Pacing profiles during world records in olympic track long-distance running events by men and women

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Summary

Introduction: Pacing strategy plays a crucial role in running performance. However, pacing profiles from world records (WRs) in women have not been reported in the scientific literature yet. Therefore, the aims of the present study were to determine the pacing strategies used to achieve WRs in Olympic track long-distance running events, and to compare them between sexes.
Material and method: Overall finishing and split times for 3,000-m steeplechase, 5,000-m and 10,000-m WRs until 2014 were collected where available. Those broken from 2015 to 2021 were extracted from the website (www.worldathletics.org). Pacing profiles were obtained for 37 3,000-m steeplechase, 44 5,000-m, and 42 10,000-m world records.
Results: Both 5,000-m and 10,000-m WRs displayed a U-shaped pattern characterised by faster first and last kms than those in the central part of the race. Accordingly, significant overall variations in pace were found across the race during 5,000-m (P <0.001, η^2 = 0.302) and 10,000-m (P <0.001, η^2 = 0.22) WRs in both sexes. Furthermore, the first km was relatively faster in men than women in the 10,000-m event (P = 0.001, d = 0.70).
Conclusions: Current 5,000-m and 10,000-m WRs followed a more even pacing strategy and with faster endspurts than previous records, potentially due to the assistance of new wavelight and shoe technologies. In addition, men's and women's 3,000-m steeplechase WRs followed U-shaped and even pacing strategies, respectively. Future world record attempts will likely benefit from the combined assistance of pacemakers and the wavelight technology, in order to facilitate even rather than U-shaped pacing strategies, especially in men.

Key words:
Strategy. Endurance.
Elite athletes. Performance.

Perfiles de ritmo durante los récords del mundo en pruebas olímpicas de fondo en pista de hombres y mujeres

Resumen

Introducción: La estrategia del ritmo desempeña un papel crucial en el rendimiento en carrera. Sin embargo, los perfiles de ritmo de los récords del mundo en mujeres aún no se han publicado en la literatura científica. Por lo tanto, los objetivos del presente estudio fueron determinar las estrategias de ritmo utilizadas para lograr los récords mundiales en las pruebas olímpicas de fondo en pista, y compararlas entre sexos.
Material y método: Los tiempos totales y parciales de los eventos de 3.000 m obstáculos, 5.000 m y 10.000 m hasta 2014 fueron recopilados. Aquellos batidos de 2015 a 2021 se extrajeron del sitio web (www.worldathletics.org). Se obtuvieron los perfiles de ritmo de 37 carreras de 3.000 m obstáculos, 44 de 5.000 m y 42 de 10.000 m.
Resultados: Las marcas de 5.000 m y 10.000 m mostraron un patrón en forma de U caracterizado por unos primeros y últimos kilómetros más rápidos que los de la parte central. En consecuencia, se observaron variaciones globales significativas en el ritmo a lo largo de la carrera durante los récords del mundo de 5.000 m (p <0,001, η^2 = 0,302) y 10.000 m (p <0,001, η^2 = 0,22) en ambos sexos. Además, el primer km fue relativamente más rápido en los hombres que en las mujeres en la prueba de 10.000 m (p = 0,001, d = 0,70).
Conclusión: Las marcas actuales de 5.000 m y 10.000 m siguieron una estrategia de ritmo más uniforme y con finales de carrera más rápidos que los récords anteriores, debido potencialmente a la ayuda de las nuevas tecnologías de luz y calzado. Además, los récords de 3.000 m obstáculos masculinos y femeninos siguieron estrategias de ritmo en forma de U y uniforme, respectivamente. Es probable que los futuros intentos de récord del mundo se beneficien de la asistencia combinada de las liebres y la tecnología de luz, con el fin de facilitar estrategias de ritmo uniforme en lugar de en forma de U, especialmente en los hombres.

Palabras clave:
Estrategia. Resistencia.
Atletas de élite. Rendimiento.

