Title Performance characteristics of para swimmers – how effective is the swimming classification system?

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Abstract/Summary [this will be used for indexing services and does not appear with article]

Swimming is one of the inaugural sports within the Olympic and Paralympic Games. The key difference between the Olympic and Paralympic games being the classification system. The aim of this study was to investigate how effective the current classification system creates clearly differentiated Paralympic competition classes, based on performance time for all swimming strokes and events. Based on the performance characteristics of swimmers within the current classification system the relationship between impairment and swimming performance is inconsistent, potentially disadvantaging some athletes. Appropriate sports medicine tests are required for the development of an evidence-based swimming classification system.

Key Points (3–5)

- Paralympic swimming classification began with sports medicine driven medical based system.
- The current functional classification system is a swimming-specific system that assigns and integrates athletes with eligible impairments into classes.
- Based on performance characteristics of swimmers within the current classification system the relationship between swimming class and performance is inconsistent. Potentially disadvantaging some athletes.

- A new evidence-based swimming classification system is currently under development, built on the knowledge from the sport medicine assessment.

Introduction

The sport of swimming has been part of every Paralympic program since the Games began in 1960 and is one of the most popular sports for para-athletes with a physical, visual or intellectual impairment. For all Paralympic sports, an international classification system determines athlete eligibility and the subsequent 'grouping' of athletes for competition. The aim of classification is to achieve fair competition by minimising the impact of an individual's impairment on the outcome of competition so that sporting ability, skill level and training alone determine success and the final result [1]. Despite this long history of inclusion within the Paralympic Games, questions have often been raised on the effectiveness of the classification system. Indeed, the International Paralympic Committee (IPC) has mandated the development of evidence-based classification systems of classification [1], which highlights the need for a review of the current classification system for swimming.

As Paralympic sport evolved from an initial medical rehabilitation program, sports medicine formed the original swimming classification system. This inaugural classification system was based purely on a medical model with athletes 'grouped' within five classes of impairment: (i) Athletes with an amputation; (ii) Athletes with cerebral palsy; (iii) Athletes with a spinal cord injury; (iv) Athletes with a visual impairment, and; (v) Athletes with les autres.

IPC swimming introduced the Functional Classification System in 1990, which involved two forms of assessment, a sports medicine bench-test that screening the musculoskeletal function of the athlete. The philosophy of this system was to combine the previous medical assessment with sport-specific measures. This assessment involved a modified format of the traditional medical range of movement and strength assessment. The functional classification system is a sport-specific system of classification that assigns and integrates athletes with eligible impairments, predominately physical impairments, into classes in order to maintain equitable and fair competition amongst these athletes [2]. The cumulative score from these equally weighted dry-land measures would determine into which classification the athlete would be placed, as each classification was represented by a specific range of bench-test scores. This test was followed by an in-water assessment, which required the registered IPC swimming classifier to observe the athlete swim in the water, and based on this observation, if necessary, adjust the bench-test score and ultimately the final classification. This combination of medical and sport-specific assessment currently form the activity limitation tests for para swimming. The system has been in place for seven consecutive Paralympic Games from 1992 to 2016, with some modifications over time.

The separate classes distinguish between the distinct arm-dominant freestyle, backstroke, and butterfly strokes; the leg-dominated breaststroke; and the individual medley, which includes all four strokes and therefore warrants its own unique classification system. Athletes rated as a 10 on the classification scale (e.g. S10, SB10, SM10) have the greatest function. Function gradually decreases (the scope of the impairment increases) as one moves closer to a 1 rating (S1, SB1, SM1).

While the requirement for fairness and equity has been stipulated [3], there has been no quantitative research that has examined if the current classification system results in discrete categories of swimming performance for all events and genders for each class. To date, analysis of Paralympic swimming performance has focused on the factors that contribute to the final outcome, swimming time [4-6]. Therefore, the aim of this study was to investigate how effective the current classification system creates clearly differentiated Paralympic competition classes, based on performance time for all swimming strokes and events. This new knowledge provides the required evidence for the effectiveness of this important Para sport.

