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The classification in Para swimming: Analysis of a Paralympic champion's withdraw case

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Abstract

This study compared the in-water bilateral leg kick speed difference between a Paralympic and an Olympic athlete. The Paralympic (former S10) was not eligible after his reclassification in 2019, whereas the Olympic was a semi-finalist in 50 m freestyle in Rio 2016. Kick performance was assessed by a speedometer in one push-off ~15 m maximal kick sprint. Ten complete cycles were analyzed, and the average speed of each leg in each cycle was calculated. Computerized planimetry assessed plantar feet areas. Differences between right and left feet areas were –22% and –2.1% for the Paralympic and Olympic, respectively. The left kick was slower in the Paralympic ($p < 0.0001$, ES: 2.35, very large), whereas no difference was found for the Olympic ($p = 0.55$, ES: 0.27, small). There is a substantial bilateral leg kick speed difference for the Paralympic, but not for the Olympic. The impact of Paralympic's impairment on his kick performance considerably differs when using quantitative and qualitative assessments.

Keywords

Aquatic sport, disability, International Paralympic Committee

Introduction

The classification system is a fundamental factor in Paralympic sport. It has been designed to provide competitive equity 'by minimizing the impact of an individual's impairment on the outcome of the competition'.[1] The degree of activity limitation resulting from an impairment, along with the ability to execute specific tasks and activities determine one sport class.[2] In swimming, classes from 1 to 10, and from 11 to 13 include athletes with physical and visual impairment, respectively. For both, lower numbers indicate a more severe limitation. Class 14 comprises athletes with intellectual impairment.[3]

The development of a more evidence-based classification system is a topic of interest for the International Paralympic Committee (IPC) and has been fostered in the scientific community. While some studies demonstrated the impact of the impairment on swimming performance[4] and race pace strategies,[5] others tested and proposed the implementation of quantitative measures and new methods into the classification process.[4,6–9] Regarding the physical impairment classification, Oh et al.[6] analyzed the normalized passive drag and verified an inconsistent difference between adjacent classes, and high within-class variability in the lower ones. Hogarth et al.[8] verified that a battery of isometric strength tests successfully classified 95% of para

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swimmers with physical impairment and thus may be useful to infer loss of strength. Hogarth et al.[7] investigated the impact of limb impairment on 100 m freestyle performance and provided insights to improve the definition of athletes' classes through anthropometric parameters. Finally, Hogarth et al.[9] evidenced the validity of instrumented tapping tasks to classify motor coordination impairments in para swimmers with brain injury. These assessments together have the potential for improving the classification process but remain to be tested and implemented in practice. Meanwhile, more research is needed to establish a more robust body of knowledge regarding this matter.

In 2018 IPC introduced a revised version of the World Para Swimming (WPS) classification rules and regulations, and all athletes were allocated into a review status, which must be confirmed to compete in Tokyo 2020. Specifically for physical impairments, the new WPS classification rules and regulations maintained the previous physical assessment, which qualitatively evaluates muscle function, coordination, mobility and body dimensions in dry-land.[3] Major changes occurred in the in-water technical assessment, which estimates 'the effect of an athlete's impairment on different swimming strokes under standardized conditions'.[3] The general aspects observed are the individual's ability to generate propulsion and change of stroke rhythm as well as the maintenance and coordination of body positions and movements with and without breathing.[3]

The technical assessment consists of swimming multiple distances at different speeds while the classifiers watch and qualitatively score a particular body segment from 0 to 5 so that lower numbers indicate a greater impairment.[3] The score must be multiplied by the number of functional movements of that specific body segment measured in the physical assessment (e.g., the knee score is multiplied by two because of flexion and extension).[3] The combined point scores of the physical, technical and (when required) competitive observation assessments define the athlete's sports class, which is designated as 'S' for freestyle, backstroke and butterfly, 'SB' for breaststroke and 'SM' for medley events.[3] For instance, in the S classes, the maximum number of points possible combining all assessments is 300 (i.e., a person without any physical impairment). Athletes are eligible for para swimming when they score lower than 285 points, which corresponds to the upper limit of the S10 class and the so-called 'minimum impairment criteria'.[3] Below this limit, the following point score intervals define the S classes: S1: $\leq$65, S2: 66-90, S3: 91-115, S4: 116-140, S5: 141-165, S6: 166-190, S7: 191-215, S8: 216-240, S9: 241-265 and S10: 266-285.[3]

