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Communication

Sex differences in ultramarathon performance in races with comparable numbers of males and females

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Abstract

There is a prominent sex-based difference in athletic performance such that males outperform females by 7%–14% in races from 100 m to marathon. In ultramarathons, the difference is often much smaller, leading to speculation that females are “built” for the sport. However, data are confounded by the low number of female participants; just 10%–30% in any given race. This study compared data from two ultramarathons where males and females competed in comparable numbers. There were 116 and 146 starters in the 50 mile and 100 mile races, respectively (52% female). Finish times were compared using *t* tests or Mann–Whitney U tests, a Chi-squared test of independence examined the relationship between sex and ranking, and multivariable linear regressions examined relationships between sex, age, and finish time. There were 96 finishers in the 50 mile race (46% female) and 91 finishers in the 100 mile race (45% female). The median finish time for 50 miles was 12.64 ± 2.11 h with no difference between sexes (1.2%, $p = 0.441$). However, the top-10 males finished the race ∼85 min faster than the top-10 females (13.8%, $p = 0.045$). The mean finish time for 100 miles was 31.58 ± 3.36 h with no difference between sexes (3.2%, $p = 0.132$) and no difference between the top-10 males and top-10 females (4.4%, $p = 0.150$). Linear and multivariable regression models using sex and age were unable to predict overall finish time in either race. In conclusion, the sex-based performance discrepancy shrinks to 1%–3% in ultramarathons when males and females compete in comparable numbers. Top-performing males still retain a considerable advantage over shorter distances.

Key words: endurance, performance, running, trail running, ultramarathon, female

Introduction

There is a prominent sex-based difference in athletic performance. With few exceptions, males outperform females at all levels of competition, from recreational to international level. Although the performance disparity is partly influenced by historical gender bias and sociocultural constraints on women, the biological predisposition for larger male body size plays a substantial role (Hunter et al. 2023).

Much of the sex-based difference in athletic performance is thought to derive from higher testosterone concentrations in males and their prolonged exposure to higher testosterone that begins in puberty (Handelsman et al. 2018). Males also have larger airways, lung volumes, and ventilatory capacities (Sheel et al. 2004), larger hearts and cardiac outputs (St Pierre et al. 2022), higher maximal oxygen uptakes (Haugen et al. 2018), and larger muscles capable of generating more force (Nuzzo 2023). These anatomical and physiological differences, the result of sexual dimorphism, confers a distinct sporting advantage for males, explaining a sex-based performance disparity of 7%–14% in running races from 100 m to marathon (Hallam and Amorim 2022).

In ultramarathon, however, as in most ultra-endurance sports, the sex difference in performance is often much smaller. The disparity has been reported to be 4%–9% in 50 and 100 mile races (Waldvogel et al. 2019), ∼5% in 24 h timed events (Peter et al. 2014), ∼9% in Ironman triathlon (Lepers 2019), and 7% in double Ironman (Sigg et al. 2013). The difference tends to be smallest in races where females compete in greater numbers (Senefeld et al. 2016). And although the sex difference in elite ultramarathon remains at 10%–12% (Coast et al. 2004; Peter et al. 2014), females periodically outperform males on some of the world’s biggest stages*—remarkable feats of endurance that never manifest over shorter distances.

* In 2017, Courtney Dauwalter won the Moab 240, finishing 9 h ahead of the man in second place. In 2019, Jasmine Paris won the 268 mile/431 km Montane Spine Race, breaking the course record by 12 h. And, in 2023, Camille Herron set a new 48 h world record by running 270.5 miles (435.3 km), beating the previous record (also held by a female) by 15.5 miles.

