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Differences in pacing behaviour between global championship medal performances and World Records in men's and women's middle- and long-distance running track events

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Abstract

The differences in pacing demands between track distance-running championship and meet (e.g., World Record [WR]) races have not been specified yet in the current literature. Therefore, the aim of this study was to determine pacing behaviour differences between WRs and global championship (i.e., World Championships and Olympic Games) medal performances (GCMs) in middle- and long-distance running events. Percentages of mean race section speeds were compared through analysis of variance between men's and women's 169 WRs and 189 GCMs over 800m, 1500m, 3000m steeplechase, 5000m and 10,000m. U-shaped and negative pacing approaches are observed during men's and women's 1500m WRs and GCMs, respectively. The first and third 400 m of men's and women's 1500m GCMs were relatively slower and faster, respectively ($p \leq 0.05$, $1.31 \leq d \leq 1.69$). Even profiles are followed during women's 3000m steeplechase WRs and GCMs, whereas positive approaches were adopted in men's GCMs. Finally, whereas 5000m and 10,000m GCMs were finished with a fast endspurt, WRs had a U-shaped profile in men, with differences between the initial and last race stages ($p \leq 0.01$, $1.20 \leq d \leq 3.66$), and an even profile in women. Coaches should consider the different pacing demands existing among meet and global championship races to specifically implement training characteristics targeting either goal type.

Keywords: Athletics; high performance; Olympic Games; tactics; World Championships.

Introduction

An athlete's ability to distribute muscle work and energy during an exercise activity is termed pacing and is crucial for endurance performance (Foster et al., 1994). Individuals engage in multiple decision-making processes to optimise race performance while investing their energy appropriately (Renfree et al., 2014). Endurance performance is a complex system, and athletes constantly respond to opponents' behaviours and environmental conditions (Renfree & Casado, 2018). Athletes typically make strategic decisions before the race and implement these with tactical decisions during the event (Foster et al., 2023; St Clair Gibson et al., 2006). Beyond the large-scale differences attributable to physiological factors like VO_2 max, lactate threshold and critical power, performance is influenced by internal factors such as athletes' psychophysiological responses to a given effort (Casado et al., 2019) and external ones such as athletes' interactions with the environment (Pugh, 1971). Therefore, athletes need to adapt their behaviour during the race to achieve a predefined goal (i.e., either to reach the finish line as quickly as possible or to achieve the highest possible finishing position) (Renfree & Casado, 2018). In this way, Hettinga et al. (2017) showed how head-to-head competitions demand a continuous decision-making process derived from the constant interaction between competitors, ultimately determining placing-based results in championship events. With the aim of achieving a personal best or a World Record (WR), athletes tend to adopt more even pacing approaches, often while following the initial pace set by designated pacemakers (Muñoz-Pérez et al., 2022).

Pacing behaviours, however, also depend on the knowledge of distance to the finish line, environment, metabolic factors, and athletes' experience and that of opponents (Renfree & Casado, 2018). There are different types of pacing profiles: negative (an increase in speed throughout the duration of the event), positive (a gradual decrease in speed throughout the race), even and parabolic profiles, such as U-shaped (the start and end of the race are faster than the middle) and J-shaped profiles (the start is faster than the middle but slower than the end) (Casado et al., 2021). Furthermore, athletes adopt different behaviours depending on race distance (Casado et al., 2021). However, the different pacing strategies between major championships and WR performances should be considered (Thiel et al., 2012), since athletes need to optimise their pacing behaviours and train differently for each type of race.

