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Running title: Pacing analysis of UTCT 100km finishers

Pacing analysis and comparison of TOP-10 and NOT TOP-10 Ultra Trail Cape Town 100km finishers

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Abstract

Background: Pacing strategies during endurance efforts vary depending on athlete experience, race length, and terrain. In ultramarathon trail running the specific race route profile can have a significant impact on optimal pacing strategy. The purpose of this study was to determine the relationship between uphill, downhill and level running with overall performance and to compare the difference in pacing strategies between top 10 (TOP-10) and non-top 10 (NOT TOP-10) finishers of a 100km ultra-trail marathon with +5,000m elevation gain.

Methods: Fifty male finishers (TOP-10: n = 6, NOT TOP-10, n = 44) and forty-six individual segments (1.5 ± 1.2 km) were analysed based on 2021 100 km UTCT STRAVA data. Relative segment speed and CV% were used to identify pacing strategies. Spearman Rank and Mann Whitney-U tests were used to analyse the data. Significance was set at $p<0.05$.

Results: Uphill running had the strongest relationship with overall performance ($r = 0.826$, $p <0.01$). Substantially weaker relationships between overall running performance and level ($r = 0.402$, $p<0.01$) and downhill ($r = -0.382$, $p<0.01$) running performance were found. The CV% was significantly lower in TOP-10 (32.10 ± 1.81) than NOT TOP-10 (35.39 ± 4.43) ($U = 24$, $r = 0.46$, $p <0.01$).

Conclusions: Uphill running performance remains a valuable measure of overall trail running performance as it represents a higher percentage of overall running demand. TOP-10 runners have diminished decay in initial running speed than NOT TOP-10 runners, despite a generally high variation in pace and net positive split in ultra-trail running.

Keywords: trail running, marathon, ultramarathon, pacing, performance

Introduction

Ultra-endurance races have previously been defined as races longer than 4 hours[1, 2] or 6 hours[3] in duration. However, regarding running races, the Ultra Sports Science Foundation recently defined ultramarathon running by distance as, “any foot race longer than the traditional marathon distance of 42.195 km”[4, p280]. They also noted that ultramarathon races typically tend to take place in off-road environments typical of trail running[4]. In ultra-endurance running races of ≥100 km or ~24 hours in duration, optimal pacing strategy has typically been described as “more even” or with “less variation” in pace[5-10], indicated by a lower coefficient of variation (CV) in pace between segments in faster runners than slower runners. In reality, however, pacing strategies in these events are better described as a “reverse J-shaped” with runners typically starting the race quickly with a steady decrease in speed as the race progresses coupled with a surge in speed in the final section(s) of the race[5,10].

Pacing strategies are learned behaviours adopted by athletes during endurance races whereby they control the rate of energy expenditure to complete a race in the fastest possible time yet minimise the amount of homeostatic disturbance to the body[11]. An example of this is when an athlete’s prior knowledge of how to complete a race is coupled with feedback on the demand of the race by the body’s internal receptors, which collectively play an important role in pacing[11]. One might adopt many different pacing strategies during an endurance race, including negative (progressively faster), positive (progressively slower), parabolic-shaped (starting and ending faster), and even (similar throughout) pacing strategies[12]. Optimal pacing strategy, however, appears to be associated with running race distance, with varying pacing strategies considered optimal depending on race length[13].

In road marathon running for example, while contemporary world record holders adopted a negative pacing strategy[14], it has been suggested that an even pacing strategy might be the optimal pacing strategy to improve on these performances[13,14]. Pacing strategies are, however, not only affected by race distance, but by other factors, including but not limited to; pack running dynamics, environment (altitude and surface technicality), temperature, surface gradient and net gain/loss[13]. However, in two separate 100 mile ultra-trail marathons with considerable elevation gain/loss, it was found that a more even pace was associated with a faster average pace[15] and that winners had a lower CV in mean pace (12%) than other top five finishers (14 – 15%)[16].

