Institution: Manchester Metropolitan University

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

Title of case study: Swimming biomechanics transforms the World Para Swimming classification system and improves the performance of British swimmers

Period when the underpinning research was undertaken: 2000 – 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Carl Payton	Senior Enterprise Fellow, Professor	1989 – present
Ine Van Caekenberghe	Research Associate	2015 – 2020
Hannah Jarvis	Research Associate	2016 – 2017
Conor Osborough	Senior Lecturer	2009 – 2016

Period when the claimed impact occurred: 1 August 2013 – 31 July 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

Manchester Metropolitan University research on the biomechanics of Para swimming has provided the scientific foundation and evidence base used by the International Paralympic Committee (IPC) to categorise physically-impaired swimmers competing at national and international events. Specifically, changes introduced into the 'water test' in 2018 led to re-categorisation of approximately one-third of international Para swimmers, including some controversial and high profile cases. The research has also underpinned the IPC's development decisions on a new, more objective and scientifically-rigorous Para swimming classification system, which will now be implemented sometime after the rescheduled Tokyo Paralympics. Drawing on both research methodologies and findings, the body of work has also influenced GB coaches' decisions on swimmer training. Studies have been critical to individuals' performance improvements and the GB team's World Records and medal achievements at major international competitions, including a record-breaking 47 swimming medals at the Rio 2016 Paralympics. GB was the top-ranked nation in the Para Swimming World Series in 2017, 2018 and 2019.

2. Underpinning research

Professor Carl Payton has led the research programme on swimming biomechanics at Manchester Metropolitan University for over 20 years. The work uses novel applications of advanced techniques, including unsteady computational fluid dynamics (CFD), dual-medium (above and below water) 3D motion analysis, passive and active drag measurement, and tethered and semi-tethered dynamometry. The research seeks to understand how physical impairments influence technique, propulsion and drag production, and start and turn performance. The group has produced a substantial body of research in over 60 peer-reviewed scientific outputs since 2000.

Findings from key studies illustrate the scope and quality of this body of work. For example, a ground-breaking study [1] used a novel unsteady dynamic CFD model to quantify how much propulsion a swimmer's partially-amputated arm could generate and the factors influencing the magnitude of this propulsion. This study was first to show that, for any given swimming speed, the upper arm must reach a critical rotation speed to generate propulsion; below this speed, the arm creates resistance. Propulsion is also enhanced by body roll.

Payton was also the first to measure propulsive forces and fatigue in Para swimmers using tethered and semi-tethered force analysis and electromyography to determine indices of fatigue in physically-impaired swimmers. This work established that fatigue is not associated with the level of physical impairment. A key study showed that Para swimmers who rely predominantly on one arm for propulsion can sustain propulsive forces when sprinting just as effectively as swimmers using two arms [2].

A large-scale study at the London 2012 Paralympics using Payton's drag measurement techniques helped to establish a strong collaboration with researchers from the University of the Sunshine Coast (USC). The study found that within the more severe physical impairment classes (S3-6) some athletes had a substantially lower passive drag (resistance in streamlined position) than others in the same class, which in turn could translate to a significant performance advantage. This was one of the first rigorous scientific studies to question the scientific

underpinning, and hence fairness, of the International Paralympic Committee's (IPC) classification system **[3]**.

As evidence that the classification system lacked rigour continued to mount, in 2016 the IPC funded a joint project between Manchester Metropolitan and USC. IPC tasked the researchers to conduct definitive biomechanics research that could underpin an evidence-based revision of the classification system and contribute to the formulation of new classification protocols and guidelines. The project has collected data from more than 150 Para and able-bodied swimmers in the UK and overseas – the largest ever study cohort of this kind. The project is led jointly by Payton and Professor Brendan Burkett, who collaborate on all study designs, data collection and analysis.

The project's strength impairment study **[4]** used a random forest algorithm successfully to classify 95% of Para swimmers based on strength scores. The study concluded that a defined battery of tests could infer loss of strength in Para swimmers and help to guide minimum eligibility criteria. Strength scores correlate significantly with maximal swim speed, showing that reduced strength can explain activity limitation in Para swimming, although the type and aetiology of physical impairment influence some test results. In a parallel published study to evaluate coordination tests, the team found that instrumented tapping tasks can infer loss of motor coordination, resulting from brain injury and can also be used to assign sport class.

