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Original Article

Analysis of the performance of finalist swimming athletes in Olympic games: reaction time, partial time, speed, and final time

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Abstract:
The aim of this study was to verify and compare the reaction time, swimming speed, partial- and final time of freestyle swimmers at the Beijing 2008 (B08), London 2012 (L12), and Rio 2016 Olympics (R16). 109 athletes (male (n = 57) and female (n = 52)), Olympics finalists were analyzed in the 100m, 200m, and 400m freestyle swimming events. ANOVA one-way multi-compare was used to verify the difference between reaction time (RT), partial time (PT), mean speed (MS), and final time (FT) in the analyzed Olympics. Statistical differences were found in the RT in the 100, 200, and 400m freestyle in females and 400m freestyle in males over the three Olympics, while for the mean speed the first 50 meters presented differences in the partial times, and for final time only the 100m female was different over the three Olympics. The race and partial time strategies had similar characteristics during the analyzed Olympics, while the reaction time of the athletes presented significant evolution over the Olympics.
Key Words: Freestyle event, Swimming performance, Competitive performance, Swimmers.

Introduction

Performance analysis has a relevance for sports science, in an attempt to improve the sports performance. A technical committee on better performance results has also gained considerable prominence in a number of modalities, including swimming (Farto, 2010).Due to the covered distances and swimming strokes be different, swimming is a sport that involves different bioenergetic demands. It can be reported that the performance of swimming athletes varies according to several aspects, including physiological and biomechanical factors (Barbosa et al., 2010).

Considering that swimming races ranging from 50m to 1500m, analysis of swimming race strategy have fundamental importance in the athlete's performance, especially in long-distance races, where each partial time during the race will correspond to a portion of the final result, with the ability to determine the difference between first and second place (de Souza Castro, Diefenthaeler, Colpes, Peterson Silveira, & Franken, 2017). Race strategy is the way in which athletes distribute speed and energy expenditure throughout the event, and another important aspect in race strategy is the partial time adopted. In 400m freestyle, athletes adopted a race strategy which included leaving the starting block fast, at high intensity, followed by a decrease in effort in the middle part of the race, and finally an acceleration in the final part (Mauger, Jones, & Williams, 2009).

In swimming, exiting the starting block is considered an influential factor in the athletes' race outcome, as well as the most common way to quantify reaction time (RT). This factor could have undergone changes over the years, as athletes may have modified their technical block exit pattern, along with the technical swimming pattern, observed through biomechanical factors (Barbosa et al., 2010). Several resources have been developed with the aim of improving swimmers' performance. The development of high-technology swimwear which aids the performance of athletes can be mentioned, especially regarding breaking long-established records (O'connor&Vozenilek, 2011). From 2009, the International Swimming Federation (FINA) banned the use of high-technology swimwear by adopting a pattern of swimwear and material to be used by all swimmers, since it was believed that the records set would take a longer period to be broken , due the banishment established (Mountjoy et al., 2010).

Considering that some characteristics of RS may have changed over the Olympics, researchers have sought to analyze the performance of athletes through evaluation of improvement in the final time over the years

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(McGibbon, Pyne, Shephard, & Thompson, 2018). Thus, it was hypothesized that the reaction time in certain tests, together with the mean speed and partial times may have shown a change in behavior over the three Olympics studied. Therefore, the aim of the present study was to verify and compare the reaction time (RT), partial time (PT), mean speed (MS), and final time (FT) through the performance of freestyle swimmers at the Olympic Games in Beijing in 2008 (B08), London in 2012 (L12), and Rio in 2016 (R16).

Material & methods

Participants

The swimmers of 109 Olympic level athletes were analyzed, male (n = 57) and female (n = 52), of different nationalities, finalists in the 100m, 200m, and 400m freestyle swimming of the Olympic Games B08, L12, and R16.

