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**ORIGINAL ARTICLE**

# The influence of performance level, age and gender on pacing strategy during a 100-km ultramarathon

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**Abstract**

The aim of this study is to analyse the influence of performance level, age and gender on pacing during a 100-km ultramarathon. Results of a 100-km race incorporating the World Masters Championships were used to identify differences in relative speeds in each 10-km segment between participants finishing in the first, second, third and fourth quartiles of overall positions (Groups 1, 2, 3 and 4, respectively). Similar analyses were performed between the top and bottom 50% of finishers in each age category, as well as within male and female categories. Pacing varied between athletes achieving different absolute performance levels. Group 1 ran at significantly lower relative speeds than all other groups in the first three 10-km segments (all $P < 0.01$), and significantly higher relative speeds than Group 4 in the 6th and 10th (both $P < 0.01$), and Group 2 in the 8th ($P = 0.04$). Group 4 displayed significantly higher relative speeds than Group 2 and 3 in the first three segments (all $P < 0.01$). Overall strategies remained consistent across age categories, although a similar phenomenon was observed within each category whereby 'top' competitors displayed lower relative speeds than 'bottom' competitors in the early stages, but higher relative speeds in the later stages. Females showed lower relative starting speeds and higher finishing speeds than males. 'Top' and 'bottom' finishing males displayed differing strategies, but this was not the case within females. Although pacing remained consistent across age categories, it differed with level of performance within each, possibly suggesting strategies are anchored on direct competitors. Strategy differs between genders and differs depending on performance level achieved in males but not females.

**Keywords**: *Pacing, endurance, performance, ageing*

## Introduction

Effective pacing is an essential component of endurance performance (Foster et al., 1993) and has been widely studied in various modes of exercise in both laboratory and field settings in recent years. Although pacing has been proposed to be regulated through the mechanism of teleoanticipation (Ulmer, 1996) whereby afferent physiological feedback is continually interpreted in light of knowledge of the end point of an exercise bout, there is also an evidence that non-physiological factors can influence decisions informing the pacing strategy adopted. For example, analysis of the female World Championship marathon race demonstrated that pacing strategies appeared to be influenced by competitor's absolute performance level (Renfree & St Clair Gibson, 2013). Less successful athletes adopted speeds similar to the leaders in the early stages before slowing in the second half. Similar observations have also been made by Hanley (2014) and Esteve-Lanao, Larumbe-Zabala, Dabab, Alcocer-Gamboa, and Ahumada (2014) who both analysed results from the IAAF World Cross Country Championships. Although the precise mechanisms underpinning this phenomenon are unclear, it has been suggested that they may be evidence of the 'herd principle' informing athletes decision-making with regards to the starting speed selected (Renfree, Martin, Micklewright, & St Clair Gibson, 2014). This proposes that the easiest decision to make is to do the same as other group members (Bannerjee, 1992).

Other factors besides performance level have also been demonstrated to influence the pacing strategy adopted. For example, March, Vanderburgh, Titlebaum, and Hoops (2011) demonstrated gender may be important, and that females pace themselves

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more evenly than males during marathons. On a theoretical level, males have also been demonstrated to typically display higher levels of competitiveness and win orientation than females (Gill, 1988), and these factors may further influence the pacing strategy during a competitive event.

Another factor that may be expected to potentially influence the pacing strategy is increasing age. A number of physiological parameters have been suggested to be responsible for observed reductions in endurance performance with age (Reaburn & Dascombe, 2008; Tanaka & Seals, 2008), but it also seems that motivational factors change as athletes age. Reaburn and Dascombe (2008) found that older athletes display reduced motivation to train at previous intensities, and that motivation for participation in masters competition changed, with social interaction increasingly becoming the primary motivator. Given that motivation has been suggested to be a determinant of starting speed in competitive endurance events (Marcora & Staiano, 2010; Renfree et al., 2014), it would be plausible to suggest that age may influence the pacing strategy displayed in competitive endurance activities.

Despite this increasing body of research into factors influencing the pacing strategy, a limitation of previous studies is that most have examined the influence of individual factors in isolation. With regards to gender, Renfree and St Clair Gibson (2013), Hanley (2014) and Esteve-Lanao et al. (2014) all only studied either female or male athletes running in isolation from the other gender. March et al. (2011) did examine the influence of overall performance level, age and gender on pacing during marathon running, but used simple regression analysis to identify relationships between these variables and strategy displayed in three successive occurrences of the same race. Whilst valuable in identifying associations between these factors and pacing, this analysis nonetheless does not allow identification of the influence of direct competition between athletes of the same gender and age category. It could also be suggested that due to the nature of the participants analysed in the study by March et al. (2011), the findings may not be generalisable to more highly trained populations. Participants were included on the basis of achieving an average run speed of 2.3 m s$^{-1}$ which would imply that many were recreational rather than performance-orientated competitors. It would seem possible that the motivational characteristics of these competitors may differ substantially from more elite competitors who are highly motivated and goal-driven (Mallet & Hanrahan, 2004).