Although extensive literature on pacing exists, the way pacing behaviour differs between global championships (i.e., Olympic Games and World Championships) and WR attempts in middle- and long-distance disciplines has not yet been studied. On the one hand, pacing profiles during track distance running WRs shift from negative, i.e. in the 800m (Casado et al., 2021) through U-shaped, i.e., the 1500m (Casado et al., 2021; Casado et al., 2021) towards even, i.e., the 10,000m (Tucker et al., 2006). On the other hand, global championship races are characterised by sea horse- and J-shaped profiles in the 800m and 1500m, respectively (Hanley et al., 2019), and even profiles with microvariations of pace and a fast endspurt in 5000m and 10,000m events (Filipas et al., 2018; Thiel et al., 2012). In this way, it appears that pacing profiles are different depending on both type of race and distance being covered. However, race type-related pacing differences are expected to be smaller in shorter races such as the 800m in which positive pacing profiles were observed in both race types (Casado, González-Mohíno, et al., 2021; Hanley et al., 2019). Conversely, in longer races, these race type-related pacing differences are expected to be greater since athletes aiming at winning a medal at a global championship expend a large amount of energy and provide an important advantage to their rivals if they lead a big part of the race at a fast pace without the assistance of a pacemaker (Zouhal et al., 2015), typically available during WR or meet races. Therefore, the aim of the present study was to determine whether pacing behaviours differ between men’s and women’s WRs and global championship medal performances in distance track events in men and women. We hypothesised that specific pacing differences exist for each event despite more even profiles being generally adopted during WRs vs. performances of medallists at global championship races.

Materials and methods

Finishing and split times recorded during 800m (two 400-m splits in 21 men and 8 women), 1500m (three 400-m and last 300 m splits in 37 men and 12 women) 3000m steeplechase (three 1000-m section splits in 30 men and 7 women), 5000m (five 1000-m splits in 32 men and 13 women) and 10,000m (ten 1000-m splits in 37 men and 6 women) WRs from the World Athletics (WA, formerly IAAF) era (1912 onwards) until 2014 were collected from the Hymans (2020) database when available by F. G.-M. from the 27-30th May 2023. WRs ratified by WA of three other WRs broken between 2015 and 2023 were extracted from the open-access WA website (www.worldathletics.org) by L. E. R. on 31st July 2023. Overall, 169 performances were extracted and analysed.

Finishing times and split times belonging to same race sections of split times retrieved from WRs were also collected from the final races at four World Championships (WC) (Moscow 2013, London 2017, Doha 2019 and Eugene 2022) and three summer Olympic Games (OG) (Beijing 2008, Rio de Janeiro 2016 and Tokyo 2020) for the 800m and 1500m men's and women's medallists, three summer OG (Beijing 2008, Rio de Janeiro 2016 and Tokyo 2020) for the men's and women's 3000m steeplechase medallists, the men's 3000m steeplechase medallists at Eugene 2022 WC, and the men's and women's 5000m and 10,000m medallists at four WC (Moscow 2013, London 2017, Doha 2019 and Eugene 2022) and three summer OG (Beijing 2008, Rio de Janeiro 2016 and Tokyo 2020). In total, 189 performances were analysed. These championships were selected because they were the only ones with pacing data available. Global championship medal pacing and performance data were obtained from the open-access WA website by B. H. and L. E. R. from the 10th-15th May 2023. Each split time was converted to lap time, which in turn was expressed as a percentage of the mean race speed (%RS) for further comparisons. For the present study, institutional review board approval was waived regarding informed consent of participants since the data analysed are in the public domain.

Statistical analysis.

All data are presented as mean and standard deviation (mean ± SD). Data were checked for normality distribution, equality of variances, and assumption of sphericity. When the sphericity assumption was violated, the Greenhouse-Geisser correction was employed. A two-factor analysis of variance (ANOVA) with repeated measures was conducted to determine %RS differences between race sections and between race types. A Bonferroni post hoc correction was used in all pairwise comparisons. Effect sizes (ES) were calculated using eta-squared (η_p^2) for the repeated measured ANOVA test, and Cohen's *d* (Cohen, 1988) for the Bonferroni post hoc test. The η_p^2 was considered to be small (0.01), moderate (0.01-0.06) or large (>0.15) (Cohen, 1992). Cohen's *d* was considered small (0.21-0.50), moderate (0.51-0.80) or large (<0.80) (Cohen, 1988). Statistical significance was set at $p < 0.05$. All analyses were performed with JASP software (version 0.13.1 for Mac OS, JASP Team, Amsterdam, The Netherlands). Figures were created with Graph Pad Prism software (version 8.0 for Mac).

Results

Men's 800m

The ANOVA analysis of the men's 800m event showed significant differences in the race type*lap factor ($p \leq 0.01$, $\eta_p^2 = 0.067$, F = 4.289, df = 1). In WRs (Figure 1A), the second lap was covered at a significantly slower speed than the first lap ($p \leq 0.001$, $d = 2.276$).

