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Article

Pacing of Human Locomotion on Land and in Water: 1500 m Swimming vs. 5000 m Running

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Abstract: The study of pace strategy in different environments could help to understand its dependence on athletes' energetic limits or on sport-specific factors. The aim of this study was to analyse the pacing strategy of finalists during seven swimming and running world events held in 2021–2022. The speed of 32 swimmers every 50 m in 1500 m freestyle competitions, and the speed of 55 runners every 100 m in 5000 m track competitions, were analysed. Differences between swimming and running were statistically significant for Total Time ($p = 0.00$, ES = 1.9), Average Time of splits ($p = 0.00$, ES = 2.0), Median Time of splits ($p = 0.00$, ES = 2.0), and Maximal length of split sequences ($p = 0.00$, ES = 1.3), and non-significantly different for number of Sequences of splits ($p = 0.12$, ES = 0.5), Percentage of total splits faster than the median speed ($p = 0.08$, ES = 0.2), Percentage of splits faster than the median speed in the first half ($p = 0.16$, ES = 0.4) and Percentage of splits faster than the median speed in the second half ($p = 0.21$, ES = 0.3). In conclusion, despite similar metabolic requirements of 1500 m swimming and 5000 m running, the influence of specific environment and sport type on the pacing strategy of world level competitions seems to be supported.

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



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1. Introduction

Effective guidance for the best targeted training program can be provided by studying more specifically for energy optimization of previous high-level winning performances [1–4]. An analysis of word records for various forms of human locomotion in the range of 3.5–230 min demonstrated that time and distance of all sport disciplines are linked by a linear relationship [4]. Nevertheless, because of the different nature of the demands placed on the athletes, the average speed declines as the distance increases at different rates for each speciality [4,5]. There is evidence that, throughout prolonged exercise, the overall pacing strategy is modulated to avoid early exhaustion brought on by a malfunction of one or more physiological systems. It is argued, therefore, that pacing strategies are markers of the physiological regulation that underlie them, and that pacing strategies are influenced by changes in muscle activation that are anticipatory in nature [6–8]. Moreover, in competition, athletes are constantly and simultaneously presented with various external stimuli. Different competition environments influence pacing behaviour, highlighting the importance of athlete–environment interactions. To understand pacing decision-making, both the athlete's internal state and the external environment must be considered [9]. In this regard, studying the pace strategy in radically different environments, such as land and water, in run and swim races of similar durations, could help to understand if the pacing strategy is more influenced by athletes' energetic limits or by sport-specific factors, such as environmental, biomechanical, technical, and training method differences [9–11].

The velocity pattern and kinetic energy of every race are strongly dependent on the drag of the medium in which the athlete moves. The drag coefficient for swimming is thirty-fold that of running [10]. In addition to the air and water environmental differences, such as propulsion and drag, which in swimming are against the same environment, while in running propulsion and friction are against the ground and drag against the air, in pool swimming, the speed fluctuations at each stroke are small as compared to running, and drafting cannot take place [12]. As small changes in swimming velocity can cause a disproportionate rise in water resistance, a faster stroke rate will increase the amount of energy lost to the environment [13–15]. Large swimming velocity fluctuations increase the work needed to proceed at a certain velocity, both for the need to overcome inertia and drag. A “smooth motor pattern” is thus expected to minimize the energy cost of swimming [16]. Top-level performance in competition is a combination of variability within laps and stability between laps [17]. Hence, due to the importance of stroke technique in influencing energy cost and aerobic performance, the incorporation of the stroke rate count into the speed–time relationship analysis could be a useful criterion for controlling pacing, technical parameters, and training intensity [18–23]. On the contrary, in running, it seems that competing at a perfectly even pace is nearly impossible [24,25]. A notable intraindividual variability of the measurements is reported when high level endurance runners are tested to determine their aerobic ability and exercise efficiency [26]. In a prediction of 5000 m track running performance, it was shown that critical power increases when the trials are self-paced compared with constant power in laboratory conditions, thus emphasizing that gait pacing influences the speed–time relationship [27,28]. Nonetheless, both in 1500 m running and 400 m swimming, a more conservative initial speed that allowed for increases later appears to be associated with success [11].

To understand the importance of these environmental and biomechanical differences, we hypothesised that human optimisation of energy distribution in function of exercise duration, according to the metabolic requests, could lead to specific pacing strategy backgrounds in different environments. Therefore, the aim of the study was to analyse and compare the pacing strategy of 1500 m freestyle swimming and 5000 m track running of male finals at world level competitions, and to differentiate medallist from non-medallist behaviours.

