

TECHNOLOGY IN PARA SPORT: WHERE HAVE WE COME FROM AND WHERE ARE WE GOING?

THE EXAMPLE OF WORLD PARA SWIMMING CLASSIFICATION

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BACKGROUND

The Paralympic Games are the pinnacle of competition for an athlete with a disability. Outside of the competitive sporting arena, a central distinction between the Olympic and Paralympic Games is the Paralympic classification system. To maintain the integrity of this process, the International Paralympic Committee (IPC) has mandated the development of an evidence-based classification system for each Paralympic sport.

The process of classification involves grouping athletes with an eligible impairment into different classes based on their level of function. In the sport of swimming, a sport-specific evaluation is designed to appraise the impact of para

athletes' impairments on swimming performance to ensure the relevance of this process. The use of different sport classes in World Para Swimming is crucial to ensure a fair and equitable field of play, considering the diversity of impairment types and severity in the sport.

The current swimming classification system

The sport of swimming has been part of every Paralympic competition since 1960. As with other sports, at that point in time the swimming classification system was based purely on a medical assessment of the athlete. For example, athletes with an amputation formed a group of amputee-specific classes, similarly athletes with a spinal cord injury (SCI) formed a spinal cord-

specific group of classes, etc. This system was based on the somewhat limited 1960s sports medicine technology and knowledge and relied heavily on professional assessment of the impairment to assign classes. The extent to which the impairment limited the athletes' swimming potential was not considered at that point in time.

In 1990, IPC Swimming (now called World Para Swimming) moved away from this medical-based model and introduced the Swimming Functional Classification System. This new system essentially involves two forms of assessment. First, a bench-test musculoskeletal screen uses a modified format of the traditional medical range of motion (ROM) and strength assessment. The cumulative score from these equally



Figure 1: Instrumented tapping pads developed to provide quantitative measures of motor coordination impairment. In this test the participant has 15 sec to achieve as many cycles as possible, moving their hands as quickly and accurately as possible between the targets.

weighted dry land measures determine into which classification the athlete is placed, as each classification is represented by a specific range of bench-test scores. Second, an in-water assessment involves a technical (coach) observation of the athlete swimming in the water. Thereafter, the bench-test score may be adjusted, resulting in the final classification assignment. When compared to the previous classification system, the inclusion of the water test did improve the sport-specific 'functional' assessment of the athlete. Nevertheless, the system is still fundamentally an 'observational' assessment with limited use of technology.

MOVING TOWARDS EVIDENCE-BASED CLASSIFICATION SYSTEMS WITH THE USE OF TECHNOLOGY

In November 2007, the IPC approved the IPC Classification Code mandating the development of evidence-based systems of classification. An evidence-based system is one that has a clearly defined purpose, with empirical evidence indicating that the methods used for assigning class will achieve the stated purpose. The methods used to assign classification should minimise the impact of impairment on the competition outcome. In other words, the most successful swimmers should be those that have optimised their training and/or are the most 'gifted' rather than being advantaged by their impairment (or lack of). For a genuinely evidence-based classification system to succeed it is

important that the methods used to assign class are accepted to be 'correct' by both the scientific community and the wider sporting audience.

To facilitate the development of evidence-based classification systems, researchers must develop tests that describe each para-athlete's physical impairment and define the relationship between the results of these tests and sporting performance. Here, technology can play a meaningful role in providing more fair and equitable competition in World Para Swimming.

Developing instrumented tests of physical impairment

It is important to note that instrumented tests do not directly measure impairment, but rather infer impairment based on knowledge of intact, unimpaired body structures and functions. Valid impairment tests should have several measurement properties. They must be precise and reliable, specific to the impairment of interest, quantitative, parsimonious (account for the greatest variance in sporting performance) and as resistant to training as possible. In World Para Swimming, the impact of physical impairment on swimming performance can be attributed to four distinct areas:

- An impairment of ROM.
- An impairment of motor coordination.
- An impairment of strength.
- An impairment in anthropometric characteristics.