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Introduction

Pacing refers to the way in which effort is distributed throughout a given task[1]. Specific tactical behaviours and pacing profiles are displayed by elite distance runners and have been suggested to influence their performance[2]. They can be differentiated depending on the specific race distance and whether the main goal is to achieve the highest possible finishing position (i.e., championship races) or the fastest possible finishing time (i.e., meet races typically used to break world record performances [WRs])[2]. Regarding the latter, Fukuba and Whipp[3] suggested that the maximum average power/speed that can be sustained across the entire course of any endurance race is optimal to achieve the fastest possible performance. On some occasions, exceptional performances (in terms of finishing times) have also been achieved during championship races.

Olympic track long-distance running events consist of the 3000-m steeplechase, 5,000-m, and 10,000-m. While pacing profiles during men's WRs in 5,000-m and 10,000-m were studied more than a decade and a half ago[4], there is a need to update this analysis to include more recent WRs, particularly in light of recent developments in the new wavelight[5] and shoe[6,7] technologies that may have helped to considerably improve those WRs. While the wavelight technology is an electronic pacing tool comprising 400 LED lights which are installed on the drainage covers of the track and uses fluid motion to flash at an assigned pace[5], the advanced footwear technology is based on specifically positioned carbon fibre plates and foam cushioning and has been reported to confer improvements in running economy[6,8] and performance[6]. In addition, pacing profiles from WRs in women in these events (and both men and women in the 3,000-m steeplechase) have not been reported in the scientific literature, and it could be different between sexes. Knowledge of the strategies used to break long-distance track WRs may be of great value to elite athletes attempting to break them or improve their personal best times.

Men's 5,000-m and 10,000-m WRs have been typically characterised by a U-shaped pacing strategy consisting of a fast start, an even pace during the main part of the race and a fast endspurt, as previously reported in those WRs which were set up to 2004[4]. However, women's WRs in these events may have displayed a more even pace throughout as was observed during 5,000-m races at the world championships and Olympic Games[9]. The inclusion of 35 barriers of which seven are water obstacles in the 3000-m steeplechase race influences the pacing strategy used by world-class runners with respect to other long-distance flat track races[10]. A previous pacing analysis of two Olympic Games reported important speed variations within an overall U-shaped pacing strategy which is likely partially due to the absence of barriers during the first 200-m of the race which may explain the faster start[10].

Therefore, the aims of this present study were twofold: 1) to determine the pacing strategies used during 3,000-m steeplechase, and an update for the 5,000-m, and 10,000-m WRs in men and women, and 2) to compare them between sexes.

Material and method

Experimental approach to the problem

This study utilised an observational approach. Overall finishing and split times for 3,000-m steeplechase, 5,000-m and 10,000-m WRs, for men and women, from World Athletics (formerly International Amateur Athletic Federation, IAAF) era until 2014 were collected from Hymans R[11] where available. WRs ratified by WA and those broken from 2015 to 2021 were extracted from the WA website (www.worldathletics.org).

Subjects

In the men's 3,000-m steeplechase event, 32 WRs have been ratified by World Athletics from 1954 to 2004. Lap times (1000-m laps) were available for 30 races. They represented 93.75% of all WRs. In the women's 3000-m steeplechase, 12 WRs from 1999 to 2018 have been ratified by World Athletics. However, split times were only available for 7 WRs, representing 58.33% of all WRs.

In the men's 5,000-m event, 35 WRs have been ratified by World Athletics from 1912 to 2020. Split times (1000-m laps) were available for 32 (91.42%) of men's WRs. In the women's 5,000-m event, 14 WRs have been ratified by the World Athletics from 1981 to 2020. Split times for 12 WRs (85.71% of all WRs) were available.