Procedure

All results of partial race times were obtained from the FINA official website (http://www.fina.org/). As these values are in the public domain, informed consent was not required from the athletes. The partial times of the 100m, 200m, and 400m tests were manually entered into a Microsoft Excel 2016 XML file and double-checked to avoid possible errors. The mean speed values (m/s) in each partial race were obtained by calculating the length of the partial displacement (displacement is standardized in multiples of 50 meters) divided by the time taken for the analyzed distance.

Statistical analysis

Descriptive statistics are presented as mean and standard deviation. Data normality was performed using the Kolmogorov-Smirnov test. For data comparison between Olympics, one-way ANOVA multi-compare was used to verify the interaction between reaction time (RT), partial time (PT), mean speed (MS), and final time (FT) between the different Olympics. To identify differences between variables, the Bonferroni post hoc test was used. The significance level adopted was $p < 0.05$. All analyzes were performed using Statistical Package for Social Sciences software (SPSS Inc., Chicago, IL, USA).

Results

For RT in different distances, significant differences were found over the three Olympics in the male and female groups, demonstrating improvement in this variable.

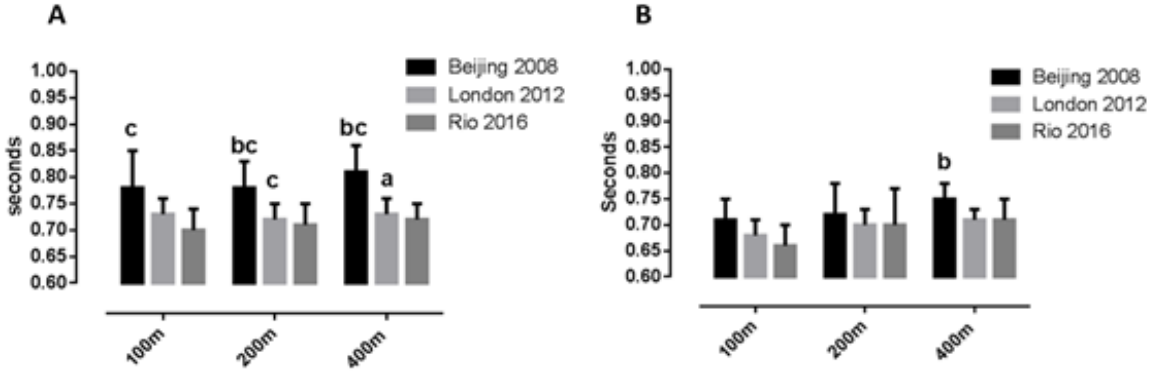

Figure 1: Comparison of RT(s) for female athletes (A) and male (B) finalists of the 100, 200 and 400m free events at the 2008 Beijing Olympics, London 2012 and Rio 2016. [a]significant difference of Beijing 2008, [b] significant difference of Londres 2012, [c] significant difference of Rio 2016 ($p<0.05$). (s)- seconds.

For the 100m test, for female athletes, a significant difference was found in the mean RT from B08 to R16 ($F = 4,79$; $p = 0.01$). For the 200m, the mean RT of the B08 Olympics demonstrated a significant difference compared to the L12 ($F = 5,30$; $p = 0.03$) and R16 ($F = 5,30$; $p = 0.02$). In addition, L12 presented a significant difference compared to R16 ($F = 5,30$; $p = 0.03$), although not to Beijing 2008.

In the female 400m, there was a significant difference in RT in B08 compared to L12 ($F = 10,09$; $p=0.003$) and R16 ($F = 10,09$; $p=0.002$), however, in L12, there was a difference only from B08 ($F = 10,09$; $p=0.003$). When comparing the RT in different Olympics for the male group, only the 400m distance demonstrated a significant difference between B08 and L12 ($F = 3,81$; $p=0.04$).

When comparing the 100m female race in the three Olympics (Table 1), it was observed that in R16, the athletes performed better partial times (seconds), influencing the result of the mean speed (meters per second). The results showed a significant difference in the first partial in time in seconds ($F = 3,62$; $p = 0.04$) and the mean speed ($F = 3,60$; $p = 0.05$) from L12 to R16. For male athletes, no significant differences were observed either for the partial race time or the mean speed.

