MODELLING COMPETITIVE SWIMMING IN DIFFERENT STROKES AND DISTANCES UPON REGRESSION ANALYSIS: A STUDY OF THE FEMALE PARTICIPANTS OF SYDNEY 2000 OLYMPIC GAMES

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The purpose of the study was to obtain the slope and y-intercept of the regression between race component times and race time for a group of top level female swimmers (the best 16 times) in the 2000 Sydney Olympic Games. All the 50, 100 and 200 m events were analyzed in this study. A multi-camera video recording system (7 cameras) was located on the catwalk 18m above the center lanes of the pool. The regression and correlation coefficients were significant in 78% of the races analyzed, excluded stroke frequency, stroke length and stroke index. The quality of the swimmers analyzed enabled the calculation of the recommended times in each phase in relation to race time. This information may allow top level swimmers to train specifically in their weakest race component.

KEY **WORDS:** swimming, competition analysis, starts, turns

INTRODUCTION: The objective in swimming competition is to cover the race distance in the least time possible. This race time (RT) can be divided into four parts: the time spent starting (ST), the time spent stroking (CT), the time spent turning (TT) and the time spent finishing (FT) (Pai, et al., 1984). The stroking component can be further described by the distance covered while stroking (SL), the stroke frequency (SF), and by the average speed (MS). The MS multiplied by SL equals the stroke index or efficiency index (EI) (McMurray, et al., 1990). These variables are called the race components (RC). The analysis of competition has been widely accepted in the scientific and coaching community during the last years. Papers such as those published by Arellano et al. (1994) showing the results of the analysis of the freestyle events in the Barcelona Olympic Games: Thomson et al. (2000) analyzing the RC of the participants in the breaststroke events, in international and national competitions in Europe; and Mason (1999) and Mason and Cossor (2000) analyzing the participants in the World Swimming Championship (1998) and Pan-Pacific Games (1999), contributed knowledge that demonstrated the importance of each RC in the final result. When planning for performance improvement, one has to consider all of these RC, however it is necessary to use some references to conduct this planning more accurately. Absaliamov and Timakovoy (1990) published the data of 1980 Moscow Olympic Games as the regression analysis of the RC related to the resulted competition time. A and B coefficients of the linear equation permitted a prediction of each RC time related to a specific race time. Arellano et al. (1996) developed the same type of analysis with the participants in the 1992 Barcelona Olympic Games. In this case, the analysis was done on all participants, more than 60 in some events, obtaining high correlation values between the RC and RT. The purpose of the current study was to obtain the slope and y-intercept of each significant regression equation ($p<0.05$). These equations will help us to calculate the proper RC time or value to obtain a RT based on the data of a group of top level female swimmers (the 16 best times), who participated in the 2000 Sydney Olympic Games.

METHOD: Subjects. The analysis of RC data was conducted on all female swimmers participating in finals (better 8) and semifinals (better 16). Because the finalist participated at least two times, to be included in the study data for the better time was selected. Table 1 shows the means (seconds) and standard deviations (s) of the RT.

Table 1 Mean and Standard Deviation *(s)* of the Race Times (RT) in the Female Group of Participants in the Sydney Olympic Games

Event*	Mean	s	Event	Mean	s
50 freestyle	25.36	0.55	100 breaststroke	68.93	1.17
100 freestyle	55.32	0.76	200 breaststroke	147.24	2.38
200 freestyle	129.06	1.69	100 butterfly	58.96	0.94
100 backstroke	61.87	0.92	200 butterfly	120.06	1.69
200 backstroke	132.84	1.95			

* Note. n = 16 in each event

Instrumentation. The Australian Institute of Sport (AIS) Biomechanics Department conducted competition analysis at the Sydney 2000 Olympic Games. The data used in this paper were obtained utilizing seven cameras (Sony TRV-900E operating at 50 Hz) located on the catwalk that ran above the center lanes of the pool and was positioned approximately 18 m above pool deck. The following is a list of the cameras used and their positions:

1. 7.5 m from the start – looks at the first 15 m of the race (all lanes)
2. 12.5 m from the start – looks at lanes 1-4 between 5 m and 20 m
3. 12.5 m from the start – looks at lanes 5-8 between 5 m and 20 m
4. 25 m – to obtain accurate information on the 25 m splits for each swimmer (all lanes)
5. 37.5 m from the start – looks at lanes 1-4 between 30 m and 45 m
6. 37.5 m from the start – looks at lanes 5-8 between 30 m and 45 m
7. 42.5 m from the start – looks at the turns (all lanes)

The competition analysis software used was written by Dr. Bruce Mason and was capable of performing analysis on all swimmers from any heat and lane. Variables that were determined from the competition analysis included: ST, the time from the gun until the swimmer's head passed through the 15 m mark; TT, the period from the swimmer's head passing the 7.5 m mark on her way to the wall until returning to this point after having completed the turn; and FT, the time that it took the swimmer's head to pass under the flags (5 m from the wall) until the swimmer's hands touched the wall at the end of the race. The analysis was also divided into 25 m sections in order to accurately determine the velocity through different phases of the race. MS was measured for each 25 m section of the race; while the free-swimming time was the time within a 25 m section that did not include any start, turn or finish sections. Stroke length (measured in meters per cycle) and stroke frequency (strokes per minute) was also calculated in each free-swimming section of the race. Stroke length was defined as the distance a swimmer travels for a complete stroke cycle (right hand entry to right hand entry). The number of stroke cycles that would occur in one minute, if the present rating was continued, is defined as the stroke frequency. The stroke or efficiency index within a section was the product of stroke length and the average swimming velocity and was measured in (m/cycle)*(m/s).