2. Materials and Methods

2.1. Experimental Approach

All procedures were conducted according to the Helsinki Declaration. The ethics committee of the University of Rome Foro Italico approved and authorised this project, assigning the code CAR 155/2023. Informed consent from athletes was not deemed necessary, since only publicly available information was used. Competitions data on the male 1500 m freestyle swimming in long and short course pools and 5000 m running on track were downloaded from the websites www.fina.org, www.omegatiming.com, www.diamondleague.com, and www.worldathletics.org, accessed 9–31 January 2023. All data were gathered and retrospectively analysed anonymously. Each competition report included a subject identification number for each athlete, the name of the competition, distance, overall finishing position (ranking), split times (split) every 50 m for swimming and every 100 m for running, and the completion time (Tot time).

A total of 87 results of 7 world events held in 2021 and 2022 were analysed. For the 1500 m freestyle swimming, the male long course finals of the Olympic Games 2021 (Tokyo 2020), FINA World Championships 2022 (Budapest), short course finals FINA Swimming World Cup 2021 (Berlin), and FINA Swimming World Cup 2021 (Budapest) were analysed. For the 5000 m running, the male finals of the Olympic Games 2021 (Tokyo 2020), World Championships in Athletics 2022 (Oregon), Diamond League 2022 (Eugene), and Diamond League 2022 (Rome), were considered. Results of 87 participants were investigated. A total of 32 swimming speeds, taken every 50 m in the 1500 m freestyle competitions, and 55 running speeds, taken every 100 m in the 5000 m track competitions, were analysed.

2.2. Time Series

An analysis was applied to test the randomness through both median and the ascendent and descendent analysis of the time series. The time series analysis consists of assessing whether the times of each split should be considered, mathematically speaking, as a true time series, and not as a random sample. In other words, is the order of the index-set t_1, t_2, \dots material, not accidental, as it would be for a sample x_1, x_2, \dots (a sequence of values of independent and identically distributed random variables), in which suffixes are arbitrary. The study of some data indexed by time, with tools from the theory of time series, is mathematically meaningless if a statistical test performed on the data did not lead to the rejection of randomness. In 1968, Kendall and Stuart exemplified this issue of randomness with 56 values of barley yields between 1884 and 1936, concluding that these measurements behave as those of a random sample [29]. The authors enumerate the standard statistical tests at our disposal to reject, or not, the null hypothesis that a sequence is a random sample: turning points, phase lengths, difference-sign, rank correlation, records, and rank serial correlation. In Aivazian 1978, two tests of randomness are discussed: the median test and a test based on the number and maximal length of monotonous phases [30]. The latter test, used in our study, is based on a statistic denoted by (ν, τ) , with critical values given by and defined as follows. The authors call a series a maximal sequence of consecutive measurements that is monotonous. Then, ν is the number of such series and τ the length of the longest one. If one of the inequalities

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

where $[x]$ denotes the integer part of x , we reject randomness; in other words, we conclude that the sequence x_1, \dots, x_n can be considered as a true time series, not as a random sample. In our case, $n = 56$ so that the critical region is given by

$$\nu > 9.723 \text{ or } \tau < 6 \text{ for swimming and } \nu > 18.140 \text{ or } \tau < 6 \text{ for running}$$

2.3. Time of Competition and Split Speed

For each finalist, the length of split sequences was calculated as the count of how many consecutive splits were held faster (indicated with – “minus” sign) or slower (indicated with + “plus” sign) than the median velocity. The Maximal length of split sequences was assessed as the longest sequence holding the same – or + sign. The number of Sequences of splits was assessed as the count of the number of – or + sequence.

For each athlete, we also considered the finish time of the competition (Tot Time), the average and the median time of the splits, the differences among the time at each split, and the average time of the competition. Afterwards, for all athletes, the percentage of splits that were held faster than the average time was calculated for the whole competition and separately for the first and the second half.

2.4. Comparison between Swimming and Running

Total Time, Average Time of splits, Median Time of splits, Sequences of splits, Maximal length of split sequences, Percentage of total splits faster than the average speed, and Percentage of splits faster than the average speed in the first half and in the second half, were compared by searching for statistically significant differences between swimmers and runners.

To graphically depict the speed variation along the competitions of both disciplines, the differences among each split time and the average time was calculated for all athletes.