Women's 800m

The ANOVA analysis of the women's 800m event showed significant differences in the race type*lap factor ($p = 0.05$, $\eta_p^2 = 0.067$, F = 4.218, df = 1). In WRs (Figure 1B), the second lap was covered at a significantly slower speed than the first lap ($p \leq 0.001$, $d = 2.486$).

Men's 1500m

In the men's 1500m event (Figure 1C), there were significant differences in the race type*lap factor ($p \leq 0.001$, $\eta_p^2 = 0.181$, F = 17.456, df = 2.344, and $p \leq 0.001$). A positive pacing profile was followed by the medallists, with increases in speed between the first and third lap ($p \leq 0.001$, $d = 2.08$) and between the second and third lap ($p = 0.023$, $d = 1.32$). A U-shape pacing profile was followed during WRs, with a decrease in speed from the first to the second lap ($p \leq 0.01$, $d = 1.13$), and a speed increase from the third to the fourth lap ($p \leq 0.01$, $d = 1.07$). Finally, medal performances were relatively slower during the first 400 m lap ($p \leq 0.001$, $d = 1.32$) and faster during the third 400 m lap ($p \leq 0.001$, $d = 1.69$) than WRs.

Women's 1500m

In the women's 1500m event (Figure 1D), there were significant differences in the race type*lap factor ($p \leq 0.001$, $\eta_p^2 = 0.141$, F = 7.715, df = 1.824). 1500m women's medallists also increased speed from the first and second lap to the third and fourth lap ($p \leq 0.001$, $1.27 \leq d \leq 2.70$). WRs followed a U-shape pacing profile, with a decrease in speed from the first to the second lap ($p \leq 0.05$, $d = 1.59$) and a speed increase from the second to the fourth lap ($p \leq 0.05$, $d = 1.63$). In addition, WRs were relatively faster during the first 400 m lap ($p \leq 0.001$, $d = 1.31$) and slower during the third lap ($p \leq 0.05$, $d = 1.69$) than medal performances.

