RACE ANALYSIS OF THE 400M FREESTYLE AT THE 1996 PARALYMPIC GAMES

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INTRODUCTION: To achieve fair competition, disability sport is organized according to a functional classification system. In swimming, athletes from a variety of impairment groups are assigned to one of 10 classes according to scores on muscle testing, range of motion, co-ordination and/or level of amputation. Freestyle and breaststroke are classified separately and Class 10 is most functional. As expected, much discussion has taken place concerning the validity and credibility of this system.
Swimming, one of the most popular Paralympic sports, has been the subject of limited performance analyses using end race result (ERR) as the basis for discriminating between classes. The distinction between classes on other race components and stroking variables has only been studied for the 100m freestyle (Pelayo, Sidney, Wille, Moretto, Randhaxe & Chollet, 1996). To better understand the performance of Paralympic swimmers, it seemed important to examine a longer distance event involving several turns and during which stroke rates and lengths could be measured at different points of the race. Study of a longer event could also have implications for the classification system, which some suggest does not sufficiently consider the hindrance experienced by certain impairment groups during exercise of a longer duration (Richter, 1993). The purpose of this investigation, therefore, was to conduct a race analysis of the 400m freestyle event at the Paralympic games and to determine which variables contribute to the ERR and how these variables differ among the four classes (S10 – S7) swimming this event. Paralympic and Olympic 400m freestyle swimmers were also compared.

METHODS: With the approval of the International Paralympic Committee Sports Assembly Executive Committee for Swimming, performances of the 400m freestyle were video recorded for all men (N=51) at the 1996 Atlanta Paralympics. The same was done for the Olympic finalists and consolation finalists (N=16), (IOC, 1996). Static surveillance cameras were placed perpendicular to the swimming direction at 7.5m, 10m, 25m and 42.5m from the start. Camera data (30fps) was fed to a video recorder via a central control panel and embedded with a time code from the official timing system. From these recordings the following variables were measured: clean swimming speed (CSS) per 25m segment, stroke rate (SR = time for two strokes for Paralympics and 5 strokes for Olympics) and stroke length (SL) during each lap, start and finish times (ST = first 10m, FT = final 7.5m), and all turn times (TT = 7.5m in + 7.5m out). For statistical analyses, ANOVA tests and Spearman correlations were calculated ($p < 0.01$) using SAS software, while group means were compared using the Student-Newman-Keuls multiple range test.

To obtain a more normal distribution of the performance results required to run ANOVA, swimming times were converted to a point score using the function:

$$Pts = \mathbf{C} * 400m\ TIME^{(-3)}$$

For this calculation, **C** is a constant based on the world record for class S10 (Van Tilborgh, Daly, Vervaecke & Persyn, 1984).

In addition, indexes were calculated to relate the time or point score for a race component to the ERR or CSS in percentage. ST, TT and FT were, therefore, also assigned a point score by converting the race component time to a time for a 400m distance and then using this time in the formula above.

RESULTS AND DISCUSSION: The means, standard deviations and group differences are shown in Table 1 for the male swimmers examined. In ERR, as well as CSS (race mean), the Olympic swimmers were, as expected, significantly faster than all Paralympic swimmers. For Paralympic swimmers ERR increased (CSS decreased) with class, although class S8 was not significantly faster than class S7. The same was found for ST. For TT (mean of all turns) all groups were significantly different (turning slower with decreasing function). For FT, class S10 was not different from S9 and S8 was not different from S7. The correlations between the race components and the ERR and CSS showed similar trends for all groups. CSS per race length correlated highly with ERR (.59 - .99) and mean race CSS (.56 - .97) for all groups. The CSS measured during the middle of the race generally showed higher relationships with ERR than the CSS values for the beginning or the end of the race. ST was significantly related to ERR only in Olympic swimmers (.59), while FT was related to ERR in all groups (.59 - .79), with the exception of S10 (with only 7 participants significance was difficult to obtain). The same was found for TT, but the correlations were somewhat higher (.68 - .88). In all cases, the lowest correlations were found for the Olympic swimmers who had the smallest range in performance.

From these findings it appears that those who swim fast, turn quickly, and finish the race fast win in Olympic, as well as Paralympic swimming. The start appears to be more important only for Olympic swimmers. In general, no race component appears to be the single determining factor in overall performance.

Table 1 also shows the mean race values for SR and SL, as well as the values measured during the first and last of the 8 lengths. Olympic swimmers clearly had a higher SR than all the Paralympic swimmers, although the difference was only significant with class S10. With the exception of the small S10 class, the range of SR was also wider in Paralympic swimmers. Furthermore, most swimmers increased their SR relative to the race mean SR in the final length of the race (with the exception of S8). Only Olympic swimmers, however, had a CSS during the final length that was faster than the race mean CSS.