Use of technology to measure motor co-ordination

Co-ordination is fundamental for effective swimming performance³. Motor co-ordination is often assessed during the classification process in para athletes, although the methods used are qualitative and lack key measurement properties that are necessary for the development of evidence-based systems. For example, the current classification of motor co-ordination impairment in World Para Swimming involves the subjective assessment of an athlete's ability to 'co-ordinate' their limbs during repetitive single-joint swimming actions (e.g. shoulder flexion and extension) that are performed at a steady pace and of increasing speed. Athletes are given a score from 0 to 5 for each joint, based on subjective criteria that includes observed restrictions in range of movement, for example "... at increasing pace, moderate range of movement, moderate spasticity with time restricting movement and/or moderate co-ordination problems..." for a score of 3.

Technology has provided instrumented tests of motor co-ordination for the purposes of classification in para athletes. Motor co-ordination tests involve participants producing discrete, reciprocal or alternating tapping tasks over a set duration as rapidly and accurately as possible, with the instrumented tapping pads registering contacts to provide quantitative outcome measures such as mean movement time (Figure 1). Research has found such tests to

have excellent reliability in non-disabled participants.

Use of technology to measure muscle strength

The development of instrumented strength tests using relatively inexpensive load cell technology has also represented significant progress towards the development of evidence-based classification in para athletes. Current classification systems use manual muscle testing techniques to assess strength impairment, wherein a classifier infers a para athlete's loss of strength by rating whether he or she can produce what is termed 'normal' resistance around a joint. Although having several advantages, including being easy to administer, widely used in clinical practice and relatively inexpensive, manual muscle testing techniques lack key measurement properties required for evidence-based classification.

Guidelines have recently been provided for the systematic development of instrumented tests of muscle strength for the purpose of classification². One of the key recommendations is to develop isometric measures of muscle strength that assess the para athlete's force generating capacity in multi-joint positions that are standardised and specific to the sport of interest. Figure 2 provides an example of an isometric (static)



Figure 2: Example of an isometric strength tests developed to determine lower limb strength impairment in Para-swimmers. Relatively inexpensive load cells allow for quantitative measures to be collected during standardised testing procedures.

strength test using a load cell, designed to infer lower limb strength impairment in a para swimmer. Such tests are suggested as they determine the maximal force generating capacity of a muscle or muscle group and are more likely to be resistant to training than dynamic muscular strength and power tests which may have already been incorporated into para-athletes' training programmes. The latter is an important attribute to consider, as impairment measures that are sensitive to sports training may predispose well-trained para-athletes being assigned an incorrect sport class due to high levels of muscular strength gained through effective training, rather than due to their lack of impairment.

Our research group has developed instrumented tests of motor co-ordination,

strength and ROM to guide World Para Swimming classification. We are currently collecting data in non-disabled participants to determine the reliability of these tests and provide normative values to allow for meaningful interpretation of results in swimmers with physical impairment. Initial analyses suggest these tests have acceptable reliability. Subsequently, our aim will be to define the relationship between the results of such impairment tests and swimming performance.

Understanding the relationship between physical impairment and swimming performance

Technology has the potential to provide an objective assessment of swimming performance, allowing for a greater

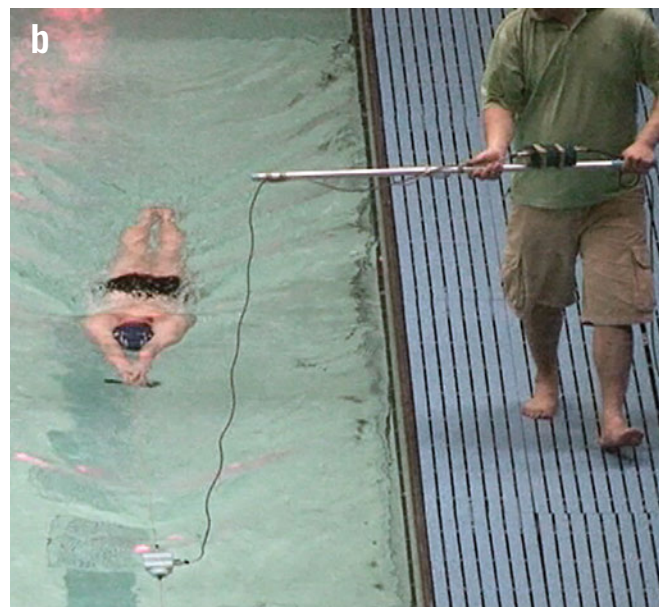


Figure 3: Towing device to measure drag, a) Custom-made electro-mechanical towing device, b) Towing device in action with swimmer in the pool.

understanding of the impact of para swimmers' physical impairments³. This is a critical step in developing evidence-based classification systems in World Para Swimming. State-of-the-art technologies can provide new knowledge on swimming performance, both in-water and in the laboratory.