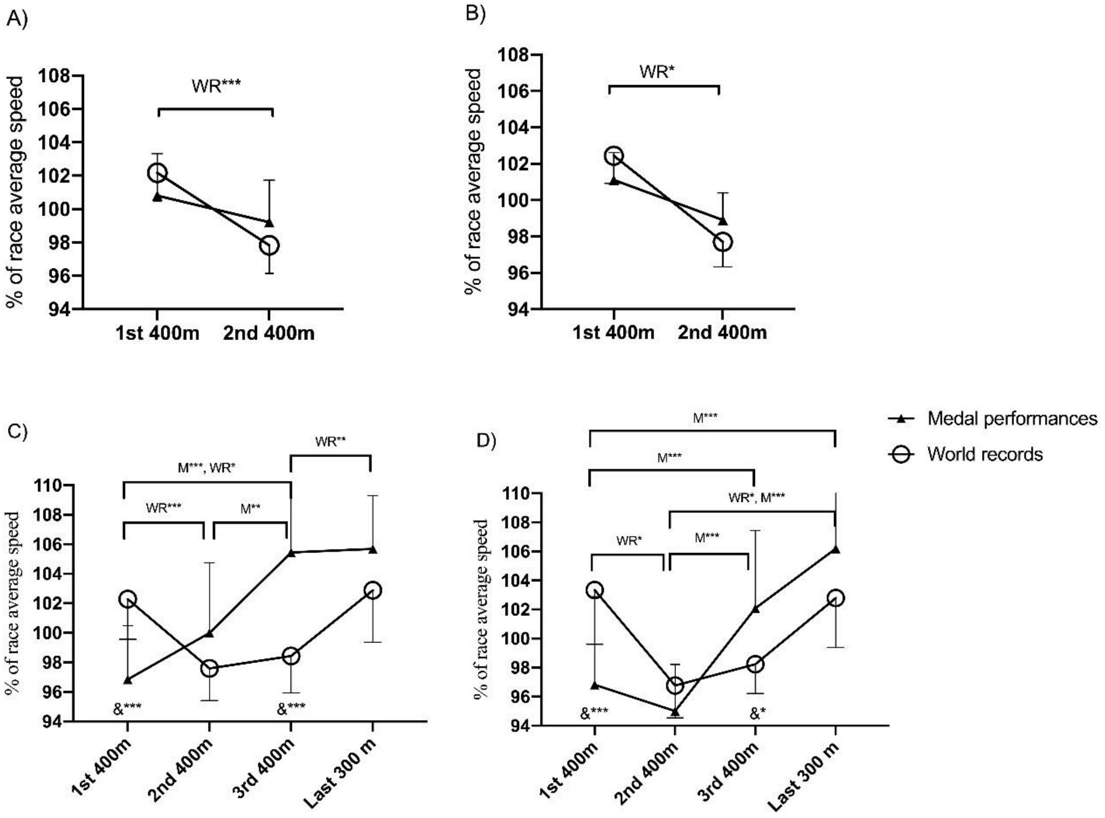

Figure 1. Mean and standard deviation of the average race speed during men's **(A)** and women's 800m **(B)** and men's **(C)** and women's 1500m **(D)** World Record (WR) and medal performances, *$p \leq 0.05$, ***$p \leq 0.001$. Differences in lap speed between groups (medalist vs. WR) were noted with &*** $p \leq 0.001$; &* $p \leq 0.05$.

Men's 3000m steeplechase

In the men's 3000m steeplechase event (Figure 2A), there were significant differences in the race type*section factor ($p \leq 0.001$, $\eta_p^2 = 0.212$, F = 20.491, df = 1.292). In WRs, the medallists covered the third 1000-m section at a faster speed than the first one ($p \leq 0.001$, $d = 4.38$), and the second section ($p \leq 0.001$, $d = 3.59$). The first section was faster ($p \leq 0.001$, $d = 1.61$) and the third section was slower ($p \leq 0.001$, $d = 2.43$) in WR than medal performances.

Women's 3000m steeplechase

In the women's 3000m steeplechase event (Figure 2B), there were no differences between 1000-m sections in WRs and medal performances nor between types of races.

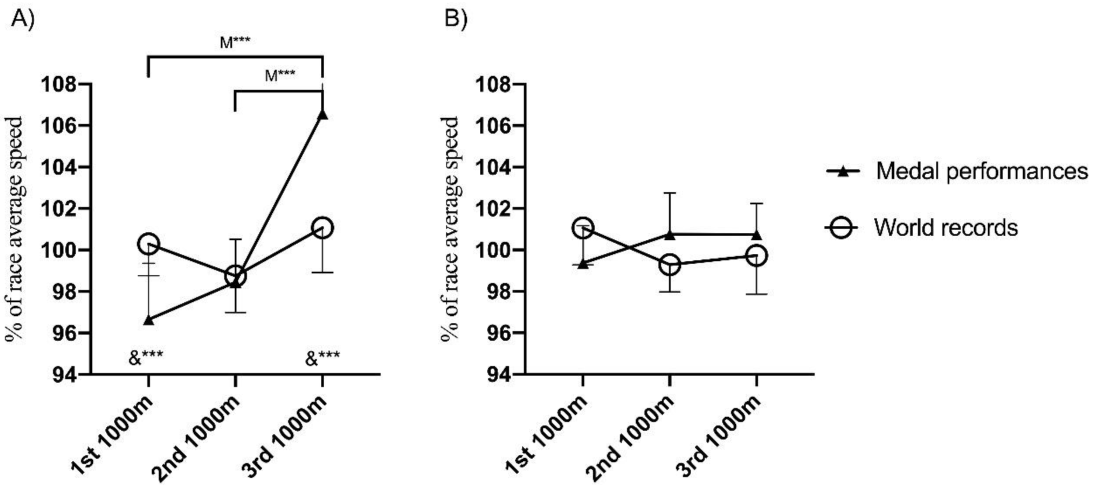

Figure 2. Mean and standard deviation of the average race speed of three 1000-m splits of men's **(A)** and women's **(B)** 3000m steeplechase WR and medal performances. *** $p \leq 0.001$. Differences in lap speed between the groups (medal vs. WR) were noted with &** $p \leq 0.01$; & *** $p \leq 0.001$

Men's 5000m

In the men's 5000m event (Figure 3A), there were significant differences in the race type*section factor ($p \leq 0.001$, $\eta_p^2 = 0.215$, F = 39.509, df = 2.686, and $p \leq 0.001$). The medallists covered the first four 1000-m sections at a constant pace, and the fifth section faster than the previous four sections ($p \leq 0.001$, $4.08 \leq d \leq 5.30$). The fourth section in WRs ($p \leq 0.01$, $d = 1.17$) was slower than the first one, and there was an increase in speed from the fourth to the last section ($p \leq 0.001$, $d = 1.69$). In addition, whereas the first section was relatively faster ($p \leq 0.001$, $d = 1.70$), the last section was slower ($p \leq 0.001$, $d = 2.93$) in WRs than medal performances.

