development of further major projects with a focus on musculoskeletal health in older adults. Key examples include two RCTs in the fields of Sarcopenia (NCT02912130) and Iron Deficiency Anaemia (ISRCTN13325706). The success of the Sarcopenia RCT, involving academics from multiple disciplines, can be judged not only by the wide dissemination of findings by means of scientific publications and conference presentations but also educational workshops to relevant communities and stakeholders (Section 4). ISRCTN13325706 is an externally funded trial and seeks to investigate the impact of intravenous iron therapy on musculoskeletal health in older patients with iron deficiency anaemia in collaboration with Liverpool University Hospitals).

Further key successes in addressing real-world issues include the study of adverse cardiovascular effects of overuse of Anabolic-Androgenic Steroids (AAS), a key focus for Dr Angell (*Exercise*

Performance and Health Physiology Research Group). Research within this field led to a number of academic outputs which formed the basis for collaboration with international colleagues. This culminated in an invited book chapter founded on Dr Angell's research [Clinical Implications of Performance Enhancing Drugs upon Cardiovascular Health in Wilson M, Drezner J & Sharma S (Eds). The Olympic Manual of Sports Cardiology. ISBN-10: 1119046866] that formed part of the International Olympic Committee's Manual of Sports Cardiology. This book is a key contemporary text for sports cardiologists and clinicians in the field. Publication extended the reach and impact of the research, including an invitation to speak at a clinical conference and appearances in local and national media: Invited conference presentation (Cardiac Effects of Doping. 13th Belgian Heart Rhythm Meeting, Brussels, 2019); BBC Horizon: Sports Doping – Winning at any cost; Radio City (appearance by Dr Angell).

Internationally Recognised Research Excellence

The second aim of our research strategy was to develop at least one area of research activity within the Unit into one of internationally recognised research excellence. This objective focused upon the *Upper Limb/Shoulder Research* strand of the *Musculoskeletal Sports Medicine Research Group*. Led by the Head of the School of Health Sciences, Professor Khaiyat has been instrumental in strategically establishing Upper Limb/Shoulder Research in the Unit as an internationally recognised research environment in the field. The Unit's key actions towards achieving this strategic goal include: 1) Organising and hosting a biannual international *Shoulder Rehabilitation Conference* (1st & 2nd conference in Nov 2017 & Nov 2019, respectively - https://www.hope.ac.uk/hopesr/). This conference has been praised as a highly credible scientific event in the field of shoulder rehabilitation due to its trending themes and high profile and research-active speakers. 2) Establishing formal partnership with the English Institute of Sport (EIS) for collaborative Upper Limb / Shoulder Research (since July 2018) and strategic collaboration with the Upper Limb Unit at Liverpool University Hospitals. 3) Organising and hosting multiple upper limb clinical research workshops for leading research-active clinicians including shoulder ultrasound, upper limb kinetics/kinematics, exercise prescription, return to sport, profiling shoulder performance, and shoulder fine-wire electromyography. 4) Coordinating and hosting educational and research collaboration/networking events at Liverpool Hope University including the *Noraxon User Group Annual Meeting 2018* and the EIS *Annual Upper Limb Research Group Meeting 2016*. 5) Undertaking several major shoulder/upper limb research projects involving academics, external clinicians and collaborators, and PhD/MRes students (Section 4 for more details). Concerted action and focus by the group has enabled the development and maintenance of a significant level of research outputs across projects investigating: the influence of kinetic chain sequencing on throwing performance in athletes with and without shoulder injuries; the pathophysiology of subacromial impingement syndrome; neuromuscular profiling of the throwing shoulder; kinematics and muscle activation profiles in reverse shoulder arthroplasty; the effect of vibration on shoulder muscle activation and fatigue; electromyographic analysis of shoulder girdle muscles in swimmers with shoulder pain; and electromyographic evaluation of a broad range of exercise modalities for shoulder rehabilitation. This resulted in an excess of 20 publications and >30 international scientific conference presentations during the current REF cycle.

The third part of the research strategy aimed to make further and substantial enhancements to the wider research environment to support strategic aims (i) and (ii). Planned enhancement targets included: a) staff research development and support, including postdoctoral and early-career researchers; b) recruitment and supervision of postgraduate research students; c) major investments in research resources and laboratory facilities; d) external research funding and grants; e) consolidation and diversification of external collaborations both nationally and

internationally. Targets 'a' and 'b' are detailed in full in (Section 2: People), c and d in (Section 3: Income, infrastructure and facilities) and e in (Section 4: Collaboration and contribution to the research base, economy and society).