Although the new WPS classification rules and regulations may have been an attempt to mitigate inconsistencies, it is still based only on qualitative measurements, and the so-claimed scientific improvements and effectiveness remain questionable. For instance, during the reclassification, some athletes have gone three classes up, whereas some from the higher classes were considered not eligible. This is the case of the athlete analyzed herein, who has polio sequels in his left lower limb (more severely in calf and ankle), used to be an S10 (from 2006 to 2019), but was not eligible after achieving 286 points in his reclassification in April 2019, that is one point above the minimum impairment criteria.

In the physical assessment, his left ankle was scored as 1, 4, 1 and 0 (out of 5) for dorsiflexion, plantar flexion, eversion and inversion in the first panel (standard), and 1, 3, 2 and 2 in the second (protest), respectively (the lowest point score out of the passive range of motion and muscle power tests must be used to calculate the final point score for each functional movement of the joint[3]). Firstly, these numbers illustrate the poor agreement between classifiers, which can be decisive for athletes who are very close to the minimum impairment criteria. They also reveal the relevant impairment effect on the athlete's dry-land joint functionality (6 out of 20 points). In the technical assessment, though, his left ankle was scored as 3 (out of 5) in both panels, which indicates 'moderate functional range of movement', 'moderate loss of muscle power' and/or 'fair balance and stability'.[3] We acknowledge the difficulty in improving between-classifiers and between-assessments (physical and technical) agreement, but commercially available technological resources can be helpful if incorporated into the classification process. The use of quantitative measurements were proposed previously,[4,6–9] but has not been introduced in the classification process so far.

Considering that the sport class 'not eligible' of this swimmer occurred by a marginal difference based on qualitative assessments with questionable reliability, we decided to reassess his in-water ankles functionality by within- and between-subject analyses with a reliable quantitative measurement. More specifically, this study aimed to assess the effect of his left ankle impairment on functional leg kick performance (i.e., hip speed generated by leg kick) with quantitative measurements, and to compare him with an Olympic sprinter, considered herein as a non-impaired reference. The quantitative assessments and the official qualitative classification results are compared and discussed.

Methods

Participants

The para swimmer herein (male, age: 34 years, body mass: 80 kg, height: 1.83 m, training experience:

26 years; personal best and actual performance: 23.20 s and 24.76 s, respectively) was enrolled into Para swimming in 2006 (S10, SM10 and SB9). The side-effects of a poliomyelitis vaccine occasioned a smaller foot, loss in ankle range of motion and a 5-cm shorter leg, all on the left side. He obtained 14 medals in three editions of the Paralympic Games. The Olympic sprinter (male, age: 27 years, body mass: 78 kg, height: 1.80 m, training experience: 10 years) was an Olympic semi-finalist in the 50 m freestyle (personal best and actual performance: 21.82 s and 22.89 s, respectively) and has been ranked in the top 80 in the World since 2014. None of the swimmers presented injuries during the study period. Participants provided verbal and written consent and ethical approval was granted by the Federal University of São Paulo Ethics' Committee (#116.075/2012).