Women's 5000m

In the women's 5000m event (Figure 3B), there were significant differences in the race type*section factor ($p \leq 0.001$, $\eta_p^2 = 0.217$, F = 15.147, df = 3.112). The medallists covered each section at a faster speed than the previous one ($p \leq 0.001$, $2.23 \leq d \leq 5.70$) whereas the WRs were characterised by an even pacing profile. Finally, the medal performances were relatively slower during the first section ($p \leq 0.001$, $d = 2.75$), and faster during the fifth one ($p \leq 0.001$, $d = 3.55$) than WRs.

Men's 10,000m

In the men's 10,000m event (Figure 3C), there were significant differences in the race type*section factor ($p \leq 0.001$, $\eta_p^2 = 0.218$, F = 41.909, df = 5.277). The first 1000-m section was covered at a significantly slower speed than the third one ($p \leq 0.05$, $d = 1.40$), and sections ranging from the seventh to the tenth section ($p \leq 0.01$, d = 1.67, 1.43, 2.45, and 7.00, respectively) during medal performances. Additionally, the tenth lap was faster than sections ranging from first to ninth ($p \leq 0.001$, $4.54 \leq d \leq 6.99$). 1000-m sections ranging from third to ninth were slower than the first section ($p \leq 0.01$, $1.06 \leq d \leq 1.43$) in WRs. In addition, in both types of races, the last section was covered at faster speed than sections ranging from the second to the ninth section, and the first section compared with the last section for the medal performances ($p \leq 0.01$, $4.08 \leq d \leq 6.29$ and $1.35 \leq d \leq 2.14$, for medal performances and WRs, respectively). The first and second section were slower ($p \leq 0.01$, d = 2.62, and 1.27, respectively) and the ninth and last section were faster ($p \leq 0.01$, d = 1.20, and 3.66, respectively) in medal performances than WRs.

Women's 10,000m

In the women's 10,000m event (Figure 3D), the first 1000-m section was slower than the second section and sections ranging from the fourth to the tenth section ($p \leq 0.01$, $1.43 \leq d \leq 5.55$) and the tenth section was faster than the sections ranging from the first to the ninth section ($p \leq 0.001$, $3.00 \leq d \leq 5.55$) in medal performances. No significant differences were found either between sections or between types of race at any section during WRs.