In summary, we have pursued a clear, realistic and focussed research strategy since REF 2014 that has distilled research focus through effective changes to the infrastructure of research groupings. Opportunities, productivity and efficiency have been augmented through the major investment in research facilities and supported through enhanced postgraduate provision, mentoring and staff development. The strong and effective establishment of partnerships and collaborations and the securement of research grants has enabled the successful translation of key areas of our research to stakeholders and end users. Upper limb/shoulder research at Liverpool Hope has gained prominence nationally and internationally as a leader in its field. Our strategy is logical, sustainable and appropriate for the School of Health Sciences and wider University for supporting and delivering high-quality sport and exercise science research.

Future Aims and Goals

The Unit has seen a period of significant maturation and further development during this REF cycle and has reaffirmed that the existing infrastructure and the research and impact strategy are fit-for-purpose (evidence of the broad success of the current strategy for research outputs and impact are reported elsewhere). The focus for the Unit 2021+ will be to prioritise planning for continued growth and the sustained procurement of research opportunities for all groups, to enable the maintenance of high-quality research and its impact.

Our strategic aims for 2021+ are therefore:

1. The continued expansion of current research specialisms, ensuring flexibility to embrace new and viable research directions via a strong staffing strategy that guides recruitment. Strategic staffing appointments will focus on enabling research teams to grow and increase their capacity to undertake and produce multidisciplinary and transdisciplinary research that is relevant, high-quality and impactful.
2. To further increase external grant funding applications as a necessity for maintaining a vibrant research environment. The Unit has had modest success in this REF period (Section 3) and will build upon its current position as a basis for the future.
3. To further enhance the development of key growth areas of research within the Unit with regards international recognition, research excellence, funding and collaboration using The *Musculoskeletal Sports Medicine Group's* notable research strategy as a template.
4. To extend, consolidate and strengthen the established *Exercise Performance and Health Physiology Group's* collaborative partnerships with local NHS trusts to augment translational research in response to national and international priorities.
5. To continue to further enhance the excellence of our high-quality outputs in mainstream, internationally recognised (and Open Access) outlets to maintain our international profile and ensure relevance and timeliness of our research and its impact.
6. To continue and extend our proactive efforts for the recruitment of high-quality postgraduate students for the further development and sustainability of our supportive PGR research environment.
7. To promote the expectation that our scientific research approach is one of openness at all stages of the research cycle. Open Access and Open Data are approaches already undertaken by the Unit to make our research findings publicly accessible and the Unit will

formalise this strategy, making use of the *Institutional Open Access Research* platform called InOAR (launched by the University).

2. **People**

a. Staffing strategy and staff development

The Unit's staffing strategy is designed to reflect on its underlying research goals and strategy while also supporting enriched research-informed teaching. Accordingly, a robust set of academic criteria have been implemented into the recruitment and appointment processes to ensure the very best academics, capable of supporting the Unit to achieve its strategic goals, are recruited. Due to the relatively small size of the Unit, the staffing strategy has been predominantly focused on the further development and growth of key research themes. Furthermore, the interdisciplinarity and broader range of research skills to support collaborative work across Unit's research groups and the ability to channel external collaborations have been carefully considered during the recruitment process.

Recruitment

The appointment of Professor Omid Khaiyat, Head of School of Health Sciences, in late 2013 stimulated the formation of a novel research theme within the Unit in Musculoskeletal Sports Medicine, the upper limb/shoulder in particular. There followed several strategic appointments aimed to further establish and strengthen this research theme and bring national and international recognition to the research group. These appointments included a lecturer in biomechanics (Dr Ginny Coyles), two post-doc fellows, a prominent and internationally renowned visiting professor with specialism in musculoskeletal science and upper limb/shoulder surgery (Professor Simon Frostick – Professor of Orthopaedics, University of Liverpool), three external research advisors with substantial clinical expertise in upper limb/shoulder (Dr Ian Horsley – Northwest Regional Physiotherapy Lead for the English Institute of Sport, Mrs Jo Gibson – an internationally recognised Upper Limb Rehabilitation Specialist, and Mr Rish Parmer – Consultant Upper Limb Orthopaedic Surgeon/Honorary Clinical Lecturer), and four PhD (scholarship) students (one completed, three current). More recently, the appointment of a Clinical Tutor in Sports Physiotherapy/Rehabilitation has been made (Jessica Law, Bolton University) who brings to the research team further clinical expertise in musculoskeletal sports medicine (British Association of Sport Rehabilitators and Trainers (BASRaT) membership) and collaborative potential with Swim England. The performance of the group was further enriched by the appointment of lecturers in motor control and movement science (Drs Greg Wood and James Roberts) which also enabled the facilitation of broader and interdisciplinary research. The unit has recently appointed another early career research-active academic in the field of motor control (Dr Robin Owen, Bangor University). As a consequence of these actions, the Musculoskeletal Sports Medicine research group is recognised nationally and internationally for its research. Examples of the research group's broad achievements are described in (Sections 1 and 4).

