Institution: Manchester Metropolitan University

Unit of Assessment: A3 Allied Health Professions, Dentistry, Nursing and Pharmacy.

Title of case study: MMU Research Impact On Combating Musculo-skeletal Disuse In Older People.

1. Summary of the impact

Manchester Metropolitan University's (MMU's) novel research on the musculoskeletal adaptations to resistance training has directly informed what has been called the "gold-standard" for exercise, physical activity and rehabilitation guidelines for older adults published in the USA, as well as the UK Department of Health's guidelines on physical activity and exercise for older adults. MMU's musculo-skeletal research has led to commercial impacts as it has directly informed the design, and modifications to the design of 'Technogym' (an international exercise equipment manufacturer) and vibration training devices. Clinical impacts have been realised through the contribution of musculoskeletal research into rehabilitation programmes for children with muscle weakness across Europe. And finally, MMU's research has also raised awareness of, and informed local Government decision-making and policy on, ageing and musculoskeletal deterioration.

2. Underpinning research

Whilst life expectancy is widely acknowledged to be increasing, research shows that years of "good health" are not increasing at the same rate. This puts a large and unsustainable economic and health burden on society. Previously the importance of the musculo-skeletal system to activities of daily living was known along with the fact that skeletal muscle deteriorates with disuse and during ageing. The subtleties in the association between muscle-tendon ageing and habitual physical function were unchartered.

MMU's research team included Neil Reeves – Professor of Musculoskeletal Biomechanics (2003 - present), Dr.Gladys Onambele-Pearson (2002 – present), Marco Narici – Professor of Ageing Physiology (2000 – 2012), Joern Rittweger – Professor of Clinical Physiology (2007 – present) Constantinos Maganaris – Professor of Musculoskeletal Biomechanics (2000 – 2012). Between them they visualised the musculo-skeletal system with Dual-energy X-ray absorptiometry (DEXA), Magnetic resonance imaging (MRI), peripheral quantitative computed tomography (pQCT) and B-mode ultrasound imaging. This allowed accurate observations of the multi-systems interaction associated with ageing and strength training. We refined techniques to measure tendon properties in vivo **[1]**, individual force components within muscle groups, and specific force properties **[2,5]**.

Our research evaluated different interventions to combat muscle, tendon and bone deterioration associated with ageing and sedentary lifestyle (e.g. microgravity and bed-rest). We validated, tested and had final input into the final designs of human centrifuge, vibration, yo-yo flywheel and telemetric percutaneous electrical stimulation therapies **[3]**.

Key research findings:
This research has set the "gold standard" (American College of Sports Medicine) for protocols/techniques to quantify muscle-tendon in vivo characteristics. It has highlighted, for the first time, that not only can the effects of ageing and immobilisation be slowed down/reversed in most physiological systems, but also that, in the particular case of older persons, the intensity of exercise does not have to be high for the benefits to be substantial **[1-5]**.

MMU researchers were the first to recognise and confirm several major novel observations:
a) adaptation of tendon properties in older individuals **[1]**
b) age-related changes in muscle-tendon characteristics explain 69-90% of the variance in single-leg and tandem postures
c) after correcting for each component of force output the "specific force" of older muscle is reduced **[5]**
d) "accurate specific force" increases after long-duration strength training **[2]**

e) tendon is modulated to the same (if not greater) degree as muscle with loading and unloading **[1]**
f) older female tendons preferentially respond to lower loads whereas older male tendons respond to loads above 40% of maximum voluntary effort **[4]**
g) the effectiveness of training is not limited to the intensity of the exercise but is improved through a careful nutritional supplement regime and loading up on a carbohydrate drink in the hours prior to a bout of exercise. Taking an easily absorbable form of protein (preferably branch-chain amino – acids) in the hour following exercise also has a positive effect **[4]**.
h) eccentric loading maximises the response of the muscle-tendon unit
i) resistive vibration exercise can prevent bed rest-induced muscle and bone loss, relevant to clinically induced immobilisation and space flight **[3]**.

3. References to the research

[1] Reeves ND, Maganaris CN, Narici MV. Effect of strength training on human patella tendon mechanical properties of older individuals. *J Physiol*. 2003; 548 (Pt 3):971–81. (*Impact Factor 4.88; citations: 151*) **DOI**: 10.1113/jphysiol.2002.035576

[2] Reeves ND, Narici MV, Maganaris CN. Effect of resistance training on skeletal muscle-specific force in elderly humans. *J Appl Physiol*. 2004; 96 (3):885–92. (*Impact Factor 3.75; citations: 80*) **DOI**: 10.1152/japplphysiol.00688.

