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Pacing Strategy of 800 m and 1500 m Freestyle Swimming Finals in the World Championships According to the Performance in Males and Females of Different Age Groups

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Abstract: Pacing strategy refers to the distribution of effort and speed throughout the race to achieve optimal performance. This study aims to understand whether the choice of pacing strategy in swimming depends on the length of competitions and how sex, age, and performance level influence this strategy. Participants were the finalists of the 800 m and 1500 m freestyle events at the elite and junior world championships in 2022–2023. Race outcomes and pacing parameters were compared between the two distances and across different groups of swimmers. Swimmers in both distances did not break world records. Pacing strategy generally followed a U-shape with significant differences in the frequency and duration of speed changes between the two distances. The 800 m exhibited more frequent changes in acceleration, while the 1500 m events generally followed a more consistent time-series pattern. There were differences in pacing strategies between males and females and between junior and elite swimmers. Swimmers closer to world records showed more consistent pacing patterns compared to those farther from records. This study suggests that pacing strategies are influenced by race distance, sex, age, and performance level. The research highlights the complex interplay between physiological and psychological factors that shape a swimmer's decision-making during a race.

Keywords: energy cost; endurance; training; technique; tactic; fatigue; performance; time series; mathematical modelling; sex difference

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1. Introduction

The successful execution of the race strategy at the major competitions of the season represents the final challenge after months of training and preparation. To perform to the best of their abilities while remaining healthy, engaged, and injury-free, athletes must be mentored and coached in proper energy management through an appropriate pacing strategy, whether during training or competitions. Given the highly resistive properties of water, pacing strategy in swimming is a crucial aspect of performance, and it can significantly impact training and race outcomes [1–9].

Events of different lengths support various pacing strategies [3,10]. An "all-out" sprint strategy may be advantageous for sprints lasting less than 60 s, whereas athletes' longer-duration endurance performances may be enhanced by distributing energy resources more evenly, with minimal speed variation from lap to lap and an end spurt [5,6,11]. In open water swimming, it has been reported that swimmers competing in the shortest event had a minimal gap between them, and the leaders had begun the race in the head group [12]. Successful swimmers in the longer events adopted a more cautious strategy in the first half of the race by positioning themselves in the middle group [12]. Differences among events makes them an invaluable source for furthering our understanding of the pacing behaviours used by men and women, by the successful and unsuccessful, and by young and elite athletes [10]. It is important to note that reports of ~2.1% per decade improvements in swimming ability have been made [13]. However, the long-distance pool swimming race splits showed improvements, but not consistently. The percentage changes in the first, second, penultimate, and last splits did not coincide with the percentage changes in race time, indicating that the gain in race time was primarily attained in the middle of the race. The slight decrease in lap-to-lap variability, which indicated that swimmers had gradually developed smoother pacing profiles, was the other notable change in pacing parameters [14]. It is therefore evident that the study of pacing strategy must be continuously updated in light of the evolution of sports performance [10].

Evidence suggests that the overall pacing strategy is adjusted during prolonged exercise to prevent early exhaustion brought on by a malfunction of one or more physiological systems. Therefore, it is asserted that pacing strategies are indicators of the physiological regulation that underlies them and that pacing strategies are influenced by adjustments in muscle activation that are anticipatory in nature, based on afferent data from a variety of physiological systems [15–17]. Due to the low mechanical efficiency of swimming, the correct administration of the available energy is also highly dependent on technical abilities [18]. However, in competition, the athlete's surroundings constantly and simultaneously present various external stimuli, requiring decision-making regarding where and when to allocate their accessible energy resources. These calls for action can appear and disappear over time and prompt an athlete to decide whether to maintain their current speed, slow down, or speed up [19]. It could be assumed that swimmers would be more or less exposed to those external stimuli depending on the length of the race. At least 90% of the energy used during the 800 and 1500 m freestyle competitions is thought to come from aerobic metabolism [18,20]. Indeed, numerous swimmers actually compete in both distances due to their similar energy requirements. Although few studies have compared their race tactics, it appears plausible that they adopted similar pacing strategies, so a parallel analysis of the two events may be instructive [7,8,21]. Studying the pace strategy in events with similar energetic resources but different durations may aid in understanding how much pacing decision-making is influenced by external factors [19,22,23].

World records are an excellent paradigm of study because they led to the most optimal and outstanding performances in history. The study of world-class athletes' performance can provide a near-absolute standard of what athletes can achieve at their peak [24]. Simulating their competition strategy in training and minor races could provide useful indications to develop the swimmer's individual best pacing strategy for future events [25–31]. It has been highlighted that most studies on swimming pacing strategy have been conducted on 200 and 400 m events, while there is limited research on long-distance swimming [6]. Among long-distance pool swimming studies, some have analysed males and females 800 and 1500 m freestyle competitions, but none of them discussed the differences in pacing strategy between sexes nor between distances [7,21].

There is therefore a very strong rationale for updating the study of pacing strategy to provide the most actual individualised spectrum of the best pacing strategy. To this purpose, the analysis of real-world top-level competitions needs to be differentiated by sex, age, and competition level. The direct comparison of the pacing strategy adopted in the longest world championship swimming events could help understanding the mechanism underpinning swimmers' tactical choices.

The aim of this study was to determine whether choosing a swimming pacing strategy depends on the length of the competition and to conduct an updated parallel analysis of two endurance swimming events supported by similar energy resources but of different durations. To this purpose, the pacing strategies of all the elite and junior 2022–2023 world championships finalists in the 800 and 1500 m freestyle competitions have been compared.

To gain deeper insight into the specificity of a swimmer's tactics, the analysis was also differentiated by sex, age, and performance level.