Methodology

The swim time performances for male and female medallist swimmers since the inception of the current functional classification system were obtained from six major competitions, the

- 1992 (Barcelona),
- 1996 (Atlanta),
- 2000 (Sydney),
- 2004 (Athens),
- 2008 (Beijing) and
- 2012 (London) Paralympic and Olympic games.

The swim time performance for the male and female Olympic swimmers in corresponding events provided a benchmark comparison. In total, 2,370 race performance times were investigated, with all data downloaded from official, publicly accessible swimming and sporting websites (www.ipc-swimming.org, www.databaseolympics.com).

The swim times for male and female medallists in the Paralympic classes and the corresponding swim times for the three Olympic medallists in the following events were recorded:

- the 50 m, 100 m and 400 m freestyle,
- the 100 m backstroke,
- the 100 m breaststroke,
- the 100 m butterfly and
- the 200 m individual medley.

These events were analysed as they were common to both Paralympic and Olympic games. As the data was publicly available and de-identified human ethics approval was not required. To determine if there were clear differences between performances in each class, the mean swimming speeds (m/s) for Paralympic performances were expressed as a percentage of the corresponding Olympic performance. This percentage index allowed for a uniform comparison of race performance between classes, events and genders.

Statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS, version 17.0). Normality of distribution of data was confirmed using a Shapiro-Wilk test. The raw swim times and percentage indices of classes were compared for each sex and event using a one way Analysis of Variance (ANOVA) with an alpha value of 0.05. Bonferroni post hoc analysis was used to determine the source of statistical significance when required. A paired sample t-test was used to compare each mean percentage index to a predicted fixed percentage variable.

Based on analysis of the percentage indices, this arbitrary fixed variable was set at 85% for class S10 and decreased by 5% for each class down to 45% for class S2. For the classes of visually impaired athletes, (S11, S12 and S13), the arbitrary fixed variable was set at 90% for class 13 and decreased by 5% for each class down to 80% for Class 11. The assignment of this fixed variable was subjective, with the goal of creating equal differences between the classes.

Results

Of a total of 128 mean raw times across the classes and events, 58 (45%) were found to have no significant difference to their adjacent higher class (Table 1). Of the classes with a physical impairment (S2 to S10) a total of 38 out of 86 (44%) mean values across classes and events were found to have no significant difference in mean performance time compared to their adjacent higher class. Classes S5 (50%), S6 (67%), S8 (50%) and S9 (86%) were the most similar to their adjacent higher classes whilst S2 (0%), S3 (0%), S4 (17%), and S10 (8%) had the least number of mean values similar to their adjacent higher classes. For the visual impairment classes (S11-S13), the S12 class showed the most similar mean values compared to the adjacent higher class, with 100% of mean values having no significant difference to the S13 class.

There were less similar results between adjacent classes when performance times were expressed as a percentage index relative to the corresponding Olympic time (Table 2). When comparing the percentage indices between classes, a total of 33 out of 128 (26%) mean values were similar to their adjacent higher class. The S9 (57%) and S12 (100%) classes showed the highest number of similar mean values to their adjacent higher classes for the physical and visual impairments, respectively. Classes S2, S3, S4, S7 and S11 showed no similar mean values to their adjacent higher class when comparing the percentage indexes.

When comparing each classes' performance index to the fixed arbitrary value a total of 77 out of 128 (60%) values showed significant differences. Typically, the percentage indexes for classes S2, S3 and S13 were significantly lower than the fixed arbitrary values set for physical and visual impairments, whilst classes S6 and S7 were significantly higher than the fixed arbitrary value (Table 2). All physical and visual impairment classes showed increases in the performance index (mean for events and genders) from the 1992 to 2012 Paralympic games (Figure 1).

