Institution: Manchester Metropolitan University

Unit of Assessment: B15 General Engineering

Title of case study: Biomechanics Support for Great Britain Para-Swimming and the International Paralympic Committee

1. Summary of the impact

Research into the biomechanics of elite swimmers with a disability undertaken by Manchester Metropolitan University (MMU) has contributed directly to the development of Para-swimming both nationally and internationally. Firstly, it has made a significant and sustained contribution to the development of British Para-swimmers and their coaches, leading to outstanding performances by British swimmers at major International competitions including, most notably, the Beijing 2008 Paralympics, the IPC World Swimming Championships, 2010 and the London 2012 Paralympics. Secondly, In 2009 the IPC mandated the development of new, evidence-based classification systems for Paralympic sports and, in 2010, announced its intention to use the research findings from MMU to help devise a new classification system for Para-swimming.

2. Underpinning research

Para-swimming is the most highly-funded and successful Paralympic sport in Britain. Following a successful Beijing Paralympics, at which swimmers won 43% of Britain's medals, UK Sport significantly increased funding to Para-swimming. This was to ensure that the sport could access world class coaching and cutting edge medical and scientific support, in the run-up to London 2012. The biomechanics research undertaken at MMU formed an important part of that support.

The research undertaken by the MMU research team (details below) from Jan 2008 to July 2013 encompasses the areas of computational fluid dynamics, three-dimensional motion (video) analysis and the measurement of hydrodynamic drag and propulsive forces. Studies in these areas have added to the body of knowledge in swimming biomechanics and provided swimming coaches, teachers, scientists and classifiers with an enhanced understanding of the factors that limit the performances of swimmers with a physical impairment. Specifically, the research has helped explain:

1. How swimmers with a single arm amputation can increase the propulsion. Two ground breaking studies by Lecrevain *et al*. **[4 and 6]** used unsteady Computational Fluid Dynamics (CFD) to quantify how much propulsion a swimmer's partially amputated arm could generate and the factors that influence the magnitude of this propulsion. No previous study had looked at the contribution made by the upper arm to propulsion. The studies demonstrated that, for any given swimming speed, there is a minimum speed at which the upper arm must be rotated to generate effective propulsion. Below this, the upper arm will experience a net resistive drag force which adversely affects swimming performance.

2. How physical impairment can affect force production and fatigue in swimming. A number of studies funded by UK Sport **[2]** used tethered and semi-tethered force analysis and electromyography to measure indices of fatigue in physically impaired swimmers. The hypothesis that fatigue is associated with the level of physical impairment was rejected. No previous study has reported fatigue rates in trained swimmers with a disability. The study by Lee *et al*. **[2]** found that those Para-swimmers who have to rely predominantly on one arm for propulsion are able to sustain propulsive forces when sprinting, as effectively as those who have two arms for propulsion.

3. How physical impairment affects the amount of hydrodynamic drag (resistance) produced by a swimmer. A large scale study **[1]** has established the hydrodynamic drag of swimmers with a wide range of physical impairments. The hypothesis that there would be an inverse relationship between level of physical impairment and hydrodynamic drag was accepted. The study found that in the physical impairment classes 3-6, some athletes had a substantial advantage over others with regard to passive drag, which in turn may translate to a significant performance advantage.

4. How a single limb loss affects a swimmer's coordination and movement patterns in the water. Two studies by Osborough *et al*. **[3 and 5]** have quantified how swimming speed influences the underwater motion of swimmers with a single arm amputation. The relationships found between swimming speed, coordination and movement patterns for the physically impaired swimmers were different to those for able-bodied swimmers. Unlike able-bodied swimmers, arm amputees maintained a stable inter-arm coordination pattern, regardless of the speed they swam at.

Key Researchers
Dr. Carl Payton. Senior Enterprise Fellow in Biomechanics, MMU Cheshire, Dept. Exercise & Sport Science. (employed by MMU from Sept 1989 to present).
Dr. Conor Osborough. Senior Lecturer in Biomechanics, MMU Cheshire, Dept. Exercise & Sport Science. (employed by MMU from Sept 2009 to present).
Dr. Ian Kennedy. Senior Lecturer in Mechanical Engineering, MMU, School of Engineering. (employed by MMU from Jan 1998 to present).