Olympic swimmers had a significantly longer SL than that of class S10, which in turn was longer than that of classes S9, S8 and S7. The correlation study showed high relationships between SL and ERR and race mean CSS when both Olympic and Paralympic swimmers were considered in one group (.74 - .76). The same was not true for SR. When the groups were considered separately, only class S7 showed significant correlations between SL and ERR and CSS (.40 - .79), while in S9, SR correlated significantly (.56 - .73). In agreement with Arellano, Brown, Cappaert & Nelson (1994), these results provide evidence that SL is a greater

Table 1. Means, SDs and Group differences for Olympic and Paralympic Male Swimmers in the 400m Freestyle

	All Swimmers		Olympic		S10		S9		S8		S7		Differences between
N =	62		16		7		14		14		13		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Groups
END TIME (sec)	294.38	39.82	232.60	2.93	263.9	11.04	296.25	13.14	322.15	19.68	330.32	14.65	Oly>10>9>8=7
Clean Speed (m/sec)													
First length	1.38	0.19	1.67	0.03	1.39	0.06	1.32	0.06	1.27	0.05	1.21	0.07	
Last length	1.31	0.33	1.68	0.04	1.33	0.09	1.28	0.07	1.17	0.06	1.17	0.06	
Mean	1.36	0.30	1.67	0.02	1.35	0.06	1.3	0.06	1.21	0.06	1.18	0.06	Oly>10>9>8=7
Turn (m/sec)													
First turn	1.51	0.22	1.86	0.04	1.6	0.05	1.53	0.06	1.4	0.07	1.33	0.07	
Last turn	1.43	0.23	1.8	0.04	1.44	0.07	1.41	0.05	1.29	0.10	1.23	0.07	
Mean	1.47	0.23	1.82	0.03	1.51	0.04	1.45	0.06	1.31	0.09	1.25	0.07	Oly>10=9>8>7
Start (m/sec)	1.98	0.35	2.49	0.11	2.11	0.10	1.92	0.10	1.68	0.13	1.65	0.14	Oly>10>9>8=7
Finish (m/sec)	1.38	0.18	1.65	0.07	1.43	0.09	1.37	0.06	1.24	0.09	1.24	0.06	Oly>(10=9)>(8=7)
Power Indices (%)													
Start	315.39	73.99	334.77	39.74	381.11	46.09	330.81	66.40	234.54	35.86	280.38	94.60	10>8
Turn	130.23	13.73	131.23	6.81	110.53	12.05	110.61	13.66	122.82	6.81	120.14	12.69	(10=9)>(8=7)
Finish	111.33	17.32	97.23	10.53	118.29	16.26	118.13	11.35	109.95	20.20	116.18	18.31	(10=9=7)>Oly
Time Increase (%)													
Start	1.78	1.10	1.73	0.70	1.67	0.70	1.76	1.10	1.86	1.60	1.86	1.80	(8=7)>10
Turn	24.90	7.00	24.78	3.00	24.5	5.30	24.46	5.07	24.95	7.50	25.47	7.20	7>(8=Oly=10=9)
Finish	1.86	0.90	1.95	0.70	1.86	0.80	1.85	0.70	1.9	1.00	1.84	1.00	Oly>(9=10=7)
Stroke Rate (st/min)													
First length	44.61	5.26	45.13	3.62	39.26	6.27	44.11	5.24	44.57	5.55	44.57	5.56	
Last length	43.04	5.36	45.67	3.01	40.66	3.10	41.91	3.34	40.61	4.76	43.41	7.93	
Mean	42.09	4.02	44.55	2.92	39.20	1.89	41.42	4.01	41.34	4.33	41.65	4.52	Oly>10
Stroke Length (m)													
First length	2.03	0.34	2.36	0.16	2.33	0.51	1.93	0.12	1.85	0.27	1.78	0.22	
Last length	1.89	0.29	2.22	0.16	1.97	0.14	1.83	0.13	1.75	0.23	1.65	0.26	
Mean	1.95	0.27	2.26	0.15	2.09	0.16	1.89	0.13	1.78	0.20	1.72	0.21	Oly>10>(9=8=7)

determinant of CSS, and thus ERR, than SR. Nevertheless, male Olympic 400m swimmers were distinguished from Paralympic swimmers not only by a longer Stroke Length, but also by a higher Stroke Rate. To compare the contribution of start, turns and finish to the ERR or CSS in the various groups, indexes were formed (also see Table 1). Class S10 had the relatively best start, significantly better then S8. All S10 swimmers have at least one normally functional leg, while in S8 almost everyone has some loss of function in both their legs. Because CSS clearly reflects the arm function the start index (ST/CSS) may reflect the general relationship in a class of arm to leg function as compared to another class.
In turning, classes S10 and S9 showed significantly higher index values than those found for classes S8 and S7, while Olympic swimmers were situated in-between. The turn index is the mean TT for 7 turns, measured as the time for swimming 7.5m to and away from the wall. It is not purely an indication of explosive leg function as the start may be. The explanation is thus not as clear as for the start index. A (point) turn index >100 does indicate faster turning than swimming speed. The means and SDs for the turn index show in fact that nearly every swimmer studied turned faster than he swam.
Only the Olympic swimmers finished relatively slow. Of the Paralympic swimmers only class S8 was relatively poor in this race component. Olympic swimmers were the only group who had a higher CSS during the final length than their race mean CSS. These swimmers begin to sprint during the final 25m of the race. When the finish (final 7.5m) starts the race has already been decided.

CONCLUSION: For classes S10 and S9 the classification system used is substantiated by these results. For S8 and S7, however, no differences were found in any of the race components or for SL or SR. The correlations showed that no single race component was a greater determinant of ERR than any other in the groups studied. When individual impairment profiles of the Paralympic swimmers can be obtained, a more in-depth analysis can be made, and better information related to individual advice on racing technique can be given.

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