It could be argued that the undulating terrain in ultra-trail marathons renders even pacing impossible. This is indicative of language used in ultra-trail marathon pacing research such as "steadier"[15] pace and "limiting"[16] speed fluctuations. These contemporary analyses of pacing strategies in ultra-marathon settings have relied on checkpoint timing data and are therefore limited in their capacity to identify the relative importance of uphill, downhill and level running performance in distinguishing overall race performance. Additionally, more contemporary research on pacing in ultra-trail marathons is required in order to determine whether even pacing or reverse J-shaped strategies are optimal in races with high degrees of elevation gain/loss.

Therefore, the purpose of this study was to determine the relative importance of uphill, downhill and level running for overall ultra-trail marathon performance, and to determine whether there was a difference in pacing strategy for top 10 runners versus non-top 10 runners in a 100 km ultra-trail marathon with ~5,000m positive elevation gain. It was hypothesised that uphill and downhill running performance would be better correlates with overall performance owing to the large amount of vertical elevation gain and loss over the course of the race. Additionally, it was hypothesised that top 10 runners would present with a more even pacing profile than non-top 10 runners.

Materials and methods

This study was approved by the Stellenbosch University Health Research Ethics Committee (HREC) panel one (coordinator: Melody Shana) on 13 December 2022 (HREC No: S22/01/009) prior to data analysis. The study was conducted in accordance with the principles set forth in the Declaration of Helsinki.

Study Design

The study utilised a retrospective observational design with an analysis of quantitative data. The race from which the pacing data was derived was the 2021 edition of the Ultra Trail Cape Town (UTCT) 100 km race. The exact distance and positive elevation gain of this race (as per the race website) are 98 km +4972m with a 24-hour cut-off time for completion. On the race day, the mean day time temperature was 18.6 °C with no rain, and a mean wind speed of $30.4 km \cdot h^{-1}$ (max $46.7 km \cdot h^{-1}$) north to north-western wind (www.wunderground.com).

Study Sample

A purposive sample of male runners who completed the UTCT 2021 100 km race were included in this analysis. In order to be included, participants had to be male, have completed the UTCT 2021 100 km race within the cut-off time, have recorded their complete race via GPS technology, and have uploaded the race on their public STRAVA account to be included in the analysis. Two groups of runners were identified: Top 10 (TOP-10) finishers (n = 6) and non-top (NOT TOP-10) 10 finishers (n = 44). TOP-10 finishers were 'males who finished in the top ten of their sex categories regardless of age' and were purposively selected for the analysis. NOT TOP-10 finishers were defined as 'males who finished outside of the top ten of their sex categories regardless of age' and were a random sample of all the rest of the field participants who met the inclusion and exclusion criteria below.

Data Collection

The race pacing data of each participant were analysed by various pre-existing STRAVA segments on the UTCT 100 km route. The different segments were classified as either; 'uphill' (a segment with a net positive elevation difference of >1.0% and without any negative gradients), 'level' (a segment with a net elevation difference between -1.0% and +1.0%), or 'downhill' (a segment with <-1.0% gradient and without any positive gradients). In addition, a sub-analysis of moderate uphill (>1% till ≤10%) and steep uphill (<10%) was performed, as well as moderate downhill (> -1% till ≤ -10%) and steep downhill (<10%). An overview of the different segments within the UTCT can be found in **Table I**. The combined segments covered a total of 64 km of the 100 km UTCT distance.

Table I: Description of Strava segments existing on the Ultra Trail Cape Town (UTCT) 100 km route.