2. Materials and Methods

All procedures were conducted according to the Helsinki Declaration. This study has received approval and authorization from the Foro Italico Ethics Committee of the University of Rome, with the designation CAR 155/2023. As only information that was readily accessible to the public was used, informed consent from athletes was judged unnecessary. The competition information for the long-course 800 and 1500 metre freestyle swimming world championships for men and women was collected from the website https://www.worldaquatics.com/swimming, which was accessed from 1 August to 20 August 2023. All data were collected, then anonymously analysed in the past. Athletes' topic identification numbers, the competition's name, distance, overall finishing position (ranking), split times (split) every 50 m, and the completion time were all included in each competition report.

Procedures and methods of the present work have been previously described [9].

A total of 96 results relative to 48 male and 48 female finalists of the 800 and 1500 m freestyle at long-course elite and junior world championships held in 2022 and 2023 were studied. The results of the 19th FINA World Championships Budapest (Budapest, Hungary), 8th FINA World Junior Swimming Championships Lima (Lima, Peru), and World Aquatics Championships Fukuoka (Fukuoka, Japan) were analysed. Elite swimmers' age was 23.2 ± 3.4 years; juniors' age was 16.4 ± 1.4 years.

2.1. Data Analysis

To examine the ascending and descending trends of the time series as well as to assess the randomness of split fluctuations over the median period, a mathematical analysis was used. The goal of the time series analysis is to determine whether the split times should be viewed as a true time series or as random samples. If a statistical test conducted on the data does not result in the rejection of randomness, then the analysis of data indexed by time is mathematically useless. The null hypothesis that a sequence is a random sample was tested using a typical statistical test of randomness based on the number and the maximal length of monotonous phases by keeping track of turning points, phase lengths, difference-signs, rank correlation, records, and rank serial correlation [32]. A statistic, denoted by (ν and τ), serves as the foundation for the test, with critical values given by and defined as follows. A series is considered a maximal sequence of consecutive measurements that is monotonous; then, n is the number of such series and t is the length of the longest one. If one of the inequalities

$$v(n) > \left[\frac{1}{3}(2n-1) - 1.96\sqrt{\frac{16n-29}{9}}0\right], \tau(n) < [3.3(\log 10n + 1)]$$

where $[x]$ denotes the integer part of x, we reject randomness; in other words, we conclude that the sequence $x1, \ldots, xn$ can be considered as a true time series, not as a random sample. In our case, n = 16 and n = 30, so that the critical region is given by

n > 4.204 or τ < 5 for 800-m and n > 9.723 or τ < 6 for 1500-m

The number of consecutive splits held faster (shown with a "minus" sign) or slower (marked with a "plus" sign) than the median velocity was used to compute the length of split sequences for each finalist. The count of the number of or + sequences was used to determine how many split sequences there were. The longest sequence that had the same or + sign was determined to be the maximum length of split sequences.

2.2. Variables Analysed

Race Time% Record Time—To assess the performance level of each athlete, we considered their competition finish time as a percentage of their respective record time (Race

Time% Record Time) and divided in the performer's closest (100–105% of WR) and farthest from the record time (105–112% of WR).

Coefficient of variation—The coefficient of variation in velocity along the race was calculated as a percentage of the standard deviation of the split times divided by the mean of the split times (CV%).

Sequences Number% Splits Number—The count of the number of negative or positive (− or +) acceleration sequence as a percentage of the number of splits of each race.

Maximal length of sequences% Splits Number—The longest sequence holding the same − or + sign as a percentage of the number of splits of each race.

Time series—When the sequence represented a true time series, it was given the value 1; when half of the sequence was a true time series, it was given the value 2; and if it was a random series, the value 3 (Time series 1—Half 2—Random 3).

Normalised velocity—Each split time was expressed as percentage of the mean individual split times. To compare the split times between the two distances, the splits 2–29 of the 1500 m race were considered every 100 m, thus obtaining the same number of splits as the 800 m race (n = 16).

All variables were compared between 800 and 1500 m races in all swimmers, and then separating males and females, elite and junior, medallists (placed from 1st to 3rd) and non-medallists (placed from 4th to last), 100–105% and 105–112% of world records.

2.3. Statistical Analysis

For each category, descriptive data (mean and SD) and effect size (ES) are presented. The Shapiro–Wilk test was used to determine whether the data were normal. Depending on the distribution of the data, ANOVA, Mann–Whitney U, or Kruskal–Wallis for repeated measurements with post-hoc Bonferroni correction tests were used. IBM SPSS Statistics for Windows, version 26.0, was used to conduct statistical analyses (IBM Corp, Armonk, NY, USA). The threshold for significance was fixed at 0.05.

3. Results

As described in Table 1, none of the swimmers of the world championships analysed reached or improved the respective world record. All final times resulted within 101% and 112% of world records. Race times in percentage of respective word records presented no differences between the 800 and 1500 m competitions, except for males (p = 0.00), elite (p = 0.02), and 100-105% (p = 0.02) swimmers that reached times closer to the respective world records in the 1500 m race.

Table 1. Competitions times.

		Race Time% Record Time			
		1500 m	**800 m**		
Subjects	**n**	**Mean ± SD**	**Mean ± SD**	**SE**	***p***
All Athletes	96	105.2 ± 2.8	105.5 ± 2.1	0.1	0.07
Males	48	104.2 ± 0.0	106.0 ± 1.4	0.9	0.00 *
Females	48	106.2 ± 3.0	104.9 ± 2.5	0.5	0.43
Elite	64	103.7 ± 1.6	104.5 ± 1.7	0.4	0.02 *
Junior	32	108.2 ± 2.3	107.5 ± 1.3	0.4	0.90
Medallists	32	103.9 ± 2.1	104.5 ± 1.8	0.3	0.34
Non-medallists	64	105.9 ± 2.9	106.0 ± 2.1	0.0	0.15
100–105% of WR	48	103.1 ± 1.1	103.6 ± 1.1	0.4	0.02 *
105–112% of WR	48	107.7 ± 2.1	107.1 ± 1.2	0.4	0.76

p: differences between 1500 and 800 m freestyle results; *: $p < 0.05$.