We also made a small number of honorary professorial appointments of clinicians (Dr Philip Weston, Dr Chris Wong, and Dr Dushyant Sharma) from local NHS trusts. These strategic appointments have had multifaceted benefits for the expansion of our Unit's research capabilities and also complement the role senior colleagues play in the internal review processes, for example in enhancing grant applications and publications. Moreover such appointments fulfilled aims (i) and (iii) of the Unit's strategy, a good example being the appointment of Dr Philip Weston from the Liverpool University Hospitals NHS Foundation Trust as an Honorary Professor in Diabetes

and Metabolic Medicine. This resulted in successful collaborative research involving individuals with Type 1 diabetes from Dr Weston's diabetes clinics and importantly, the dissemination of our research findings to both clinicians and patients at the Trust.

Development and Mentoring

All colleagues in the Unit on academic contracts have one third of their workload allocation dedicated to undertaking research. There are established University-wide staff development policies, practices and procedures with which the subject area abides to monitor each individual's contribution to delivering the research strategy of the Unit, School and University. These stipulate that all staff must undergo an annual performance review with a senior member of staff, where research targets are set and any training and support needs are identified. All staff at Senior Lecturer grade and above are required each year to submit one external grant application and present at at least one conference to disseminate their research, network and represent the University. Lecturers and Postdoctoral Teaching Fellows, which we consider to be early career researchers, are strongly encouraged to attend and present at one conference per year.

The University organises and delivers a broad range of research workshops involving both senior and early-career researchers in the key areas of: research outputs, research environment and research impact and supportively encourages all staff to apply for University research and travel funds to assist with undertaking and disseminating research. The School of Health Sciences Research Committee organise further, more tailored staff training sessions, where particular skills or knowledge gaps have been identified e.g. '*Getting research out into the public through the media'.*

Since 2014, a flagship School Annual Research Day has been held that has provided academics and PGRs with a vibrant and facilitative research environment to share their latest research interests, to hear from external speakers and Unit REF advisors and obtain constructive feedback on their research. The event not only raises research awareness and places research firmly on the School agenda, but it also facilitates the opportunity for collaborations between staff from cognate Units within the School in addition to staff external to Hope. The event also has the benefit of meeting strategic priority (i), i.e. interdisciplinarity and multidisciplinarity, since it offers an explicit opportunity for the sharing of research within and between cognate Units of Assessment (the Agriculture, Veterinary, and Food Science unit is also contained within the School). Further, the Annual Research Day aids PGRs in their VITAE research skills development framework and the competitive element introduced for the best PGR/PGT presentation prepares them well for external conferences.

Other actions integral to our Unit's environment strategy of staff support and development is through the Unit's hosting of external and internal speakers as part of its research seminar series. These seminars positively impact on research consciousness and subject knowledge whilst promoting rigorous scientific debate. The seminar series have provided further research development opportunities through enabling the emergence of new collaborations and research outputs. For example a recent collaboration between an external speaker and Dr. James Roberts (now external) led to a publication in the journal '*Acta Psychologica'* on limb regulation and motor performance.

Through the Unit's infrastructure, with senior staff leading each of the Unit's research groups, we operate a mentorship scheme to facilitate the development of research skills for staff, particularly junior and mid-career colleagues, to ultimately facilitate a sustained research career. The majority

of academics in the Unit are appropriately trained Research Supervisors with the more senior staff also having Director of Studies status for PhDs. Early and mid-career researchers are encouraged to act as Research Advisors on PhD supervisory teams to immerse themselves in procedures, regulations and guidelines as well as developing supervisory skills and on-the-job mentoring to facilitate the timely attainment of full research supervisory status. Staff in the Unit are also encouraged to act as Internal and External PhD Examiners and Independent Chairs and this experiential learning has resulted in the advancement of the quality and capability of our postgraduate supervisory support by academic staff in their own subject areas. The University-wide postgraduate training programme for staff provides appropriate training for the undertaking of all PGR roles. Throughout the year, two staff from this Unit (Roche, Marwood) make large contributions to the training programme delivery. Associate Professors Roche and Marwood also both have management roles as postgraduate research coordinators for 'Sciences' at Liverpool Hope University and St Mary's University(one of our partner institutions) respectively. These positions afford membership on the University Research Degrees Sub-Committee, thus providing greater and broader immersive involvement from senior staff in this Unit in the University-wide research environment. This has significantly and positively impacted upon our remit and ability to translate actions towards improving the quality of our own PGR research environment.