In a novel approach, the team investigated cluster analysis to classify swimmers with limb deficiency **[5]**. The method uses machine learning (ML) to define the impact of physical impairments on swimming performance. The ML derives class structures by clustering Para swimmers together, based on their estimated activity limitation. In all classes of the current system, the analysis found swimmers who are advantaged or disadvantaged by the location and severity of their limb deficiency impairment. This analysis showed a cluster-based classification structure, with no more than six classes, would provide fairer and more equitable competition than the current classification system for limb-deficient swimmers.

The pivotal 2010 study on passive drag [3] was followed by an equally ground-breaking study on active drag **[6]**. This was the first ever study to report active drag (resistance whilst swimming) on elite Para swimmers, and to establish the effect of type and severity of impairment on drag. This study found that the impact of central motor and neuromuscular (CMN) impairments on active drag is substantively different to the impact caused by anthropometric impairments. It demonstrated that Para swimmers with CMN impairments are predisposed to high active drag during freestyle swimming, which affects their performance; those with anthropometric impairments are not. The effects of these two impairments are therefore not comparable and, to help achieve fair and equitable competition, the study suggests these groups should compete separately.

3. References to the research

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

2. Lee CJA, Sanders RH, **Payton** CJ, (2014). Changes in force production and stroke parameters of trained able-bodied and unilateral arm-amputee female swimmers during a 30 s tethered front-crawl swim. J. Sports Sci. 32(18):1704-1711. DOI: 10.1080/02640414.2014.915420.

3. Oh Y-T, Burkett B, **Osborough** C, Formosa D, **Payton** C, (2013). London 2012 Paralympic swimming: passive drag and the classification system. Brit. J. Sports Med. 47:1-6. DOI: 10.1136/bjsports-2013-092192.

4. Hogarth L, Nicholson V, Spathis J, Tweedy S, Beckman E, Connick M, van de Vliet P, **Payton** C, Burkett B, (2019). A battery of strength tests for evidence-based classification in para swimming. J. Sport Sci. 37(4):404-413. DOI: 10.1080/02640414.2018.1504606.

5. Hogarth L, **Payton** C, Van de Vliet P, Connick M, Burkett B, (2018). A novel method to guide classification of para swimmers with limb deficiency. Scand. J. Med. Sci. Sports 28:2397-2406. DOI: 10.1111/sms.13229.

6. **Payton** C, Hogarth L, Burkett B, Van de Vliet P, Lewis S, Oh Y-T, (2020). Active drag as a criterion for evidence-based classification in Para swimming. Med. Sci. Sports Exerc. 52(7):1576-1584. DOI: 10.1249/MSS.0000000000002281.

External Funding (PI: Carl Payton)
- Research in Disability Swimming. 2002-2019. National Lottery/British Swimming (Project ID: 68250). Total contract: GBP221,207.
- Test of Anaerobic Power using an Ergometer. 2007-10. UK Sport. Award value: GBP74,000.
- Rio Para swimming. 2015-19. High Performance Swimming Ltd (Project ID: 68726). Award value: GBP71,579.
- IPC Para swimming Classification. 2016-18. International Paralympic Committee/UK Sport (Project ID: 68742). Award value: GBP80,300.
- World Para Swimming Classification Research – Physical Impairments. 2019-21. International Paralympic Committee/UK Sport (Project ID: 174413). Award value: GBP74,435.
- Olympic Swimming Biomechanics. 2017-21. British Swimming (Project ID: 68746). Award value: GBP100,000. (GBP80,000 matched funding from Manchester Metropolitan).

Additional indicators of research quality
- Repeat, continuous funding from national/international governing bodies (UK Sport, British Swimming, IPC) based on the quality and impact of the research.
- Recent funding to embed biomechanics research into the GB Olympic able-bodied team is an indicator of the track record, quality and impact of the research with the Para swimming team and a desire to replicate the model for able-bodied swimming.

4. Details of the impact

Enhancing the performance of Para swimmers and international standing of the GB team

According to the GB team's National Performance Director, the significance of the impact of Payton's research contribution for the team is reflected in GB's record medal haul in the pool at Rio 2016 compared with London 2012 **[A]**. GB won 47 medals, including 16 gold, in Rio compared with 39 medals, of which 7 were gold, in London. This pushed GB to 3rd place at Rio compared with 7th place in London **[A,D]**. GB also topped the national ranking in the World Para Swimming (WPS) World Series in 2017, 2018 and 2019. Of the 321 Para swimming long course world records broken at least once since 1 August 2013, 39 (12%) are currently held by GB Para swimmers – the highest number by any country during this period. Payton provided evidence-based support to all of these swimmers **[D].**

Payton is the lead bio-mechanist for the British Para Swimming World Class Programme and integral to its Sports Science and Sports Medicine Team. He applies his validated techniques (see especially references [1-3,6]) and transfers the knowledge acquired from his research to guide elite swimmers and their coaches on performance improvement (e.g. optimisation of hydrodynamics, stroke rates and efficiency) **[A]**. UK Sport/British Swimming funded Payton to support the GB Team's preparation for the Rio 2016 Paralympics. Due to the significant impact of his research, described below, Payton received increased funding to continue this work for the 2016-20 Tokyo Paralympic cycle (see Section 3).