There is no definitive explanation for these trends, but it is generally thought that ultra-endurance depends less on maximal capacities (e.g., $\dot{V}O_2$max) that tend to favor males, and more on fatigue resistance and substrate efficiency that tend to favor females (Blaak 2001; Besson et al. 2021; Tiller et al. 2021). Notably, endurance performance is not only dependent on an athlete's physical status at the start line but also their ability to resist physiological perturbations as the race progresses. This quality, termed "resilience", may be an important determinant of endurance performance (Jones 2023). Indeed, we have previously shown that ultramarathon evokes less frequent physiological perturbations, with smaller effect sizes, in females compared to males with similar race performances (Tiller et al. 2022).

In the last decade, the media have speculated ad nauseam that females may be "built" for ultra-endurance sport, publishing headlines like "Why women rule", "Why women are better at ultrarunning", and "If male athletes can run fast, female athletes can run far". (Jhung 2010; Women's Running 2016; Williams 2019; Bloom 2020; Brueck 2020; Loudin 2020; Herron 2023; McKeown 2023; Palmer 2023). However, data supporting this assertion are confounded by lopsided participation numbers, with females comprising just 10%–30% of the field at any given race (Waldvogel et al. 2019; Tiller et al. 2021).

The sparse number of female ultramarathon runners probably leads to a false representation of their true abilities. On the one hand, a shallow athlete pool is unlikely to reflect the diverse capabilities of females more broadly, leading to an underestimation of their performance potential. On the other hand, females who enter extreme footraces in which they are outnumbered by males may be self-selecting as the strongest, toughest, and most determined of the sex, potentially overestimating the female propensity for ultramarathon. As such, if we are to obtain any clarity on the question of whether females are predisposed to ultramarathon, data from races where the sexes compete in similar numbers are essential (Tiller et al. 2021).

To our knowledge, only two ultramarathons have accomplished the challenging task of achieving parity in male/female participation numbers: the Baker Trail UltraChallenge, a 50 mile (80 km) race contested near Pittsburgh, Pennsylvania, and the High Lonesome 100, a 100 mile (170 km) race taking place in Chaffee County, Colorado. By equalizing participation numbers in events traditionally dominated by males, the race organizers have achieved a significant milestone for the sport. We considered this a unique opportunity to address three lingering questions in the scientific literature: (i) how is the sex-based discrepancy in ultramarathon performance affected when males and females compete in comparable numbers? (ii) are males or females more likely to place higher in 50 and 100 mile events? And (iii) does sex predict finish time in 50 and 100 mile races? Given that the disparity tends to be smallest in races where females compete in greater numbers, we hypothesized that the sex difference in performance would be mitigated or eliminated in races where males and females compete in comparable numbers, and that sex would not be a significant predictor of finish time.

Materials and methods

Study design

A retrospective analysis was performed on publically available race results from 2022 and 2023. To achieve parity in participation numbers, race organizers launched initiatives to expand the recruitment of females. These included free group training runs that provided safety and confidence-building for females running on trails, and equal allocation of places in the event to both sexes.

The 50 mile race (The Baker Trail UltraChallenge) is a point-to-point course, predominantly on compact and rocky trail, with 6320 ft (1926 m) of cumulative ascent. The male record of 07:29:56 was set in 2020, and the female record of 08:19:46 was set in 2012. The 100 mile race (the High Lonesome 100) is a high-altitude, single-loop course, predominantly on mountainous trail, with 23 500 ft (7163 m) of cumulative ascent. The male record of 20:58:57 and the female record of 23:40:29 were both set in 2022. Course profiles are shown in Fig. 1. Overall, 116 runners started the 50 mile race, of which 56 were male (48%) and 60 were female (52%); 143 runners started the 100 mile race, of which 69 were male (48%) and 74 were female (52%).

Data analysis

Anonymized data were sorted into groups of "males" and "females" based on the sex classification participants gave during online signup to the race. Thereafter, descriptive and inferential statistics were performed on age, sex, race rankings, and finish times using IBM SPSS Statistics v24 (IBM; Chicago, IL).