Strava Segment Name	Distance (km)	Lowest Elevation (m)	Highest Elevation (m)	Elevation Difference (m)	Average Gradient (%)	Category (sub category)
UTCT 2018 Signal/Lions Transition	5.34	74	301	227	4.1	Uphill (M)
Lion's Head Boom to Top of Jeep Track	0.86	303	375	72	8.2	Uphill (M)
LionHeart TT Split to Canons	1.24	313	469	-156	-10	Downhill (M)
Lions Head Signal Hill Final Climb	0.99	262	328	66	6.6	Uphill (M)
Noon Gun Fireroads Down	0.92	192	343	-151	-16.4	Downhill (S)
Hill Road Climb	1.23	151	262	111	9	Uphill (M)
Kloof Nek Rd to India Venster start	1.86	233	493	260	13.8	Uphill (S)
UTCT TM Contour	1.97	489	502	-13	-0.4	Level
UTCT Platteklip	1.4	507	960	453	32.2	Uphill (S)
Platteklip to Maclear's Beacon – Cliff Face Route	1.9	1054	1077	23	0.7	Level
Ultra-trail CT: Smuts	0.71	909	1059	-150	-21	Downhill (S)
UTCT Echo Valley	1.06	872	911	-39	-1.5	Downhill (M)
Theresa Ave Climb	0.97	872	965	93	9.5	Uphill (M)
UTCT Dams>Nek	5.11	283	767	-484	-9.5	Downhill (M)
UTCT Orangekloof	2.62	148	270	-122	-2.5	Downhill (M)
Hunters Way Climb	0.3	169	215	46	15.1	Uphill (S)
UTCT Ruyteplaats	1.76	193	213	20	0.9	Level
Roots to car	0.42	140	200	-60	-13.6	Downhill (S)
UTCT Coastal Stretch	4.25	51	85	34	0.8	Level
UTCT Rocket House Climb	0.4	85	198	113	27.8	Uphill (S)
UTCT Rocket Rd	1.74	213	230	17	1	Level
UTCT Suther Peak	1.36	234	645	411	30.2	Uphill (S)
Bay View Road Climb	0.68	527	597	70	10.2	Uphill (S)
Down the Karbonkel	3.98	301	759	-458	-11.5	Downhill (S)

UTCT Hout Bay Harbour & Beach	1.16	63	66	3	0.1	Level
Chappies – The steep part	1.1	9	68	58	5.3	Uphill (M)
Manganese Mines Climb	4.54	62	526	464	10.2	Uphill (S)
Bay Rd Climb	0.79	389	533	143	18.1	Uphill (S)
Vlakkenberg Rocky ST Descent T-J to Hiking Sign	1.86	244	536	-292	-15.2	Downhill (S)
Half Alphen Down	1.82	57	189	-132	-7.2	Downhill (M)
Klaasenbosch Trail	1.35	106	172	66	4.8	Uphill (M)
Cecelia Commute to Kirstenbosch Contour Juncture	1.39	201	343	142	10.2	Uphill (S)
Nursery Ravine Climb	0.62	341	378	46	7.4	Uphill (M)
Contour to Skeleton Gorge	1.36	298	370	72	1.5	Uphill (M)
UTCT Dragon	0.77	370	507	137	9.8	Uphill (M)
Pyramid Step-down (Northside)	0.5	343	437	-94	-18.5	Downhill (S)
UTCT Newlands Forest	1.76	399	413	14	-0.4	Level
Ultra-trail CT: Saddle Link down	0.43	241	354	-113	-26.1	Downhill (S)
Snakebite ST down, lower section (Deadman's hill to road)	0.24	199	254	-55	-22.3	Downhill (S)
UTCT Rhodes Estate	0.84	120	203	83	-9.8	Downhill (M)
Lion cage heading up	0.42	115	172	57	13.3	Uphill (S)
Road to peak (The Orcs)	0.82	183	237	54	6.6	Uphill (M)
Last climb UTCT	0.8	218	433	215	26.8	Uphill (S)
Tafelberg Rd Climb	0.37	461	535	74	20	Uphill (S)
TT chase the beers	1.6	418	514	-96	-6	Downhill (M)
UTCT Deadmans Descent	1.56	238	382	144	-9.1	Downhill (M)

Key: +m = meters above sea level, Avg = average, Elev = elevation, M = moderate, S = steep, UTCT = Ultra Trail Cape Town

