Sport Science and Coaching in Paralympic Swimming

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ABSTRACT

This research documents the sport science and coaching interaction that occurred with a national swimming team from the 2002 World Championships, 2004 Athens Paralympic Games, and the 2006 World Championships. The research was driven by the head coach of the swimming program, and biomechanical measures were made during competition and in national training camps to provide feedback to coach and athlete. By understanding the swimmers' race strategy, a 10 percent improvement in performance was attained. This was followed by an additional 2.6 percent improvement resulting in a new world record time. In addition, race-pattern comparisons were made between swimmers with visually impairment or total blindness at the Sydney 2000 Games. Surprisingly, there was no difference in the race strategy between these swimmers, highlighting that the ability to "see" the opposition swimmer and racing them may not be as important as employing a suitable race strategy. A key point of difference in the race analysis conducted within this research, when compared to existing research, was the use of video feedback in conjunction with the calculated race parameters.

Key words: Paralympic, Performance Enhancement, Swimming, Video Feedback

INTRODUCTION

The purpose of this research was to apply sport science techniques to enhance the sporting performance of the Australian Swimming team at the Athens 2004 Paralympic Games. People with a disability often depend on some form of equipment to be able to participate in physical exercise. Past sport science research has identified significant technical developments in wheelchair design and prostheses [1, 2]. In the endeavour to go higher, faster and longer, athletes have found that the standard devices can inhibit their sporting performance [3, 4]. The coach and sport scientist need to be open to new ideas. Radical equipment designs such as the J-Leg, seated throwing chairs, and running arms have revolutionised the way of thinking in sports science and the options available to coaches and athletes. This demand has also driven the need for sport science to move from within the controlled laboratory and onto the sporting arena, a reported necessary requirement for the

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contemporary high-performance sport [5].

The common performance indicators in swimming include the swimmer's stroke rate and stroke length, as well as the relationship between these measures and clean swimming speed [6-10]. Swim race analysis identifies to the swimmer and coach what factors contribute to swim performance; when compared to an opponent, it highlights critical performance differences. Sport scientists have completed competition race analysis at most international swimming events with official video recordings conducted above water during the Olympic Games since 1988 [11-13]. Variables that are commonly measured include start, turn, and finish times, as well as 25- and 50-m segment split times [14-16]. Using time data and segment distances from competition swimming races, clean swimming speed at various points in a race can be calculated [11, 17, 18], which provides objective insight to the coach and athlete on what is happening within elite swimming performance.

Similar competition swim race analysis has also been conducted at Paralympic Games, starting at the 1996 Atlanta Games [19, 20]. Swimmers with a loco-motor disability competing at Paralympic level have been found to exhibit some similar patterns of stroke rate and race speed patterns [21], whilst other components such as start, turn and finish times differ when compared to the higher swimming velocity of Olympic swimmers [22]. Some disabilities, such as visual impairment or blindness, have been found to not influence the race strategy when compared to Olympic swimmers [23, 24]. Other research on elite well-trained swimmers has found differences in the index of coordination [25], when comparing able-bodied swimmers to swimmers with a disability.

Regardless of whether the swimmer is able bodied or not, a key question pertains to the relationship between swimming speed in various sections of the race and the end-race result, as well as changes in swimming speed within a race as related to changes in stroke length and rate [26-30]. Of particular interest to the swim coach is why this happens. Is this due to a deficiency in the swimmers' level of fitness? Or does the problem lie in the race strategy adopted by the swimmer? To address these issues, the objectives of this research were:

1. To determine the race strategy for a Paralympic swimmer with a loco-motor disability (class S9) competing in the 100 m freestyle events over past international meets.
2. To compare the race strategy of Paralympic visually impaired and Olympic swimmers.

METHOD

The swimming research at the 2002 World Championships, the 2004 Athens Paralympic Games, and the 2006 World Championships had the approval of the International Paralympic Committee. Similar approval was obtained from the other swim meets prior to data collection. The race analysis followed the Swimming Australia format and the equipment included a 3CCD digital video camera (Sony TRV 950, shutter 1/125), connected via a firewire to a laptop. The video and race analysis data was captured and calculated in real time using purpose-built software for swim race analysis. This involved using the internal clock of the computer and combinations of mouse clicks at pre-defined positions. The real time data was cross checked against the video in a frame-by-frame mode after the swim race to ensure correctness of the real-time analysis. The reference marks in the pool were determined from the international lane markings of the 15 m false-start line, the 25 m half-way mark, the 7.5 m mark from the turn, and the 5 m mark from the finish. The data collection for the Olympic and Visually Impaired swimmers was gathered at the Sydney 2000 Olympic and Paralympic Games under a different research project, but also had consent from the International Paralympic Committee. In 2000, the data were not analysed in real time; the procedure is presented elsewhere [31]. The data were captured by the operator as the swimmer's head passed under the reference line for each of the following swim-segments:

- Start Time – head at 15 m mark; Turn Time – head at 7.5 m from the wall, feet/hand on wall, and 7.5 m out of turns; Finish Time – head 5 m from finish wall
- Free swim segments (for 100 m swim) - segment 1 = 15 m to 25 m; segment 2 = 25 m to 42.5 m, segment 3 = 57.5 m to 75 m; segment 4 = 75 m to 95 m
- Stroke Rate – the number of arm strokes divided by the time of that segment

There was a change in the definition of the turn distance following the 2000 Games, which defined the turn distance as 5 m in and out from the wall. This new distance was selected as this 5 m distance could be more accurately identified (from both the turn flags and lane markers), this distance could also accurately measured in the home coach program, and finally the Paralympic swimmers generally all surface within this 5 m zone. For data from 2002 onwards, the reference line was as follows (a consistent set-up was used when comparing swimmers such as Olympic versus Paralympic):

- Start Time – head at 15 m mark; Turn Time – head at 5 m from the wall, feet/hand on wall, and 5 m out of turns; Finish Time – head 5 m from finish wall
- Free swim segments (for 100 m swim) - segment 1 = 15 m to 25 m; segment 2 = 25 m to 45 m, segment 3 = 55 m to 75 m; segment 4 = 75 m to 95 m

After the competition, the results of the swim race analysis were scrutinised statistically to determine the optimal race strategy for that individual athlete. This involved determining the means, standard deviations, and minimum and maximum values for the race analysis parameters. One-way ANOVA's were used to compare functional classes and in some cases Olympic swimmers. Effect size was calculated by beta squared and differences between classes were specified with the Student Newman-Keuls multiple range test. Differences within a race in race-segment swimming speed, stroke length, and stroke rate were evaluated using repeated measures ANOVA ($p < .01$).

RESULTS

Table 1 presents a summary of the typical comparison data for 100 m freestyle swimmer with a locomotor disability (class S9) that has been monitored. This includes a segmental breakdown of the components of the race as well as the averages for each of these sections. Table 2 presents the mean and standard deviation of the race variables for the male 100 m events for swimmers who have a visual impairment or blindness, as well as the percentage changes in swimming speed, stroke rate and stroke length between consecutive race segments.

DISCUSSION

This research has quantified the race strategy used by Paralympic swimmers and provides useful information for both the coach and swimmer. In addition, this research identifies innovative applications of sport science for improving the training and race-preparation strategies of swimmers, especially the development of specific software to enable the collection of video images and the subsequent swim-race analysis. This information then provides the coach and athlete with essential pacing required for specific sections of the race, as well as providing information on the design requirements for the swimmers training program. Past research has identified fluctuations in velocity within a race [6]. The current research has collated the velocity profile from within a race to determine the extent of any variations. As seen in Table 1, the individual swimmer's performance improved 10 percent from the final appearance performance at the 2002 World Championships, to the medal performance at the 2004 Paralympic Games, and an additional 2.6 percent to produce a world-record performance at the 2006 World Championships. More importantly, this data identifies the details that contribute to this, such as stroke rate, stroke length, segmental velocity, start times, turn times, etc. Key areas of improvement for this swimmer were to improve his turn and finish times, and to evenly pace the race. Similar studies on swim race analysis have highlighted the need for documentation and a database for the swimmer to allow their performance to be monitored and tracked [29, 30, 32, 33]. This information on race management should guide the physiological recovery for training prescription [16, 27]. Feedback from the head swimming coach and the swimmer's home coach have clearly demonstrated that this sport science information has provided them with data they were not aware of and has contributed to the design of future race plans and training programs. In addition, the ability of the sport scientist to gather this race data allows the coach to "observe" the race and to use their "coaching art" to compliment the coaching science, rather than the traditional approach where the coach would gather race characteristics such as stroke rate and section-time splits during the race.