Table 1: Partial race times (s) and mean speed (m/s) of female and male athletes, finalists in the 100m freestyle and 200m freestyle races in the Olympic Games in Beijing 2008, London 2012, and Rio 2016.

		Olympic games	50m	100m	150m	200m
PT (s)	Woman	Beijing 2008	25.70 ± 0.31	28.10 ± 0.50	-	-
		London 2012	25.77 ± 0.32[c]	27.72 ± 0.45	-	-
		Rio 2016	25.36 ± 0.34	27.68 ± 0.43	-	-
	Men	Beijing 2008	22.72 ± 0.24	25.05 ± 0.28	-	-
		London 2012	22.88 ± 0.29	24.95 ± 0.26	-	-
		Rio 2016	22.85 ± 0.30	25.10 ± 0.38	-	-
	Women	Beijing 2008	27.65± 0.37[c]	29.28 ± 0.36	29.81 ± 0.36	29.59 ± 0.66
		London 2012	27.37± 0.28[c]	29.18 ± 0.45	29.75 ± 0.40	29.95 ± 0.51
		Rio 2016	26.97± 0.21	29.02 ± 0.35	29.55 ± 0.31	29.56 ± 0.43
	Men	Beijing 2008	25.01 ± 0.39	26.76 ± 0.37	27.13 ± 0.41	26.89 ± 0.64
		London 2012	24.84 ± 0.21	26.49 ± 0.36	27.09 ± 0.5	27.16 ± 0.65
		Rio 2016	24.65 ± 0.53	26.76 ± 0.21	27.10 ± 0.43	26.96 ± 0.38
MV (m/s)	Woman	Beijing 2008	1.94 ± 0.02	1.77 ± 0.03	-	-
		London 2012	1.94 ± 0.02[c]	1.80 ± 0.02		-
		Rio 2016	1.97 ± 0.02	1.80 ± 0.02	-	-
	Men	Beijing 2008	2.20 ± 0.02	1.99 ± 0.02	-	-
		London 2012	2.18 ± 0.02	2.00 ± 0.02	-	-
		Rio 2016	2.18 ± 0.02	1.99 ± 0.03	-	-
	Women	Beijing 2008	1.80 ±0.02[c]	1.70 ± 0.02	1.67 ± 0.02	1.69 ± 0.03
		London 2012	1.82 ± 0.01[c]	1.71 ± 0.02	1.68 ± 0.02	1.66 ± 0.02
		Rio 2016	1.85 ± 0.01	1.72 ± 0.02	1.69 ± 0.01	1.69 ± 0.02
	Men	Beijing 2008	1.99 ± 0.03	1.86 ± 0.02	1.84 ± 0.02	1.86 ± 0.04
		London 2012	2.01 ± 0.01	1.88 ± 0.02	1.84 ± 0.03	1.84 ± 0.04
		Rio 2016	2.02 ± 0.04	1.86 ± 0.01	1.84 ± 0.03	1.85 ± 0.02

Note: PT – Partial Time; MV – Mean speed. [a] significant difference of Beijing 2008, [b] significant difference of London 2012, [c] significant difference of Rio 2016 ($p<0.05$)

The results demonstrated that although some partial times did not present significant differences, in R16, in all partial times, female 200m athletes had lower partial times in relation to B08 and L12 (table 1), as well as mean speed, where all partial times had a higher speed than the previous two Olympics.

In the 400m, there were no significant differences in different partial times (table 3) for either female or male swimmers, however, it is possible to note that in the Olympics of R16, from 75m to 350m, female athletes maintained an average of 30 seconds every 50m, thus demonstrating better maintenance of the pace of the race and a possible change in race strategy compared to the previous two Olympics.

Table 3: Partial race times (s) and mean speed (m/s) of female and male athletes, finalists in the 400m freestyle in the Olympic Games in Beijing 2008, London 2012, and Rio 2016.