2.5. Athlete Ranking

To differentiate athletes by their competitive level, the speed variations along splits were calculated separately and compared between medallists, from 1^o to 3^o, and non-medallists, from 4^o to last.

2.6. Statistical Analysis

Descriptive statistics (mean and SD) are reported for each category. The normality of the data was analysed by the Shapiro–Wilk test. ANOVA, Mann–Whitney U, or Friedman, for repeated measures with post-hoc corrected for Bonferroni tests, were applied when appropriate depending on data distribution. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp, Armonk, NY, United States). Level of significance was set at $p < 0.05$.

3. Results

3.1. Descriptive Statistics

Table 1 represents the descriptive data as means and standard deviations, along with the Shapiro–Wilk test results. The distributions were significantly non-normal * for 19 of the 26 variables.

Table 1. Descriptive statistics; mean and standard deviation (St. Dev.).

| Variables | | Discipline | Mean | St. Dev. |
|--|---|-----------------|-------|----------|
| Total Time | s | 1500 m Swimming | 892.2 | 13.1 |
| | | 5000 m Running | 785.0 | 9.9 |
| Average Time of splits | s | 1500 m Swimming | 29.7 | 0.6 |
| | | 5000 m Running | 15.9 | 0.3 |
| Median time of splits | s | 1500 m Swimming | 15.9 | 0.5 |
| | | 5000 m Running | 24.6 | 1.3 |
| Sequences of splits | n | 1500 m Swimming | 13.3 | 14.8 |
| | | 5000 m Running | 13.0 | 4.6 |
| Maximal length of split’s sequences | n | 1500 m Swimming | 10.9 | 13.0 |
| | | 5000 m Running | 15.2 | 4.4 |
| Splits faster than median speed in the whole competition | n | 1500 m Swimming | 14.9 | 0.3 |
| | | 5000 m Running | 24.4 | 1.9 |
| Splits faster than median speed in the first half | n | 1500 m Swimming | 9.0 | 3.1 |
| | | 5000 m Running | 13.0 | 3.8 |
| Splits faster than median speed in the second half | n | 1500 m Swimming | 5.9 | 3.1 |
| | | 5000 m Running | 11.5 | 4.3 |
| Percentage of splits faster than median speed in the whole competition | % | 1500 m Swimming | 49.6 | 1.0 |
| | | 5000 m Running | 48.9 | 3.9 |
| Percentage of splits faster than median speed in the first half | % | 1500 m Swimming | 30.0 | 10.3 |
| | | 5000 m Running | 25.9 | 7.5 |
| Percentage of splits faster than median speed in the second half | % | 1500 m Swimming | 19.6 | 10.4 |
| | | 5000 m Running | 22.9 | 8.7 |

3.2. Time Series

All athletes’ competition split times analysis results were negative for randomness, through both median and the ascendent and descendent, meaning that their speed variations can be considered true time series.

3.3. Split Speed Variations by Athlete’s Ranking

Figure 1 and Table 2 depict the swimmers’ speed variation of each split around the average. As expected, the faster first split and the spurt of the last split are evident. The speed variations of each split with respect to the average along the rest of the competition shows that the medallist swimmers maintained a significantly slower pace from split 1 to 13, and a significantly faster pace from split 20 to 29, with respect to non-medallist swimmers, who started at a faster pace but then rose above the average speed in the second half.