In the men's 10,000-m event, 39 WRs have been ratified by World Athletics from 1911 to 2020. Split times (1,000-m laps) were available in 37 of these WRs (94.87%). In the women's 10,000-m event, 11 WRs from 1981 to 2021 were ratified by World Athletics. Split times were available in 5 WRs, which represented 50% of all WRs. Each split time was expressed as a percentage of the average race speed (%RS) for further analyses. Institutional review board approval for this study was waived concerning informed consent because these data 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 2-factor analysis of variance (ANOVA) with repeated measures with 'race average speed at each split' as between splits' factor and sex as between subjects' factor was conducted to determine the differences between %RS at each split and between sexes, respectively. A Bonferroni post hoc correction was used in all pairwise comparisons. In addition, the variation of pace was assessed by the coefficient of variation (CV) of the %RS by each lap to compare the new WRs with wavelight and new footwear technology and previous WRs. Effect sizes (ES) were calculated using eta-squared (η^2) for the repeated measured ANOVA test, and Cohen's d[12] for the Bonferroni *post hoc* test. The η^2 was considered to be small (0.01), moderate (0.01-0.06) or large (>0.15)[13]. The Cohen's d was considered to be small (0.21-0.50), moderate (0.51-0.80) or large (<0.80)[12]. 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

The repeated measures ANOVA revealed a non-significant difference in %RS between sexes for the 3,000-m steeplechase and 5,000-m running events (Table 1). In the case of the 10,000-m event, there was significant difference in %RS between sexes ($P = 0.017$, $\eta^2 = 0.052$). In addition, there were significant differences in %RS within the distance events in both sexes depending on the race.

In the 3,000-m steeplechase event (Figure 1A), the third lap was covered at significantly faster speed than the second lap ($P = 0.002$, $d = 0.67$) in men, but no difference was found in women.

In the men's 5,000-m event (Figure 2A), the first lap was covered at a significantly faster speed than the second lap ($P = 0.019$, $d = 0.54$), the third lap ($P < 0.001$, $d = 0.69$) and the fourth lap ($P < 0.001$, $d = 0.81$). In addition, the fifth lap was covered at significantly faster speed than the second ($P < 0.001$, $d = 0.89$), third ($P < 0.001$, $d = 0.89$) and fourth lap ($P < 0.001$, $d = 1.17$). In women, the third ($P = 0.003$, $d = 0.60$) and fourth lap ($P = 0.012$, $d = 0.56$) were covered at slower speed than the fifth lap.

Finally, in the men's 10,000-m event (Figure 2D), the first lap was covered at significantly faster speed than that observed from the third to the ninth lap ($P < 0.001$, d = 0.83, 1.00, 0.98, 1.06, 1.06, 1.12, 1.08). In addition, the last lap was covered at significantly faster speed than that in previous ones ($P < 0.001$, d = 1.06, 1.39, 1.56, 1.54, 1.61, 1.62, 1.68, and 1.64, for the second to the ninth lap, respectively), with the exception of the first lap. In the women's 10,000 m event (Figure 2D), the first, second, and those from the fourth to the ninth lap were covered at significantly lower speed than the last lap ($P < 0.001$, $d = 0.82$; $P = 0.009$, $d = 0.63$; $P < 0.001$, $d = 0.79$; $P = 0.002$, $d = 0.68$; $P = 0.048$, $d = 0.56$; $P = 0.012$, $d = 0.62$; $P < 0.001$, $d = 0.69$; $P = 0.008$, $d = 0.63$; for the first and second lap, and those ranging from the fourth to the ninth lap, respectively). The only difference between sexes was found in the first lap, which was covered at a significantly faster speed in men than women (101.83 ± 2.79 and 98.64 ± 1.96%, for men and women, respectively) ($P = 0.001$, $d = 0.70$).