Table 1. Summary of Race Comparison for Swimming Class 9

	Worlds Final (2002)	Canada Final (2003)	Grand Prix (2004)	Athens Heat (2004)	Athens Final (2004)	Commonwealth Games (2006)	Worlds Final (2006)
Key Times							
Total time	1:03.97	1:02.78	0:59.64	0:58.77	0:58.15	0:57.41	0:56.67
Start Time (s)	7.81	7.85	7.31	6.70	7.17	6.86	6.89
25m Time (s)	13.94	13.88	13.29	12.60	12.67	12.58	12.57
Finish Time (s)	3.42	3.37	3.01	3.48	3.28	3.24	3.11
Start, Turns, Finish (s)	17.14	17.06	16.00	15.94	15.89	15.40	15.08
Free Swim Time (s)	46.83	45.72	43.64	42.83	42.26	42.01	41.59
Splits							
50m:	0:30.50	0:30.54	0:29.20	0:28.53	0:28.34	0:28.21	0:27.87
100m:	1:03.78	1:02.63	0:59.64	0:58.77	0:58.15	0:57.41	0:56.67
50m Times							
1st 50m:	30.51	30.54	29.20	28.53	28.34	28.21	27.87
2nd 50m:	33.28	32.09	30.44	30.24	29.81	29.20	28.80
Turns							
Turn 1 (s)	5.91	5.84	5.68	5.76	5.44	5.30	5.08
Stroke Count							
Lap 1:	56	58	52	48	52	50	52
Lap 2:	64	64	58	56	60	54	56
Averages							
Avg Velocity (m/s)	1.49	1.53	1.60	1.63	1.65	1.65	1.68
Avg Stroke Rate (str/min)	63.8	65.5	62.7	60.6	64.9	61.4	64.6
Avg DPS (m)	1.43	1.42	1.54	1.63	1.54	1.61	1.57

Note: Turn time measured as 5 m from wall.

Table 2. Means and Standard Deviations of Race Variables in Male Olympic and Paralympic Finalists with a Visual Impairment in the 100-m Freestyle at the Sydney 2000 Games

	Olympic	**S13**	**S12**	**S11**			
Number of subjects	**72**	**13**	**25**	**16**	**F**	**p**	**Difference**
Time (sec)	48.94 (0.40)	58.81 (1.34)	58.61 (1.06)	63.02 (2.06)	151.38	.001	11>(12=13)>Oly
Start (%)	12.12 (0.26)	12.17 (0.28)	12.29 (0.37)	12.01 (0.33)	1.08	.37	
Turn (%)	14.68 (0.30)	14.59 (0.30)	14.69 (0.19)	15.07 (0.38)	4.15	.015	11>(12=Oly=13)
Finish (%)	5.09 (0.11)	5.16 (0.24)	5.08 (0.26)	5.32 (0.27)	1.91	.151	
Start (m/s)	2.53 (0.06)	2.13 (0.06)	2.08 (0.05)	1.98 (0.04)	95.08	.001	Oly>(13=12)>11
Turn (m/s)	2.09 (0.04)	1.78 (0.06)	1.74 (0.01)	1.58 (0.02)	111.76	.001	Oly>(13=12)>11
Finish (m/s)	2.01 (0.05)	1.68 (0.06)	1.68 (0.09)	1.50 (0.03)	59.04	.001	Oly>(12=13)>11
Race segment (%)							
1 (15 m – 25 m)	9.74 (0.19)	9.79 (0.27)	9.83 (0.15)	9.04 (0.22)	6.53	.002	(12=13=Oly)>11
2 (25 m – 42.5 m)	17.66 (0.13)	17.68 (0.31)	17.90 (0.36)	17.43 (0.50)	2.41	.088	
3 (57.5m – 75m)	18.41 (0.28)	18.34 (0.22)	18.60 (0.30)	18.33 (0.43)	1.20	.327	
4 (75m – 95m)	22.10 (0.20)	22.21 (0.52)	21.88 (0.30)	22.17 (0.58)	0.91	.45	
Race Segment (speed)							
1 (15m – 25m)	2.10 (0.05)	1.77 (0.07)	1.74 (0.04)	1.69 (0.05)	94.71	.001	Oly>(13=(12=)>11)
2 (25 m – 42.5 m)	2.02 (0.02)	1.71 (0.05)	1.67 (0.02)	1.60 (0.05)	184.46	.001	Oly>13>12>11
3 (57.5 m – 75 m)	1.94 (0.03)	1.65 (0.05)	1.61 (0.05)	1.52 (0.05)	113.97	.001	Oly>(13=12)>11
4 (75 m – 95 m)	1.85 (0.03)	1.56 (0.05)	1.56 (0.04)	1.43 (0.06)	112.94	.001	Oly>(12=13)>11
Stroke Rate (str/min)							
1 (15 m – 25 m)	55.55 (3.3)	52.62 (5.23)	53.65 (2.94)	54.68 (6.88)	0.31	.820	
2 (25 m – 42.5 m)	51.47 (3.0)	49.00 (4.68)	49.34 (3.86)	50.51 (6.86)	0.44	.520	
3 (57.5 m – 75 m)	50.80 (2.7)	49.33 (5.89)	47.41 (2.48)	50.06 (6.27)	0.45	.719	
4 (75 m – 95 m)	50.40 (4.0)	47.70 (5.04)	48.68 (4.52)	49.51 (5.69)	0.45	.719	
Stroke Length (m)							
1 (15 m – 25 m)	2.31 (0.11)	2.02 (0.17)	1.94 (0.09)	1.87 (0.22)	11.73	.001	Oly>(13=12=11)
2 (25 m – 42.5 m)	2.36 (0.14)	2.11 (0.18)	2.03 (0.15)	1.92 (0.22)	9.53	.001	Oly>(13=12=11)
3 (57.5 m – 75 m)	2.29 (0.13)	2.03 (0.18)	2.04 (0.16)	1.84 (0.20)	9.48	.001	Oly>(13=12=11)
4 (75 m – 95 m)	2.21 (0.17)	1.98 (0.17)	1.93 (0.20)	1.75 (0.19)	8.47	.001	Oly>(13=12=11)