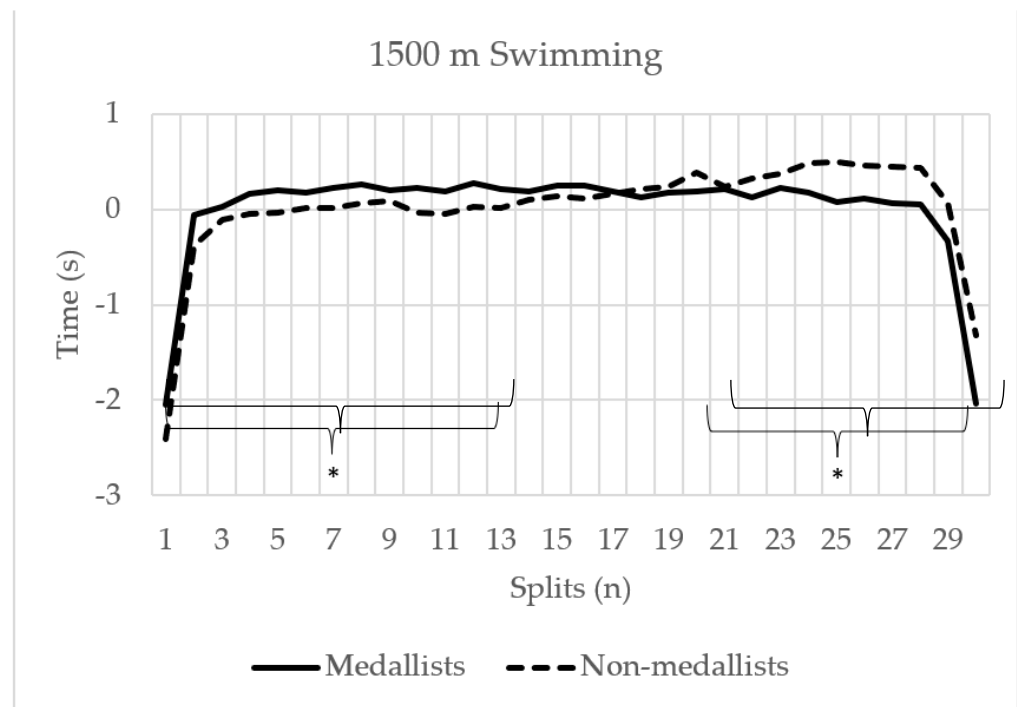


Figure 1. Pacing strategy of swimming competition. Speed difference among each split and the average speed of swimming competition. Mann–Whitney U significance values for the differences between medallists and non-medallists; * = $p < 0.05$. Variation of the speed of each split around the average, for medallists, from 1° to 3°; non-medallists, from 4° to 8° placement in the 1500 m swimming finals.

Table 2. Differences between medallist and non-medallist swimmers.

| Splits | Mann–Whitney U | Effect Size |
|----------|----------------|-------------|
| Split 1 | 0.01 * | 0.2 |
| Split 2 | 0.01 * | 1.1 |
| Split 3 | 0.11 | 0.6 |
| Split 4 | 0.04 * | 0.9 |
| Split 5 | 0.03 * | 0.7 |
| Split 6 | 0.22 | 0.5 |
| Split 7 | 0.04 * | 0.7 |
| Split 8 | 0.02 * | 0.7 |
| Split 9 | 0.33 | 0.8 |
| Split 10 | 0.02 * | 0.8 |
| Split 11 | 0.02 * | 0.2 |
| Split 12 | 0.00 * | 0.4 |
| Split 13 | 0.03 * | 0.5 |
| Split 14 | 0.31 | 0.3 |
| Split 15 | 0.14 | 0.6 |
| Split 16 | 0.17 | 0.4 |
| Split 17 | 0.79 | 0.5 |
| Split 18 | 0.05 | 0.3 |
| Split 19 | 0.37 | 0.5 |
| Split 20 | 0.01 * | 0.4 |

Table 2. Cont.

| Splits | Mann–Whitney U | Effect Size |
|----------|----------------|-------------|
| Split 21 | 0.46 | 0.5 |
| Split 22 | 0.01 * | 0.4 |
| Split 23 | 0.18 | 0.6 |
| Split 24 | 0.00 * | 0.5 |
| Split 25 | 0.00 * | 0.5 |
| Split 26 | 0.00 * | 0.4 |
| Split 27 | 0.00 * | 0.5 |
| Split 28 | 0.00 * | 0.3 |
| Split 29 | 0.03 * | 0.4 |
| Split 30 | 0.10 | 0.5 |

Mann–Whitney U significance values and effect size for the differences between medallists and non-medallists; * = $p < 0.05$.

Figure 2 and Table 3 depict the runners’ speed variation of each split around the average. An even pace was maintained in the first part of the race, with a slower second part and a marked spurt of splits from 45 to 48. The analysis of the speed variations of each split with respect to the average shows that medallist and non-medallist runners maintained a similar pace from splits 1 to 43, while in the last 7 splits medallists attain a pace significantly faster than non-medallists.