Finally, staff and research groups within the Unit are able to apply to the University funding streams locally and centrally (including Research Environment Development Fund (REDF); REFine and REFresh) to support their research environment and potential impact of their research. There is a clear expectation of staff within the Unit to actively demonstrate the University's mission of engaging with the world beyond academia. Many of the Unit's activities have demonstrated alignment with Open Science, for example, public dissemination of science via the annual British Science Weeks, public science engagement via Randox Health Week (Roche).

b. Research students

Our Unit prioritised the need to grow the postgraduate research community following REF2014, as we considered it fundamental for a sustainable research environment. Subsequently, during this REF cycle, the Sport and Exercise subject area have seen postgraduate research significantly expand and flourish through enhanced opportunities and the continued development of a supportive research environment. In 2015, the University made significant investments into the postgraduate research environment by introducing fully-funded Vice-Chancellor's PhD Scholarships. The subject area took this opportunity to drive forward aim (iii) of our research strategy, *'Enhancing the Wider Research Environment'*, and successfully secured (via competitive process) 4 VC-scholarship PhD student positions (full-supervision) and a further 2 VC-scholarship PhD students (interdisciplinary) with shared supervision from within the School of Health Sciences. Other actions include the proactive creation of two funded Shoulder PhD Scholarships through protecting a portion of the income generated by the Shoulder Rehabilitation Conference organised by Professor Khaiyat in 2017. External funding streams have effectively been targeted through collaborations and grant applications in a bid to maintain continued growth of the PGR environment. For example, Dr Malone secured externally funded PhD and MPhil scholarships through collaborations with the FA (Football Association) and Real Science Food Ltd respectively. Additional targeted action by the Unit for this second part of our research strategy was the decision to change our postgraduate teaching provision from an MSc in Applied Exercise Physiology to an MRes in Sport and Exercise Science. This was actioned in order to stimulate postgraduate research activity, facilitate staff research and to establish an avenue for producing an increasing

number of well-rounded PGR students, some of whom may progress onto PhDs and remain in academia.

All our PGRs have a dedicated shared office and computer facilities on the Hope Park campus. They have fully bookable access to the Sport and Exercise Science laboratories and technical/specialist support is provided by the Sport Science lab Manager. This arrangement means they are close to academic colleagues, laboratory facilities, the library and learning resources. The dedicated postgraduate office space has enabled a sense of community and collegiality amongst PGRs and has enabled informative support mechanisms to prosper.

Each postgraduate research student is monitored and supported by a supervisory team comprising a minimum of two approved research supervisors and an approved director of studies (DoS). We make use of our professional and practitioner network wherever possible, including them as external research advisors within supervisory teams (e.g. Dr Ian Horsley, English Institute of Sport) is part of the supervisory team for Ben Ashworth). For interdisciplinary theses, supervisors from different disciplines are brought together to form the supervisory team (e.g. Parr's thesis 'Evaluating and alleviating the cognitive burden associated with upper-limb prosthetic hand control' was supervised by Professor Khaiyat (Sport and Exercise Science) from this Unit, along with Dr Harrison (Department of Psychology).

PGR supervisory team meetings provide the best possible advice, guidance, monitoring and support to the student, within the context of their emerging thesis and future career and follow the University Code of Practice for PGR Degrees. The formal monitoring of academic progression (AMRs, CREs) are undertaken in accordance with institutional regulations and help identify training needs of our students. Further, there is a dedicated University-wide Postgraduate Research Skills Programme (RSP) for PGR students for generic and transferable skill development alongside their PhD. This is structured using the Vitae Researcher Development Framework UK which aligns with the Concordat to Support the Career Development of Researchers (2008) (see Institutional Research Environment Statement). Subject-specific training needs are usually met within the Unit, but, if required, external assistance is arranged. For example, the Unit arranged for Romano to attend a training course (University of Roehampton, London) on TMS and the Noraxon Myosync and Noraxon Sync light systems. Employability support for PGR students aspiring to join academia is provided by teaching opportunities with support and mentoring from colleagues within the Unit. For those wishing to gain teaching experience, the University provides training to develop the appropriate skill sets. PGRs are limited in their role in teaching in line with RCUK guidelines to protect their research progress.