Discussion

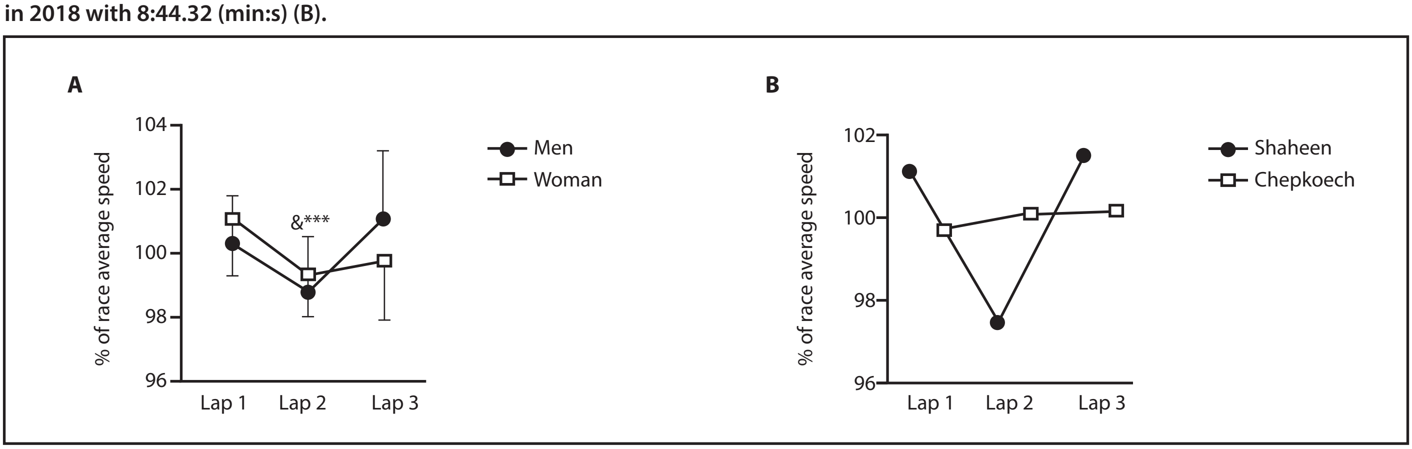
The aims of the present study were to determine the pacing profiles used to achieve 3,000-m steeplechase, 5,000-m and 10,000-m WRs, and to compare between men and women. The most important finding is that men covered a faster first km relative to average race speed than women during 10,000-m WRs, which also was faster than the rest of kms except for the last one in men, suggesting that women displayed a more even pace than men. This theoretically more optimal pacing behaviour demonstrated by women than men was also previously observed in other similar running events such as 10-km road[14] and

Table 1. Repeated Measures ANOVA outcomes of lap and sex interaction.

		Repeated Measures ANOVA							
		Between lap				Lap and sex interaction			
Event	Number of laps	*P*	F	df	ES	*P*	F	df	ES
3,000-m steeplechase	3	0.038	3.670	1.710	0.091	0.221	1.558	1.710	0.039
5,000-m	5	<0.001	19.087	3.234	0.302	0.354	1.099	3.234	0.017
10,000-m	10	<0.001	12.381	4.514	0.220	0.017	2.957	4.514	0.052