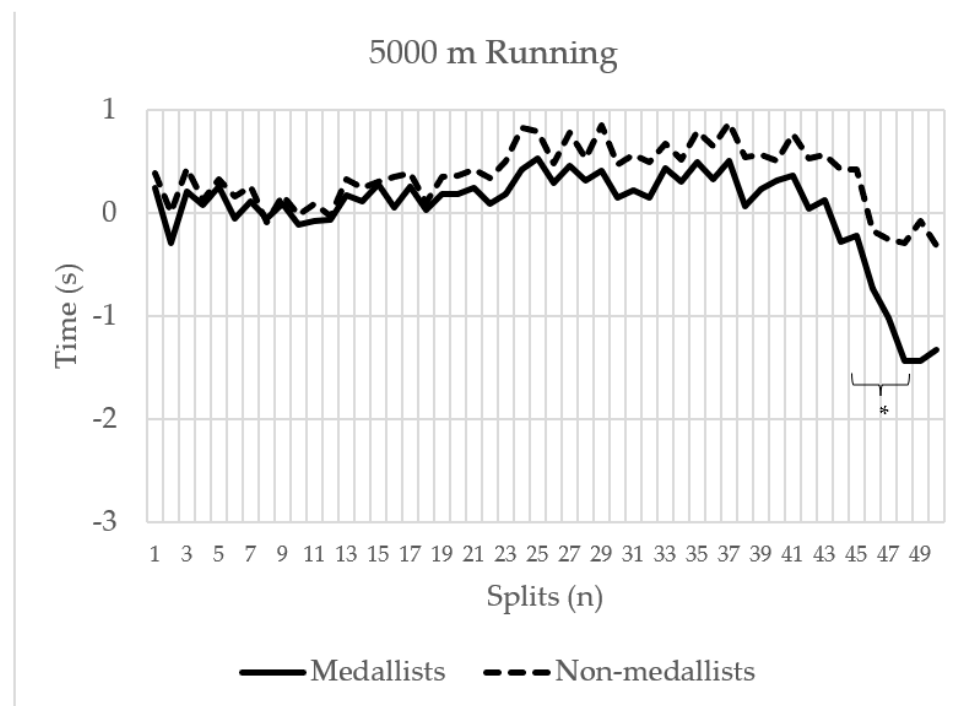


Figure 2. Pacing strategy of running competition. Variation of the speed of each split around the average, for medallists, from 1° to 3°; non-medallists, from 4° to last placement in the 5000 m running finals. Mann–Whitney U significance values for the differences between medallists and non-medallists; * = $p < 0.05$.

Table 3. Differences between medallist and non-medallist runners.

| Splits | Mann–Whitney U | Effect Size |
|----------|----------------|-------------|
| Split 1 | 0.30 | 0.3 |
| Split 2 | 0.01 * | 1.0 |
| Split 3 | 0.23 | 0.5 |
| Split 4 | 0.91 | 0.1 |
| Split 5 | 0.65 | 0.2 |
| Split 6 | 0.15 | 0.6 |
| Split 7 | 0.44 | 0.4 |
| Split 8 | 0.89 | -0.1 |
| Split 9 | 0.57 | 0.3 |
| Split 10 | 0.45 | 0.4 |
| Split 11 | 0.02 * | 0.8 |
| Split 12 | 0.47 | 0.2 |
| Split 13 | 0.21 | 0.5 |
| Split 14 | 0.25 | 0.3 |
| Split 15 | 0.18 | 0.1 |
| Split 16 | 0.03 * | 0.7 |
| Split 17 | 0.20 | 0.4 |
| Split 18 | 0.57 | 0.2 |
| Split 19 | 0.16 | 0.5 |
| Split 20 | 0.53 | 0.3 |
| Split 21 | 0.20 | 0.3 |
| Split 22 | 0.14 | 0.6 |
| Split 23 | 0.10 | 0.6 |
| Split 24 | 0.08 | 0.6 |
| Split 25 | 0.24 | 0.4 |
| Split 26 | 0.29 | 0.3 |
| Split 27 | 0.13 | 0.5 |
| Split 28 | 0.25 | 0.4 |
| Split 29 | 0.04 * | 0.7 |
| Split 30 | 0.15 | 0.6 |
| Split 31 | 0.03 * | 0.8 |
| Split 32 | 0.07 | 0.6 |
| Split 33 | 0.27 | 0.5 |
| Split 34 | 0.55 | 0.4 |
| Split 35 | 0.19 | 0.6 |
| Split 36 | 0.08 | 0.6 |
| Split 37 | 0.20 | 0.7 |
| Split 38 | 0.02 * | 0.8 |
| Split 39 | 0.12 | 0.5 |
| Split 40 | 0.63 | 0.2 |
| Split 41 | 0.25 | 0.6 |
| Split 42 | 0.10 | 0.6 |
| Split 43 | 0.12 | 0.5 |
| Split 44 | 0.02 * | 0.7 |
| Split 45 | 0.03 * | 0.7 |
| Split 46 | 0.03 * | 0.3 |
| Split 47 | 0.04 * | 0.7 |
| Split 48 | 0.00 * | 0.9 |
| Split 49 | 0.00 * | 0.9 |
| Split 50 | 0.01 * | 0.9 |

Mann–Whitney U significance values and effect size for the differences between medallists and non-medallists; * = $p < 0.05$.