The Kolmogorov–Smirnov test, which is suitable for large samples ($n \geq 50$), was used to assess data for a normal distribution. Finish time comparisons between males and females were subsequently made using the independent-samples t test for parametric data or the Mann–Whitney U test for nonparametric data. To account for the false discovery rate with multiple comparisons, all p values were adjusted using the Benjamini–Hochberg method. Estimates of effect size for parametric data were made using Cohen's d (0.2 = small, 0.5 = medium, 0.8 = large) and for nonparametric data using a point biserial test (r) (-1.0 = perfect negative correlation and 1.0 = perfect positive correlation). Univariable and multivariable linear regressions were used to assess the relationships between sex, age, and finish time in each race. Lastly, a Chi-squared (χ^2) test of independence was used to examine the relationship between sex and race ranking, specifically to determine if males or females were more likely to finish in the top 20% of the field. Descriptive data were reported as mean ± SD for parametric data and median ± IQR for nonparametric data. Alpha was set at 0.05.

Results

Fifty miles

From 116 who started the race, there were 96 finishers of which 52 were male (54%) and 44 were female (46%). Finish times are compared in Table 1 and Fig. 2. The median overall

Fig. 1. Course profiles for the 50 mile race (top panel) and the 100 mile race (bottom panel).

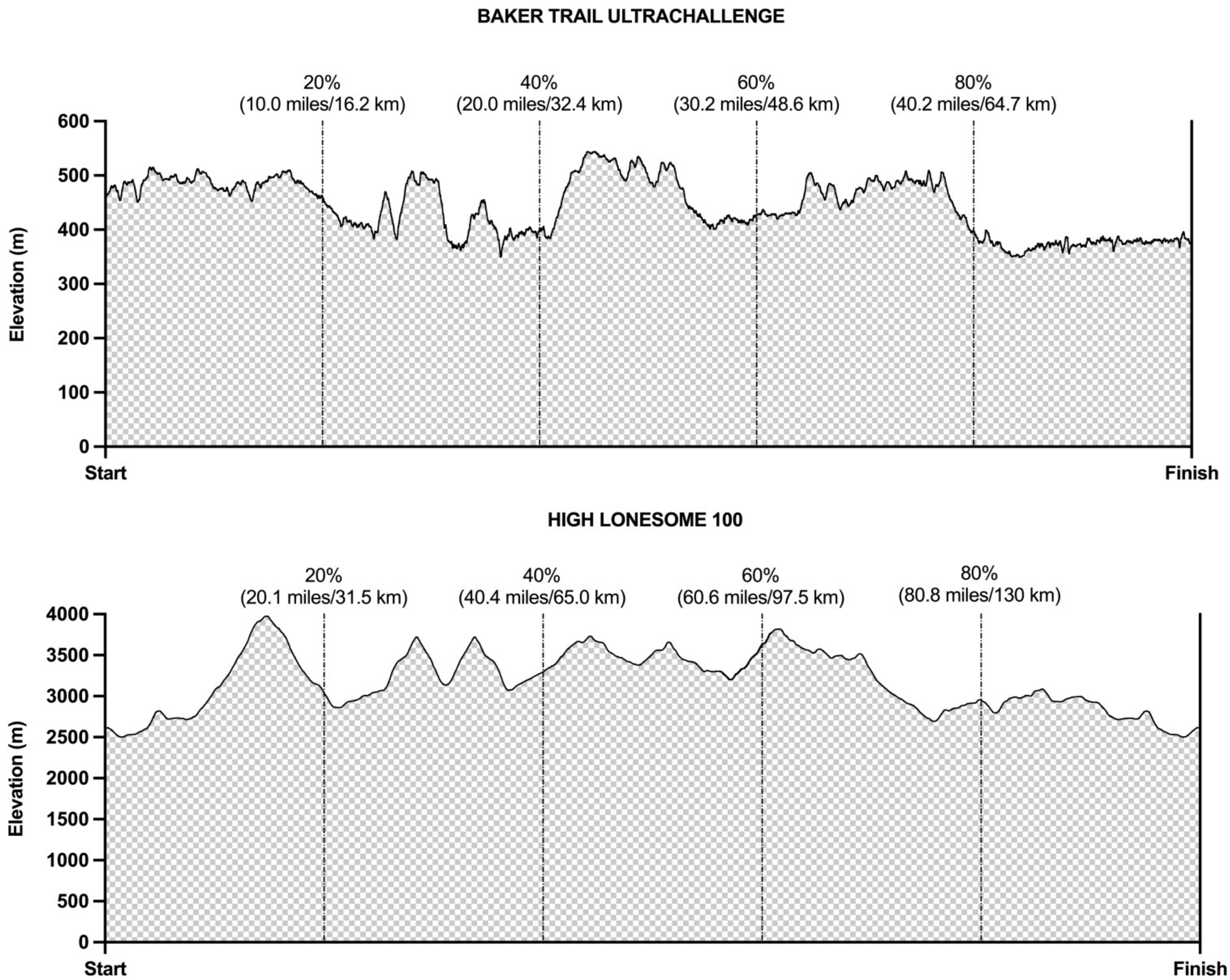


Table 1. Finish times for the 50 mile and 100 mile races.

	50 miles ($n = 96$)		100 miles ($n = 91$)	
	Overall	Top 10	Overall	Top 10
Males	12.49 ± 2.41	9.61 ± 1.25	31.13 ± 3.41	26.07 ± 2.29
Females	12.64 ± 1.98	11.03 ± 0.85	32.13 ± 3.25	27.24 ± 2.00
Percent difference	1.2%	13.8%	3.2%	4.4%
P	0.441	0.009*	0.079	0.120
ES	Small	Large	Small	Medium

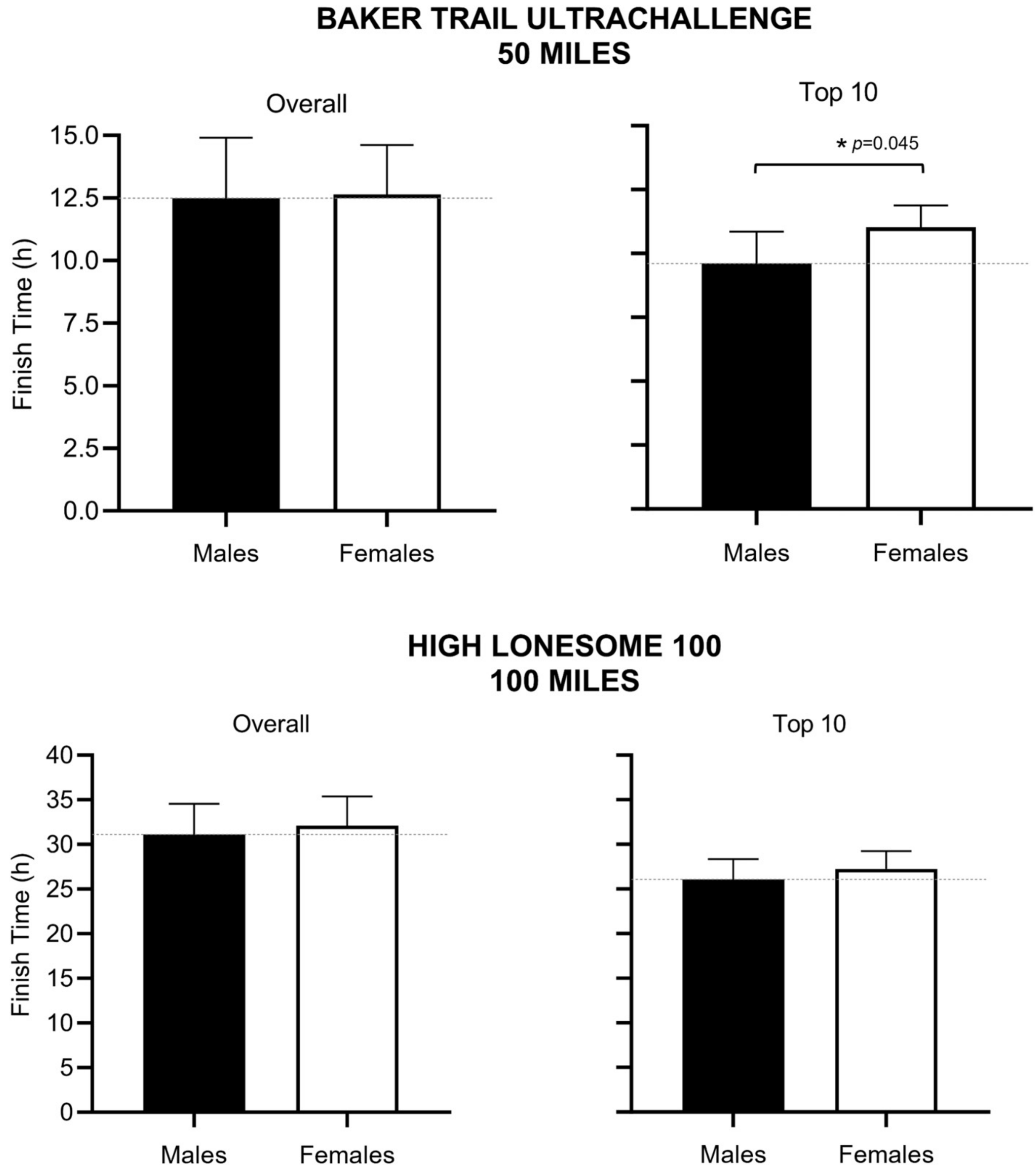
Note: ES, effect size; *p*, Benjamini–Hochberg adjusted *p* value from relevant test; *, significantly different (male vs. female). 50 mile data are median ± IQR, 100 mile data are mean ± SD.