Study design

Swimmers reported to the pool (water temperature: 27 °C), and after ~20min of warm-up, their kick performance (using both legs together) was assessed. A speedometer (CEFISE, Nova Odessa, Brazil) attached to the hips at the central point of the lumbar region measured the instantaneous speed during one push-off ~15-m maximal kick sprint. Swimmers used a board (shoulders flexed, elbows fully extended and hands holding the board) and a snorkel to ensure legs were the only source of propulsion and to avoid breath effects on body position. One digital underwater camera (ELP/FHD01M-L21) attached to a trolley video recorded the swimmer's motion from a sagittal view. A custom-designed software synchronized both filtered speed (250 Hz) and video data (30 Hz) and allowed to detect which part of the curve was related to either right or left kicks. Speed data were smoothed using a fourth-order Butterworth low pass digital filter with a cut-off frequency of 8 Hz, determined through residual analysis. To attenuate push off effects, the first six cycles and transition were discarded (Figure 1). The beginning and the end of each leg kick was defined by minimum speed values (Figure 1). Ten cycles were analyzed and the average speed of each leg in each cycle was calculated using values within two minimum points (Figure 1).

Prior to the data collection, the high speedometer reliability was confirmed by comparing kick speeds of two maximal sprints performed at the same testing session for both swimmers (Paralympic: typical error of measurement = 0.02 m/s; CV = 0.8%, ICC = 0.99, CI 95% = 0.92-1.00, F = 384.07, p = 0.0001, and Olympic: typical error of measurement = 0.01 m/s; CV = 0.8%, ICC = 0.99, CI 95% = 0.89-1.00, F = 285.04, p = 0.0002).

The trial intensity was monitored in an attempt to mitigate the potential effects of athletes' willingness. The kick rate was quantified through the time to complete 10 cycles. Swimmers' maximum kick rates were calculated by multiplying stroke rates of their best 50 m freestyle performances in the last Paralympic/Olympic cycle (i.e., from 2012 to 2016) by three kick cycles/arm cycle[10,11] resulting in 180.3 (Paralympic) and 196.4 cycles/min (Olympic). A full-stroke underwater analysis performed regularly within their training schedules confirmed that both swimmers use a six continuous beat kick pattern per one complete arm movement in maximal intensity. The high intensity was ensured by adopting 85% of their maximum kick rate (= 153.3 and 167 cycles/min) as a criterion to validate the trial.

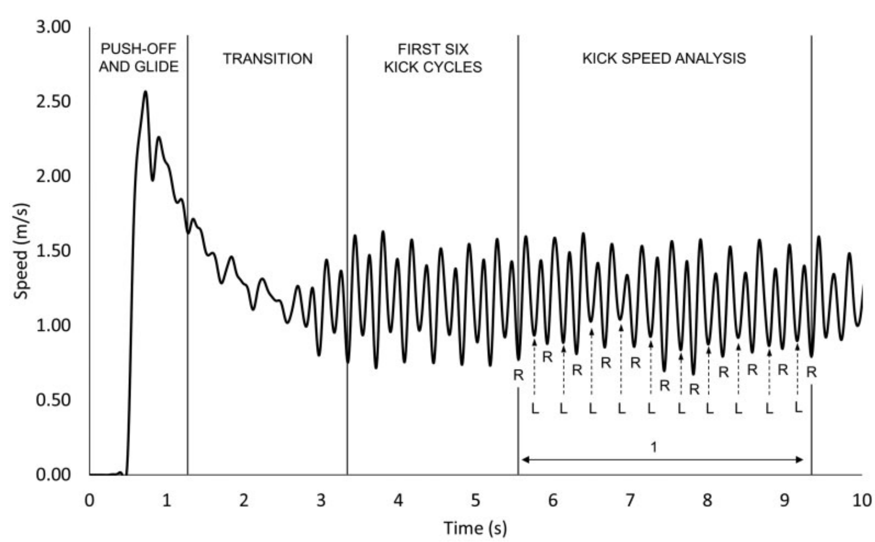

Figure 1. Example of a kicking speed-time curve. 1 = average speed; R = beginning of right leg descendent phase, L = beginning of left leg descendent phase.

Plantar feet areas were assessed by computerized planimetry (ImageJ v.1.43, National Institute of Health, Bethesda, USA), which presented high test–retest reliability (ICC = 0.999; CI 95% = 0.996–1.00; F = 2062.10; $p < 0.0001$; CV = 0.46%; CI 95% = 0.27–0.65%).