When swimming and running are compared, the graphical depiction of the speed variations of each split along the competition indicates that runners undergo speed alterations at every split, while swimmers appear to avoid swift variations.

As represented in Figure 3, medallist swimmers spent around 24% of the first half and 26% of the second half of the competition at speeds faster than the average; non-medallist

swimmers spent around 34% of the first half and 16% of the second half of the competition at speeds faster than the average.

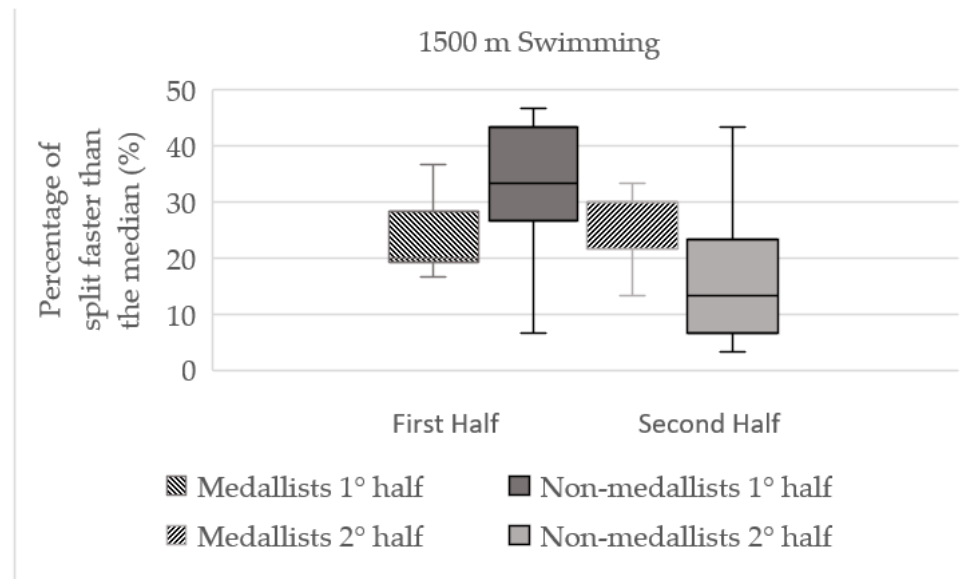


Figure 3. Pacing strategy of the swimming competitions. Splits swam faster than the median velocity of the competition. Percentage of splits faster than the median, for medallists and non-medallist swimmers in the two halves of the competitions.

As represented in Figure 4, runners of all levels spent around 20% and 30% of both halves of the competition at speeds faster than the average.

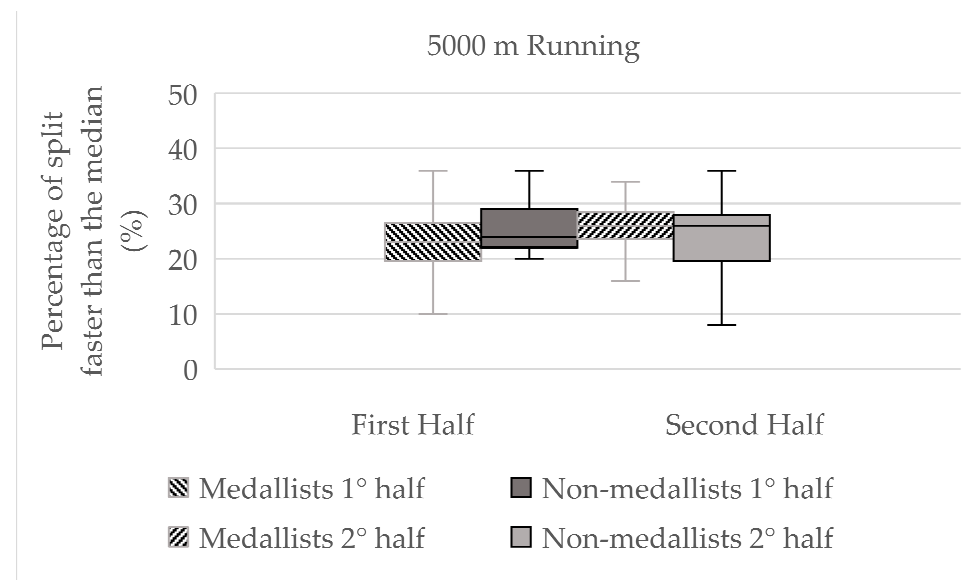


Figure 4. Pacing strategy of the running competitions. Splits ran faster than the median velocity of the competition. Percentage of split faster than the median, for medallist and non-medallist runners in the two halves of the competitions.