3. References to the research

1. Oh, Y-T., Burkett, B., Osborough, C., Formosa, D. &. Payton, C.J. (2013). London 2012 Paralympic swimming: passive drag and the classification system. *British Journal of Sports Medicine*, *47*, 1-6. **DOI:** 10.1136/bjsports-2013-092192 (Included in REF2)

2. Lee, C.J., Sanders, R.H. & Payton, C.J. (2013) Changes in force production and stroke parameters of trained female able-bodied and unilateral arm amputee swimmers during a 30 s tethered front crawl swim. *Journal of Sports Sciences*.

3. Osborough, C., Payton, C.J. & Daly, D. (2010). Influence of swimming speed on inter-arm coordination in competitive unilateral arm amputee front crawl swimmers. *Journal of Human Movement Science*, *29*, 921-931. **DOI:** 10.1016/j.humov.2010.05.009

4. Lecrivain, G., Payton, C.J., Slaouti, A. & Kennedy, I. (2010). Effect of body roll amplitude and arm rotation speed on propulsion of arm amputee swimmers. *Journal of Biomechanics*, *43(6)*, 1111-1117. **DOI:** 10.1016/j.jbiomech.2009.12.014

5. Osborough, C., Payton, C.J. & Daly, D. (2009). Relationships between the front crawl stroke parameters of competitive unilateral arm amputee swimmers, with selected anthropometric characteristics. *Journal of Applied Biomechanics*, *25(4)*, 304-312. http://www.ncbi.nlm.nih.gov/pubmed/20095451 (Included in REF2)

6. Lecrivain, G.M., Slaouti, A., Payton, C.J. & Kennedy, I. (2008). Using Reverse Engineering and Computational Fluid Dynamics to Investigate a Lower Arm Amputee Swimmer's Performance. *Journal of Biomechanics*, *41*, 2855-2859. **DOI:** 10.1016/j.jbiomech.2008.06.036 (Included in REF2)

Relevant Grants to indicate research quality
UK Sport Graduate Innovation Project: *Development of a Swimming Specific Test of Anaerobic Power using an Isokinetic Ergometer* (October 2007-September 2010). Amount £74,000. Awarded to Dr. Carl Payton.
British Disability Swimming, High Performance Swimming Ltd (HPS Ltd): *Biomechanics Support for British Para-swimming* (April 2000 – June 2013). Amount £290,000. Awarded to Dr. Carl Payton.

4. Details of the impact

The research has helped enhance the performances of British Para-swimmers at major competitions and improved coaching practice in Britain; it has impacted on the international system for classifying Para-swimmers and has also helped promote the sport to the wider public.

i) Biomechanics Support for Great Britain Para-swimming
The first impact of the research was its significant and sustained contribution to the development of British Para-swimmers and their coaches, leading to outstanding performances by British swimmers at International competitions including, most notably, the Beijing 2008 Paralympics, the IPC World Swimming Championships, 2010 and the London 2012 Paralympics. The new knowledge gained through the research has been used to educate and inform Britain's leading coaches and elite swimmers such as multi world champions Ellie Simmonds and Amy Marren, helping them to identify strategies for optimising their performances.

Direct application of the knowledge generated by the research was achieved through Dr. Carl Payton in his role as Biomechanics Lead for the British Para-swimming squad **[A].** As a member of the High Performance Science and Medicine Team throughout the impact assessment period, Dr.

Payton was responsible for the delivery of biomechanics support services to elite athletes on the British Para-swimming World Class Programme **[E, F]**. The primary aim of the support was to provide swimmers with evidence-based advice on how to improve technical aspects of their performance, e.g. turning technique, arm coordination, streamlining. A number of research tools were developed to monitor the progress of Programme athletes, e.g. velocity meter, semi-tethered ergometer **[B].** Dr. Payton worked directly with British Para-swimming coaches and swimmers at the High Performance Centres in Swansea and Manchester, at UK and overseas training camps, and at international competitions (including the last four Paralympic Games).

The impact of the research on the performances of British Para-swimmers is difficult to quantify directly. However, British Para-swimming clearly believes that the work is having a significant impact as they continue to fund it. Funding in Paralympic sports is limited. National Governing Bodies will not continue to fund applied research unless they perceive it to be of significant benefit to them. In the London 2012 Paralympics, Britain had more individual swimming medallists than any other nation (24) and finished with a medal haul of 7 gold, 16 silver and 16 bronze. The sport science support, including the biomechanics, is perceived by other nations as World-Leading and to have contributed significantly to the ongoing success of British swimmers. A testimonial on file from the Sport Science and Sport Medicine Manager at British Swimming confirms, *"The biomechanical support we receive from Carl Payton falls into 2 areas: 1) on deck support to athletes and coaches and 2) major development projects which answer the big performance questions for Rio 2016. Working with Carl Payton, British Para-Swimming are able to tap into an extensive pool of expertise. The link with MMU has allowed British Para-Swimming to benefit from several applied projects which would be considered cutting edge within the Paralympic swimming environment."* **[C]**