Data Analysis

A total of 46 segments were identified resulting in n = 2,300 (46 x 50 participants) individual segments for analysis. In total, 39 individual segments were excluded from the analysis due to incomplete GPS data for a final sample of n = 2,261. The relative pace for each segment ($segment_{rel}$) was determined using the following formula:

$$Segment_{rel} = Segment_{abs} \div \text{Average pace}$$

where $segment_{abs}$ = absolute pace of the segment (mm:ss·km^{-1}) (6) and average pace = average pace (mm:ss·km^{-1}) of the entire race as per electronic timing system.

Data Availability

The data associated with the paper are not publicly available but are available from the corresponding author on reasonable request.

Statistical Analysis

All pacing analyses were conducted on the relative pace ($segment_{rel}$) of the runners, which is expressed as a percentage of the overall race pace. All data included in the analysis was tested for normality using the Shapiro Wilk test. The majority of data was not normally distributed. As such, all data is presented as medians and interquartile ranges, and all correlation tests are Spearman Rank correlations. Pace variation between various $segment_{rel}$ segments through the race was calculated via a coefficient of variation (CV%)[6, 15, 16]. CV% in pace was determined using the following formula:

$$SD\ segment_{rel} \div \text{mean } segment_{rel} \times 100$$

where SD = standard deviation, and mean $segment_{rel}$ = average of relative segment pace for the n=46 segments.

The relationship between climbing category performance ($segment_{rel}$) and total finish time was explored using Spearman Rank correlations. Correlation coefficient descriptors were considered; negligible (rho = 0.00 – 0.10), weak (rho = 0.10 – 0.39), moderate (0.40 – 0.69), strong (0.70 – 0.89) and very strong (rho = 0.90 – 1.00)[17)].

For comparisons between TOP-10 and NOT TOP-10 runners, a series of Mann Whitney-U tests were conducted on all 46 segments $segment_{rel}$ and for CV%. Effect sizes (r) were calculated using the following formula:

$$r = Z \div \sqrt{n}$$

where Z = the standardised test statistic and n = the number of pairs[18)]. The r value was interpreted as small ($r < 0.3$), medium ($r = 0.3 – 0.5$) or large ($r > 0.5$)[19)]. For all analyses statistical significance was set as $p < 0.05$.

Results

There are two levels of analyses presented the first of which is related to uphill, level and downhill segments, the second of which is related to the differences between TOP-10 and NOT TOP-10 runners.

Uphill, level and downhill segment analysis

The total race distance captured for pacing analyses was 69.2 km with 29.7 km of uphill running segments, 14.5 km of level running segments, and 24.9 km of downhill running segments. The average distance of the n = 23 uphill segments was 1.3 ± 1.2 km, while the average distance for the n = 7 level segments was 2.1 ± 1.0 km and the average distance for the n = 16 downhill segments was 1.6 ± 1.4 km. The average gradient for uphill segments was 13.1 ± 8.8%, while the average gradient for all level segments was 0.4 ± 0.6% and the average gradient for downhill segments was -12.5 ± 7.0%. The average pace ($mm:ss \cdot km^{-1}$) for all runners on uphill segments was 13:41 ± 05:49, while it was 08:53 ± 02:11 for level segments and 10:23 ± 03:56 for downhill segments. The relationship between various categories of climb and overall race time is presented in **Table II**.

Table II: Spearman's correlation between climb categories segment$_{rel}$ and overall race time.