3.4. Comparison between Swimming and Running

The competitions times (Total Time) were in the range of 14:33–15:17 min:s for swimming and 12:47–13:26 min:s for running. Table 4 shows that competition times were significantly longer for swimming than for running. The swimming Average Time of splits was significantly longer than running, while the Median Time of splits was significantly

lower than those of running. No differences were found between the number of Sequences of splits in the time series, while the Maximal length of split sequences was significantly shorter for swimming. The Percentage of splits faster than the median speed was non-significantly different between swimming and running, in both the whole competition and in each of the two halves.

Table 4. Total and split times differences between swimming and running competitions.

| Variables | | Discipline | Mann–Whitney U | Sign. | Effect Size |
|--|---|-----------------------------------|----------------|--------|-------------|
| Total Time | s | 1500 m Swimming 5000 m Running | 0.000 | 0.00 * | 1.9 |
| Average Time of splits | s | 1500 m Swimming 5000 m Running | 000 | 0.00 * | 2.0 |
| Median Time of splits | s | 1500 m Swimming 5000 m Running | 1024.0 | 0.00 * | 2.0 |
| Sequences of splits | n | 1500 m Swimming 5000 m Running | 626.5 | 0.12 | 0.5 |
| Maximal length of splits' sequences | n | 1500 m Swimming 5000 m Running | 864.0 | 0.00 * | 1.3 |
| Percentage of total splits faster than the median speed | % | 1500 m Swimming 5000 m Running | 404.0 | 0.08 | 0.2 |
| Percentage of splits faster than the median speed in the first half | % | 1500 m Swimming 5000 m Running | 406.5 | 0.16 | 0.4 |
| Percentage of splits faster than the median speed in the second half | % | 1500 m Swimming 5000 m Running | 606.0 | 0.21 | 0.3 |

Mann–Whitney U and (Sign.) significance values for the differences between the two disciplines; * = $p < 0.05$.

4. Discussion

The aim of this study was to highlight possible points of similarity and difference between the pace strategy of two competitions of approximately the same duration performed in two radically different environments, i.e., land and water. To this purpose, 1500 m swimming and 5000 m running competitions, at the highest male world level of performance, were analysed. The novelty of this study was the use of a rigorous mathematical procedure already employed for marathon running [25]. Moreover, the comparison of locomotion in two extremely different environments can shed some light on the prevalence of energetics over tactics in which pacing strategy is employed in endurance events.

The mathematical analysis showed that both swimming and running split timing does not change randomly over time, but adjust over the course of the race following a time series model. Recently modelled performances of 800 m runners, 200 m swimmers, and 1500 m speed skaters demonstrate that pacing patterns are different for these events, despite very similar net energetic requirements. This raises the issue of why these races, which take relatively similar amounts of time and therefore energy, are competed with such distinct velocity patterns. The difficulty of accelerating at the start of the race, the size of the slowdown caused by the loss of power output due to fatigue, the power losses to the environment, and the amount of wasted kinetic energy at the end of the race are the factors that could determine the pacing pattern in each competition. In every event, the chosen pacing strategy probably represents an ideal compromise between the variations of these elements and the athlete's capacity for generating energy [10].

In swimming, the first split represents the fastest section of the race, because of the dive start and underwater component, where the highest speeds can be achieved from a grab dive start [11,31,32]. The same cannot be attained by the bunched standing start of the 5000 m track running. On the other hand, both disciplines present the spurt of the final splits, which is comprised in the last two splits in swimming [31] and in the last seven in running [33]. Power output and velocity increases towards the end of both simulated and actual middle-distance events are commonly observed. In running, to advance through qualifying rounds, it is essential to have the capacity to run a quick final race segment, which can be developed with the right training. Medal-winning athletes in major middle-distance running championships display a greater increase in speed in the closing stages [34]. An

athlete's final increase in intensity typically occurs when he or she becomes aware of how long or how far remains in the trial. This effect is thought to result from increased motor unit recruitment and the use of anaerobic energy reserves [35].

