13th FINA WORLD CHAMPIONSHIP FINALS: STROKE KINEMATICS AND RACE TIMES ACCORDING TO PERFORMANCE, GENDER AND EVENT

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The aim of this work was to compare the stroke kinematics and race times of the freestyle final races at the 13th FINA World Championships between: (i) the three medalists versus the last three finalists; (ii) males versus female swimmers; (iii) all events in each gender. Data was collected from the champioships official web site. There were no significant differences in the stroke kinematics neither in the race times between medallists and non-medallists. There were significant effects in the stroke kinematics and race times according to race event. There were significant effects in the stroke kinematics and race times according to swimmers gender. It seems there are different tactics and biomechanical strategies according to gender and swimming event.

KEY WORDS: swimming event, event time, stroke length, stroke frequency, swim velocity.

INTRODUCTION: Swimming research can be done collecting data during: (i) training sessions; (ii) specific control and evaluation sessions and; (iii) competitions. Collecting data during competition has the advantage that we may be able to understand the swimmer's biomechanical strategies in a more ecological context. This is even more obvious if the swimmers are analyzed during high-standard competitions as World Championships (Okuno et al., 2003) or Olympic Games (Wilson et al., 2001). On a regular basis, during these competitions the following variables are usually compared: swim velocity, stroke length, stroke rate and stroke index (Wilson et al., 2001; Okuno et al., 2003); or the starting time, swimming time and the turning time (Cossor & Mason, 2001; Mason & Cossor, 2001) between some selected cohort groups.
Major advances happened in the last couple of years in competitive swimming. Some coaches suggest that female swimmers are getting performances closer to the male ones and differences between genders in some swimming events are becoming less obvious. However, there are almost no studies reporting biomechanical race analysis for the last two years. Furthermore, to the best of our knowledge there is not any study comparing the medalists with the remaining finalists. The 13th FINA World Championships (Rome, July 2009) was the most recent chance to analyze world-ranking swimmers and try to answer to these issues. The aim of this work was to compare stroke kinematics and race times during the 13th FINA world Championships between: (i) the three medalists versus the last three finalists in each freestyle final by gender; (ii) males versus female freestyle finalists in each event; (iii) freestyle events in each gender.

METHODS: Seventy two swimmers (36 male swimmers and 36 female swimmers) were assessed in all the freestyle final race events (50-m, 100-m, 200-m, 400-m, 800-m and 1500-m) of the 13th FINA World Championships. The three medalists (from 1st to 3rd position) and the three last finalists (from 6th to 8th position) of each event were selected for the analysis.
Data was downloaded from a public domain (official web site of the 13th FINA World Championships). Data was uploaded in the web site at the end of each competition day or in the following ones. Data collection procedure is reported in the public domain (www.roma09.it) and was done by the Institute of Sport Medicine and Sport Science "Antonio Venerando" (Italy). It was used an integrated multichannel video recording system, consisting of fixed cameras (Sony and Panasonic) synchronized with each other and with the official timing acquired from the official chrono system (Omega). The video analysis was done using

DartFish 5.0 software, with the technical cooperation of the Italian Swimming Federation. Race times and the kinematical data in each lap of all participating swimmers were provided.
Were selected as dependent variables the: (i) stroke rate (SR); (ii) stroke length (SL); (iii) stroke index (SI); (iv) swim velocity (v); (v) swimming time (SwT); (vi) start time (StT) in the first 15-m and; (vii) turning time (TT). The mean values of all laps in each race event were considered for analysis. Were selected as independent variables the: (i) performance level (medalist versus non-medalist); (ii) gender (male versus female swimmer) and; (iii) race distance (50-m versus 100-m versus 200-m versus 400-m versus 800-m versus 1500-m). The 50-m male freestyle event was not possible to assess since data was not uploaded.
Data normality was determined by Shapiro-Wilk test. Whenever appropriate, parametric or non-parametric procedures were adopted. To compare swimmers according to their competitive level, Mann-Whitney U ranking tests were computed (α=0.05). To assess the gender and the race event effect on dependent variables, one-way ANOVAs were selected with Scheffé as post-hoc test (α=0.05).