Climb category	r value	p value
Uphill	0.826	<0.01
Moderate uphill	0.776	<0.01
Steep uphill	0.733	<0.01
Level	0.402	<0.01
Downhill	-0.381	<0.01
Moderate downhill	-0.493	<0.01
Steep downhill	-0.150	0.298

Difference between TOP-10 *and* NOT TOP-10 *runners*

The average race time (hh:mm:ss) for all (n = 50) runners was 17:24:05 ± 03:53:23 with TOP-10 runners (n = 6) completing the race in 10:48:03 ± 00:41:42 and NOT TOP-10 runners (n = 44) in 18:18:05 ± 03:12:21. The average pace (mm:ss·km^{-1}) for all runners was 10:39 ± 02:23 with TOP-10 runners' pace at 06:37 ± 00:26 and NOT TOP-10 11:12 ± 01:58. The difference in absolute speed between TOP-10 runners and NOT TOP-10 runners for each segment is illustrated in **Figure 1** below.

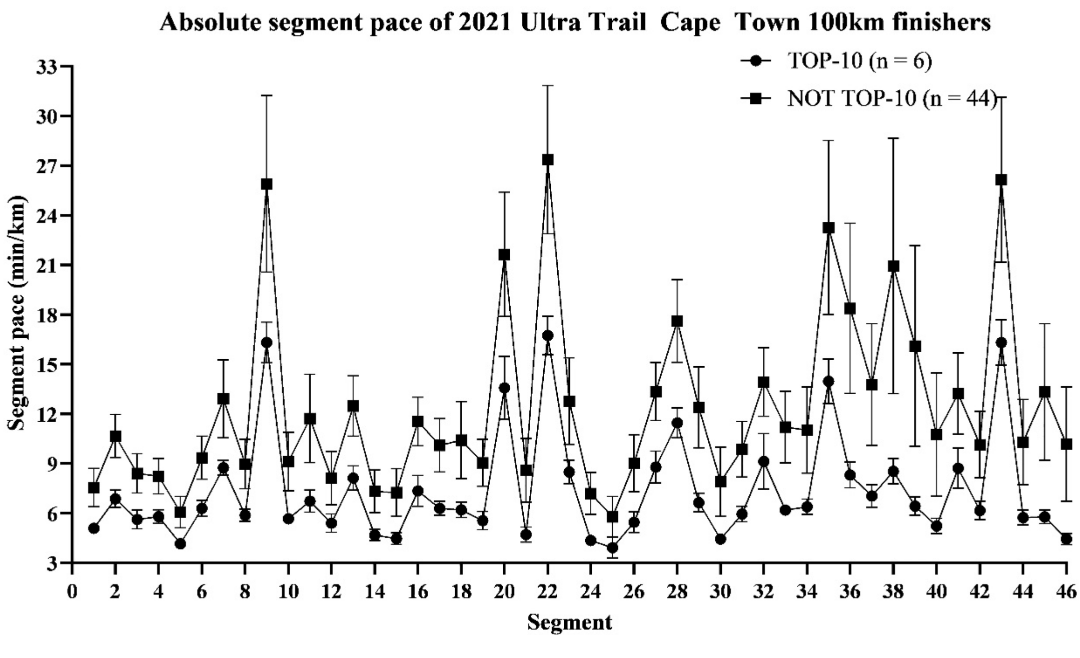

Figure 1: Difference Between TOP-10 and NOT TOP-10 Runners in Absolute Running Speed

When comparing relative pace (segment$_{rel}$) of TOP-10 to NOT TOP-10 runners there was a significant difference in pace within 26 of the 46 segments (56.5%) observed during the race, including 10 uphill segments (moderate = 4, steep = 6), 4 level segments, and 12 downhill segments (moderate = 6, steep = 6) (see **Figure 2**). Of the 26 statistically significant differences in segment$_{rel}$ pace between TOP-10 and NOT TOP-10 runners, 18 segments (69.2%) were run faster by NOT TOP-10 runners. When further subdividing the 46 segments into quartiles (Q1 – Q4), the distribution of the 26 statistically significant differences between groups was as follows: Q1 (n=8), Q2 (n=5), Q3 (n=5), and Q4 (n=8). Of the 26 segments with statistically significant differences between groups, NOT-TOP 10 runners segment$_{rel}$ pace was faster in 100% of Q1, 100% of Q2, 80% of Q3 and 12.5% of Q4 segments.