The quality of student supervision and PGR training from Unit colleagues is attested by the fact that recently completed PGR students have gone on to secure post-doctoral research fellowships on externally-funded research projects at the Kobe Design University, Japan & Vrije University, Amsterdam (Goulding); the University of Melbourne, Australia (Kirk) and Liverpool John Moores University (Parr).

Our PGR students are expected to attend and present their research at the School of Health Sciences Annual Research Day and Unit's Research Seminar Series (See Section 2 Development and Mentoring). PGR students are also expected to make a broader contribution to the research environment of the Unit by supporting the activities of research groups more generally (e.g. training others (staff/students) in specific technical and analytical techniques gained while conducting their own research). Postgraduate students are encouraged to present and disseminate their research at national and international conferences, for example: *British*

Association of Sport and Exercise Science, American College of Sports Medicine (Goulding); European College of Sports Science, British Psychological Society Division of Sport and Exercise Psychology (Romano); International Sport & Exercise Nutrition Conference (Kirk). Funding for conferences is available to PGRs from the Health Sciences Research Committee budget and also the PVC-Research central fund. PGRs may also apply to these funding streams for financial support for data collection, laboratory and field-work and the attendance of any necessary training courses.

c. Equality and diversity

The Unit takes the philosophy that all colleagues should have equal opportunities in being able to undertake and produce high quality, impactful research. For the development of a more inclusive research culture and consequently a sustainable future, we believe that diversity and equality are paramount when recruiting, developing and managing colleagues.

The Unit upholds and fully adheres to the Liverpool Hope policies. In addition to conforming to the Equality Act 2010, the University has established its own Equality and Diversity policies with full commitments to the fulfilment of underpinning principles and the elimination of discriminatory practices.

The Unit, in line with the University's Equality and Diversity policies and "The Code", seeks to achieve its strategic targets while nurturing equality and inclusivity across all colleagues within the Unit. Despite a relatively small size, the UoA has historically fulfilled a diverse and balanced proportion of male and female staff members from a variety of ethnic groups.

Professor Khaiyat, who is a member of Unit and also Head of School of Health Sciences, is a member of University's Equality and Diversity Steering Committee as the representative for University's Senior Management. This has ensured further safeguarding and adherence to the policies and principles integral to the University's mission and values which are also reflected in the REF 2021 Code of Practice. Equality and Diversity is a fixed agenda item in School meetings during which the representative reports all relevant updates and new developments to the academics.

The University's REF steering group meets on a regular basis during which a senior HR manager, who oversees the Equality and Diversity aspects of the REF procedures, provides Unit representatives and coordinators with the latest development according to the University's Code of Practice ("The Code") for the REF2021. The Head of School disseminates these updates to colleagues in the Unit, which subsequently adheres to these policy updates. All new and existing staff are expected to undergo annual Equality and Diversity training to ensure their knowledge is maintained. Relevant statistics are also regularly reviewed to ensure that the University is operating in-line with these policies.

3. Income, infrastructure and facilities

External research funding and research grants were noted by the Unit as a challenge following the last REF cycle. As a result of this, the Unit placed priority and value on reinforcing and fostering strong academic and research links between itself and colleagues external to the University. This has actively been met through concerted and sustained collaborative grant applications. During the census period, the Unit's research groups have collectively applied (principally in collaboration with external researchers) for £1.2M of external research funding, resulting in a successful income

of £252,425, a substantive enhancement to the previous REF exercise: Musculoskeletal Sports Medicine Group £208,000 (Vifor Pharma); Exercise Performance and Health Physiology Group £28,768 (Real Science); and Psychology of Action and Learning of Movement Group £14,657 (Royal Society). The biannual Shoulder Rehabilitation Conference hosted by the Unit in 2017 and 2019 (chaired by Professor Khaiyat) generated around £41,550 external income which has been returned to the Unit to further promote upper limb/shoulder research and the Unit's research environment by means of specialised equipment and two fully funded "shoulder" PhD scholarships (Hawkes and Ashworth). A collaborative upper limb research project with the EIS and POWERPLATE^{R} provided the Unit with a Power Plate® my5™ (£3,499). The Unit is highly motivated to use the lessons and experience from these achievements to further enhance its research environment in line with its 2021+ key strategic aims (Section 1; aims 1&6).

Since the previous REF, the University has invested heavily (~£16m) in the research environment for the Unit. The *'Health Sciences Building'*, which houses the research facilities for the Unit, was completed in January 2016 representing a deliberate move to support the research environment for the Unit. The development of this £8.5m facility produced >320m^2 dedicated to research for the Unit including specialised laboratories: Sport Biomechanics, Sport & Exercise Physiology, Cardiovascular Physiology, Sport Performance, Body Composition and Sport Psychophysiology.