RESULTS: Table 1 presents the descriptive statistics. There were no significant differences between medalists and remaining finalists for the stroke kinematics (SR, SL, SI and v) neither for the race times (SwT, StT and TT) in all race events for both genders.
For male swimmers, significant effects were verified in the SR ($F_{(4;7)}$=16.004; p<0.001), v ($F_{(4;7)}$=12.250; p<0.01), SwT ($F_{(4;7)}$=810.068; p<0.001), StT ($F_{(4;7)}$=13.360; p=0.01) and TT ($F_{(4;7)}$=5.118; p=0.03). Post-hoc test identified that: (i) SR was higher in the 100-m than in the 200-m, 400-m, 800-m and 1500-m (p <0.01); (ii) v was higher in the 100-m than in the 400-m, 800-m and 1500-m (p<0.01); (iii) SwT was lower in the 100-m than in the 400-m, 800-m and 1500-m (p<0.01), in the 200-m than in the 400-m, 800-m and 1500-m (p<0.01), in the 400-m than in the 800-m and 1500m (p<0.01), in the 800-m than in the 1500-m (p<0.01); (iv) StT was lower in the 100-m than in the 400-m, 800-m and 1500-m (p<0.01) and; (v) TT was lower in the 100-m than in the 400-m race events (p<0.01).
For female swimmers, significant effects were verified in the SR ($F_{(5;8)}$=22.065; P<0.001), v ($F_{(5;8)}$=15.714; p<0.001), SI ($F_{(5;8)}$=4.285; p=0.03), SwT ($F_{(5;8)}$=2934.468; p<0.001), StT ($F_{(5;8)}$=25.921; p<0.01) and TT ($F_{(4;5)}$=9.258; p<0,001). It was verified that: (i) the SR was higher in the 50-m event than in the 200-m, 400-m, 800-m, 1500-m (p<0.01); (ii) the v was higher in the 100-m than in the 400-m, 800-m, 1500-m (p<0.01), in the 200-m than in the 400-m (p<0.01); (iii) SwT was lower in the long course events (400-m, 800-m and 1500-m) than in the shorter ones (50-m, 100-m, 200-m) (p<0.01); (iv) the StT was lower in the 50-m than in the 400-m, 800-m, 1500-m (p<0.01) and; (v) the TT increased with longer race distances (p<0.01).
Regarding gender, there were significant effects in the: (i) 100-m race event for the SI ($F_{(1,2)}$=31.89; p=0.03), v ($F_{(1,2)}$=94.867; p<0.01), SwT ($F_{(1;2)}$=86.820; p=0,01) and TT ($F_{(1,2)}$=113.337; p<0,01); (ii) 200-m race event for the SwT ($F_{(1,2)}$=34.610; p=0.03) and TT ($F_{(1,2)}$=42.462; p=0.02); (iii) 800-m event for the SL ($F_{(1,2)}$=21.119; p=0,04), SI ($F_{(1,2)}$=22.283; p=0.04), SwT ($F_{(1,2)}$=86.906; p=0.01), TT ($F_{(1,2)}$=61.114; p=0.02) and StT ($F_{(1,2)}$=146.074; p<0.01); (iv) 1500-m event for the v ($F_{(1,2)}$=17.504; p=0,05). The v, SI and SL were higher in male swimmers than in female ones, while the race times were lower in males.

DISCUSSION: There were no significant differences in the stroke kinematics neither in the race times between medalists and non-medalists. Medalists and non-medalists have a very small gap performance. Data was compared for small sub-sample size groups, leading to some difficulty to clearly identify a trend. Additionally, some swimmers probably adopt the same biomechanical and motor control (i.e. stroke kinematics) and tactical (i.e., race times) strategies whatever the sub-sample group they belong to. Therefore, differences between both groups might be explained by other variables that were not considered in this research.