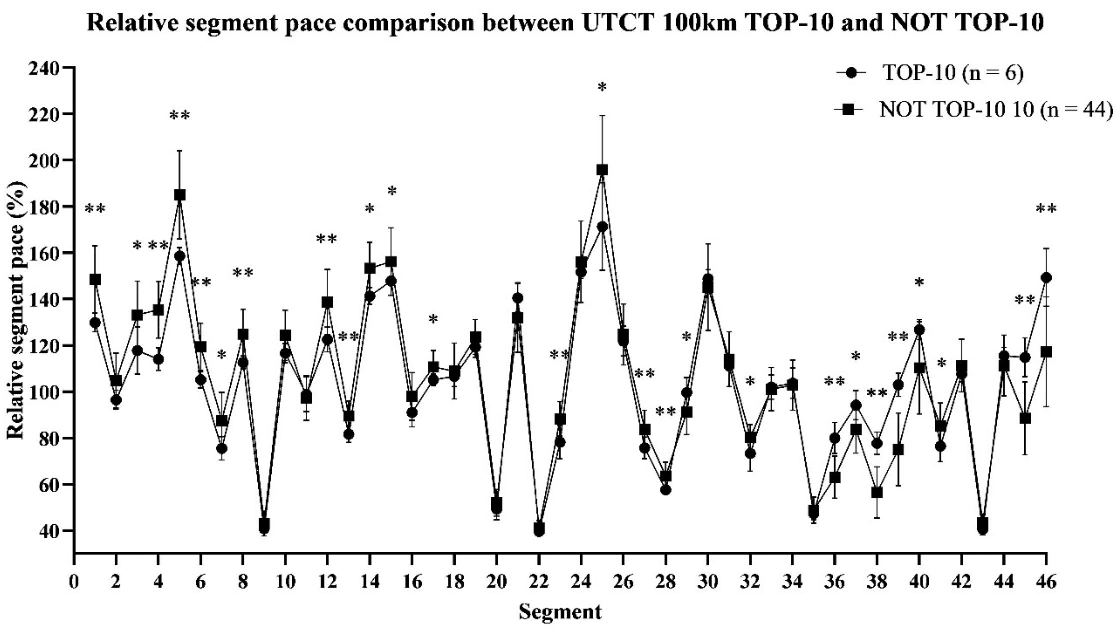

Figure 2: Difference Between TOP-10 and NOT TOP-10 Runners in Relative Running Speed

The CV% between all segments for the entire group (n = 50) was 34.82 ± 4.26 with a statistically significant difference in overall race CV% (U=24, p<0.01, r=0.46) between TOP-10 (32.10 ± 1.81) and NOT TOP-10 (35.39 ± 4.43). Furthermore there were statistically significant differences in CV% between groups for level (TOP-10: 21.98 ± 7.03, NOT TOP-10: 27.96 ± 6.46; U=37.5, p<0.01, r=0.40), downhill (TOP-10: 21.79 ± 2.06, NOT TOP-10:

32.82 ± 10.27; U=3.5, p<0.01, r=0.54), moderate uphill (TOP-10: 22.58 ± 1.68, NOT TOP-10: 24.90 ± 3.00; U=51, p<0.05, r=0.35), steep downhill (TOP-10: 28.08 ± 1.85, NOT TOP-10: 44.98 ± 11.82; U=2, p<0.01, r=0.55), and moderate downhill (TOP-10: 12.46 ± 2.74, NOT TOP-10: 19.61 ± 12.33; U=31.5, p<0.01, r=0.42) but not for uphill (TOP-10: 35.33 ± 2.85, NOT TOP-10: 34.63 ± 3.34; U=130.5, p=0.964, r=0.01) or steep uphill (TOP-10: 35.23 ± 1.06, NOT TOP-10: 33.73 ± 4.91; U=91, p=0.217, r=0.17).