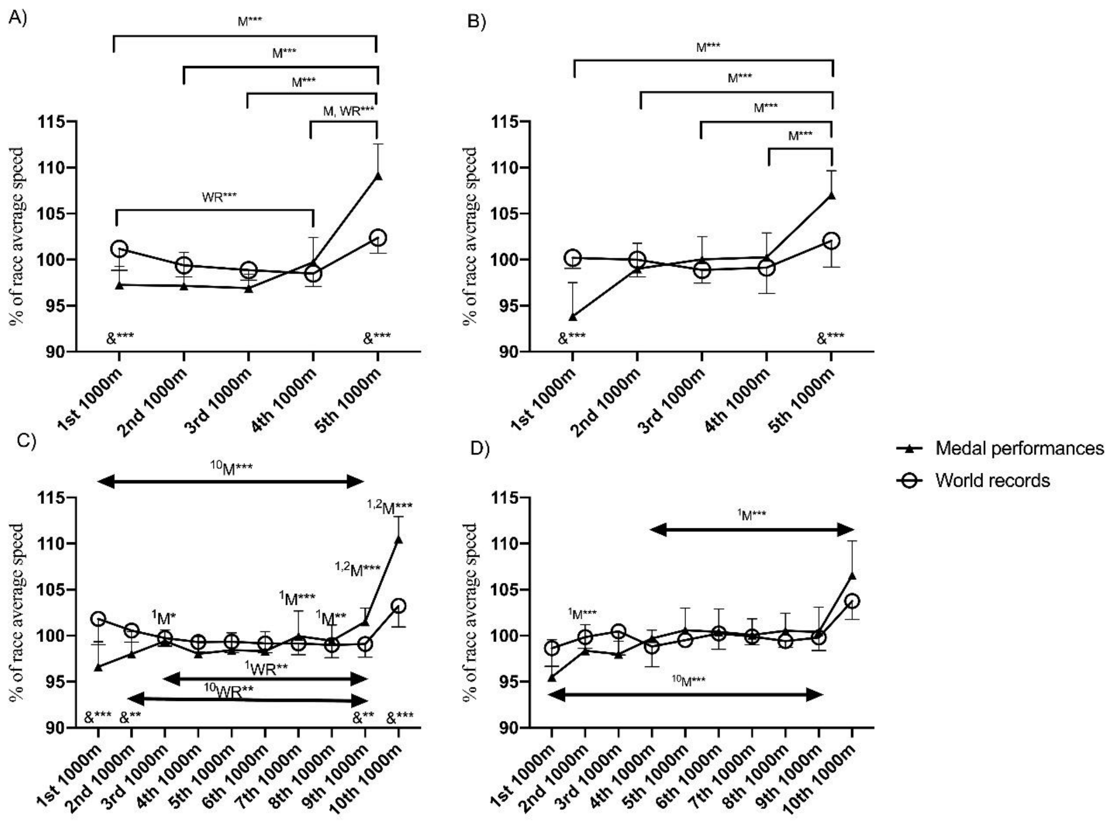

Figure 3. Mean and standard deviation of the average race speed of 1000 m laps of men's **(A)** and women's 5000m **(B)** and men's **(C)** and women's 10,000m **(D)** WR and medal performances. * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$; Range of laps were noted with a bidirectional arrow; Differences in lap speed between the groups (medal vs. WR) were noted with & ** $p \leq 0.01$, *** $p \leq 0.001$. Number in superscript indicate the difference with the corresponding lap number.

Pacing profiles for each track distance running event and race type in men and women are indicated in Table 1.

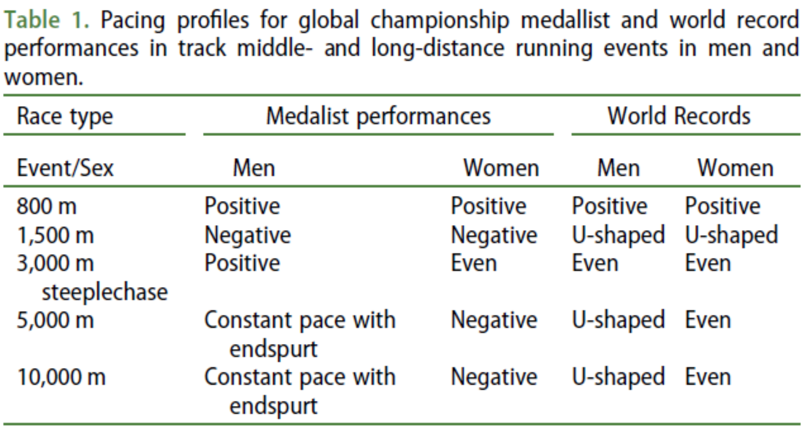

Table 1. Pacing profiles for global championship medallist and world record performances in track middle- and long-distance running events in men and women.

Race type	Medalist performances		World Records	
Event/Sex	Men	Women	Men	Women
800 m	Positive	Positive	Positive	Positive
1,500 m	Negative	Negative	U-shaped	U-shaped
3,000 m steeplechase	Positive	Even	Even	Even
5,000 m	Constant pace with endspurt	Negative	U-shaped	Even
10,000 m	Constant pace with endspurt	Negative	U-shaped	Even