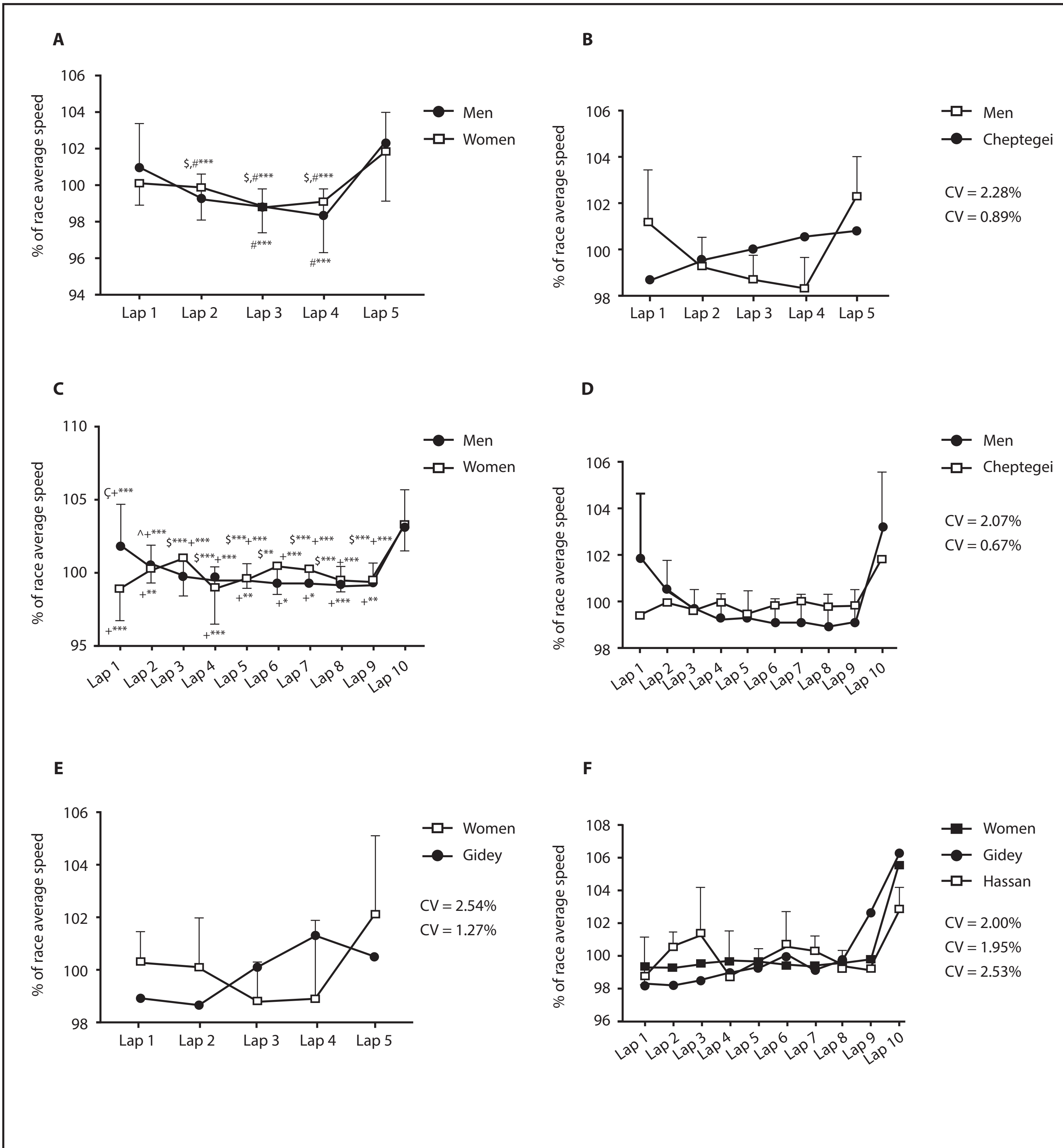
F: variation between sample means / variation within the sample; df: degrees of freedom; ES: effect size (η^2).

Figure 1. Means and standard deviations of average race speed for three 1,000 m laps during men's and women's 3,000 m steeplechase world records (WRs) (A), and current WRs set by Qatary Saif Saaeed Shaheen in 2004 with 7:53.63 (min:s) and Kenyan Beatrice Chepkoech in 2018 with 8:44.32 (min:s) (B).



&: Different to the third lap. ***$P < 0.001$.