Figure 1, Table 1 & 2 about here.

Discussion

The purpose of this study was to investigate whether the functional classification system creates an equitable delineation between its classes based solely on performance outcome. The functional classification system was found to delineate performances between some classes, but failed to do so for others. This finding is in agreement with research that has found inconsistent differences in determinants of swimming performance between adjacent classes indicating that the current functional classification system does not always differentiate clearly between swimming groups [7]. In particular, physical impairment classes S9 and S10, and visual impairment classes S12 and S13 showed the most similar swimming performances for events and genders based on both raw times and performance indices expressed relative to Olympic performances. These results highlight the shortcomings of the current functional classification system to promote fair and equitable competition, and the need for a revised evidence-based classification system. Sports medicine can play a lead role in this process as Paralympic swimming relies on the effectiveness of sports-specific activity limitation tests.

When examining the raw performance times for the physical impairment classes (S2-10) the higher classes with less severe impairments (>S5) reported more similar performances to one another compared to classes S2 to S4 (Table 1). This may partly be attributed to the lower number of events competed by the more severely impaired classes. Although, another contributing factor that may cause this disparity between the higher and lower classes is the impact that impairment severity has on sporting participation and training progression.

Swimmers competing in classes S2 to S5 have lower physical function than those in higher classes, and are predominately confined to a wheelchair, have little or no use of their upper and lower extremities and their trunk, have moderate to severe coordination difficulties, and/or a degree of limb loss in up to four limbs. These swimmers need more assistance for transportation, accessing facilities, starting races, and have considerably less training time that might negatively impact their training progression compared to swimmers with higher physical function. This may also explain swimmers in lower classes (S2 to S4) having less consistency in their race-to-race performances as oscillations in movement and function make consistent performances more difficult to produce, thus causing greater variances in performances within and between the lower classes [8]. Comparatively, increased participation rates and trainability of less impaired swimmers likely promotes more consistent swimming performances and higher competitiveness within these classes causing greater progressions in performance.

Despite these barriers to participation and training for the more severely impaired classes, it is interesting to note that all of the physical impairment classes showed similar progressions in performances over competition cycles (Fig 1). From 1992 to 2012 classes had a mean increase of 7.3±1.6% of Olympic performance with no clear differences between the lower (S2 to S4 = 5.4 to 8.0%) and higher classes (S5 to S10 = 5.7% to 8.1%). These results are complimentary to the advancements of the Paralympic movement as they demonstrate Paralympic swimming performance has progressed more so than Olympic swimming performance over the past two decades. However, the similarity in progression between lower and higher classes suggests that the shortcomings of the functional

classification system to delineate performances between higher classes is more likely due to limitations in the classification methods, rather than greater training progression or competitiveness within the higher classes.

A key finding from this study is the lack of strong connection between impairment and swimming performance. This is evidenced by the similarities in both raw times and performance indices between physical impairment classes S9 and S10, and visual impairment classes S12 and S13 (Table 1 and 2). Although swimmers in these classes have been found to have increasing "sport-specific" impairment severity (e.g. from S13 to S11), the lack of difference between swimming performances between these classes suggests that current classification methods are not effective in grouping athletes. The integration of appropriate sports medicine test would be beneficial in addressing this issue. This finding is reinforced from earlier studies on the effectiveness of the medical bench-tests against swimming kinematics [9]. In this previous study data was collected via three different procedures: (i) the musculoskeletal range of motion, as per the swimming classification protocol; (ii) the 3D kinematic range of movement when simulating swimming, and; (iii) the bilateral hand force the swimmer generated on a swimming ergometer. The study found there were inconsistent and generally weak correlations (approximately three-quarter of all measures) between the musculoskeletal range of motion and the 3D kinematic range of motion and the force output measures.