Statistical analysis. All data were printed and exported by the software cited previously. A linear regression analysis was developed to export the data to a statistical computer software (STATISTICA I Mac, Statsoft™). Only the regression equations with a significant correlation coefficient are presented in the study. The type of equations obtained were:

$$\text{Race component} = (A \text{ 'Race Time}) + B$$

Where A is the slope and B is the y-intercept. To determine RC to swim 100 m freestyle in 55 seconds, coefficients from Table 2 are used. This would result in ST = 6.80 s, CT= 37.01 s, MS= 1.74 ms^{-1} TT=7.84 s, and FT= 2.87 s.

RESULTS AND DISCUSSION: Variables, SF, SL and SI did not correlate significantly with the RT. The arguably best swimmers in the world makes it difficult to see trends in these variables on the basis of stroke variations. ST, CT, MS, TT, and FT showed significant correlation in 78%

of the results (Table 2). The ability to predict RT from variables such as swimming speed was reported by Thomson et al. (2000) in breaststroke swimmers of high level. Our results showed similar predictability but with lower correlation coefficients. Only FT in 100 m breaststroke and ST in 200 m were not significant in this study with 16 swimmers. There were low correlations found between RC and ST, TT or FT in some cases (10) (Table 2). This is different than a study by Arellano et al. (1996) in which high correlations were in all the RC with the RT. The Barcelona (1992) study was of all participants, not just finalists as in Sydney 2000, which may explain these differences in that correlations are less meaningful in homogeneous groups. The applicability of the equations is restricted to a population with an Olympic swimming ability. Other factors may be more important in determining RT in other groups of swimmers.

Table 2 **Slope (A), Y-intercept (B) and Co**efficients of Correlation between Race Time **and Race Components**

Var.	Stroke	A	B	r	p	Var.	stroke	A	B	r	P
ST	50 fr	0.29	-0.77	0.84	**	ST	100 br	0.11	0.70	0.52	•
CT	50 fr	0.59	0.99	0.93	**	CT	100 br	0.86	-12.93	0.96	**
MS	50 fr	-0.07	3.64	-0.93	**	MS	100 br	-026	3.19	-0.96	**
FT	50 fr	0.09	0.14	0.67	**	TT	100 br	0.11	2.77	0.65	**
ST	100 fr	0.16	-2.00	0.78	**	FT	100 br	0.05	-0.23	0.48	ns
CT	100 fr	0.68	-0.39	0.93	**	ST	200 br	0.04	2.07	0.46	ns
MS	100 fr	-0.03	3.54	-0.92	**	CT	200 br	0.73	-4.63	0.89	**
TT	100 fr	0.14	0.14	0.63	**	MS	200 br	0.01	2.66	-0.88	**
FT	100 fr	0.05	0.12	0.34	ns	TT	200 br	0.06	2.19	0.60	*
ST	200 fr	0.01	6.39	0.06	ns	FT	200 br	0.05	-3.13	0.61	*
CT	200 fr	0.57	14.86	0.78	**	ST	100 bt	0.16	-2.65	0.62	**
MS	200 fr	0.01	2.86	-0.76	**	CT	100 bt	0.55	7.28	0.87	**
TT	200 fr	0.03	4.70	0.28	ns	MS	100 bt	-0.02	3.14	-0.93	**
FT	200 fr	0.06	-4.13	0.82	**	TT	100 bt	0.10	2.61	0.68	**
ST	100 bk	0.10	1.37	0.30	ns	FT	100 bt	-0.07	-1.11	0.37	ns
CT	100 bk	0.74	-3.77	0.82	**	ST	200 bt	0.16	-2.65	0.62	**
MS	100 bk	0.03	3.25	-0.83	**	CT	200 bt	0.50	24.22	0.78	**
TT	100 bk	0.14	-0.14	0.73	**	MS	200 bt	0.01	2.59	0.75	**
FT	100 bk	0.02	1.50	0.24	ns	TT	200 bt	0.10	2.61	0.68	**
ST	200 bk	0.08	-2.89	0.59	*	FT	200 bt	0.07	-1.10	0.37	ns
CT	200 bk	0.83	0.83	0.92	**						
MS	200 bk	0.01	3.18	-0.92	**						
TT	200 bk	0.05	3.27	0.45	ns						
FT	200 bk	0.03	-0.86	0.57	•						

'significant at $p<0.05$, ** significant at $p<0.01$ level, ns = not significant

Table 3 Sample Table of the Application of Regression Equations to Predict the Race Components in 50 m Freestyle Female

	Predicted	Predicted	Predicted	Predicted
RT (s)	ST (s)	CT (s)	MS (mls)	FT (s)
24,00	6,19	15,15	1,96	2,30
24,50	6,34	15,45	1,93	2,35
25,00	6,48	15,74	1,89	2,39
25,50	6,63	16,04	1,86	2,44
26,00	6,77	16,33	1,82	2,48

26,50	6,92	16,63	1,79	2,53

CONCLUSIONS: We calculated the times of each race component in relation to race time for Olympic swimmers. Using these data as a benchmark allows top level swimmers and their coaches to identify their weakest race component and to train specifically for improvement. Nevertheless, the wach has to determine the most convenient competition model for each swimmer, and make the appropriate adaptations based on the individual characteristics of each swimmer. Testing the RC during the season will help to monitor for any improvement and determine whether the swimmer has been able to adopt the proposed model.

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