	G	Olympic Games	50m	100m	150m	200m
Time (s)	M	Beijing 2008	26.26 ± 0.23	28.23 ± 0.19	28.54 ± 0.13	28.63 ± 0.16
	M	London 2012	26.08 ± 0.33	28.23 ± 0.33	28.58 ± 0.15	28.84 ± 0.37
	M	Rio 2016	26.03 ± 0.27	28.10 ± 0.26	28.53 ± 0.17	28.65 ± 0.23
Time (s)	W	Beijing 2008	28.66 ± 0.18	30.55 ± 0.1	30.94 ± 0.13	31.21 ± 0.22
	W	London 2012	28.27 ± 0.33	30.43 ± 0.25	30.87 ± 0.22	31.09 ± 0.2
	W	Rio 2016	28.50 ± 0.41	30.47 ± 0.49	30.67 ± 0.47	30.98 ± 0.42
Speed (m/s)	M	Beijing 2008	1.90 ± 0.01	1.77 ± 0.01	1.75 ± 0.01	1.74 ± 0.01
	M	London 2012	1.91 ± 0.02	1.77 ± 0.02	1.74 ± 0.01	1.73 ± 0.02
	M	Rio 2016	1.92 ± 0.01	1.77 ± 0.01	1.75 ± 0.01	1.74 ± 0.01
Speed (m/s)	W	Beijing 2008	1.74 ± 0.01	1.63 ± 0.05	1.61 ± 0.007	1.60 ± 0.01
	W	London 2012	1.76 ± 0.02	1.64 ± 0.01	1.61 ± 0.01	1.60 ± 0.01
	W	Rio 2016	1.75 ± 0.02	1.64 ± 0.02	1.63 ± 0.02	1.61 ± 0.02

	G	Olympic Games	250m	300m	350m	400m
Time (s)	M	Beijing 2008	28.31 ± 0.24	28.29 ± 0.37	28.02 ± 0.48	27.39 ± 0.91
	M	London 2012	28.50 ± 0.36	28.69 ± 0.40	28.40 ± 0.75	28.16 ± 0.97
	M	Rio 2016	28.60 ± 0.47	28.55 ± 0.34	28.28 ± 0.78	27.54 ± 1.09
Time (s)	W	Beijing 2008	30.90 ± 0.36	31.02 ± 0.52	31.09 ± 0.78	30.49 ± 1.07
	W	London 2012	30.94 ± 0.4	31.23 ± 0.34	31.01 ± 0.44	30.28 ± 0.65
	W	Rio 2016	30.81 ± 0.51	30.95 ± 0.44	30.78 ± 0.61	29.89 ± 0.57
Speed (m/s)	M	Beijing 2008	1.76 ± 0.01	1.76 ± 0.02	1.78 ± 0.03	1.82 ± 0.05
	M	London 2012	1.75 ± 0.02	1.74 ± 0.02	1.76 ± 0.04	1.77 ± 0.06
	M	Rio 2016	1.74 ± 0.02	1.75 ± 0.02	1.76 ± 0.04	1.81 ± 0.07
Speed (m/s)	W	Beijing 2008	1.61 ± 0.01	1.61 ± 0.02	1.60 ± 0.03	1.64 ± 0.05
	W	London 2012	1.61 ± 0.02	1.60 ± 0.01	1.61 ± 0.02	1.65 ± 0.03
	W	Rio 2016	1.62 ± 0.02	1.61 ± 0.02	1.62 ± 0.03	1.67 ± 0.03

Note: [a]significant difference of Beijing 2008, [b] significant difference of London 2012, [c]significant difference of Rio 2016 (p<0.05). G- Gender; W- Women; M- Men.

Continuity table 3: Partial race times (s) and mean speed (m/s) of female and male athletes, finalists in the 400m freestyle in the Olympic Games in Beijing 2008, London 2012, and Rio 2016.