Discussion

The purpose of the present study was to compare pacing behaviour between GCMs and WRs in track distance running events for men and women. Differences were found between race types in all events, except the men's 800m and women's 10,000m. This reveals that World-class runners generally use different pacing approaches depending on the race type they are competing in. Both 800m WRs and medal performances were characterised by a positive pacing profile (Figure 1A and 1B), in line with findings of other studies analyzing WRs (Casado, González-Mohíno, et al., 2021; Tucker et al., 2006) and global championship medallists (Hanley et al., 2019). This positive pacing profile can be explained by the substantial proportion (34%) of energy supplied through non-oxidative pathways in the 800m event (Spencer & Gastin, 2001). These pathways provide energy at a faster rate than oxidative ones do, thereby being used to sustain high intensities (i.e., fast speeds), and are predominantly employed in the earlier stages of 800m races (Spencer & Gastin, 2001). Therefore, 800m runners usually benefit from the use of the non-oxidative pathways to provide energy, while optimising performance through the setting of a fast early pace also allows them to adopt an advantageous race intermediate position (Casado & Renfree, 2018). Accordingly, these 800m runners’ pacing strategies agree with the existence of a metabolic limit on the ability to make up for lost time in the later stages of the race (Fukuba & Whipp, 1999; Tucker et al., 2006), in which oxidative pathways of energy supply are in turn employed (Spencer & Gastin, 2001).

Whereas men’s and women’s 1500m medallists displayed a negative pacing profile, 1500m men’s and women’s WRs were characterised by a U-shaped pacing approach. (Figure 1C and 1D). More specifically, 1500m men’s medallists displayed increases in speed from 400 m to 1200 m whereas during the last 300 m they could maintain that high speed. However, women’s medallists accelerated from 800 to 1200 m and also maintained the fast final speed for the last 300 m. This disagrees with findings by Hanley et al. (2019) who observed J-shaped pacing behaviour in 1500m medallists using 100-m splits. Nonetheless, the present study might generalise to a greater extent since it uses a wider sample size to that described by Hanley et al. (2019) with three more global championships analysed. By contrast, both men’s and women’s WRs are characterised by a U-shaped pacing profile, in agreement with Casado et al. (2021) despite the current men's WR being characterised by a parabolic J-shaped pacing profile (Casado et al., 2021). Furthermore, the relatively faster first 400 m and middle part of the race by WR performers than medallists underline the different tactical requirements among both types of race, since medallists need to reach a faster top end speed to beat their opponents because the goal is to win the race rather than covering the race distance as quickly as possible (Foster et al., 2014; Hanley & Hettinga, 2018; Thiel et al., 2012). Unlike 800m runners, 1500m runners were able to sustain the fastest speed achieved during the race for the last 300 m. It is also important to note that differences in pacing behaviour observed between 800m and 1500m events might be also related to the greater percentage of energy supplied through oxidative pathways in the latter (i.e., 66±2% vs. 84±1% in 800m vs. 1500m, respectively) (Spencer & Gastin, 2001). In this sense, longer events than 800m in which energy is mostly obtained through oxidative pathways do not allow athletes to adopt a positive pacing approach since surpassing the fatigue threshold speed (i.e., the greatest overall speed which can be kept across any event according to body’s physiological limitations such as blood acid-base status and ventilatory gas exchange) too early in the race would result in a premature fatigue state leading to underperformance (Fukuba & Whipp, 1999; Tucker et al., 2006).

Whereas the men's 3000m steeplechase medallists displayed a negative pacing approach, men’s WR performers adopted an even pacing profile (Figure 2A). These medallists’ behaviours are consistent with those observed by Hanley and Williams (2020) who described the pacing patterns by men’s and women’s steeplechasers during two OG. However, women’s medallists’ pacing approaches (Figure 2B) do not differ from those of WR performers, both displaying an even profile, which also agrees with findings by Hanley and Williams. However, although not significantly different, the mean speed for the women’s WR performers during the first 1000 m is the fastest of the whole race. That outcome is related to the absence of barriers and water jump during the first 200 m of the race. Indeed, that circumstance could also explain to a certain extent how female medallists adopted an even rather than negative pacing approach. However, since the male medallists executed a negative pacing profile, the even profile observed by their counterparts might also be related to the fact that the water pit dimensions are equal in men’s and women’s races, yielding a relatively greater fatigue in women than men (Hanley & Williams, 2020), which could affect their ability to accelerate more in the last stages of the event.

