RESEARCH IN SPORTS MEDICINE
https://doi.org/10.1080/15438627.2020.1860051

Routledge
Taylor & Francis Group

How do swimmers pace the 400 m freestyle and what affects the pacing pattern?

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ABSTRACT

To describe the pacing pattern of elite 400 m freestyle swimmers, understand how athletes select the first half compared to their 200-m race pace, and correlate critical speed (CS) and D' with pacing parameters. The best all-time 400 m performances were obtained, and 200 m performances were retrieved from the same competition. Twenty-four performances were selected and, when possible, 50 m-splits were obtained. CS and D' were calculated based on the 200 m and 400 m performances. Most athletes adopted a parabolic pacing pattern. Performance in the 400 m correlated with that of the 200 m (rho = 0.418, p = 0.042), the % difference between 200 m performance and 200 m split correlated with CS (rho = –0.595, p = 0.002) and with D' (rho = 0.808, p < 0.001). The correlation between D' and % difference between average speed and CS was nearly perfect (rho = 1.000, p < 0.001). Recommendations of having the first half of the 400 m 4–5 s slower than their 200 m race do not seem to be appropriate for all swimmers and depends on physiological abilities.

ARTICLE HISTORY
Received 27 August 2020
Accepted 27 November 2020

KEYWORDS
Aerobic fitness; swimming; training

Introduction

Pacing is the adjustment of power output/speed during a sporting event which allows the athlete to complete the distance in the shortest possible time. This has been a topic of interest in several sports because energetic reserves need to be used effectively to perform well while avoiding premature fatigue. In swimming, as in other cyclic sports, performance is determined by finishing in the shortest time possible, but pacing has received considerably less attention so far (Foster et al., 2012).

Adopting a suitable pacing pattern is critical in swimming due to the water resistance (i.e., drag), which increases disproportionately to the speed and imposes low levels of efficiency (Toussaint et al., 2000). Because of the large drag, if power output decreases from fatigue, it is possible to rapidly lose velocity in swimming. Most studies about pacing in swimming have focused on 400 m freestyle and their results indicate the prevalence of either a parabolic or a fast-even-pacing patterns (Mauger et al., 2012).

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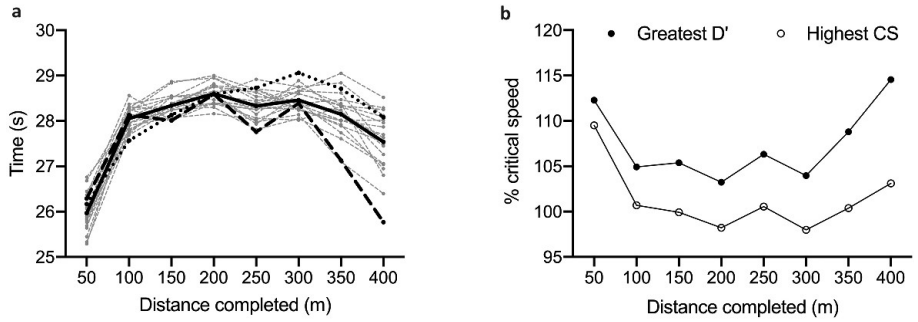

Figure 1. Panel A – Individual (in grey dashed lines) and average (in black continuous line) pacing pattern of the 21 swimmers. Black dotted line represents the slowest swimmer while black dashed line represents the fastest swimmer. Panel B – Illustration of pacing pattern represented as speed of the swimmers with the greatest D' (#1) and the highest critical speed (CS, #12) in relation with their respective CS.

Nearly 40% of the males who competed in 400 m freestyle in the 2019 World Championship also swam the 200 m freestyle (FINA, 2020). Swimmers who compete in both races often discuss pacing strategies with their coaches to decide how they should start the 400 m in comparison to their 200 m performance. It is generally accepted that the first 200 m of a 400 m should be 4–5 s slower than their 200 m performance, which represents approximately 3–5%. However, it is unknown if this anecdotal pacing "guideline" is optimal. Therefore, this study aimed first to investigate the pacing pattern of the all-time world best performers in the 400 m freestyle and understand how they select the first half of the 400-m race compared to their 200-m race pace. Secondly, critical speed (CS), as a marker of aerobic fitness, and D', as a marker of anaerobic fitness, were calculated based on the 400 m and 200 m results and correlated with pacing parameters.