Statistical analysis

Absolute data and percent changes compared plantar feet areas. Speed data were presented as means ± SD. After testing normality (Shapiro-Wilk) and homogeneity (Levene), the t-test for independent samples compared right and left kick speeds within-subjects and the Mann-Whitney test compared the percent difference between athletes. The effect sizes were calculated by the Cohen's d and interpreted as: < 0.2: trivial; >0.2 – 0.6: small; >0.6 – 1.2: moderate; 1.2 – 2.0: large; 2.0 – 4.0: very large.[12] The significance level was set at $p < 0.05$.

Table 1. Plantar feet areas.

	Paralympic			Olympic		
	Right	Left	Δ%	Right	Left	Δ%
Area (cm^2)	174.7	135.4	–22%	175.1	171.5	–2.1%

Δ% corresponds to the difference between left and right feet.

Results

Plantar feet areas are in Table 1. Kick rates were 158.4 and 175.2 c/min for the Paralympic and the Olympic athletes, respectively, which correspond to 88 and 89% of their maximum estimated kick rate.

Speed data are in Table 2. The curves obtained from both swimmers are shown in Figure 2. To ensure that the push-off was not influencing the athletes differently, the result of the first leg kick was normalized by the push-off mean speed, calculated in the first 0.1 s after the peak speed. Push-off mean speeds were 2.26 and 2.59 m/s for the Paralympic and the Olympic swimmers, respectively, whereas their relative values were 0.54 and 0.55. This corresponds to a 2.2% difference and indicates that both analyses started from similar relative speeds. Then, the push-off was not considered as a source of systematic error. The Paralympic left kick was 6.4% slower than the right. A 1.3% non-significant difference was found for the Olympic athlete. These bilateral speed differences correspond to 'very large' and 'small' effect sizes, respectively (Table 2). The percent difference between athletes

Table 2. Right and left average speeds (all expressed in m/s) in all 10 cycles analyzed.

	Paralympic			Olympic		
	Right	Left	Δ%	Right	Left	Δ%
Cycle 1	1.22	1.17	–4.3%	1.46	1.46	0.0%
Cycle 2	1.25	1.17	–6.9%	1.51	1.48	–2.1%
Cycle 3	1.25	1.18	–5.7%	1.50	1.52	1.5%
Cycle 4	1.24	1.14	–7.6%	1.52	1.52	–0.1%
Cycle 5	1.21	1.13	–7.2%	1.49	1.49	–0.1%
Cycle 6	1.18	1.09	–7.5%	1.45	1.43	–0.9%
Cycle 7	1.17	1.09	–6.7%	1.42	1.37	–3.7%
Cycle 8	1.17	1.11	–5.7%	1.38	1.33	–3.9%
Cycle 9	1.20	1.12	–6.7%	1.39	1.33	–4.4%
Cycle 10	1.19	1.12	–5.6%	1.36	1.37	0.9%
Mean ± SD	1.21 ± 0.03	1.13 ± 0.03	–6.4 ± 1.0%	1.45 ± 0.06	1.43 ± 0.08	–1.3 ± 2.1%
P/O						
p value						0.0002
ES						3.20 (very large)
R/L						
p value	<0.0001			0.55		
CI 95%	0.05/0.11			–0.05/0.08		
ES	2.35 (very large)			0.27 (small)		

P/O: Between-subject comparison using Δ% of Paralympic and Olympic; R/L: Within-subject comparison using right and left leg speeds. SD: standard deviation; Δ%: percent difference from right and leg kicks; CI 95%: 95% confidence interval; ES: effect size.