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Table 1: Kinematical race analysis variables: descriptive statistics

Race event	Gender	Conditions	SR [c/min]	SL [m]	SI [m^2/c.s]	V [m/s]	SwT [s]	StT [s]	TT [s]
50-m	Male	Medalist	*N.P*	*N.P*	*N.P*	*N.P*	*N.P*	*N.P*	
		Non-medalist	*N.P*	*N.P*	*N.P*	*N.P*	*N.P*	*N.P*	
		Overall	*N.P*	*N.P*	*N.P*	*N.P*	*N.P*	*N.P*	
	Female	Medalist	59.73± 2.17	1.96± 0.04	3.77 ±0.04	1.94 ±0.02	23.90 ±12	6.17 ±0.11	
		Non-medalist	56.00± 1.64	2.07 ±0.06	3.99± 0.11	1.93 ±0.01	24.30 ±0.16	6.26 ±0.01	
		Overall	57.86± 2.63	2.02±0. 08	3.99± 0.15	1.93 ±0.01	24.10 ±0.28	6.21 ±3.06	
100-m	Male	Medalist	53.09± 3.33	2.30± 0.13	4.67± 0.23	2.03± 0.03	47.09± 0.17	5.47± 0.19	6.83± 0.12
		Non-medalist	54.62± 1.33	2.20± 0.05	4.39± 0.10	2.00± 0.00	47.77± 0.35	5.49± 0.20	6.83± 0.20
		Overall	53.85± 2.42	2.25± 0.10	4.53± 0.22	2.02± 0.02	47.43± 0.45	5.48± 0.18	6.83± 0.15
	Female	Medalist	55.66± 0.49	1.93± 0.00	3.47± 0.03	1.79± 0.02	52.62± 0.48	6.39± 0.06	7.67± 0.12
		Non-medalist	50.43± 0.40	2.09± 0.01	3.67± 0.05	1.76± 0.02	53.64± 0.31	6.55± 0.30	7.84± 0.21
		Overall	53.05± 2.89	2.01± 0.09	3.57± 0.12	1.77± 0.03	53.13± 0.66	6.47± 0.21	7.75± 0.18
200-m	Male	Medalist	42.27± 2.83	2.64± 0.15	5.29± 0.98	2.00± 0.25	103.04 ±0.96	5.93± 0.14	7.17± 0.01
		Non-medalist	44.28± 0.95	2.47± 0.06	4.50± 0.13	1.82± 0.01	106.19 ±0.20	6.31± 0.10	7.40± 0.11
		Overall	43.27± 2.18	2.55± 0.14	4.89± 0.76	1.91± 0.18	104.61 ±1.86	6.12± 0.24	7.29± 0.14
	Female	Medalist	46.30± 2.32	2.18± 0.07	3.67± 0.07	1.68± 0.04	114.53 ±1.38	6.91± 0.27	8.12± 0.05
		Non-medalist	42.02± 3.33	2.29± 0.31	3.78± 0.50	1.65± 0.01	116.89 ±0.54	6.83± 0.20	8.29± 0.04
		Overall	44.16± 3.48	2.23± 0.21	3.72± 0.33	1.67± 0.03	115.71 ±1.60	6.87± 0.22	8.20± 0.10
400-m	Male	Medalist	39.37± 0.65	2.64± 0.05	4.54± 0.07	1.72± 0.01	221.05 ±0.33	6.25± 0.07	7.47± 0.16
		Non-medalist	45.05± 3.70	2.29± 0.20	3.88± 0.37	1.69± 0.02	226.64 ±0.36	6.48± 0.09	7.88± 0.32
		Overall	42.21± 3.91	2.46± 0.23	4.21± 0.43	1.71± 0.02	223.85 ±3.08	6.36± 0.14	7.67± 0.32
	Female	Medalist	45.07± 3.54	2.24± 0.04	3.62± 0.06	1.62± 0.01	240.18 ±0.90	7.32± 0.09	8.60± 0.10
		Non-medalist	43.27± 3.73	2.21± 0.21	3.49± 0.36	1.58± 0.02	245.19 ±2.18	7.41± 0.22	8.65± 0.04
		Overall	44.17± 3.40	2.22± 0.14	3.56± 0.24	1.60± 0.02	242.69 ±3.12	7.36± 0.16	8.63± 0.08
800-m	Male	Medalist	40.51± 1.63	2.47± 0.10	4.10± 0.19	1.66± 0.03	456.44 ±5.00	6.38± 0.05	7.54± 0.09
		Non-medalist	40.41± 5.98	2.45± 0.40	3.98± 0.67	1.62± 0.01	469.12 ±0.59	6.48± 0.26	7.75± 0.19
		Overall	40.46± 3.92	2.46± 0.26	4.04± 0.45	1.64± 0.03	462.78 ±7.64	6.43± 0.18	7.64± 0.18
	Female	Medalist	42.77± 2.91	2.19± 0.14	3.41± 0.23	1.56± 0.02	496.60 ±0.65	7.31± 0.20	8.90± 0.61
		Non-medalist	44.92± 3.56	2.04± 0.19	3.10± 0.33	1.52± 0.02	532.02 ±46.69	7.21± 0.14	8.69± 0.03
		Overall	43.84± 3.24	2.12± 0.18	3.26± 0.31	1.54± 0.03	514.31 ±38.06	7.26± 0.16	8.80± 0.37
1500-m	Male	Medalist	39.19± 2.95	2.67± 0.32	4.41± 0.54	1.65± 0.00	881.83 ±4.80	6.72± 0.17	7.80± 0.23
		Non-medalist	41.81± 4.07	2.34± 0.20	3.79± 0.34	1.62± 0.04	906.11 ±11.75	7.05± 0.17	8.07± 0.09
		Overall	40.50± 3.49	2.50± 0.30	4.10± 0.53	1.64± 0.03	893.97 ±15.53	6.98± 0.24	8.02± 0.22
	Female	Medalist	41.63± 2.25	2.23± 0.12	3.46± 0.16	1.55± 0.01	948.95 ± 582	7.26± 0.16	8.21± 0.19
		Non-medalist	44.63± 0.82	2.04± 0.04	3.09± 0.06	1.51± 0.00	971.66 ±3.85	7.3 ±0.16	8.36± 0.14
		Overall	43.13± 2.23	2.14± 0.13	3.28± 0.23	1.53± 0.02	960.31 ±13.20	7.29± 0.15	8.29± 0.17