The Sport Biomechanics and Performance Analysis Lab is a spacious 216m^2 equipped with eight 3D (Vicon) motion capture cameras that can be mounted throughout the entire area and a 62inch monitor supports operation of the system together with a dedicated workspace to both operate the system and process the data once received. The length of this space is served by four high-specification (Kistler) force plates which can be located into 16 separate spaces on the floor and supplemented by two high-speed cameras (Bonita, Vicon), two 16-channel wireless DTS EMG systems (Noraxon), a 16-sensor full Body inertial 3D motion capture system (Noraxon), a Zebris pressure and gait analysis platform, various strength measurement systems, and Noraxon wireless inclinometer/accelerometer. This lab also accommodates a 23-meter track for gait/running analysis and a 12m*4m double-ceiling height area with impact wall at one end area to facilitate shoulder/upper limb/overhead research. This high-quality research environment was instrumental in the achievement of our strategic priorities since it has promoted collaboration with external partners (English Institute of Sport (EIS), Royal Liverpool Broadgreen University Hospitals NHS Trust, and Aintree Hospital NHS Trust) for the benefit of real-world, multi- and interdisciplinary research. Moreover these facilities enabled the hosting of upper limb clinical research workshops during the timescale of the Shoulder Rehabilitation conferences and the Noraxon User Group meeting (2018).

More than 100m^2 of further space is dedicated to research across separate rooms to support specialist areas of Exercise Physiology & Sport Performance, Cardiovascular Physiology, Psychophysiology and Body Composition. These areas are supported by specialised equipment invested into the Unit including eye-tracking system (ALS), further 8-channel wireless EMG system (Delsys), transcranial magnetic stimulator (MagStim), 3 online breath-by-breath expired gas analysis systems (LoveMedical), near infrared spectrometer (Oxiplex TS), cardiac ultrasound (VividQ), vascular ultrasound (Terason), laser Doppler (Perimed), Dual-energy X-ray absorptiometry (GE Lunar iDXA), pulse wave velocity (SphygmoCor), motorised (h/p/cosmos) and non-motorised (Woodway Curve) treadmill, isokinetic dynamometer (Kin-Com), programmable (Lode Excalibur Sport with pedal force measurement, Lode Corival, Tacx) and non-programmable (SRM trainer) cycle ergometers, cardiac stress-test / supine ergometer table (Lode Angio), automated desktop systems for blood lactate and glucose concentration (Biosen) and standard haematology.

The Health Sciences Building also houses dedicated research facilities for the Biosciences, representing a shared space with other units of assessment for analysis of human blood and tissue samples. This 309m^2 space includes a dedicated phlebotomy suite and facilities for the measurement of metabolic and molecular markers of human function in a regular biosciences area. Two most recent additions to these labs include a semi-automated clinical chemistry testing system (RX Masino, RANDOX) and a sophisticated Biochip Immunoanalyser (Evidence Investigator, RANDOX); both have broad applications in Sport and Exercise Science research. Measurement techniques via HPLC, colorimetry, ELISA and biochip array technology are supported. The size and scope of these facilities enabled the high volume of research outputs from simultaneous staff and postgraduate research projects, across the various Research Groups in the Unit and School of Health Sciences as a whole.

The Health Sciences Building was supplemented by further investments of £7.5m in adjacent on-campus indoor and outdoor sport facilities (sports building including modern gym and strength & conditioning suite, 3G football pitch, tennis/netball courts, rugby pitch). Crucially, the University explicitly dedicated these resources not only as leisure and teaching facilities for students and staff, but for research space for the Unit. Moreover, this component of the overall investment also houses on-site physiotherapy and sport rehabilitation clinical facilities as dedicated support for the Musculoskeletal Health Research Group, which was the result of a further £80k investment to repurpose a portion of the newly developed facilities.

The comprehensive nature of these facilities was instrumental in undertaking an interventional RCT in older adults (NCT02912130), which involved an interdisciplinary team of academics and two PhD students. With a multidisciplinary approach, the study recruited >100 participants into four intervention groups (Exercise Training, Protein Supplement, Exercise Training + Protein Supplement, and Control) to investigate their impact on musculoskeletal health and function through a broad range of measurements including bioelectrical-impedance (skeletal muscle mass), muscle strength, neuromuscular fatigue and activation of key upper and lower extremity muscles (EMG), blood biomarkers, 3-D gait analysis, and measurements of physical performance. The involvement of researchers from Nutrition and Psychology disciplines enabled correlational analysis between musculoskeletal health and other key factors. Hence the physical research environment enabled achievement of one of our key strategic priorities, namely the solving of real-world issues through multi- and interdisciplinary approaches.