Discussion

The main findings of this study were that relative uphill pace had a stronger relationship with overall performance than level and downhill running. Additionally, pacing strategies differed between TOP-10 and NOT TOP-10 runners, with both groups demonstrating a positive pacing strategy but with TOP-10 runners starting the race at a slower relative pace and finishing with a faster relative pace than their NOT TOP-10 counterparts. Both groups elicited a large CV%, and although TOP-10 runners had a lower CV% in relative pace, the pacing strategy of both groups should not be described as even.

The segmental analysis in this study only allowed for 69.2 km of the 100 km race to be analysed, with uphill running representing 29.7 km, downhill running 24.9 km, and level running 14.5 km of the 69.2 km respectively. While difference in uphill running distance and downhill running distance was just 4.8 km, there was a marked difference in the mean amount of time spent running uphill (6hr 18min) and downhill (3hr 36min) during the 46 segments analysed. This 2hr 42min difference in the total amount of time spent between uphill and downhill running due to the difference in average uphill running pace (12:42$\cdot$km^{-1}) and downhill running pace (09:13$\cdot$km^{-1}) in this study. Previous ultra-trail marathons between 100 km and 100 miles have reported a mean difference in pace between uphill and downhill running of -57.03%[20)] which is similar to the difference in this study (-37.75%). Uphill running has a much greater physiological/metabolic demand than downhill running[21)] owing to the greater mechanical work and stronger, more energetically demanding, concentric muscle actions[22)]. It is therefore likely that the stronger correlation between uphill running and overall performance in this study is due to a) the greater proportion of uphill running in the segmental analysis, and b) the greater proportion of overall race performance spent in uphill conditions due to slower movement over this terrain.

Both groups demonstrated a net positive pacing strategy over the course of the ultra-trail race, consistent with findings in races of similar distance[6,8)] and terrain[16,20,23)]. However, faster (TOP-10) runners had a much more gradual decline in relative pace than slower (NOT TOP-10) runners - starting the race relatively slower and finishing the race relatively faster. Indeed, of the first 17 segments in the race, there were 12 segments in which a statistically significant difference in $segment_{rel}$ was determined between groups and, in all 12 of these segments, the TOP-10 group was always relatively slower than NOT TOP-10. This is consistent with previous literature which found that better runners start the race more conservatively[5,8,9)] which is likely due to an improved 'teleoanticipatory system'[24)] or better physical adaptations to the terrain of ultra-trail marathons[20)]. This increasing margin between faster and slower runners as the race progresses could be exacerbated by herd behaviour[5,10)] in which fatigue ensued prematurely in slower runners[5)]. Related to this, 8 of the final 11 segments of the race displayed statistically significant differences in $segment_{rel}$ between the top 10 and NOT TOP-10 runners. Again, consistent with prior research[5,8,9)], faster (TOP-10) runners ran faster than slower (NOT TOP-10) runners in the latter portion of the race with 7 of the 8 statistically significant differences indicative of faster $segment_{rel}$ in TOP-10 runners.

In a recent publication[20)] it was found that, during ultra-trail running, better finishers typically run the uphill segments at a slower relative pace than worse finishers while running downhill segments at a faster relative pace than worse finishers. Additionally, this effect was exacerbated later on in races, possibly due to the improved ability of better finishers to tolerate the neuromuscular fatigue associated with ultra-trail running. In this study, of the 12 segments at the beginning of the race in which the NOT TOP-10 ran faster, 41.67% (n = 5) were uphill segments, 41.67% were downhill segments, and 16.67% (n = 2) were level segments. However, of the 8 segments towards the end of the race, 75.00% (n = 6) were downhill segments, 12.50% (n = 1) were uphill, and 12.50% were uphill and the only segment in which the NOT TOP-10 runners ran a significantly faster $segment_{rel}$ was in the one uphill segment.