Methods

The ranking for the all-time best performances in the men's 400 m freestyle was obtained from FINA website (www.fina.org), and only the best result of each swimmer was considered. The 50 m split times were obtained online from the official event website, or (when not available) from www.swimrankings.net. Performances without available split data were excluded from the analysis. We also retrieved the 200 m freestyle results for the same athlete in the same competition. Performances were not included in the analysis if the 200 m and 400 m results from the same meet were not available. Critical speed (CS) and anaerobic capacity (D') were calculated as the angular coefficient (i.e., slope) and intercept of the regression line between distance-time of these two distances (Wakayoshi et al., 1992), respectively.

Shapiro-Wilk tested the assumptions of normally distributed samples. Normality was not confirmed for 400 m performance, CS, D', % difference between 200 m performance and 200 m split, and % difference between average 400 m speed and CS. Spearman coefficient assessed the relationship between 200 m and 400 m performances, between CS and D' and % difference between 200 m performance

Table 1. Individual data of 200 m and 400 m performance, critical speed (CS), and D′, coefficient of variation of each 50 m split (CV) for the 24 swimmers included in the study. * – 50 m splits were not available.

Ranking in the 400 m	200 m performance (s)	400 m performance (s)	CS ($m.s^{-1}$)	D′ (m)
1	102.00	220.07	1.694	27.22
2	104.71	220.08	1.734	18.48
3	104.93	220.14	1.736	17.85
4*	106.11	222.51	1.718	17.68
5	105.14	223.11	1.695	21.75
6	106.74	223.36	1.715	16.94
7	106.60	223.40	1.712	17.47
8	108.98	223.46	1.747	9.61
9	108.27	223.70	1.733	12.41
10	106.96	223.71	1.713	16.77
11	105.14	223.75	1.686	22.71
12	110.57	223.80	1.766	4.70
13	105.47	223.85	1.689	21.81
14	105.89	223.90	1.695	20.54
15	105.23	224.01	1.692	21.93
16	106.13	224.11	1.695	20.09
17	107.68	224.16	1.702	16.68
18	107.40	224.19	1.712	16.08
19	106.39	224.43	1.694	19.74
20	106.91	224.68	1.698	18.44
21	106.44	224.89	1.688	20.28
22*	106.70	225.00	1.691	19.61
23	105.66	225.04	1.675	22.99
24*	106.29	225.11	1.683	21.09
Average (SD)	**106.35 (1.64)**	**223.52 (1.47)**	**1.707 (0.022)**	**18.45 (4.62)**
Median	**106.34**	**223.78**	**1.697**	**19.05**
Maximum	**110.57**	**225.16**	**1.766**	**27.22**
Minimum	**102.00**	**220.07**	**1.675**	**4.70**

and 200 m split, and between D′ and % difference between average 400 m speed and CS. The correlations were interpreted as (when significant): >0.30: small, 0.31–-0.49: moderate, 0.50–0.69: large, 0.70–0.89: very large, and 0.90–1.00: nearly perfect. The significance level was set at $p \leq 0.05$.

Results

A total of 21 performances were considered for the pacing description and 24 for the determination of 200 m split. Performance data for the 400 m and 200 m, as well as CS and D′ are in Table 1. A parabolic pacing pattern (faster-slower-faster) was predominant (Figure 1a). Average 50 m splits in the 400 m freestyle were 25.97 ± 0.40 s, 28.05 ± 0.26 s, 28.34 ± 0.24 s, 28.60 ± 0.22 s, 28.33 ± 0.33 s, 28.46 ± 0.27 s, 28.15 ± 0.49 s and 27.54 ± 0.69 s. The 200 m split (111.10 ± 0.73 s) was 4.5 ± 1.7% slower than the 200 m performance in the same competition (106.35 ± 1.64 s). The second 200 m split in the 400 m race was 1.2 ± 1.4% slower than the first 200 m split (112.42 ± 1.31 s *vs* 111.10 ± 0.73