As shown in Table 2, sequence numbers were significantly higher in the 800 m competitions for all the swimmer groups. The maximal length of sequences of the same sign (− or +) were longer in the 800 m competitions, but the difference reached a significant level only when all swimmers were analysed as a whole (p = 0.01) and for the junior (p = 0.00), medallists (p = 0.04), and 105–112% (p = 0.04) groups.

Table 2. Splits sequences.

		Sequences Number (%)				Maximal Length of Sequences (%)			
		1500-m	**800-m**			**1500-m**	**800-m**		
Subjects	**n**	**Mean ± SD**	**Mean ± SD**	**SE**	***p***	**Mean ± SD**	**Mean ± SD**	**SE**	***p***
All Athletes	96	31.3 ± 11.0	34.6 ± 12.8	0.3	0.00 *	32.6 ± 9.5	37.6 ± 9.9	0.5	0.01 *
Males	48	33.1 ± 0.2	37.2 ± 13.4	0.3	0.00 *	28.5 ± 11.5	35.7 ± 10.0	0.7	0.09
Females	48	29.4 ± 10.5	32.0 ± 12.0	0.2	0.00 *	36.7 ± 7.3	39.6 ± 9.7	0.3	0.07
Elite	64	31.7 ± 10.8	34.0 ± 13.1	0.2	0.00 *	32.3 ± 9.4	37.3 ± 10.8	0.5	0.32
Junior	32	30.4 ± 11.7	35.9 ± 12.6	0.4	0.00 *	33.1 ± 10.1	38.3 ± 8.2	0.5	0.00 *
Medallists	32	31.7 ± 8.9	37.9 ± 13.6	0.5	0.00 *	31.3 ± 8.7	35.2 ± 10.2	0.4	0.04 *
Non-medal.	64	31.0 ± 33.0	33.0 ± 12.3	0.2	0.00 *	33.2 ± 10.0	38.9 ± 9.8	0.6	0.12
100–105%	48	32.4 ± 33.2	33.2 ± 13.0	0.1	0.00 *	30.6 ± 9.0	38.1 ± 9.8	0.7	0.20
105–112%	48	29.8 ± 12.8	35.8 ± 12.8	0.5	0.00 *	34.8 ± 9.8	37.3 ± 10.2	0.2	0.04 *

p: differences between 1500 and 800 m freestyle results; *: $p < 0.05$.

As displayed in Table 3, the time-series analysis revealed that the 1500 m competitions presented a significantly higher occurrence of "true" time series with respect to the 800 m competitions when all swimmers' results were taken as a whole (p = 0.01) and for the male (p = 0.04) and the elite (p = 0.02) groups. The coefficient of variation in velocity along the race (CV%) was not significantly greater in the 800 m competitions for all groups.

Table 3. Variability of splits times along races.

		Time Series 1—Half 2—Random 3				CV%			
		1500-m	**800-m**			**1500-m**	**800-m**		
Subjects	**n**	**Mean ± SD**	**Mean ± SD**	**SE**	***p***	**Mean ± SD**	**Mean ± SD**	**SE**	***p***
All Athletes	96	1.0 ± 0.1	1.3 ± 0.7	0.5	0.01 *	2.9 ± 0.5	2.9 ± 0.6	0.1	0.60
Males	48	1.0 ± 2.2	1.4 ± 0.8	0.6	0.04 *	2.9 ± 0.5	2.9 ± 0.6	0.0	0.94
Females	48	1.0 ± 0.0	1.2 ± 0.6	0.4	0.15	2.8 ± 0.5	2.9 ± 0.6	0.3	0.56
Elite	64	1.0 ± 0.2	1.4 ± 0.8	0.6	0.02*	2.8 ± 0.5	2.8 ± 0.5	0.0	0.98
Junior	32	1.0 ± 0.0	1.1 ± 0.5	0.4	0.78	2.9 ± 0.6	3.1 ± 0.6	0.3	0.40
Medallists	32	1.0 ± 0.0	1.5 ± 0.9	0.7	0.24	2.8 ± 0.4	2.8 ± 0.5	0.0	0.96
Non-medallists	64	1.0 ± 0.2	1.2 ± 0.5	0.4	0.16	2.9 ± 0.6	3.0 ± 0.6	0.2	0.55
100–105% of WR	48	1.0 ± 0.2	1.3 ± 0.7	0.5	0.20	2.9 ± 0.4	2.9 ± 0.4	0.1	0.91
105–112% of WR	48	1.0 ± 0.0	1.3 ± 0.7	0.6	0.77	2.8 ± 0.6	3.0 ± 0.7	0.2	0.47

p: differences between 1500 and 800 m freestyle results; *: $p < 0.05$.

Figure 1 illustrates how the normalised velocity of the whole group of swimmers in the 1500 m with respect to the 800 m competitions resulted significantly faster from the 5th to the 12th split (p = 0.00). The 1500 m velocity remained close to the mean velocity (100%) from the 3rd to the 7th split and declined afterwards until the spurt of the two last splits. The 800 m were competed at a velocity notably below the mean from the 5th to the 14th split.