Payton has provided expert scientific support to every GB Para Swimming World Class Programme athlete over the past 20 years (approximately 35-40 swimmers a year, 97 swimmers since 2013) **[A]**. He conducts studies and draws on his research to answer a broad range of performance-related questions. He works extensively with British Para Swimming coaches and swimmers at the National Performance Centre in Manchester, at training camps, and at international competitions, including World Championships and Paralympic Games **[A]**.

Improvements in the performance of any individual or a team is a combination of the accumulated effects of training, nutrition, skills development and much more. However, according to British Para Swimming's National Performance Director, *"Payton's continued employment in the team over 20 years is testament to the recognition and perceived contribution he makes to swimmers' competition success. His expertise has made a material contribution to Great Britain's sustained position as one of the top nations in international Para swimming competition"* **[A]**.

There are strong indicators of significant impact on the team and individuals. As an example, Payton applied his drag research expertise [3,6] to test all of the leading manufacturers' swimsuits for the women's squad prior to Rio 2016. He found drag differences of up to 10% between some suits, which would equate approximately to a 1s difference in a 100m race. From these findings, swimmers made informed decisions about their swimsuits and bespoke adjustments. The significance of this study is revealed in the marginal performance gains

achieved in the Women's 4x100m Medley Relay at the Rio Paralympics. GB broke the World Record by 0.98s, 0.62s ahead of Australia, which also swam faster than the previous World Record time. The accumulation of marginal gains, including evidence-based swimsuit selection and adjustments, made the difference between gold and silver medals **[A,B]**.

The significance of the impact is evident in how the competition performance of individual swimmers has improved. For example, Payton collaborated with Para swimmer, Maisie Summers-Newton, and her coach Jacquie Marshall. Marshall identified the backstroke leg as the weak element in her swimmer's 200m Individual Medley. Payton used knowledge from his passive and active drag research and his studies on limb-deficient swimmers to co-develop a 12-month technical intervention. This culminated in a 0.93s improvement in the swimmer's backstroke leg and a new World Record at the World Para Swimming Championships in London in 2019 **[C]**. Marshall coached three medallists, including Summers-Newton, for this competition and was named British Swimming's Para swimming Coach of the Year 2019 **[C]**. The record-breaking swim contributed to Summers-Newton making it to the three-person shortlist for the BBC Young Sports Personality of the Year Award 2019 **[C]**.

Transforming the IPC/World Para Swimming classification system

There has been growing disquiet in the swimming community about the unfairness and lack of scientific rigour behind elements of the existing Para swimming classification system (see Section 2). To address these concerns, the IPC funded research to underpin development and global implementation of a comprehensively-revised international classification system for all Para swimmers. The Managing Director of World Para Sports and IPC Member confirms the significant impact of this work on the sport: *"There has been considerable progress made toward measures for evidence-based classification in Para swimming over the initial 24-month research project and the work is already having a significant impact on the classification process"* **[E]**.

This impact is significant because WPS/IPC is developing a classification system based on objective measurements rather than on expert, but subjective, opinion. Subjective assessments can discriminate against elite athletes, whose superior training puts them in a higher class than some competitors with the same level of impairment, but who train less. The Managing Director of World Para Sports states: *"This project has enabled Para athletes worldwide to obtain a better understanding of the importance of scientific research in Para swimming, and gave them the possibility to directly take part in the formation of a new classification system… The ongoing project has resulted in the publication of findings in renowned scientific journals which have added the legitimacy required for WPS to translate research into a revised classification system for Para athletes"* **[E]**.