finish time ($n = 96$) was 12.64 ± 2.11 h, with no difference between sexes ($z = -0.77$, $p = 0.441$, $r = -0.13$). However, the top-10 males were faster than the top-10 females ($z = -2.61$, $p = 0.045$, $r = -0.59$).

Univariable and multivariable linear regressions were used to assess the relationships between sex, age, and finish time. The univariable analysis showed that neither sex ($r^2 = 0.02$, $p = 0.224$) nor age ($r^2 = 0.02$, $p = 0.211$) predicted finish time in the 50 mile race. Moreover, the multivariable model combining sex and age did not predict finish time ($R^2 = 0.03$, $p = 0.267$).

The χ^2 test of independence examined the relationship between sex and ranking. The relationship was significant for the top 20% of finishers (χ^2 $(1 = 96) = 5.86$, $p = 0.015$), indicating that males were more likely than females to finish in the top 20% (19 places) (Fig. 3).

Fig. 2. Finish times for males and females in the 50 mile race (top panels) and the 100 mile race (bottom panels). In 50 miles, the difference in overall finish time was 1.2% ($p > 0.05$), with a difference of 13.8% ($p < 0.05$) for the top 10 finishers in each group. Over 100 miles, the difference in overall finish time was 3.2% ($p > 0.05$), with a difference of 4.4% ($p > 0.05$) for the top 10 finishers in each group.



Hundred miles

From 143 who started the race, there were 91 finishers of which 50 were male (55%) and 41 were female (45%). Finish times are compared in Table 1 and Fig. 2. The mean overall finish time ($n = 91$) was 31.58 ± 3.36 h, with no difference between sexes ($t = -1.42$, $p = 0.132$, $d = 0.30$). Moreover, there was no difference in finish times between the top-10 males and top-10 females ($t = -1.21$, $p = 0.150$, $d = 0.54$).