Swimming drag and propulsion technology

A swimmer's performance is determined largely by their capacity to produce propulsion effectively while minimising the resistive or drag forces from the water⁴. A fair classification system should, therefore, evaluate objectively the extent to which an individual's impairment limits his or her capacity to achieve these two important determinants of performance.

It has recently been argued⁵ that the current classification system allocates insufficient importance to evaluating a swimmer's drag. This work showed that for swimmers in the current classes of S1 to S6, some athletes appear to have a substantial advantage over others regarding passive drag, which in turn may translate to a performance advantage. Whether this is an unfair advantage depends critically on whether the swimmer's relatively low drag is a consequence of superior training versus impairment type. If it is the latter, then the current classification system is unfairly advantageous for certain swimmers by placing insufficient weighting on drag assessment.

To address this issue, a custom-made electro-mechanical towing device with an in-line submersible load cell will be used by our research group to scientifically measure para swimmers' drag at a known towing velocity (Figure 3A and 3B). Data collection will aim to collect passive and active drag measures on a large sample (>50) of highly trained para swimmers (classes S1 to S6). Direct measurements of passive drag will be obtained using the towing method previously described⁵ and estimates of active drag will be obtained on the same swimmers using the Naval Architecture Based Approach⁶. Impairment measures of motor co-ordination, strength and ROM will also be collected. If active and passive drag increase proportionately with the level of physical impairment (in equally

trained individuals) due to reduced joint ROM and/or poor movement co-ordination, this should be accounted for in a revised classification system.

The same technology can be used to determine the impact of physical impairment on the amount of propulsive force that swimmers can generate. Using an in-line load cell attached to a fixed point, swimmers can undertake fully tethered swimming trials to determine intra-cyclic force outputs (Figure 4A and 4B). Such analysis provides insights into the impact that physical impairments have on the ability of swimmers to produce propulsion in water. For example, research has shown swimmers with a unilateral upper arm amputation to produce approximately 20% less tether force output than able-bodied swimmers of a similar training status.

Swimming kinematics and co-ordination technology

Although the relationships between strength and swimming performance have been well documented in non-disabled swimmers, there is limited knowledge on this topic in para swimmers with impaired strength, for example swimmers with cerebral palsy or spinal cord injury⁷. This knowledge is essential for the development of a revised classification system in Paralympic swimming.

Joint ROM also influences the amount of propulsion a swimmer can generate and their ability to reduce drag. This characteristic should therefore be featured in a revised classification system. To date, remarkably little work has been done on joint ROM in physically impaired swimmers. Research efforts from our group aim to improve our understanding of the relationship between joint ROM, propulsion and drag, so that joint ROM can be given appropriate weighting in the revised classification system.

In previous research, a custom-built bilateral swim bench ergometer system was used to collect upper-limb kinematic and hand force performance measures⁸. There were inconsistent and generally weak correlations between the current classification system ROM scores and the actual 3D kinematic ROM scores, with similar weak correlations to hand force. These findings highlight firstly the deficiencies

in the current classification system, as well as the advantages of implementing sport-specific technology to objectively address this issue.

To understand the impact of restricted joint ROM on propulsion, it is first necessary to identify what joint ROMs are used by able-bodied swimmers when performing the different strokes (freestyle, backstroke, butterfly and breaststroke). This information will be used to identify joint ROM boundaries, for each joint, beyond which propulsion is compromised and/or drag is increased.

Planned research will aim to use video technology to obtain normal joint ROM profiles for each swimming stroke in a small sample of well-trained able-bodied swimmers. A standard three-dimensional video analysis protocol, involving four full HD underwater cameras (MAKO G-223C) and four HD above water cameras (Sony HDR CX700), will be used to obtain three-dimensional co-ordinates of the full body. True (Euler) joint angles and joint ROMs will be calculated from these co-ordinates using a bespoke MATLAB programme developed at Manchester Metropolitan University.