N.P – not published in the official web site from the 13th FINA World Championships

There was a trend for SR and v to decrease and SL to be approximately constant with increasing distances. The v depends on SR and SL. World-ranked swimmers already maintain a high SL since this variable is related to subject's efficiency. Thus, the biomechanical strategy to increase v is to increase SR. Probably some swimmers have specific SR strategies throughout the event laps. This might be a research issue in the near future. For race time variables, shorter distances imposed lower SwT and TT. In short distance races, turning phase is more determinant for the performance than in longer events (Hay & Guimarães, 1983). As the v decreases with increasing distance, the SwT decreases as well. In this sense, not only the swim phase is important to enhance performance, in short distances events, but also turning and to some extend starting phases are. In the future it can be interesting to understand if there is any race time strategy, throughout the swimming event from lap to lap.
Male swimmers presented a higher SL, v and SI with lower race times (SwT, StT, TT) than female swimmers. Male swimmers spend less time to travel a given distance than female ones. Hence, male swimmers have to spend also less time in each specific phase of the race, including the StT and TT. The lower SwT for male swimmers are related to their higher SL and SR, imposing a higher v than female swimmers. This is related to a kineanthropometrical gap based on gender. Male swimmers tend to be taller, presenting a higher arm span that will impose a higher SL. Male swimmers present also a higher muscle power leading to an improvement in the block start impulse, in the wall impulse during turning and even during stroking.

CONCLUSION: There are different biomechanical and/or tactical strategies between medalists and non-medalists that were not possible to identify based on the selected variables. Although some speculation, major differences still exist in race time and stroke kinematics of world-ranked swimmers, according to their gender and swimming event.

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