Univariable and multivariable linear regressions were used to assess the relationships between sex, age, and finish time. The univariable analysis showed that neither sex ($r^2 = 0.02$, $p = 0.159$) nor age ($r^2 = 0.00$, $p = 0.515$) predicted finish time in the 100-mile race. Moreover, the multivariable model combining sex and age did not predict finish time ($R^2 = 0.02$, $p = 0.351$).

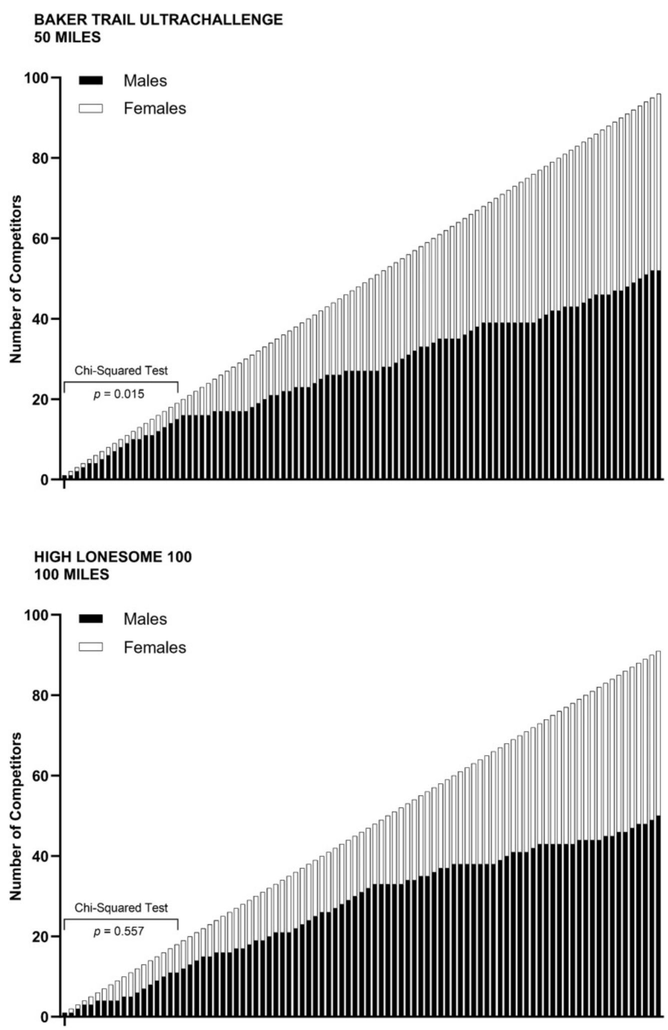


Fig. 3. Distribution of males and females by race rank in the 50 mile race (top panel) and the 100 mile race (bottom panel). For example, the top 20 places in 50 miles comprised 16 males and four females. A Chi-squared test of independence revealed that males were more likely to finish in the top 20% over 50 miles but not 100 miles.

The χ^2 test of independence was nonsignificant for the top 20% of finishers (χ^2 $(1 = 91) = 0.34$, $p = 0.557$), indicating that males and females were equally likely to finish in the top 20% (18 places) (Fig. 3).

Discussion

This is the first sex-based comparison of ultramarathon performances in races with comparable numbers of male and female finishers. The main finding confirms our hypothesis that there would be no significant difference in overall finish times between males and females in either 50 mile or 100 mile events and that sex would not be a significant predictor of performance. However, contrary to our expectations, the top-10 males in the 50-mile race were faster than the top-10 females, with the former more likely to finish in the top 20%. These differences did not manifest in the 100-mile race. Our data provide much needed clarity on several ongoing points of contention in the ultramarathon literature.

Main findings

Previous studies show a sex-based performance discrepancy of ~10% at the marathon (Deaner et al. 2015), ~9% over 50 miles (Waldvogel et al. 2019), ~5% over 24 h (Peter et al. 2014), and ~4% over 100 miles (Waldvogel et al. 2019). In addition, an analysis of nearly 40 000 trail races from 1989 to 2021 concluded that "The gap between men and women shrinks when trail running distance increases… the top male performers still outperform the top women [sic]". (Le Mat et al. 2023).