The speed variations of each split, with respect to the average speed, shows that runners of all ranking and non-medallist swimmers maintain a speed close to the average for the first part of the competition, and then climb above the average speed in the second half, until the acceleration of the end spurt. This is supposedly due to the athlete's inability to tolerate constant loads during extended maximal performances, being more inclined to drop-offs in work [26]. Due to excessively fast starts among these athletes, major disturbances of muscle oxidative capacity, tissue oxygen saturation index, and the recruitment of additional type I and II motor units with muscle fatigue can impair performance in endurance events by earlier disruption of muscle contractile processes, causing poorer technique [36,37]. Optimal pacing strategy during long races, both on land and in water, may be attained by improving the athlete's physiological parameters, such as the ability to delay the accumulation of blood lactate or a higher maximal oxygen uptake, but also by a lowered energy cost of locomotion through improved biomechanical abilities [38]. Medallist swimmers maintained a nearly even pace throughout the competition, while non-medallists completed a significantly faster first half and a significantly slower second half of the race. Energy expenditure can vary substantially from individual to individual during swimming because of different strokes and skill levels. For any given speed in the aerobic range, the more proficient swimmers expend 50% less energy than less proficient ones [16]. Thus, energetic and propulsive efficiencies, although not collected in the present study, could explain the differences between the groups of swimmers in relation to pacing. Consistently, a review study on pacing behaviour in swimming demonstrated that medallists adopt a more conservative pacing behaviour compared to swimmers ranked fourth to eighth place [39]. A more conservative initial pace that allows for later increases of speed seems to be associated with success, but athletes need mental confidence and physical talent to put these strategies into practice [11].

On the contrary, no significant differences were found among medallist and non-medallist runners for the whole race. In the case of endurance running races, individuals of lower absolute ability were reported to be able to maintain contact with superior athletes through taking advantage of drafting benefits, which cannot be utilized in lane swimming [34]. This could respond to the so called "herd behaviour" of competitions where drafting is allowed, and athletes follow the behaviour of surrounding opponents regardless of their rational decision making [5]. Typically, the winners of a 5000 m race tend to remain in the top five runners throughout the race in order to not use unnecessary energy taking the lead or setting the pace. The goal of this tactic is to minimise physiological interference, by keeping a steady pace at the beginning and acquiring a good position for the sprint at the end [40].

Decisions about energy expenditure during the race are based on relationships between internal factors, such as the athlete's physiological/biomechanical capacity, and external factors, such as the opponents. In competition, the opponents present a variety of affordances that affect motivation, attentional focus, ability to endure fatigue and pain, positioning, drafting, fall risk, and collective behaviour [9,41]. This could explain the homogeneity of pacing strategy among runners, independent of ranking. Meanwhile, in swimming, competitions are characterized by lanes separating participants, which impedes tactical behaviour such as trailing behind another competitor. Therefore, swimmers do not have to compete for the ideal line, and their speed profile resembles that of time trial athletes, allowing them to be more independent of each other.

The limitations of this study are derived from different factors. In real competitions, there are several uncontrolled factors which could have an impact on pacing strategy. Conditions that may differ from competition to competition include the behaviour of the lead group, different times of day, and environmental conditions (such as wind, humidity, and temperature). For this reason, no comparisons of overall or split times were made

between competitions, and the description of the strategy used in the two disciplines was conducted on percentage, and not in absolute values.

Swimming either in long or short course leads to different final times; however, in the present study, only split six showed a significant difference between the two pool lengths, with slower speed in the short course than in the long one ($F = 4.912$, $p = 0.34$), so the integrated analysis could be considered acceptable.

An analysis of swimmers' and runners' energetic expenditure and techniques was not conducted in the present study and could be the focus of future studies to deepen our knowledge of race tactics in different competitive disciplines.

5. Conclusions

In conclusion, both elite swimmers and runners do not change their speed randomly over time but adjust it over the course of the race following a time series model.

It appears that the pacing strategy may vary depending on the level of the swimmer, while runners seem to follow a more coherent strategy regardless of their rank. This could be due to the opportunity for runners to take advantage of the drafting effect during the first half of the competition. Thus, despite similar metabolic requests of 1500 m swimming and 5000 m running, the influence of specific environment and sport type on the pacing strategy of world level competitions seems to be supported. Nonetheless, in both disciplines, athletes need to save enough energy to tackle the spurt of the last splits, which was completed significantly faster by the medallists of both disciplines.

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