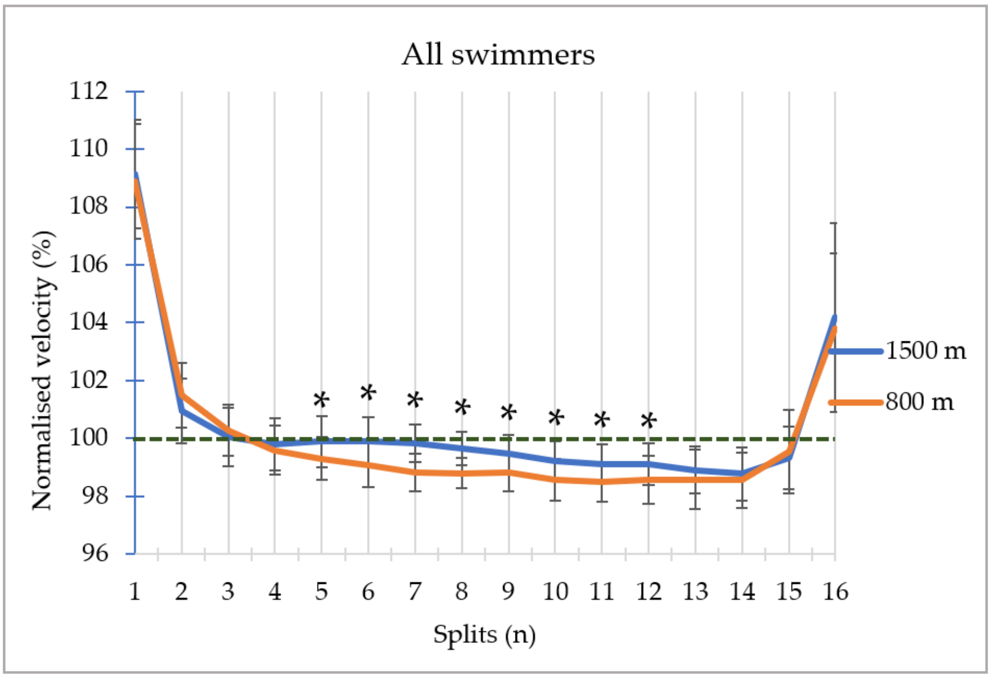

Figure 1. Splits times of all swimmers. *: $p < 0.05$ for the difference between 800 and 1500 m swimming.

Figure 2a,b represent how the male swimmers' normalised velocity was significantly lower in the 2nd and 3rd ($p = 0.00$ and $p = 0.04$, respectively) and higher from the 6th to the 12th spilt ($p = 0.00$) in the 1500 m than in the 800 m competitions. Females' normalised velocity resulted significantly higher in the 1500 m than in the 800 m competitions from the 4th to the 11th split ($p = 0.00$).

Female swimmers presented significantly lower normalised velocity with respect to men in the 10th ($p = 0.035$) and 15th ($p = 0.004$) split of the 1500 m competition and in the 8th ($p = 0.018$), 9th ($p = 0.004$), 12th ($p = 0.037$), 15th ($p = 0.014$), and last ($p = 0.000$) splits of the 800 m competition. Their 1st splits velocity of the 800 m competition was significantly higher than male swimmers ($p = 0.023$).

As depicted in Figure 3a,b, elite swimmers' normalised velocity was significantly higher in the 1500 m than in the 800 m competitions from the 5th to the 12th spilt ($p = 0.00$). Juniors' normalised velocity resulted significantly higher in the 1500 m than in the 800 m competitions from the 5th to the 11th split ($p = 0.01$), except for split 9 that presented no significant differences ($p = 0.09$).

In the 1500 m competitions, junior swimmers performed the 2nd and 3rd split at a significantly slower normalised velocity ($p = 0.010$ and 0.005, respectively) than the elites. In the 800 m competitions, junior swimmers' normalised velocity was significantly slower in the 2nd split ($p = 0.002$) and significantly faster in the 8th ($p = 0.023$) than the elites.

Figure 4a,b show that both medallists' and non-medallists' normalised velocity was significantly higher in the 1500 m than in the 800 m competitions from the 5th to the 12th spilt ($p = 0.02$ and $p = 0.01$, respectively).

No significant differences were found between the normalised velocity of the medallists and non-medallists in the 1500 m freestyle. In the 800 m, the normalised velocity of the non-medallists was significantly faster than the medallists in the 7th split ($p = 0.008$) and significantly slower in the 11th split ($p = 0.022$).

As represented in Figure 5a,b, better performers' (100–105%) normalised velocity was significantly higher in the 1500 m than in the 800 m competitions from the 5th to the

12th spilt ($p = 0.01$). The 105–112% swimmers' normalised velocity resulted significantly higher in the 1500 m than in the 800 m competitions from the 5th to the 11th split ($p = 0.01$).