The joint ROM profiles of physically impaired swimmers measured statically on dry land will be compared with those achieved dynamically when swimming (three-dimensional video analysis). This will establish the validity of using static joint ROM measures in the classification process. These joint ROM data will be obtained from a large sample ($n > 50$) of well-trained, high-level swimmers with joint restrictions, drawn from across the current IPC classes (S1 to S10) where possible.

The effect of restricted joint ROM on propulsion will be assessed by considering the kinematics (movement patterns) of the affected limb(s), e.g. arm. As propulsion is proportional to the limb speed (squared), the orientation of the limb relative to the water and the path followed by the limb, these three key determinants of propulsion (limb speed, orientation and direction) will be measured from the three-dimensional analysis and compared to the 'normal' values obtained from able-bodied swimmers.

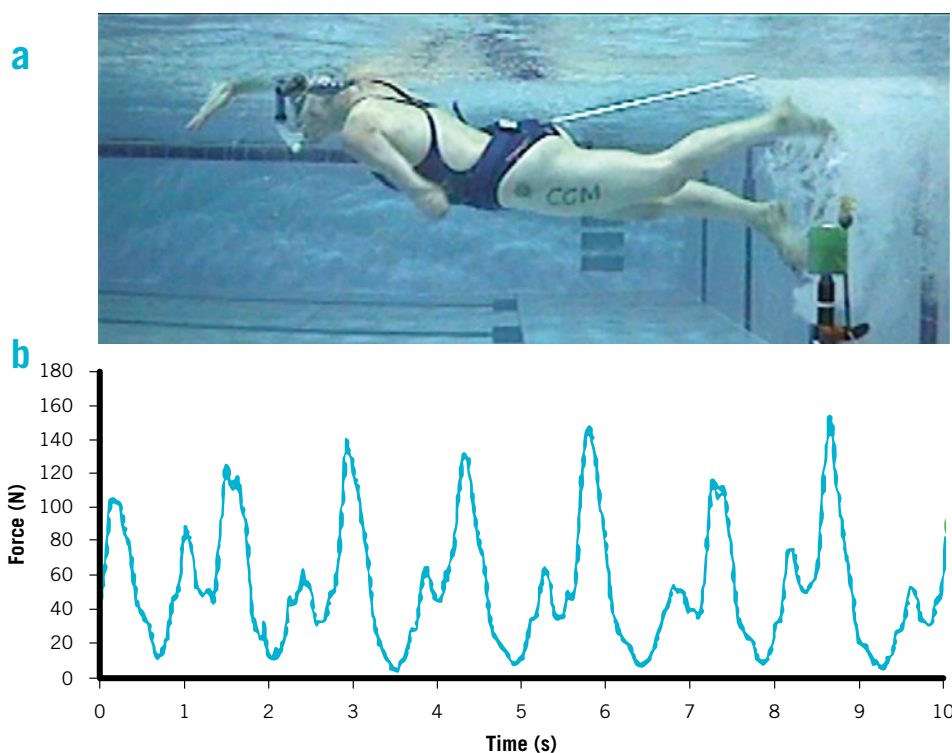


Figure 4: Tethered swimming technology to measure intra-cyclic force outputs. a) Showing swimming attached to the tether. b) Force-time output of intra-cyclic force when swimming.

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CONCLUSION

Technology plays a key role in the training, competition and safety of para athletes. To develop a new evidence-based World Para Swimming classification system requires an objective evaluation of where the sport has come from, as this knowledge will guide the future of the sport. Technology and the sport-specific application of technology, has been key to the development of a new swimming classification system. Although still a work-in-progress and with planned implementation after the Tokyo 2020 Games, these developments have enabled use of a custom-made technology for the objective measurement of motor co-ordination, muscle strength, ROM and the measurement of swimming drag. This information quantifies 'what is happening' when the para athlete performs in his or her chosen sport and provides essential feedback to the coach and/or support staff (e.g. doctors, physiotherapist etc.) on the safety and effectiveness of training.

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