Notes: Oly = Olympic

% = Race section time/predicted section time (based on section percentage of total race distance);

Class differences are listed from highest to lowest value from left to right. Symbols indicate that one class or group of classes had a significantly greater (>) value than a second or that the difference was not significant (=);

Turn time measured as 7.5m from the wall.

Following the swimmer's 'cool down', the coach, swimmer and sport scientist reviewed the race. This included a normal speed and slow-motion video, as well as the tabulated and graphical swim report. The procedure for video feedback was to first play the video at normal speed for both the swimmer and coach in order that both parties obtain an overview of the race. This was followed by looking at the data shown in Table 1. From the race data, it was ascertained if any specific parts of the race need further investigation; for example, if there was a change in the race variables within a 25 m segment of the race. In addition, the start and water entry position, the body position in and out of the turn, and any good/poor breathing mechanics were also reviewed. These targeted sections of the video were then replayed in slow motion, usually at 50 percent speed, freeze framing; and moving one frame forward or back was also used to identify what was happening within the race. Discussion took place between the swimmer, coach and sport scientist, with each race critically reviewed by the support team and (if possible) using comparison with past swimming performances (as the database was constantly growing since 2002) to identify any necessary changes, prior to the next race. The swimmer and coach indicated that this immediate feedback was very effective in making any adjustment to the race strategy. This type of race analysis and feedback has been found to be an effective mechanism for swimmers and coaches alike [15, 17, 18].

Within a race, the stroke rate is the most common measure the swimmer and coach use to develop the desired race strategy [11, 21, 34]. Stroke rate can be recorded by the coach using a stopwatch. More importantly, the swimmer can "feel" the arm timing and can readily adjust this within their race. When comparing the Olympic and Visually Impaired swimmers at the Sydney 2000 Games within the four clean swimming sections of the 100-m event, there were no significant differences in stroke rate between the Olympic and Paralympic swimmers. Despite the difference in average swimming velocity, as the stroke rate was not normalized for time, this suggests that a very similar race strategy is adopted by both the Olympic and Paralympic swimmers. This result of similar race patterns between Olympic and Paralympic swimmers has been found in other studies [21, 22]. For the visually impaired swimmers in the current study this demonstrates that the ability to "see" the opposition swimmer and racing them may not be as important as employing a suitable race strategy. As shown in Table 2, there was no significant difference between class 12 and class 13 swimmers (they have different levels of visual impairment, whereas class 11 are total blind). This similarity raises the controversial question of whether these two classes should be combined [23, 24].

PARALYMPIC SWIMMING CHALLENGES

To address the demands of the swimming coach and athlete, objective data on the swim performance is required. There needs to be a consistent format for race analysis. If possible, an international policy or set of guidelines should be created so that comparison with other studies is possible. Unfortunately, the format for the turn time was changed within the seven years of data collection for this project. As access to the most appropriate areas is often difficult, the challenge is the ability to gather this information at the international competitions. The challenge for the sport scientist is to expedite the data processing, particularly with the large video files. Continuous feedback is required from the coach to the sport scientist on the "usefulness" of the data collected and the presentation format. Simple, correct, and quick analysis is essential. In competition, the Paralympic swimmers are not allowed to use any equipment other than swimming goggles and swimming costume. In their home training environment, however, there is an opportunity for training devices to monitor stroke rates, body roll; or for speed assistance or speed resistance. There are further opportunities to develop disability-specific equipment, particularly for the spinal-cord athletes and the more severely disabled swimmers.

CONCLUSION

The athlete's performance and safety can be improved by simple, but effective, modifications to their technique and equipment design. For each specific swimmer, the factors that contributed to their race performance were tracked and identified, the key areas of improvement for this swimmer were to improve turn and finish times, and to evenly pace the race. When comparing the race patterns between Olympic and Paralympic swimmers, a similar race pattern was identified, highlighting that the ability to "see" the opposition swimmer and racing them may not be as important as employing a suitable race strategy.

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