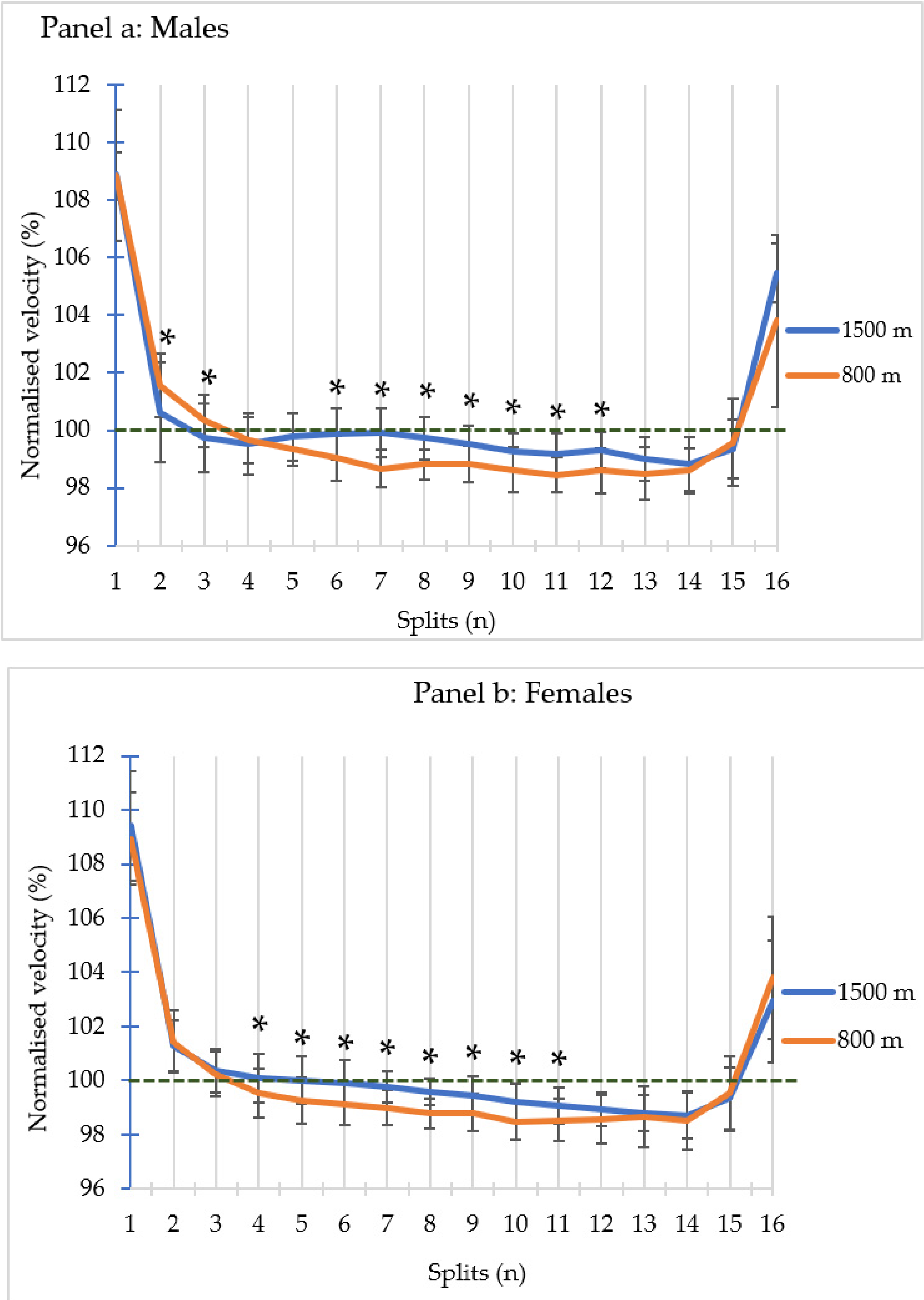

Figure 2. Splits times of males (**a**) and females (**b**). *: $p < 0.05$ for the difference between 800 and 1500 m swimming.

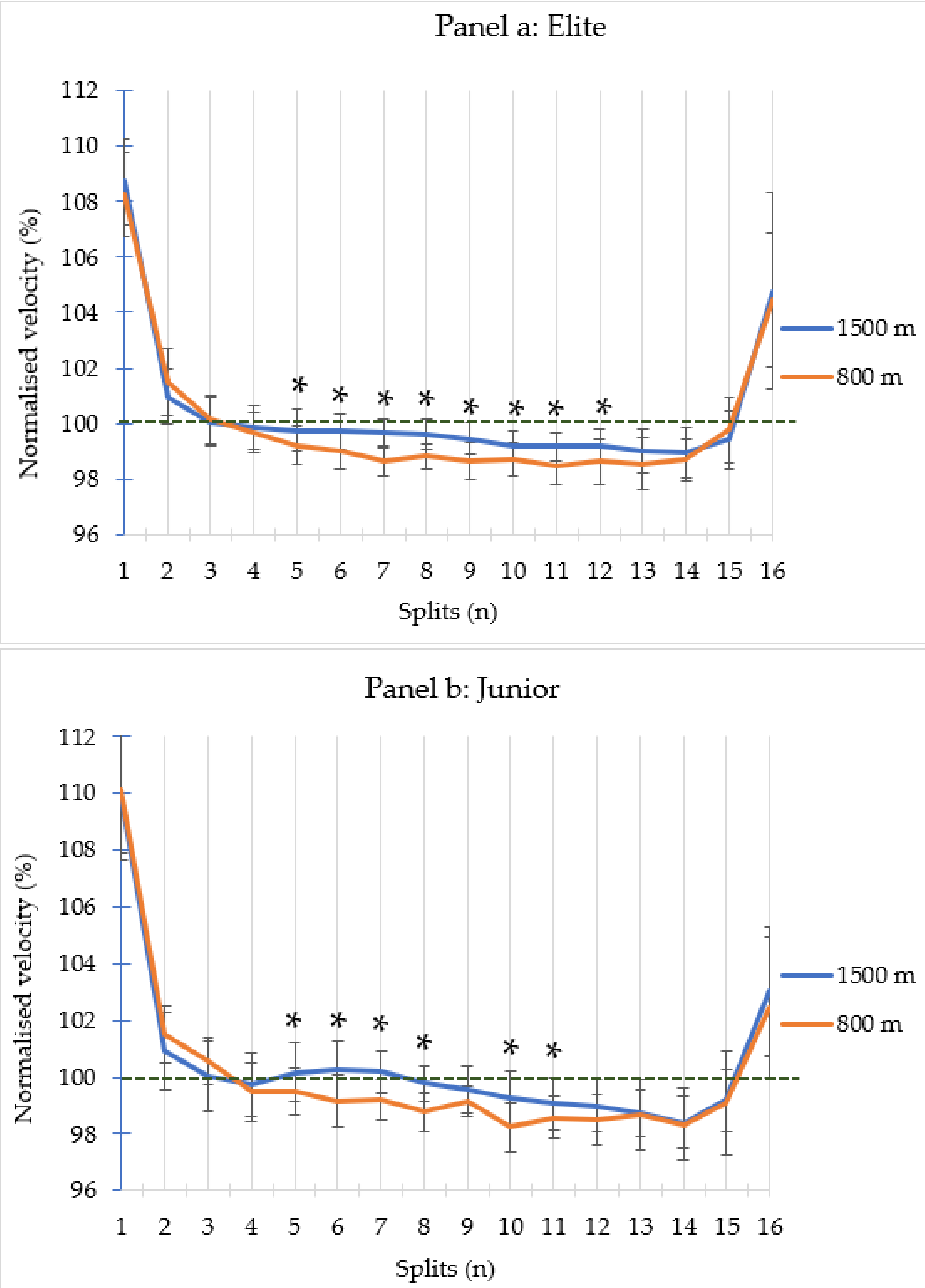

Figure 3. Splits times of elite (**a**) and junior (**b**). *: $p < 0.05$ for the difference between 800 and 1500 m swimming.