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

The fostering of key research collaborations external to the university at local, national and international level has been a central strategic aim (i.e. strategy iii) to enable research groups to enhance the research environment and produce impactful research. Consolidation and diversification of external collaborations have been achieved through a concentrated effort by Unit members to establish and nurture research collaborations, networks and partnerships. To this end, the Unit has forged external links resulting in local, regional, national and international collaborations and partnerships. During the current assessment period, the Unit has published a considerable number of papers in collaboration with UK-based and internationally-based researchers to achieve its overall strategic aim. The following section provides details of key research collaborations and wider contributions specific to each of the Unit's research groups.

Professor Khaiyat has been an Honorary Senior Clinical Research Fellow for the past 15 years with a major clinical Upper Limb unit in the region (Liverpool Upper Limb Unit – Liverpool University Hospitals). This has served as a basis for a deliberate strategy for the Musculoskeletal Sports Medicine research group to develop a robust, internationally recognised upper limb research profile with a strong and broad range of networks. Consequently, a firm research collaboration

with the Liverpool Upper Limb Unit at the Liverpool Royal and Broadgreen University Hospitals NHS Trust is now in place, with the latest collaborative project currently ongoing in relation to reverse shoulder replacements. Five upper limb consultants and three upper limb physiotherapy specialists are involved in this research collaboration. In addition, the research group has formed a Shoulder/Upper Limb Research Partnership with the English Institute of Sport (EIS) which is now a formal research partnership agreement signed in July 2018, after four years of informal collaboration, leading to two major research projects and research outputs. This has also led to a new joint research collaboration involving both EIS and the School of Calisthenics (https://schoolofcalisthenics.com/). Professor Khaiyat has also been an Honorary Fellow with the University of Liverpool (Musculoskeletal Science Research Group and Musculoskeletal Biology II, Faculty of Health and Life) since 2013, fostering collaborative work with renowned researchers including Professor Frostick (Head of Musculoskeletal Science Research Group), Professor Graham Kemp (Head of the Department of Musculoskeletal and Ageing Science), Professor Fisher (Head of the Medical Physics and Clinical Engineering), and Professor TakTak (Consultant Clinical Scientist).

Links with several other key stakeholders enrich the strategic aim of the Musculoskeletal and Sports Medicine research group. The development of an interdisciplinary research project investigating the health benefits of tennis (as described in Section 1) further exemplifies our successful collaborative approach to research. The research team established key collaborations and partnerships both locally (e.g. Liverpool International Tennis Tournament, local tennis clubs, local governing and health bodies) and nationally (e.g. Lawn Tennis Association). The research received a broad range of media coverage (e.g. BBC Breakfast, BBC Northwest, BBC Radio Merseyside, and Echo Daily). One of the key collaborative areas of research for this group has been around healthy ageing interventions (with a focus on older adults >65 years old) leading to a number of clinical trials. Findings from the *'Exercise and Nutrition Interventions in Age-related Sarcopenia'* trial (NCT02912130) produced a number of nutritional and exercise related guidelines for older adults, which were disseminated during invited national (e.g. North-west Frailty Unit NHS, British Dietetic Association) and international (e.g. American Academy for Nutrition and Dietetics in Washington) talks and a series of local interactive events in the Liverpool area (e.g. at the Liverpool Central Library and the Randox Health Week). The *'Musculoskeletal Health and Function in Older Adults with Iron Deficiency Anaemia'* trial (ISRCTN13325706) led by Professor Khaiyat is an externally funded RCT in collaboration with the Liverpool University Hospitals NHS Foundation Trust (Dr Chris Wong). The research team, having secured ethical approval, now seeks to fund the appointment of a research fellow. In addition to the above, the research group led on an impactful interventional RCT (NCT02904980) in children with Developmental Coordination Disorder in collaboration with researchers from Exeter University and University of Calgary.

More widely, this research group has published with colleagues across the UK (e.g. University of Exeter, Manchester Metropolitan University, University of Liverpool, Northumbria University, Liverpool John Moores University, English Institute of Sport), and also internationally (e.g. India [Karamsad], Canada [Calgary], Australia [Melbourne], Iran [Tehran]). The biannual Shoulder Rehabilitation Conference, organised by the Musculoskeletal Sports Medicine group hosted more than 150 delegates from Costa Rica, Turkey, Belgium, Sweden, Norway, Ireland and from across the UK. The conference hosted a number of educational workshops for delegates provided by commercial sponsors such as Physiquipe (UK), VICON (United States), GE Healthcare (UK) and Noraxon (United States). These workshops, centred on key research equipment with multidisciplinary applications, positively facilitated networking and discussions around potential collaborative projects.