However, in all these published reports, females scarcely represented more than one-third of participants, with the actual number usually between 10% and 30%. We show that, when there were comparable numbers of male and female finishers, the average difference in finish time shrank to 1.2% over 50 miles ($z = -0.77$, $p = 0.441$, $r = -0.13$), a difference of 9 min, and to 3.2% over 100 miles ($t = -1.42$, $p = 0.132$, $d = 0.30$), a difference of 60 min. For context, this difference equates to 3–7 min over a typical nonelite marathon. Furthermore, sex, age, and a composite of the two failed to predict performance in either distance. Our findings support the notion that females diminish the performance gap to males in ultramarathons when the groups compete in comparable numbers (Tiller et al. 2021; Le Mat et al. 2023).

Although 60 min over 100 miles is a large difference at an individual level, it was not statistically significant in our cohort of 91 finishers ($p = 0.079$), and the overall effect size (i.e., the magnitude of the between-group difference) was small ($d = 0.30$). In addition, the pooled variance in finish time over 100 miles was around 3.3 h, which was three-times the between-group difference. This suggests that a considerable portion of the performance variance over 100 miles is not explained by sex. This observation is reinforced by results of the regression analysis which failed to predict finish time with either sex or age or a combined multivariable model ($R^2 = 0.02$, $p = 0.351$).

Top performers over 50 miles exhibited a markedly different trend, with the top-10 males approximately 14% (~85 min) faster than the top-10 females. In addition, the Chi-squared analysis revealed that the top 20% of finishers were more likely to be male (χ^2 $(N = 96) = 5.86$, $p = 0.015$) (Table 1, Figs. 2 and 3). Others have noted similar discrepancies in 50-mile ultramarathons. For instance, in races contested in Germany from 1971 to 2012, the 10 fastest males were, on average, ~17% faster than the 10 fastest females (Zingg et al. 2015). A difference of 17% was also reported for the world's fastest males and females in 50-mile events in North America (Coast et al. 2004). As such, although comparable finish numbers eliminated the sex difference in overall performance over 50 miles, a substantial discrepancy remained between the fastest males and females.

This finding is biologically intuitive because running at faster velocities places greater demands on maximal aerobic metabolism, a metric that tends to favor males. Indeed, running speeds at the metabolic thresholds predict ~95% of the performance variance over half-marathon (Gómez-Molina et al. 2017); maximal oxygen uptake ($\dot{V}O_2$max) predicts ∼60% of the variance in the marathon (Billat et al. 2001); and peak velocity at $\dot{V}O_2$max (v$\dot{V}O_2$max) predicts ∼80% of the variance over 50 miles (Coates et al. 2021). A composite of $\dot{V}O_2$max, maximal isometric strength, and body fat predict ∼92% of the performance variance over 100 km (Pastor et al. 2022). It therefore stands to reason that males, who tend to exhibit larger aerobic capacities (Santisteban et al. 2022), greater relative muscle torque (Besson et al. 2023), and less body fat, will retain a competitive advantage over females at higher running velocities.

That said, the relative contribution of aerobic capacity to running performance likely diminishes with increasing distance and decreasing speed (Davies and Thompson 1979). Several studies have shown that metrics of aerobic metabolism (e.g., $\dot{V}O_2$max and O_2 uptake at the metabolic thresholds) correlated with performance in races of 50–100 km but with no similar correlates in races of 100–170 km (Gatterer et al. 2020; Coates et al. 2021; Pastor et al. 2022). At the very least, this suggests that additional factors play increasingly important roles over "longer" distances; these factors likely include fatigue resistance and fat metabolism, both of which are greater in females (Blaak 2001; Besson et al. 2021). Also note that females tend to have lower body masses than males, a characteristic generally advantageous in endurance running, especially when running uphill (Berzosa et al. 2021; Lember et al. 2021). Accordingly, the 100-mile race, with its long duration (31.6 h), slow pace (5.13 km/h, 3.2 miles/h), large cumulative ascent (7163 m), and high altitude (>2500 m) may provide the very conditions that permit uniformity in finish times between the sexes.