In the 1500 m competitions, the normalised velocity of the non-medallist swimmers resulted significantly faster in the 6th split ($p = 0.025$) and significantly slower in the 14th split ($p = 0.003$) than that of the medallists. In the 800 m competitions, the normalised velocity of the non-medallist swimmers resulted significantly slower than the medallists in the 11th split ($p = 0.004$).

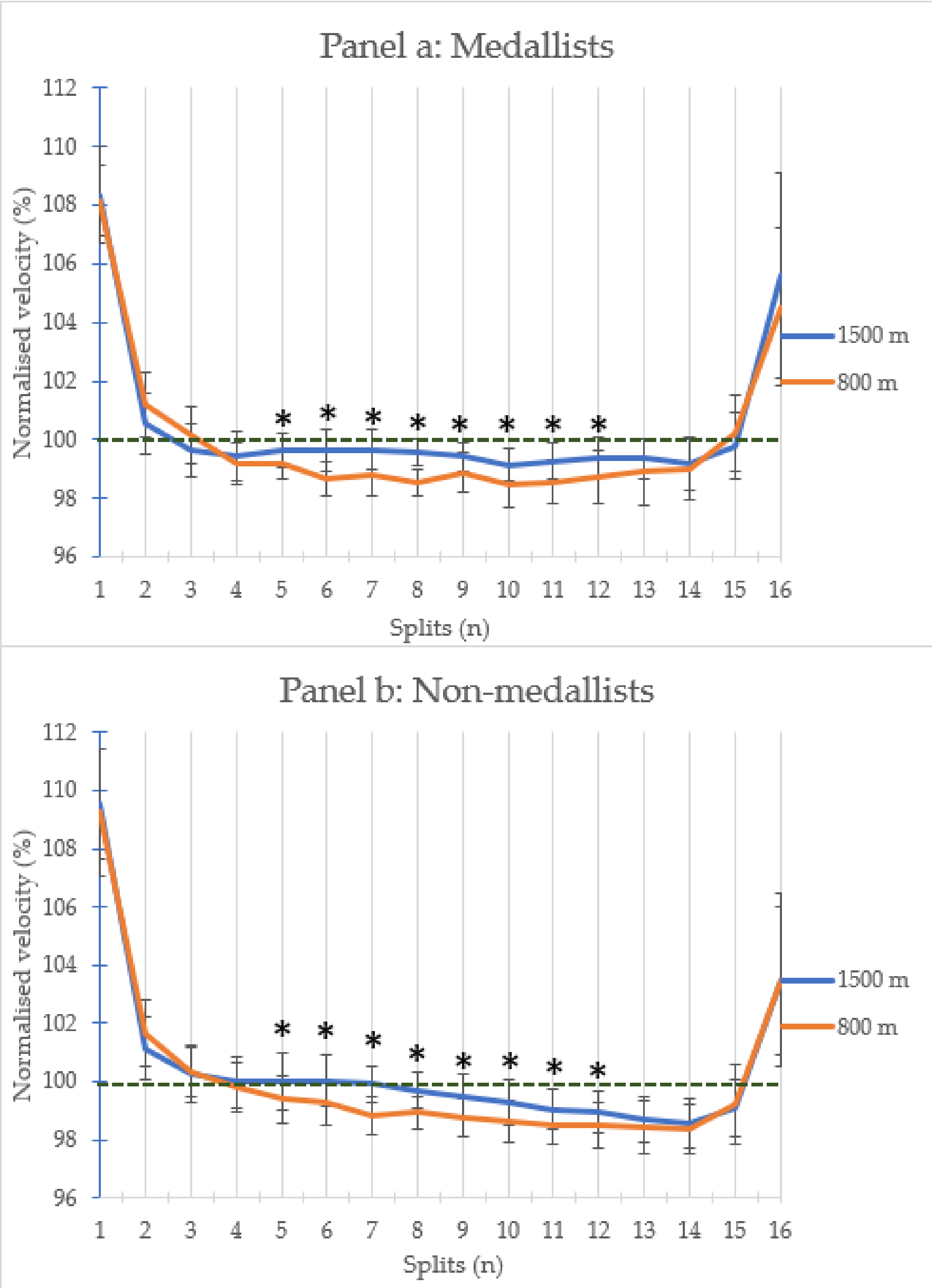

Figure 4. Splits times of medallists (**a**) and non-medallists (**b**). *: $p < 0.05$ for the difference between 800 and 1500 m swimming.