[3] Rittweger J, Beller G, Armbrecht G, Mulder E, Buehring B, Gast U, Dimeo F, Schubert H, de Haan A, Stegeman DF, Schiessl H & Felsenberg D. (2010). Prevention of bone loss during 56 days of strict bed rest by side-alternating resistive vibration exercise. *Bone* 46**,** 137-147. (*Impact Factor 4.02; citations: 33*) **DOI:** 10.1016/j.bone.2009.08.051

[4] Onambélé-Pearson GL, Breen L, Stewart CE, 2010. Influence of exercise intensity in older persons with unchanged habitual nutritional intake: skeletal muscle and endocrine adaptations. Invited manuscript. *Age (Dordr).* 32(2):139-53. (*Impact Factor 3.9; citations: 4*) **DOI:** 10.1007/s11357-010-9141-0

[5] Morse CI, Thom JM, Mian OS, Birch KM, Narici MV. Gastrocnemius specific force is increased in elderly males following a 12-month physical training programme. *Eur J Appl Physiol*. 2007 Jul; 100(5):563-70. (*Impact Factor 2.14; citations: 8*) **DOI:** 10.1007/s00421-006-0246-1

Indicators of research quality:

1. External funding
Funding sources: European Space Agency (e.g. ESA: n° ESA-AO-LS-99-MED-030; £57,715), EU FP5, EU FP7, NDA (e.g. Exercise & Nutrition Preparatory Network £28,465), BBSRC (e.g. BBSRC: n° 333/ERA16254; £226,612), SPARC (e.g. Exercise & Diet £28,245), MRC programme grant on sarcopenia (£2.84M). Sponsorships were also obtained from Glaxo-SmithKline nutrition R&D and Holland and Barrett R&D, Erasmus Mundus MOVEAGE, at total of >£5m.

2. Peer-reviewed research outputs (2002-2010)
MMU researchers have published 306 peer reviewed journal articles from 2002 – 2010.

4. Details of the impact

Impacts on International Guidelines and Healthcare Policy for Older Adults
In 2009, MMU research into muscle-tendon properties was incorporated into the development of exercise and physical activity guidelines for older people from the US American College of Sports Medicine **[A]**. These guidelines are used as the “gold standard” by more than 45,000 medical and healthcare professionals in the US and internationally. They offer local government and other stakeholders the knowledge and opportunity to establish physical activity sessions specifically tailored to the needs of older people. By design, the exercise will help to improve health, mobility

and independence in older age, promote confidence and quality of life, and reduce the risk of falls and reliance on social and healthcare services. The physical activity guidelines cite dozens of original research articles and our specific research is used as a major reference of evidence in support of exercise interventions to benefit skeletal muscles and tendons. Through the uptake of the findings from MMU studies (via presentations to government, health bodies worldwide, and the global media), the reach of our work, can be directly associated back to us. Research was also cited in earlier UK Department of Health Guidelines: "*At least five a week: Evidence on the impact of physical activity and its relationship to health – A report from the Chief Medical Officer (2004)".* These guidelines, whose primary audience was NHS professionals, were current for 7 years until 2011, cite Narici's work, and acknowledge him as an expert reviewer (p91) **[B].** MMU research also informs World Health Organisation diet and physical activity guidelines for older people **[C]**.

Commercial Impacts on International Exercise Equipment Manufacturers

Since 1990 MMU research has guided the work programme of 'Technogym', a worldwide supplier of resistance exercise equipment to clinical facilities, rehabilitation units and gyms. As such our research has directly impacted upon the exercise equipment used in facilities around the world and has influenced the design of their exercise equipment leading to significant commercial impacts. MMU musculoskeletal research influenced 'Technogym' projects including *Fit Age* where MMU research directly influenced the presentation of 'Technogym' devices to potential customers leading to significant sales increases. Researchers have also helped 'Technogym' to make significant financial savings through testing new devices for consistency and through calculating the calorific expenditure of a range of new devices. As a letter from the Scientific Research and Communication Manager testifies, *"The research publications from MMU have directly informed our policies and work programs in relation to resistance exercise training for elderly adults. The resistance exercise devices present in facilities around the world have been produced based on careful research and development. The impact upon sales for Technogym was significant."* Technogym has an annual turnover of more than 400,000 Euro and is among the biggest players in the fitness industry **[D]**