Dropout rates

We did not anticipate a higher dropout rate in females. In fact, although females made up 52% of the starting field in both races, they comprised 45%–46% of finishers. We speculate the higher dropout rate in females was due to psychosocial rather than physiological factors. Parity in participation rates was achieved through recruitment strategies that targeted females. In particular, race organizers offered free group-training runs that provided safety in numbers and helped females that may be new to trail running to build confidence. While this may have helped athletes overcome the main barrier to entering ultramarathons (namely "finding the time to train" (Valentin et al. 2022)), it also encouraged the participation of some females who would never have normally entered an ultramarathon. In other words, these novel recruitment initiatives got disproportionately more females to the start line than the finish line. Our findings may, therefore, inform the development and implementation of similar recruitment initiatives in the future.

Relative to the male cohort, six fewer females completed the 50-mile course, and nine fewer females completed the 100-mile course. To determine if this was a meaningful difference, we compared the variance parameters of the two groups (male vs. female) in both races using an F-test—a ratio of the between-group variance to the within-group variance. An F-score with a value close to 1.0 would indicate samples with equal variances. We found no difference in variance between male and female finish times in the 50-mile race ($F_{51,43} = 1.48$, $p = 0.188$) or the 100-mile race ($F_{49,40} = 1.10$, $p = 0.759$). The lack of statistical significance suggests that any additional finishers would likely exhibit finish times in the existing range. We are confident therefore that the discrepancy in finish rate does not meaningfully influence the overall results. It is also worthy to note that the ratio of male-to-female finishers is still higher than in any previously published analysis on sex differences in ultramarathon performance.

Study limitations

First, this report examined just two races among several thousand contested each year around the world. Each race is run on various terrains with unique, sometimes extreme, environmental conditions. We therefore urge caution before extrapolating our findings to ultramarathon more broadly.

Second, given that we distinguish between "overall" and "top tier" performances, we do not know to what extent race organizers may have inadvertently discriminated against or encouraged the recruitment of top-tier females; it is unclear if the athletes recruited represented the "normal" population.

Third, it is worth considering whether our relatively small cohort (totaling 187 finishers) was appropriate for the statistical model. A sample size calculation revealed that 102 subjects (51 per group) would be required to detect a significant one-tailed, between-group difference (alpha 0.05, moderate effect, statistical power of 0.80). Due to a relatively high dropout rate in both sexes, we performed statistics on an average of 47 per group. Therefore, the analysis may be slightly underpowered. We encourage further studies in more datasets when/if they become available.

Conclusions

In ultramarathons with a comparable number of male and female finishers, the overall performance discrepancy shrinks to a nonsignificant 1.2% and 3.2% in 50- and 100-mile events, respectively. Moreover, sex is not a significant predictor of finish time. Yet, for the top-10 males and top-10 females over 50 miles, the disparity remains at ∼14%, suggesting that the top-performing males exhibit characteristics, likely physiological, that predispose them to better performances over shorter distances. The complexity of longer ultramarathons, and the additional factors underpinning performance, may lead to females competing on more equal terms. Our observations are preliminary and were only possible due to targeted initiatives that expanded the participation of females in ultramarathon. We hope these races will lay a foundation on which the future of the sport can be built.

Take-home message

The sex-based discrepancy in performance is not significant in ultramarathons characterized by comparable numbers of male and female finishers. However, the top-10 males are considerably faster than the top-10 females in 50 mile races.

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Data availability

The data used in this study are publicly available. Our analyses can be made available on reasonable request.

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Data curation: NBT
Formal analysis: NBT, CRI
Investigation: NBT
Methodology: NBT, CRI
Writing – original draft: NBT, CRI
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Competing interests

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