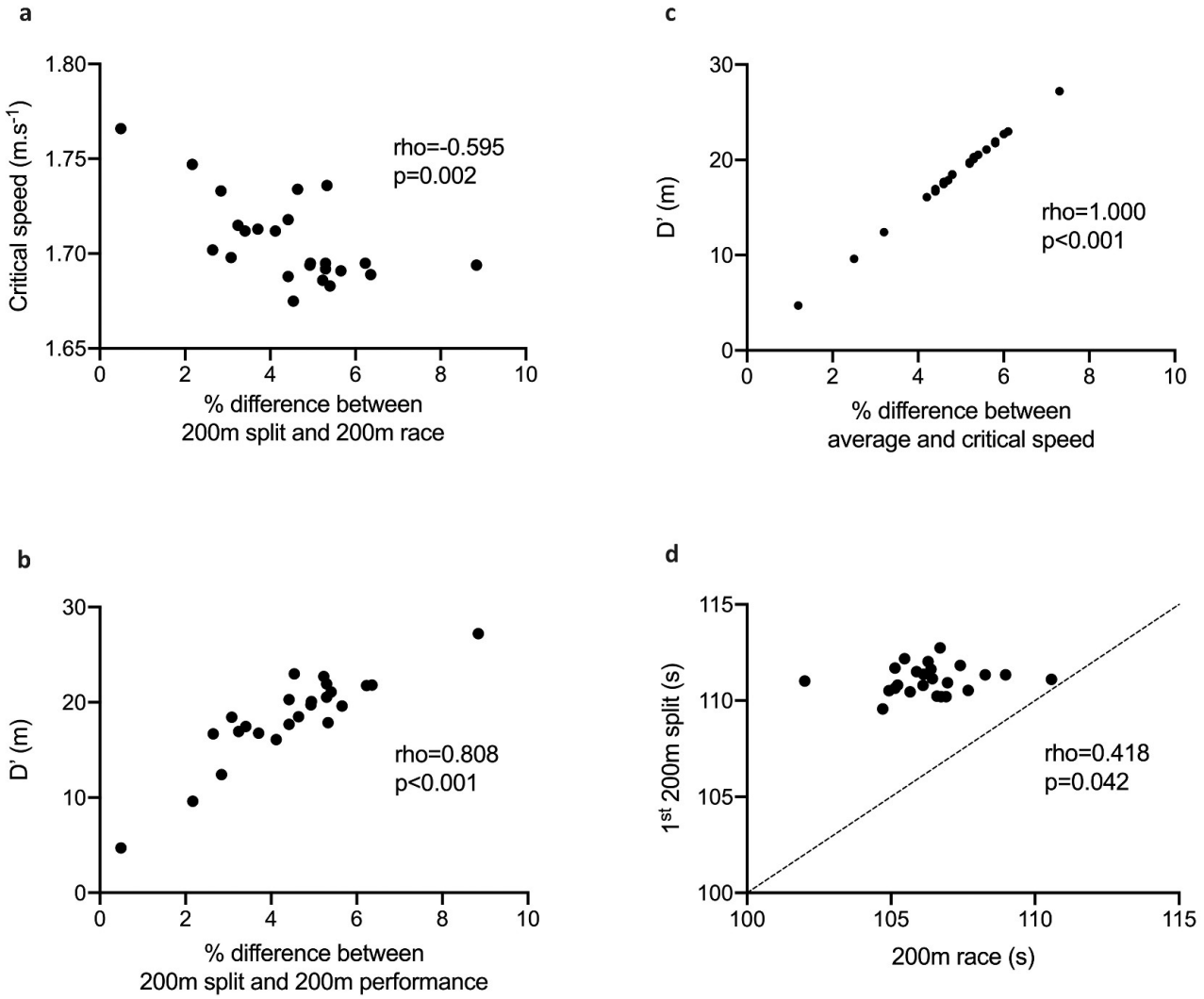

Figure 2. Scatter plots of the % difference between 200 m performance and 200 m split and critical speed (Panel A) and D′ (Panel B). Panel C – scatter plot of the % difference between average and critical speed and D′. Panel D – scatter plot of the 1st 200 m split and the 200 m race (dashed line represents the line of identity).

s, respectively). The 400 m performance was correlated with the 200 m performance (rho = 0.418, p = 0.042, moderate).