Exercise equipment has also been developed by Novotec Medical (Stratec Medizintechnik), a Germany-based designer and manufacturer of training and therapy devices that utilised MMU research into microgravity and bed rest. **[3]**

Clinical Impacts related to vibration intervention and bedrest across Europe

Research into the musculoskeletal effects of bed rest **[3]** also led to the implementation of (i) vibration intervention in hospitals across Europe; (ii) widespread use of vibration exercise as a clinical therapy to combat muscle weakness in children. MMU's work has crucial importance in the clinical application of vibration as an exercise modality. As testimony from the Zentrum for Kinderrehabilitation (Centre for Child Rehabilitation Germany) demonstrates: "*…These recognitions have been instrumental when conceiving the 'Cologne strategy' for the rehabilitation of children with neuromuscular disturbances with various underlying pathologies. Whole body vibration are the main constituents of this strategy…the Queen Rania hospital for prevention and rehabilitation is seeing 300 patients per year and is serving as a role model in Germany and world wide. Besides the impact of his publications, Dr. Rittweger has also been a continuous source of information for us in joint meetings and collaborations and has substantially contributed."* **[E].**

In order to improve the quality of reports about whole body vibration treatment studies, the International Society of Musculoskeletal and Neuronal Interactions invited experts in the field to provide suggestions on how the intervention should be described in reports. MMU research underpinned these recommendations which were published in 2010 and have impacted on the way in which this work is carried out ever since **[F].**

Impacts on Local Government Policy in relation to Ageing in the UK

MMU researchers have changed attitudes and raised awareness of the effects of ageing and musculoskeletal disuse amongst policy-makers and the wider public. Onambélé-Pearson has formulated responses to parliamentary questions on exercise physiology and the self-management of chronic conditions in 2008 and 2012 and has informed government policy on ageing research

through invited ministerial presentations (e.g. Royal Society of Physicians presentation in 2007). Awareness has also been raised at a local and regional level through engagement with LARCI (Local Authorities Research Council Initiative) and through participation on the academic advisory committee of the flagship SPARC (Strategic Promotion of Ageing Research Capacity) initiative (link to final report here: http://www.sparc.ac.uk/final_review/Final_Report_Ch5.html) and membership of the prestigious Cochrane Musculoskeletal Group. Media coverage of our ageing research has also underpinned policy lobbying efforts with a major press campaign on the benefits of maintaining a healthy diet for older people taking place in 2008 **[G,H]**. In summary MMU researchers have impacted on government funding priorities for healthy ageing and rehabilitation practice by using dissemination opportunities to justify investment and promote the maintenance of continued funding support.

5. Sources to corroborate the impact

[A] Link to the American College of Sports Medicine 2009 position stand / guidelines on exercise and physical activity for older adults with MMU specific references number 193-195 (corroborating impacts around the design of exercise interventions for older people around the world) http://journals.lww.com/acsm-msse/Fulltext/2009/07000/Exercise_and_Physical_Activity_for_Older_Adults.20.aspx

[B] Link to archived UK Department of Health guidelines corroborating impact on national guidance for physical activity for older people: http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4080994

[C] Link to World Health Organisation diet and physical activity guidelines for older people: (http://www.who.int/dietphysicalactivity/factsheet_olderadults/en/index.html)

[D] Testimonial / Letter on file from the Technogym Scientific Director describing the impact of our work influencing the initial design of resistance exercise equipment, modifications to existing designs, and influence over use as resistance exercise training for the elderly.

[E] Testimonial / Letter on file from Professor at the German Centre for Child Rehabilitation corroborating the clinical impacts of vibration research.

[F] Link to “Reporting whole-body vibration intervention studies: recommendations of the International Society of Musculoskeletal and Neuronal Interactions” (including a contribution from J Rittweger) evidencing impacts on setting clinical standards and providing guidance in vibration intervention: http://www.ncbi.nlm.nih.gov/pubmed/20811143

[G] http://www.express.co.uk/posts/view/61129/Steak-s-a-fillip-for-tired-gardeners In The Daily express on Sunday)

[H] http://www.thaindian.com/newsportal/india-news/nutritional-supplements-moderate-exercises-combo-can-help-elderly-stay-fit-for-long_10095086.html In Business Standard. By the Press Trust Of India.