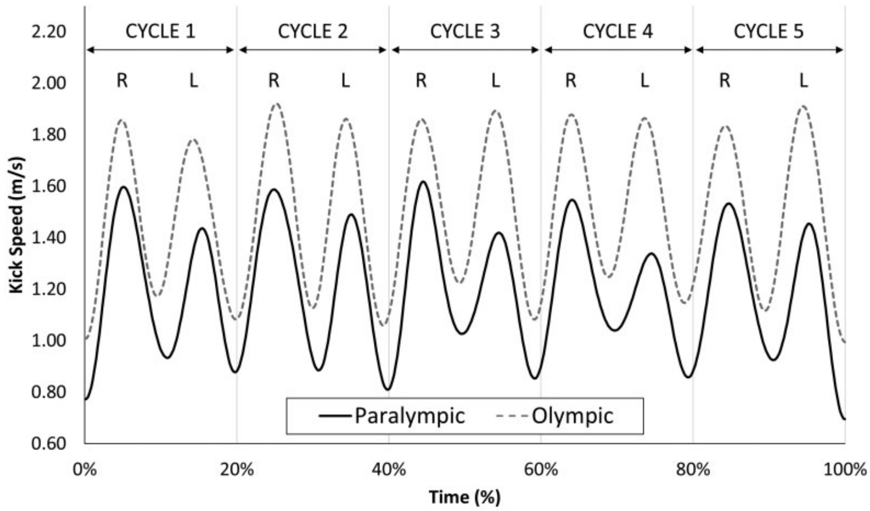

Figure 2. Five kick cycles from both swimmers. R = Right kick, L = Left kick.

was significant and reached a 'very large' effect size (Table 2).

Discussion

This study estimated feet areas and assessed bilateral kick speed differences of both Paralympic and Olympic swimmers. The Olympic athlete's data were adopted as reference for between-subject comparisons, assuming that both athletes would have analogous competitive levels and that they would demonstrate the expected bilateral speed differences in both disabled- and able-bodied elite swimmers.

The results herein revealed that the polio sequels decreased the left foot area of the Paralympic swimmer by 22%, whereas the Olympic sprinter data indicated that a minimum bilateral foot area difference should be expected. The loss of foot area (i.e., 'S' in the following equation) affects one's capacity to produce propulsive force (D), which can be described as[13]

$$D = 1/2 \cdot \rho \cdot Cd \cdot S \cdot v^2$$

where ρ = water density, Cd = drag coefficient, v = foot speed. Assuming the same Cd and orientation with respect to the water flow for both feet, a smaller foot implies a reduction of the amount of water that the swimmer pushes backward, and, consequently, may hamper kick performance. In other words, the smaller foot area may decrease the efficiency of the leg kick,[14] especially in the downward phase and reduces propulsion.

Other factors may also affect leg kick performance, such as lower limbs' power and ankles' flexibility. McCullough et al.[15] verified a correlation between vertical jump height and 22.86 m kicking times ($r = 0.61$; $p = 0.045$) for competitive female swimmers. The authors also noticed that a greater ankle's flexibility is associated with a higher leg kick speed ($r = 0.51$; $p = 0.022$). Altogether, either from a technical or a neuromuscular perspective, these factors can influence the swimmer's ability to accelerate the mass of water backwards and generate vortices, which are critical factors for generating propulsive force.

The 'very large' functional loss of the para swimmer verified in both within- and between-subject comparisons differ from the moderate rating defined in his 2019 official technical assessment. The Olympic reference indicated that a ~1.5% non-significant bilateral speed difference should be expected (i.e., small effect size). Since the bilateral speed difference in the para swimmer was around four times greater than the Olympic (6.4% vs. 1.3%, i.e., very large effect size), there seems to be a mismatch between qualitative and quantitative assessments.