While TOP-10 runners did exhibit a statistically significantly lower CV% in $segment_{rel}$ compared to the NOT TOP-10 runners in this study (32.10 ± 1.81% vs 35.39 ± 4.43), these were significantly higher than previously reported in top 5 runners of a 100 mile ultra-trail marathon[16)]. This could be to do with the sensitivity of the segmental analysis in this study, with 46 segments included with an average distance of 1.5 ± 1.2 km as opposed to previous pacing analyses, which have relied on electronic timing system data only. As such, this analysis provides further clarity to the extent of pace variation caused by constantly fluctuating gradients during trail running. That being said, a "more even" approach to pacing still seems to indicate a more optimal approach to pacing during ultra-trail marathons[15,16,20)], and recreational ultra-runners should adopt a more patient approach to their race start in order to improve ultra-marathon performance[10)].

Strength, weakness, limitations, implications for future research

The unique strength of this study was in the sensitivity of the segmental analysis. The use of STRAVA data and segments created by the public users resulted in low levels of bias in the analysis, and also allowed for a unique pacing analysis in the ultra-trail marathon space. Previous research has relied on electronic chip timing implemented by race organisers for participant tracking which typically resulted in long segments incorporating both uphill, level, and downhill running between timing points. This study utilised a strict inclusion criterion for segments whereby no downhill running was allowed in uphill running segments and vice versa. This allowed for detailed insights into uphill, level and downhill running performance as well as much shorter segments (1.5 ± 1.2 km) to examine changes in pacing behaviour. This strength, however, was also a weakness as not all race finishers met the strict inclusion criteria requiring complete race GPS data and a STRAVA profile. Additionally, not all the 100 km route was captured due to the reliance on publicly available segment data. Future researchers should consider conducting prospective research studies whereby participants (both male and female) are contacted prior to a race of interest. Races of multiple distances and over multiple years should be conducted in order to create a clearer picture of optimal pacing strategy and the differences in approach between uphill, level and downhill segments. Furthermore, future researchers should consider using alternative methods for pacing analysis capable when doing prospective research, such as the use of heart rate, power, or rating of perceived exertion coupled with absolute and relative pace.

Practical applications

The findings of this study have important implications for ultra-trail runners and coaches/practitioners. For novice and recreational runners, it is advised not to begin the race too hard and rather adopt a more conservative pacing strategy. This ‘herd behaviour’, characterised by NOT TOP-10 runners consistently running faster relative segment pace in the first three quartiles of the race, results in a significant decay in speed in the last quartile of the race and particularly during downhill segments. It is also important to note that a decay in speed over the course of an ultra-trail marathon is to be expected and participants should not be alarmed if this is the case. Ultra-trail runners and coaches/practitioners are advised to include a high degree of race specific stimulus in their training and testing, most importantly in the uphill running condition. Previous research[25)] has suggested that trail runners be tested in uphill running conditions in both maximal and submaximal tests at a variety of degrees of gradient to better simulate the demands of racing. Finally, trail runners are encouraged to use pacing measures other than absolute or relative speed when pacing themselves during an ultra-trail race. The fluctuations in absolute speed make for difficult understanding and therefore heart rate, power and/or perceived effort are proposed to be used alongside speed.

Conclusions

Pacing during ultra-trail marathons is characterised as a positive pacing strategy with both TOP-10 and NOT TOP-10 demonstrating a steady decline in speed over the duration of a 100 km race with +5,000 m elevation gain. Relative pace CV% is high amongst all levels of 100km ultra-trail marathon runners (34.82 ± 4.26) and, although TOP-10 finishers exhibit a lower CV% than NOT TOP-10 finishers, optimal pacing strategy should not be described as even. NOT TOP-10 finishers start the race with a greater relative segment pace which persists throughout the first three quartiles of the race. However, the TOP-10 runners consistently run at a faster relative pace in the last quartile of the race. Additionally, the magnitude of the difference between groups increases later on in the race, particularly during downhill segment running. Uphill segment running performance had the strongest association with overall running performance in an ultra-trail marathon likely due to a higher proportion of overall race demand.

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Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Authors' contribution

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