Regarding the 5000m and 10,000m events (Figure 3), whereas both men’s and women’s medallists adopted a negative pacing behaviour, in agreement with findings by Filipas et al. (2018), WR women's performers followed an even approach and WR men's performers displayed a U-shaped profile, the latter findings being also in agreement with those by Tucker et al. (2006). Whereas in the men's and women's 5000m event, the first and last 1000 m were relatively faster and slower in WRs than medal performances, respectively, these differences were found only in the two first and last 1000 m in men in the 10,000m event. In this way, the fact that female medallists during the longest track event adopted the same pacing approach as WR performers reflects a greater predisposition in women than men to achieve faster overall performances through more even pacing strategies, as mentioned previously regarding the 3000m steeplechase event.

On the other hand, both men's 5000m and 10,000m medallists established a constant speed until they accelerated during the last 1000 m of the race through a tremendous endspurt, emphasizing the need to develop the ability to sustain a very fast pace during the last 1000 m under conditions of neuromuscular fatigue (Barry & Enoka, 2007). Even though female 5000m medallists increased speed throughout the event more progressively than men, the need for a top end speed appears also to be critical for them to achieve a medal. In any case, apart from the negative pacing trend during global championship 5000m and 10,000m finals, pacing profiles at the 2008 OG were characterised by the existence of constant microvariations in pace, likely occurring because of the absence of pacemakers and the attempts of contenders to drop their rivals off across the race (Thiel et al., 2012). Regarding men's 5000m and 10,000m WRs, it seems that the U-shaped approach adopted reflects how these distance runners constantly deal with the 'fatigue threshold' without surpassing it across the race which allows them to increase the pace considerably during the last 1000 m (Tucker et al., 2006).

A limitation in the present study should be acknowledged. From the performances being analysed, GCMs were accomplished from 2008 to 2023, and WRs were achieved from 1912 to 2023. This important time window difference might have affected our results.

Conclusions and practical applications

This study highlights how pacing strategies in the middle-distance disciplines of athletics change depending on the type of event (i.e., global championship performances or WRs) in World-class athletes. In all events, except for the 800m, significant differences were found between global championship medal performances and WRs in the way runners distribute their energy expenditure across the race. Furthermore, within-event pacing differences were also found in most events, except the 3000m steeplechase. Specifically, both 800m WRs and GCMs are characterised by positive profiles for both sexes. In the 1500m, a U-shaped pacing profile is observed in the WRs and a negative one in the medal performances in men and women. Whereas men's 3000m steeplechase WRs followed an even pacing profile, a positive pattern was observed during medal performances. However, both women's 3000m steeplechase WRs and medal performances followed an even approach. Finally, whereas both men's 5000m and 10,000m medal performances adopted a constant pace for most of the race with a fast endspurt during the last 1000 m, both WRs followed a U-shaped pacing profile. However, whereas women's 5000m and 10,000m medallists increased pace progressively across the race, women's WR performers adopted an even pacing profile in both events. Accordingly, elite coaches and athletes should be aware about the existing differences in pacing successful approaches among global championship races and personal record attempts at each distance running track event. These differences demand different abilities in runners and therefore training characteristics to achieve them. In general, although championship races in 1500m races or longer require the development of both aerobic and anaerobic capacities since typically moderate paces are expected during the main part of the race with a fast endspurt to have real choices to achieve a medal, aerobic capacity is more relevant during WR attempts since a faster overall pace and a lower variation of pace and a slower endspurt are requested to break them. In this way, whereas small training volumes and an emphasis of running at a faster pace than race pace might be recommended to properly peak at championship races, greater volumes and specific race pace training could be more adequate to prepare meet races or WR attempts in 1500 m or longer track events.

The present study is the first one to specify the differences in pacing demands between global championship and WR races at each Olympic track distance running event. Therefore, it provides critical information regarding the way athletes need to behave during these two different types of race to succeed and how training might differ depending on the type of goal being targeted. Findings from the present study are derived from highly ecologically valid performance data; however, they provide scarce information regarding the underpinning mechanisms explaining the behaviours described. Therefore, further research in which psychophysiological responses to the different pacing behaviours observed in the present study belonging to either championship or meet races are measured through exercise protocols performed in controlled simulated competitive environments is encouraged.

Disclosure of interest

The authors report no conflict of interest.

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