Besides the contribution for the total amount of propulsion, leg kick also supports a more effective arm action increasing stroke length,[16] counteracts the torque generated by the hydrodynamic forces acting on the hands,[17] and assists the maintenance of a more horizontal body position by reducing trunk inclination,[18] which increases propulsion and reduces drag. Therefore, the loss in the left kick performance may likely affect other aspects of the para swimmer's full stroke performance, although to an unknown degree. On the other hand, his full stroke performance depends on how he deals with this organismic constraint, which is his bilateral structural difference.[19] Then, the leg kick asymmetry effect may be partially attenuated by other actions (such as arm movements) within the stroke and could highlight the individual's outlier swimming ability. In other words, highly trained disabled athletes may present outstanding performances regarding in-water positions and movements, indicating that their functional losses are mitigated in spite of their impairment. However, the impairment should not be judged as milder by the classifiers as it compromises the initial conditions needed for a fair competition against able-bodied athletes.

The trial intensity was monitored in an attempt to mitigate the potential effects of athletes' willingness. The swimmers were asked to perform the test at maximum intensity, and yet both reached ~90% of their maximum kick rates, that is 158.4 and 175.2 c/min for the Paralympic and the Olympic swimmers, respectively. Not achieving the maximum kick rates can be related to the nature of the task. Similar to what happens in the full stroke, the swimmer must find a balance between leg frequency and amplitude during leg kicking in order to get propulsion and drag at their highest and lowest levels, respectively, and thus increase speed. Although this balance shifts towards the amplitude in the leg-only condition (i.e., a lower kick rate), the kick rates remained high. From a motor control perspective, by achieving such intensity it would be harder for the swimmers to control legs differently and eventually influence the test outcome. As exercise intensity can be decisive for the final classification result, its control should be a major point in any classification test in order to reduce any possible willingness effect. Other explanations for the lower kick rate include, but are not limited to: (1) the current athletes' training statuses are likely different in comparison to their best competitive periods in the last Paralympic/Olympic cycle; (2) they did not use competitive suits during the testing session; (3) the test started from a push-off start, which is different from a competitive situation when a dive is allowed.

In summary, the classification system is crucial for Paralympic sport, but the inclusion of technology into the process seems necessary. The use of more evidenced-based and quantitative assessments could improve the accuracy of decision making and reduce the occurrence of inconsistencies in the classification process, especially in borderline cases like the current. Interestingly, this study also provided useful insights for a more quantitative classification, such as: (1) the testing intensity determination (based on maximum kick rate), (2) the use of quantitative, specific, practical and relative low-cost technology for quantifying the disability's effect on functional performance, and (3) the use of simple (but robust) statistical procedures for rating the extent of the impairment (effect size's thresholds).

There are some limitations to the present study. Firstly, we acknowledge that a greater number of Olympic swimmers would characterize a more robust sample for defining the leg kick bilateral speed reference. Then, our results are difficult to generalize as conclusions may vary according to the individuals' characteristics and impairment. Nevertheless, the outlier performance of these athletes by definition limits gathering a larger sample. Besides, the idea of using one able-bodied athlete as a reference may give a different perspective of the same phenomenon and hopefully provide some useful insights for the classification ahead. Finally, although lower limbs have a considerable influence on start and turns performances, the impact of the impairment on these aspects was not assessed.

Practical applications

The classification system is a crucial factor to provide competitive equity in Paralympic sport and, by definition, comprises multiple within- and between-subject comparisons. Basic principles such as validity and reliability must then be ensured regardless if the assessments are qualitative or quantitative. Therefore, classifiers must be provided with well-defined references that allow to quantify the level of functional impairment of a given athlete. In this regard, the use of technology should be considered as it can considerably improve the accuracy of some assessments (e.g., the so-called the passive range of motion and muscle power tests) and, therefore, improve the decision making of the classifiers, especially in the occurrence of marginal differences. We acknowledge that improving the classification process is a complex task, so the IPC could benefit from new ideas allowing studies like the current to be included together with the athlete's medical record prior to his/her classification. Thus, Regional and National Paralympic Committees would be encouraged to develop science to support the classification of their athletes.

Conclusion

There was a substantial bilateral leg kick speed difference in the para swimmer, and it was considerably lower than in the Olympic swimmer. Therefore, the impact of his sequels on kick performance differs when using quantitative and qualitative assessments.

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Declaration of conflicting interests

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