The % difference between 200 m performance and 200 m split correlated with CS (rho = −0.595, p = 0.002, large, Figure 2a) and with D′ (rho = 0.808, p < 0.001, very large, Figure 2b). The correlation between D′ and % difference between average speed and CS was nearly perfect (rho = 1.000, p < 0.001, nearly perfect, Figure 2c). In Figure 2d, the scatter plot between 1st 200 m split and the 200 m race is shown.

Discussion

This study investigated the pacing pattern in the 400 m freestyle and the relationship between the 200 m split in the 400 m and 200 m freestyle performances. Results indicate that the 200 m split is 4.5% slower than the 200 m performance, and that the 400 m performance correlates with the 200 m performance. Also, swimmers with higher CS and D′ had the 200 m split closer and farther to the 200 m performance, respectively.

The parabolic and the fast-start-even are the most common pacing profiles observed in elite 400 m freestyle swimmers (Mauger et al., 2012). de Koning et al. (2011) suggested that speed should be evenly distributed, as it likely provides physiological or biomechanical advantages (Toussaint, 2002). Although the first 50 m is expected to be faster as a consequence of starting from the blocks, it requires attention as starting too fast augments the need for power production to overcome resistive forces, which may compromise the remaining of the race. Thereafter, the speed decreases and stabilizes for the next 300 m, until the last lap. This speed adjustment is particularly important in swimming as small speed variations can dramatically affect the energy cost (Toussaint et al., 1990). Interestingly, some of the swimmers were not able to increase speed in the last 50 m, indicating they were fatigued. Also, only one swimmer (the fastest) was able to split the last 50 m faster than the first lap.

We also noticed that the first 200 m of the 400 m freestyle race was on average 4.5% slower than the 200 m freestyle race, which represented 4.75 s for these world-class swimmers. This follows the anecdotal recommendations of having the first half of the 400 m 4–5 s slower than their 200 m race. However, this recommendation does not take into account individualities, and does not seem to be appropriate for all swimmers (Figure 2d).

Swimmers with higher CS were able to swim closer to their 200 m race pace, contrary to those with larger D′ who were farther from the 200 m race pace (Figure 1b illustrates pacing pattern for the swimmers with highest CS and D'). Although correlation does not mean causation, this is an important finding as it may present a recommendation for coaches and athletes on how to pace themselves during the 400 m race according to individual abilities. In association with the correlation between 400 m and 200 m performances, this finding suggests that athletes who compete in 400 m should also consider training for the 200 m, as it may provide some potential physiological benefits to improve performance. In other words, as CS roughly represents the maximal speed an athlete can swim under sustainable oxidative metabolism (Jones et al., 2010), improving CS allows swimmers to split the first 200 m closer to their 200 m race pace. However, the nearly perfect correlation between D′ (which represents the finite capacity for swimming above CS) and the % difference between average race speed and CS indicates that enhancing D′

allows swimmers to complete the 400 m in speeds greater than CS. Thus, modifications in pacing pattern require a re-evaluation of the training load, so the physiological adaptations obtained in training can properly match the competitive requirements.

Tolerating high-intensity efforts, such as the 400 m freestyle, maximally taxes both aerobic and anaerobic components and requires that training be tailored to improve both aerobic and anaerobic adaptations (Ferri et al., 2012). Therefore, swimmers and coaches who want to succeed in this event must carefully design their training programming to improve both aerobic and anaerobic fitness components. Swimmers have also to consider improving anaerobic capacity, which may be accomplished by incorporating training for a shorter event as the 200 m.

Conclusions

The results of this study partly support anecdotal suggestions that swimmers should split the first 200 m 4–5 s slower than 200 m race performance, as it was the average difference observed in these world-class swimmers. However, when individual aerobic and anaerobic fitness are considered, this pacing pattern may be altered. Thus, a "sprinter type" swimmer with greater D', will have a much more hyperbolic pacing pattern, whereas an "endurance type", with higher CS, will have a much flatter pacing pattern.

Acknowledgments

No financial support was received by any of the authors.

Disclosure statement

No potential conflict of interest was reported by the authors.

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