The IPC Athlete Classification Code stipulates that athletes should be grouped based on the impact of their impairment on their given sport, not simply by their impairment severity [1]. The ineffectiveness of the current functional classification system to delineate between certain classes may have resulted from issues with measurement weighting (i.e. relative contribution of different impairment measures to classification outcome) and measurement aggregation (i.e. aggregation of different types of impairment measures to classification outcome). It is also possible that impairment tests included in the functional classification system do not account for the greatest variance in Paralympic swimming performance. For example, research has found inconsistent and weak correlations between the current functional classification system range of motion scores, and actual 3D kinematics and hand force production measures during simulated swimming on a swim bench ergometer [9]. Collectively, these findings demonstrate the requirement for research to more accurately define the relationship between existing impairment measures and the determinants of swimming performance [10], as well as exploring other impairment measures that may have a greater impact on swimming performance.

The development of evidence-based classification systems in Paralympic swimming require validated measures of impairment that are impairment specific, account for the greatest variance in swimming performance and are as resistant to training as possible. Several of the current impairment measures used as part of the current functional classification system may be problematic as they are subjective and have high dependency on user judgment, including methods of manual muscle testing and motor coordination assessment [9].

Instrumented tests that provide objective measures of impairment will likely provide more valid and reliable measures that allow for clearer definitions between impairment and swimming performance.

Research in Paralympic track and field has defined the impact of instrumented measures of strength and motor coordination impairment on sporting performance to guide the development of evidence-based classification [11]. Similar research examining the relationship between instrumented tests of impairment and their relative impact on swimming performances is warranted in Paralympic swimming to guide the development of a new evidence-based classification system.

Another important consideration of the revised classification system is the impact that impairment has on swimming performance in different events (swimming strokes) and distances. Currently, the functional classification system does aim to account for swimming stroke (i.e. S, SB and SM) although the impact of impairment on swimming performances in each swimming stroke has not been fully addressed. The current functional classification system does not account for how different impairments may interact with swimming performances for a given swimming stroke over different distances. This study found the current functional classification system to be particularly ineffective in differentiating raw performance times between the higher classes (>S6) in the shorter distance events in comparison to the longer distance events. For example, for the higher classes (>S6) there were a greater number of similar raw mean values between adjacent classes for the 50 m Freestyle (90%) compared to the 100 m Freestyle (70%) and 400 m Freestyle (50%) (Table 1).

These findings are supportive of Daly's and Vanlandewijck's [3] criticism of the functional classification system for not accounting for short- and long-distance events, as the physical abilities that contribute to swimming performance are likely to change for different event distances. They suggest that the contribution of the arms and legs to net propulsion changes over increased distance, and that impairment tests of the upper and lower limbs should be weighted accordingly for short- and long-distance events. Future research should define the impact of impairments on swimming performance for different swimming strokes and distances.

A limitation of the current study is the arbitrary fixed variable comparison of the Paralympic swimming performance with the respective Olympic swimming performance. As stated in the methods section this nominal ratio was set at 85% of the Olympic swimmers for Paralympic class S10 athletes. A second limitation was the nominal 5% variation in swimming performance time for the different Paralympic swimming classes. There were no relevant previous studies to establish these guidelines so the assumption was made there should be a consistent 'difference' between each Paralympic swimming class.

Conclusion

This study found the current classification system to delineate performances between some classes, but fails to do so for others. This inconsistency can largely be attributed to a lack of understanding of the impact that different impairment types and severities have on swimming performance. The subjective measurement of impairment is also a key concern that likely limits the validity of impairment measures as they relate to swimming performance, as well as causing inconsistencies in athletes' classification due to a high dependency on user judgement. Impairment tests should be instrumented allowing for

objective measurement, impairment specific, account for the greatest variance in sporting performance, and be as resistant to training as possible. Future research that identifies valid and reliable impairment measures as well as defining their impact on swimming performance will have significant implications for the development of a new evidence-based classification system that allows for fairer and more equitable competition than the current classification system. This information forms the blueprint for the new International Paralympic Committee (IPC) swimming classification system.

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