The Exercise, Performance and Health Physiology research group has published with colleagues from numerous other academic institutes from across the UK (e.g. University of Hull, Liverpool John Moores University, Edge Hill University, University of Huddersfield, York St John University, Wythenshawe Hospital Manchester, University of Surrey, Leeds Beckett University, University of Chester, Swansea University, University of Leeds) and internationally (e.g. France [Lyon], Tunisia [Sfax], Australia [Melbourne, Sydney], The Netherlands [Groningen], Belgium [Leuven], Japan [Kobe, Tokyo], United States [Atlanta, Manhattan], Iran [Rasht], Switzerland [Bern], Hungary [Budapest], Italy [Bologna]). Associate Professor Marwood's research in relation to critical power and type 1 diabetes has led to a number of key collaborations both nationally (Dr Carrie Ferguson, University of Leeds) and internationally (Dr Shunsaku Koga, Kobe University, Japan; Professor Harry Rossiter, Lundquist Institute). The research findings of Associate Professors Marwood and Roche, in relation to exercise tolerance and type 1 diabetes, has led to strong collaborations with the Royal University Liverpool Hospital, working with clinical populations to provide novel exercise interventions.

Sports performance collaborations are also a key aspect for the research strategy of the Exercise, Performance and Health Physiology research group. Dr Malone's research in this area, particularly with a focus on professional football (soccer), has led to a series of key collaborations with both university institutes (e.g. Prof. Barry Drust - University of Birmingham, Prof. Werner Helsen - University of Leuven, Belgium) and professional teams/organisations (e.g. English Football Association (the FA), Union of European Football Associations (UEFA), English Premier League). Research by Dr Malone investigating the link between football training practices and injury rates has led to a number of media appearances (e.g. Manchester Evening News; https://bit.ly/34BCuln, talkSPORT, BBC Football Show) and dissemination of the work to practitioners working at professional clubs (e.g. Bournemouth FC, Everton FC, Atlanta United FC, FC Groningen). Dr Malone's recent work investigating maturation effects within elite youth football has led to collaboration with UEFA to disseminate the recommended maturation calculations for players at their international coaches' education workshops. Dr Malone recently received an external research grant from a commercial company (Nuroco Energy, UK) to investigate the impact of medium chain triglyceride supplementation on cognitive performance. The initial work has resulted in several media appearances disseminating the positive findings relating to the supplement (e.g. Brain Booster Podcast: https://bit.ly/2Tx1GTN).

The Psychology of Action and Learning of Movement (PALM) research group has published research with a number of both UK-based (Liverpool John Moores University, Manchester Metropolitan University, Bangor University, University of Chester, University of Exeter, Edinburgh Napier University and international (Canada [Hamilton, Ontario]) institutes. Key external collaborators across the research group include Dr Greg Wood (Manchester Metropolitan University), Dr Moira Lafferty (University of Chester) and Dr Gavin Lawrence (Bangor University). The CHANGES (Challenging Hazing and Negative Group Events in Sport) research project led by Associate Professor Wakefield has led a large number of workshops delivered in collaboration with the University of Chester with the aim of impacting society's views on sport hazing (ICS2: Transforming the culture of student sport initiation ceremonies: time for a CHANGE). These intervention workshops have been delivered across a number of universities within the UK, culminating in a presentation at the annual British Universities & Colleges Sport (BUCS) conference. The positive feedback from this presentation has led to a formal partnership with Scottish Student Sport (SSS) to deliver the CHANGES workshops and help to further train others at a regional level (https://bit.ly/37M6k8U). Recent research from the research group into the effects of football heading on potential concussion and memory loss received national media attention, with interviews published in the Daily Mail (shorturl.at/ovxP9), Liverpool Echo

(https://bit.ly/3oB3LfS), talkSPORT and BBC Radio Merseyside. This work has led to further discussions with the FA around future collaborative research projects regarding best practice guidelines for both grassroots and adults playing football to limit the negative health impacts of football heading.

A key aspect of the strategic aim across the Unit's research groups was to enhance the research environment and produce impactful research (Section 1). Throughout Section 4 we have described the various research projects, external activities and impact that our research has had to benefit the research base, economy and society. Our future aim is to continue with the dissemination of our research to the public to ensure both scientific rigor and the translation of outcomes to the key stakeholders.