Note: [a]significant difference of Beijing 2008, [b] significant difference of London 2012, [c]significant difference of Rio 2016 (p<0.05). G- Gender; G- Gender; W- Women; M- Men.

Dicussion

The study aimed to verify and compare the pattern of the reaction time, partial race time, mean speed, and final time in the competitive performance of freestyle swimmers at the Beijing 2008, London 2012, and Rio 2016 Olympics. As main findings of this study, it was found that the reaction time of male and female athletes showed a reduction (a) over the three Olympics, both in short distance (100m, 200m) and medium distance races (400m).

For the partials, the results showed that during the three Olympics the (b) partial times did not demonstrate major changes, athletes of both sexes continued swimming with similar strategies for each race , as the results showed that significant differences between partial times occurred only in the 100m and 200m female events, while no significant differences between partial times were observed in any male event in the different Olympics. Regarding the final times, the study showed that in R16, in all tests analyzed for (c) female athletes', the final time was better when compared to previous Olympics. It is hypothesized that despite the use of technological swimwear in B08, and decreased times in L12, female athletes' improved their performance, possibly due to factors related to variables not analyzed in this study, but which empower athletes to improve their results.

In the current study the performance analysis for swimmers was evaluated through 4 variables; RT, partial race time, mean speed of partial, and final time. According to Reischle (1993), two or more swimmers can perform the same time in a given race, however, the manner in which the athlete achieves this result may vary. The race tactic, motor development, and technique used during swimming can be differentiated between swimmers. Haljand & Saagpakk (1994) describe that when intending to perform analysis of a competition, it is necessary to break it down into its constituent elements. In this way it is understood that competition analysis consists of measuring different components of the total race time, that is, starting time, swimming time, turning time, and arrival time.

Based on these test components, Arellano (1993) describes the variability between chronometric variables and concludes that the importance of departure and arrival decreases as the race distance increases; the importance of relative turning time increases as the distance of the race increases; and the relative swimming time increases as the race distance increases.

In another study, the authors report that during the first 50m in a freestyle-style race, the swimming velocity was influenced by the exit from the starting block, due to the distance offset by the horizontal thrust from the block, and the swimmers started the race at rest, so the partial time that has the lowest effect of fatigue; thus, the higher swimming speed is justified (Castro & Mota, 2011).

It appears that over the course of the three Olympics, reaction time demonstrated some importance in the final performance of athletes, not just in short distance events, as the reaction time improved in the three race distances analyzed. According to Ruschel, Araujo, Pereira, & Roesler (2007), the improvement of the swimming technique start together with the RT it is possible to improve the athlete performance in the FT of event . Hay (1988) describes that the exit from the starting block can constitute 5 to 11% of total swim time, although this tends to decrease with increasing distance (Breed & Young, 2003). This shows that elite athletes' are aware that even in long-distance events, this variable is important in the competitive result, since milliseconds can make the difference between first and second place.

The results of the study also showed that there were few partial event times that were significantly different between Olympics. This demonstrates that the race strategy of the Olympic finalists remained similar along the years. The same occurs for the mean partial speed for both male and female athletes.

According to Damasceno et al. (2013) the distribution of energy expenditure as well as the travelling speed during the race is called race pacing St Gibson et al. (2006) reports that for an athlete to reach the end point of a race in the shortest possible time without reaching exhaustion before finishing the race, it is necessary to choose a pacing that corresponds to the type of race being swum. Other authors (Castro & Mota, 2011) also describe that the end result in certain tests is influenced by biomechanical and physiological factors, that are directly related to the way in which the swimmer completes the swim race, and different types of pacing may occur.

According to Abbiss e Laursen (2008), the speed of the race is determined by two factors, the distance to be traveled and/or duration of the race. In analysis of Olympic athletes, Maglischo (2003) describes that in 400m freestyle, athletes' pacing can present uniform or negative patterns. Similar results occurred in our study, with the 400m swimmers maintained uniform patterns in all the Olympics. However, at the start of the race, the partial times were lower due to the exit from the starting block, and in the final partials, before finishing the race, the swimmers increased the pace, ending the test with a final sprint.