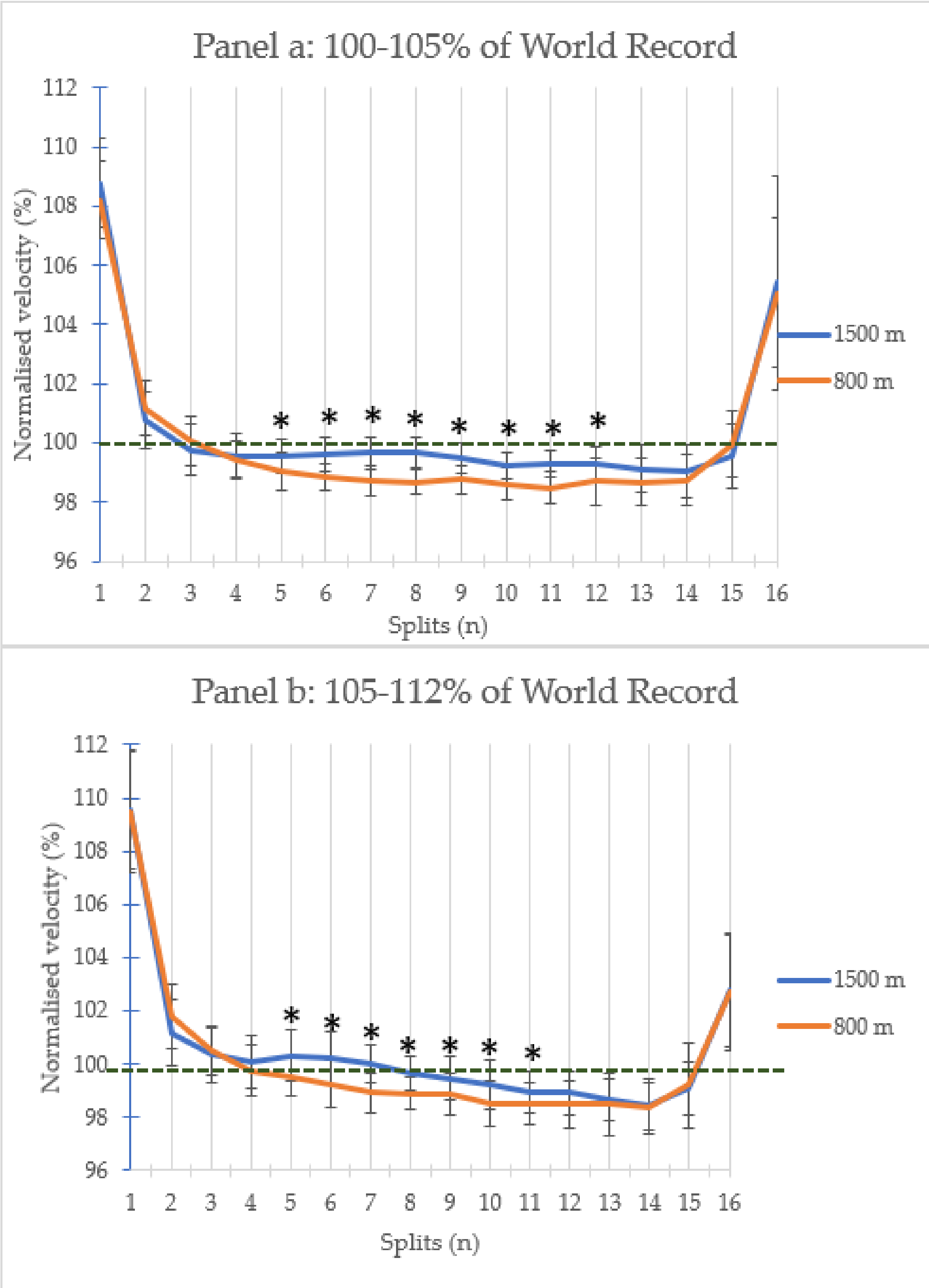

Figure 5. Splits times of swimmers performing at 100–105% (**a**) and 105–112% (**b**) of world records. *: $p < 0.05$ for the difference between 800 and 1500 m swimming.

4. Discussion

The aim of this study was to conduct an updated parallel analysis of endurance freestyle swimming events of different durations to inquire whether decision-making on pacing strategy in swimming is dependent on the length of the competition despite their comparable energy properties. To this purpose, all the elite and junior 2022–2023 world championships finalists in the 1500 and 800 m freestyle competitions were analysed as a whole and differed by sex, age, and performance level. To assess the performance level, the final time of each athlete was calculated as a percentage of the respective record time so that swimmers were divided as lower level, those closest to their record time (100–105% of WR), and higher level, those farther from their record time (105–112% of WR).

The key findings of the study highlighted that the swimmers taken into consideration in the study did not match or break the corresponding world record in either the 800 or 1500 m races of any of the world championships. In both the 800 or 1500 m competitions, swimmers followed the parabolic U-shaped pace but presented significant differences between the two distances in terms of the frequency and duration of speed changes. The number of sequences maintaining an acceleration of the same sign occurred significantly more frequently, and the maximal length of sequences resulted significantly longer in the 800 than in the 1500 m for all groups of swimmers. All the 1500 m competitions were characterised by "true" time series, while the 800 m competitions presented at least one swimmer that did not uphold a time series for the whole competition. The difference between sexes showed that females significantly lowered their normalised velocity in the central part of the competition in both distances with respect to males. In the 800 m competition, females presented a significantly faster start and males a faster end spurt. Swimmers who reached better performances tended to maintain more constant speeds with smoother pacing patterns.

Performance Level and Records—No significant differences were found in the performance level with respect to world records between the two distances except for males, elite, and 100–105% swimmers that reached times significantly closer to the respective records in the 1500 m than in the 800 m competition. The swimmers did not equate or overtake the respective world records in the 800 m and 1500 m competitions of all world championships considered in the study. All final times resulted within 101% and 112% of world records. It appears that the level of swimmers' performances notably decreased.

Pacing Strategy—Swimmers included in the present study followed the well-established parabolic U-shaped pace for the 800 and 1500 m freestyle competitions. Their coefficient of variation in velocity (CV%) along the race presented no significant differences between the two distances. However, there were significant differences between the two distances in terms of the frequency and duration of speed changes.

Sequence Analysis—The number of sequences holding an acceleration of the same negative or positive sign (Sequences Number%) occurred significantly more frequently in the 800 than in the 1500 m competitions for swimmers of all sex, age, and performance level. Also, the maximal length of sequences representing a positive or a negative variation of speed (Maximal length of sequences%) were significantly longer in the 800 m competitions for the whole group of swimmers and for the junior, medallists, and 105–112% groups. This suggests that shorter races involve more frequent adjustments in speed.