The knowledge generated by the research has also been disseminated to coaches and other practitioners at International, National and Regional level through presentations at coaching conferences, workshops, seminars and publications in coaching journals (examples listed at end).

ii) Biomechanics Support for the International Paralympic Committee (IPC)

The second impact of the research is the provision of new scientific knowledge that led to the decision by the IPC in 2010 to use the research to improve the fairness and objectivity with which elite swimmers are classified for international competitions.

An effective classification system should provide athletes who have a disability with an equitable starting point for competition by minimising the impact that their impairment has on the outcome of the event. The current swimming classification system relies on expert, but predominantly subjective, opinion, rather than on empirical evidence. In 2009 the IPC mandated the development of a new, evidence-based classification system for swimming. Research groups from Australia, USA, France and the UK were then invited to contribute to the project, with the UK group (led by Dr. Payton) taking the lead on the assessment of drag (resistance). Over 200 elite swimmers have been tested and preliminary results (Oh *et al*., 2013) indicated that the current classification system significantly disadvantages certain swimmers by placing insufficient weighting on drag assessment. These findings highlighted an important deficiency in the current system and provided an understanding of how drag assessment could be incorporated into the new system.
The knowledge generated by the drag research has been communicated directly, in written reports, to swimmers and coaches in over 41 countries and indirectly to an even broader audience via the IPC website (http://www.paralympic.org). As the Medical and Scientific Director for the International Paralympic Committee writes (in a statement on file at MMU **[D]**)**"***The further development of sport-specific classification systems on the basis of scientific evidence is critical to the continued growth of the Paralympic Movement and for opportunities available to athletes with a disability. This project will form the basis for the revision of the classification system for IPC Swimming to become credible, valid, transparent and consistent with the IPC classification code. The IPC recognises the lead role of MMU in this project."*

iii) Direct Impact through Coaching, Workshops, Newsletters and Media Dissemination
Secondary impacts have been achieved through the dissemination of Dr. Payton's research findings at a range of conferences, workshops and events to the professional and amateur coaching community throughout the impact period. Most notably Payton has run workshops for the

British Para-swimming Coaches Annual Meeting, Liverpool (2011), provided the keynote address and various demonstrations on *Biomechanics Support for Elite Swimmers with a Disability* to the 16th FINA Sports Medicine Congress, Manchester (2008) and in 2013 he was a speaker at the first ever World Coaches Conference.
Payton has also contributed many articles to coaching publications including the *Peter Harrison Centre Newsletter* (2011) **[E],** *SportEX medicine* newsletter **[F]** and the chapter on *Biomechanics* in the *British Disability Swimming Delivering on Deck Handbook*. His role and his approach to using biomechanics within it was featured in an Independent newspaper article: http://www.independent.co.uk/student/career-planning/getting-job/biomechanics-the-gold-standard-434485.html

5. Sources to corroborate the impact

Reports, reviews, web links or other documented sources of information in the public domain.

[A] Link to full swimming team list from London 2012 Olympic Games – evidencing Carl Payton's role as biomechanics lead within the squad (p2)
http://www.swimming.org/assets/uploads/library/Team_List_-_London_2012_Paralympic_Games__GBR_Swim_Team_Holding_Camp.pdf

[B] Swimming Times Article – *Science and the Paralympian, June 2012* (electronic copy of the article available on request) corroborating Carl's work with the British Paralympic team.

[C] Full testimonial on file from Sports Science & Sports Medicine Manager – Para-swimming, British Swimming corroborating the impact of MMU biomechanics research on the British Paralympic Swimming team.

[D] Full testimonial on file from Medical and Scientific Director - International Paralympic Committee corroborating impacts on international IPC classification systems for Paralypmic Swimming.

[E] Biomechanics Support for Great Britain Disability Swimming. *Peter Harrison Centre Newsletter (available on request)*

[F] Biomechanics Support for British World Class Disability Swimming. sportEX medicine newsletter *(available on request)*

The following individuals have agreed to be contacted to further corroborate the contribution of the research undertaken at MMU to the development of Paralympic swimming

[G]National Performance Director – Para-swimming, British Swimming

[H]Classification Research Manager - International Paralympic Committee