In 200m race, independent of swimming style, the race may be characterized as a more complex, since it is performed at high intensity, but is not as short as the 50 and 100m events. Due to its duration and the great use of the glycolytic energy system, the 200m event can cause high levels of fatigue during the race. In the current study, female athletes in 200m races showed a uniform partial-time pattern from 50m in the three different Olympics. However, male swimmers demonstrated variations in the partial times of the race. For the 100m, the race strategy adopted in the three different Olympics for female athletes was to average the first partial

to 25 seconds, and the male athletes to 22 seconds, with the second partial time being a variation of two to three seconds above the first time for both female and male groups.

This variation in test time may be due to intra-cyclic speed variation between men and women (Schnitzler, Seifert, Ernwein, & Chollet, 2008). Regarding this variation, it was identified that female athletes' presented lower values than male athletes', which occurs as female swimmers present lower values of height, weight, and arm span compared to male swimmers (Schnitzler et al., 2008; Toussaint et al., 1988).

When comparing the final race time in the three Olympics, Rio 2016 demonstrated the lowest times achieved, as well as the highest speeds for female athletes in the 100, 200, and 400m freestyle races. Some authors report that improvements in swimming times are due to the advancement in training techniques, and changes in regulations such as pool depth, block angle, and water height and temperature. It is important to highlight that high-technology swimwear also helped to improve athlete performance, reducing final race times.(Arellano, Brown, Cappaert, & Nelson, 1994; Chatterjee & Laudato, 1996; Costa et al., 2010; O'connor & Vozenilek, 2011).

According to the regression model in the study by Stanula et al., (2012), it was predicted that the 100m freestyle results at the London 2012 Olympics would be 51.46 seconds for men and 46.19 seconds for men. However, in our study the results were higher than expected. Women achieved a mean time of 53.49±0.29 seconds and men a mean time of 47.87±0.29 seconds.

In the 200m freestyle, the same authors, using the mathematical regression model, predicted that athletes' in L12 could attain 114.25s for female and 103.24s for male swimmers. In the results of our study, it was found that female swimmers achieved a mean time of 116.26±1.35s and male swimmers achieved 105.59±1.44s. In the 400m analysis by the regression model, the authors describe that female swimmers could attain a time of 227.29s and male swimmers 215.62s, however the results achieved for the female swimmers was 244.14±1.94s and 225.52±3.12s for male swimmmers. However, the authors report that this prediction model could overestimate the performance time values (Stanula et al., 2012).

It can be considered that the evolution of technology has helped in improving athlete race times (Maglischo, 2003; O'connor & Vozenilek, 2011), however, the mean partial times and speed of the three Olympics analyzed are close, and this improvement may be related to the quality of swimming technique and the evolution of training.

It is important to note that although technology has helped to improve athletes' performance, it can be seen that throughout the swim races the differences between partial times and speed did not present significant differences, however, it is worth considering that the exit from the starting block improved considerably from the B08 to R16.

The main limitation of the present study is the low variety of variables analyzed to understand athletes' performance during the Olympics. Biomechanical, anthropometric, and physiological factors could explain and broaden the discussion and analysis regarding the aim and results of our study. Future studies with different variables and different swimming strokes are suggested to understand the performance of Olympic swimmers.

Conclusion

We concluded that during the three Olympics, the athletes' RS didn't change, however it is possible to observe that different initial partials were adopted for each race and, in the majority of the analyzes, the first 50m of each race were faster in R16 than in B08. Another important factor to be considered is that in B08, high-technology swimwear helped the reduction in athletes' finish times, and compared to R16, these times continued to fall, despite the banishment on this swimwear, which demonstrates maximization of sports performance by the athletes'. One of the variables analyzed, reaction time, was shown to be a possible determining factor in short and long-races, with the decrease in RT over the three Olympics.

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