Figure 2. Means and standard deviations of average race speed for five and ten 1,000 m laps during men's and women's 5,000 and 10,000 m world records (WRs) (A and C), current WRs set by Ugandan Joshua Cheptegei in 2020 with 12:35.36 (min:s) and 26:11 (min:s) and all previous WRs and their coefficients of variation (CVs) (B and D for 5,000-m and 10,000-m, respectively), current 5,000-m WR set by Ethiopian Letesenbet Gidey with 14:06.62 (min:s) and all previous WRs and their CVs (E) and the latest two women's 10,000-m WRs set by Dutch Siffan Hassan and Ethiopian Letesenbet Gidey in 2021 with 29:06.82 and 29:01.03, respectively (min:s) and all previous WRs and their CVs (F).



Ç: Differences between sexes; $: Different to the first lap; #: different to the last (fifth) lap; #: different to the tenth lap; **P* <0.05; ***P* <0.01; ****P* <0.001.

cross-country[15] races. It has been suggested that the most likely mechanism underpinning this sex difference in 10 km running events is attributed to decision-making rather than physiological processes[14]. In addition, by contrast to championship races, WRs are usually achieved through the use of pacemakers who set a preassigned pace from the start of the race in order to provide drafting benefits to the runners who follow them and to minimise their emotional and cognitive cost of pacing decision-making[16]. Therefore, they have to keep to a pre-agreed stable pace during part of the race (i.e., typically until the halfway point) from where WR performers have to pace themselves. According to the present results, it seems that during men's 5,000-m and 10,000-m WR attempts, the pace set during the first km by pacemakers is too fast to achieve optimal performances.

Additionally, the pacing strategies observed in both men's 5,000-m and 10,000-m WRs are similar to findings from a previous study[4] and are characterised by a U-shaped pattern with an even pace during the main part of the race. This pacing strategy was also observed recently during men's 1,500-m WRs[17]. However, during current WRs which were assisted by advanced footwear technology and wavelight technologies[5], this pacing strategy has turned into a more even pace without running so fast during the first km (i.e., 5,000-m and 10,000-m WRs) and with an even faster endspurt (i.e., women's 10,000-m WRs) than during previous WRs (Figures 2B, 2C, 2E, and 2F). On the one hand, the wavelight technology assists to set a more even pace[5] through the reduction in speed during the first km while preserving the physiological reserve capacity[18] until later in the race. On the other hand, the faster endspurt than previous WRs may be also explained by the decrease in muscular fatigue at the end of the race through both the more optimal pacing approach adopted without previous pace variations and the use of the advance footwear technology[7].

Pacing strategies during men's 3,000-m steeplechase WRs were similar to those reported during two Olympic Games[10] as they were also characterised by a U-shaped pacing pattern, without significant pace differences between the first and the other two laps though (Figure 1A). However, during women's 3,000-m steeplechase WRs, the even pacing strategy observed may be explained by their ability to distribute their effort more efficiently than men, as previously observed during 10,000-m WRs. In any case, pacing strategies were more even during these WRs than during championship races[10], given that only one significant pace difference was observed between laps (i.e., between the second and third lap in men).

The lack of official electronic splits for some of the WRs analysed have to be acknowledged as the main limitation of the present study. In addition, the study would have benefitted from more detailed data, such as 100-m split times, which may have allowed for the identification of pace microvariations but, unfortunately, they were not available. Finally, the present study is observational in nature and therefore an observation of a certain pacing behaviour does not mean that it is optimal.

Conclusions

Current 5,000-m and 10,000-m WRs followed a more even pacing strategy and with faster endspurts than previous records, potentially due to the assistance of new wavelight and advanced footwear technologies. In addition, men's and women's 3,000-m steeplechase WRs followed U-shaped and even pacing strategies, respectively. New attempts to break WRs at Olympic long-distance running events will likely benefit from the assistance of pacemakers and the wavelight technology, in order to facilitate even rather than U-shaped pacing strategies, especially in men. Furthermore, given the extremely fast endspurts displayed in recent women's 10,000-m WRs, new attempts may also consider the adoption of faster paces throughout the entire race in order to maximise utilisation of the physiological capacity of athletes.

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Conflict of interest

Authors report no conflict of interest.

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