The new system will be mandatory and adopted for all competitions from local and national meets to World Championships and the Paralympics. It will be rolled out sometime after the rescheduled Tokyo Paralympics and will immediately affect all 2,105 elite Para swimmers currently registered with the IPC for international competition along with thousands more competing at national and club level world-wide **[F]**. Britain, alone, has 517 registered Para swimmers; 93 GB Para swimmers are internationally-classified **[F]**. WPS/IPC are already considering how to operationalise the new classification system, including the necessary training and reaccreditation of hundreds of Para swimming national and international classifiers and the possible creation of world-wide classification centres, where the new measurement-based classifications will be conducted **[F]**. These significant changes are currently under discussion within WPS/IPC.

The research has already informed significant and far-reaching changes on the classification process. Ahead of awaited full amendments, WPS introduced major revisions to the classification rules and regulations on 1 January 2018. WPS Head of Classification confirms that *"Payton's research, particularly his work on passive and active drag, helped shape the development of the new water test and elevate the importance of drag assessment in the existing classification system"* **[E]**.

All international swimmers with a physical impairment took the new water test prior to competing at the World Championships in October 2019. WPS organised 22 classification events world-wide from January 2018 to October 2019. Between 2018 and 2020 a total of 1,114 elite Para swimmers (about half of all registered international Para swimmers) followed the new assessment protocols. Of the swimmers who already held an international classification, 71% remained in the same class, 13% were re-classified to a higher, less impaired class, and 16%

were re-classified into a lower, more impaired class. Notably, ten swimmers were deemed to be ineligible for Para swimming competition as a result of the new assessment **[G]**.

Re-classification has a profound impact on individual swimmers as they find themselves in easier or harder classes, or even forced to retire from international Para swimming competition. Re-classifications also affect the medal prospects of competing nations. Most controversially, 14-times S10 Paralympic medallist, André Brasil, was deemed ineligible for Para swimming after undertaking the new water test **[H]**. Conversely, Alice Tai, eight-time World Champion, moved from the S9 class to the 'easier' S8 class, subsequently winning four World Championship gold medals in London 2019, and ending the ten-year winning streak of USA legend, Jessica Long, in the S8 class **[H]**. Tai won seven world titles in this new class during 2019 earning her the British Swimming Athlete of the Year Award 2019 **[C]**.

Recent independent research evaluated the impact that the new water test re-classifications have had on competition results by analysing race performances of Para swimmers reclassified before the European Championships in Dublin 2018. The work confirms that the race times of these swimmers were significantly more congruent with the mean times of their new classes **[I]**. Despite the legitimate concerns of swimmers, this study provides first evidence that the new water test assigns swimmers to a more appropriate class for competition, despite the "heart break and confusion" **[H]** reported by individual swimmers reclassified into harder groups.

5. Sources to corroborate the impact

A. Statement from the National Performance Director, British Para Swimming *highlights the sustained and significant impact of Payton's research insights and the impact of his evidence-based advice on individual and team performance.*

B. YouTube video (https://www.paralympic.org/video/swimming-women-s-4x100m-medley-relay-34points-final-rio-2016-paralympic-games) *shows the GB World Record victory and the time differential between GB's gold and Australia's silver medal times.*

C. Statement from Coach to WPS Champion Maisie Summers-Newton and British Swimming/BBC Sport news items *give evidence of Newton-Summers' research-informed training, her improved performance, and details of the 2019 award winners/shortlists*

D. World Para Swimming database exports *provide* evidence *of long course World Records and GB's WPS World Series rankings.* IPC Rio Paralympics webpage *shows GB's final Para swimming medal count at Rio 2016.*

E. Statements from the Managing Director, World Para Sports and WPS Head of Classification *provide evidence of the contribution of the research to defining the new classification system, revisions to the water test, outcomes from its introduction and discussions around how to operationalise the new classification system.*

F. Extract and analysis of the IPC Classification Master List and statement from the Classification Coordinator, British Para-swimming *provide evidence of the number of Para swimmers registered and classified worldwide for international competition and for national GB competition.*

G. Data provided by WPS on *outcomes from international classifications since introduction of the new water test in 2018.*

H. Articles from SwimSwam and IPC Paralympic websites about *the reclassifications of André Brasil, Ollie Hynd and Alice Tai, and Alice Tai's four S8 wins at London 2019.*

I. Puce L, Marinelli L, Pallecchi, I. *et al.* (2020). Impact of the 2018 World Para Swimming classification revision on the race results in international Paralympic swimming events. Ger. J. Exerc. Sport Res. 50:251-263 (DOI: 10.1007/s12662-019-00637-7) *provides an independent analysis of the race performance of reclassified swimmers and also highlights the significance of the World Para Swimming Classification Review Project.*