Time Series Analysis—All the 1500 m competitions represented "true" time series as given by the value 1. On the contrary, all groups of the 800 m competitions presented values higher than 1, meaning that at least one swimmer maintained a true time series only along half of the sequences (value 2) or that at least one swimmer completed the whole competition as a random series (value 3). The differences in time series between the two distances were statistically significant for the whole group and for the male and the elite groups. It could thus be claimed that in the shortest distance, swimmers are induced to accelerate and decelerate from split to split more frequently and for a longer time, while in the longest distance, swimmers need to avoid abrupt changes of speed.

Sex and Age Differences—In the present study, differences between sexes were found in the central part of both distances; females had a significantly slower normalised velocity than males. In the 800 m competition, significant differences were also found in the first and last splits; females had a faster start and males had a faster end spurt.

Impact of Performance Level—Swimmers who were closer to world records (100–105% of WR) tended to have more consistent pacing patterns compared to those farther from records (105–112% of WR). The latter presented accelerations between the 5th and the 7th split, followed by a strong deceleration afterwards.

Our results are consistent with previous analysis of the world records trend. The progression of world records exhibits an exponential decaying pattern, according to an epidemiological analysis of sporting events published in 2008. For the following 20 years, half of all world records will not be improved by more than 0.05% [33,34]. More recently, the impact of the COVID-19 pandemic on performance has been studied, revealing that the level of performances has decreased significantly in long-distance swimming rather than in the short distances [35–37]. However, a study inspecting ways to enhance front-crawl performance concluded that even at the very elite level, a fine-tuning of each aspect of performance in the different phases of the race could elevate an elite swimmer to podium-level performance. The swimming phase of the freestyle event, which lasts the longest, is the one with the greatest potential for improvement (60%), followed by the start (26%) and turn (14%) phases. The potential for improvement was estimated to be between 0.013 s for the start phase reaction time and 1.0 s by maximising mid-pool kicking [38].

In agreement with earlier studies, long-course pool endurance swimmers adopt a pace with the highest velocity at the beginning and on the last laps of the race, with a stable velocity in the middle of the race [7–9,14,20,21,39–42]. Indeed, swimmers with parabolic pacing profiles performed significantly better than the swimmers who displayed other pacing profiles [3]. The tele-anticipation model, whose goal is to conserve energy so that a final sprint can be performed afterward, is a likely explanation for athletes engaging in a slower rhythm in the second half of the 1500 m and in the middle of the 800 m race [43]. Consistent results have been reported for 3000-metre poll swimming with a first half of the race faster than the second half [44]. Changes in stroke frequency and length that reflect the onset of local fatigue may be the cause of a decreased velocity in the second part of the race [45]. While shorter races could involve more frequent adjustments in speed, success in long-distance pool swimming seems to be associated with a more conservative pace that allows for increases in speed in the final laps [8,46,47]. The increase in speed at the last splits of the races has typically been observed in head-to-head competitions, where winning depends on outperforming rivals by a small margin [3,48]. Winners of such competitions appear to have the energy reserves necessary for an end-spurt to possibly outsprint a rival in the final few metres [8,9]. The ability of the swimmer to generate propulsion in the most efficient way possible has been shown to be a crucial factor in determining swimming performance [18,49–53]. The ability to effectively allocate energy develops in relation to an individual's cognitive and physical characteristics and is dependent on the amount of prior specific experience [54–57]. The ideal pacing technique can thus be acquired by a wealth of training and competition experience [16,18,58,59]. Since an ideal ratio between stroke rate and stroke length is necessary to maintain the pace throughout the race, key variables like stroke rate, stroke count, split times, and rating of perceived exertion are probably crucial training tools to optimise the development of pacing skills [50,60–67].

The different mental and physical abilities required to implement these strategies could explain the different approaches taken by male and female competitors [17]. Additionally, women exhibit an energy cost that is 80% than the one reported for men when swimming the crawl at any given speed and with equivalent technical ability. The anthropometric differences between the male and female body types account for this disparity between the sexes [51]. Therefore, males and females may benefit from slightly different pacing behaviours [4]. Junior swimmers showed a faster central part of the race in the 1500 m than in the 800 m competitions. Their first part of the race resulted slower than the elites in both distances. It is likely that pacing skill development needs to begin at a young age as a crucial step towards elite performance [1,4,50,68–70].

Given that most swimmers compete in multiple events of varying distances and sometimes strokes, it can be difficult to balance the training programme to ensure that each swimmer's needs are met. Swimmers may race alternate events early in the season to gain race experience and become more specific in event selection as the season progresses. This approach may be beneficial in increasing the frequency of practise in each event and developing the ability to switch paces with ease [58]. Trainers can provide feedback on split times during training sessions on a regular basis and, if possible, during races to assist athletes in developing their performance template. It is hypothesised that by doing so, athletes can learn to link bodily sensations (such as perceived exertion, heart rate frequency, breath frequency, fatigue, and pain) to their performance [58].

The main limitation of this study was that it was purely observational and examined the pacing strategy retrospectively without knowing the race tactics expected before the competition. Information regarding the underpinning mechanisms that explain the behaviours could not be provided. It is therefore only possible to speculate on the physiological, biomechanical, and psychological mechanisms at play. Limitation of the study may also include the small number of subjects in each group, since only eight swimmers take part in the finals of the world championships. Future study could be implemented by analysing the health and semi-finals of the events to include more subjects in each group. Different strategies could emerge among the different stages of the championships due to strategical issues that need to be considered when planning a meet.

5. Conclusions

In conclusion, both the 1500 and 800 m competitions follow the parabolic U-shaped pacing strategy. However, the split-by-split analysis of the time series revealed significant difference between the two distances. The pacing strategy results were also differentiated by sex, age, and performance level of swimmers. The research highlights the complex interplay between physiological and psychological factors that shape a swimmer's decision-making during a race. It could thus be suggested that training programmes should be differentiated for each distance and for different swimmers' groups to meet the needs of each swimmer for each event.

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