Given the potential influence of numerous internal and external factors in informing decisions regarding selection of strategies adopted, it is necessary to analyse the influence of those previously identified in a competitive environment where all are present. The aim of this study is, therefore, to examine the influence of absolute performance level, age and gender on pacing strategy during a single endurance event incorporating both male and female athletes competing in a range of differing age categories.

## Methods

A quasi-experimental design was used to address the aims of the study which had prior ethical approval from an institutional ethics committee. Given that the raw data were already freely available in the public domain, the gaining of informed consent from individual athletes was not considered necessary.

Final results and intermediate split times (individual 10 km segments) of all finishers ($n$ = 196) in the open 100-km race incorporating the 2011 World Masters Athletics Ultra Championships event held in Winschoten, the Netherlands were accessed via the championship website (http://www.world-masters-athletics.org/files/results/winschoten/2011_100k_Laps.pdf). This race was selected because of the large volume of data available and the fact that male and female athletes representing senior and masters age groups competed directly against one another. In total, there were 139 male competitors and 57 female competitors, and there were 93, 52, 26, 13, 12 and 7 athletes in the open (SEN), over 40 (V40), over 45 (V45), over 50 (V50), over 55 (V55) and over 60 (V60+) age groups, respectively. As speeds are more symmetric, normally distributed, and linearly related to other variables (Nevill & Whyte, 2005), times were converted to average running speeds (m s$^{-1}$).

To identify any differences in pacing strategy displayed by age groups, mean relative speed expressed as a percentage of mean overall race speed was calculated for all intermediate 10-km segments for each group.

In order to assess the influence of absolute performance level on pacing strategy displayed, competitors were split into four groups dependent on overall finishing position, regardless of gender or age group. Groups 1, 2, 3 and 4 comprised of the first, second, third and fourth quartiles of finishers, respectively. Mean relative speed expressed as a percentage of mean overall race speed was calculated for all intermediate 10-km segments.

Similar analyses were performed to identify differences between ‘top’ and ‘bottom’ performing athletes within each individual age group. A median split based on finishing time was used to divide athletes in each category into two separate groups.

The coefficient of variation (CV) and 95% confidence intervals (95% CI) were calculated in order to indicate segment-to-segment variability in running speed for each group throughout the race. One-way analysis of variance (ANOVA) was used to identify differences in overall performance characteristics (race speeds) in each age group, and an independent *t*-test was used to identify overall performance differences between genders. Two-way repeated measures ANOVA was used to identify differences in relative speed in 10-km segments in overall finishing quartile, age groups, top and bottom performing competitors in each age group, in males and females, and in top and bottom male and female groups (specific groups vs 10-km segment speeds as factors). When a significant difference was observed, a Bonferroni post hoc test was applied. Statistical significance was accepted at the $P < 0.05$ level and analyses were performed using GraphPad (Version 6).

## Results

Within the 196 total race finishers, there was a continual reduction in average race speed with age (Table I). Statistically significant differences were found between SEN and V45 ($P = 0.001$), V50 ($P = 0.009$), V55 ($P < 0.0001$) and V60+ ($P < 0.0001$), between V40 and V45 $P = 0.02$), V50 ($P = 0.03$), V55 ($P = 0.0034$) and V60+ ($P = 0.0007$).

Despite these differences in overall performance level between age group, there were no significant differences in speed expressed relative to mean race speed between any groups in any intermediate segment. The CV for mean speed over intermediate segments was 8.57% (95% CI = 3.20, 13.95), 9.33% (95% CI = 3.48, 15.18), 9.86% (95% CI = 3.68, 16.04), 12.00% (95% CI = 4.41, 19.60), 10.84% (95% CI = 4.02, 17.65) and 11.79% (95% CI = 4.37, 19.23) for the SEN, V40, V45, V50, V55 and V60+ age groups, respectively.

Despite these similarities in pacing strategy displayed by athletes in each age group, when finishers are split into quartiles equating to overall finishing position (regardless of age or gender), it is apparent that there are differences in distribution of relative race speeds displayed by each.

Group 1 athletes ran at a lower percentage of average race speed than competitors in all other groups for the first, second and third 10-km segments (all $P < 0.0001$) and faster than Group 3 in the fourth segment ($P = 0.01$). Group 4 athletes ran at significantly higher relative speeds than Group 2 athletes in the first ($P = 0.003$), second and third (all $P = 0.0061$) segments, and Group 3 athletes in the first ($P = 0.0014$), second and third both $P = 0.0013$) segments. Although there was a tendency for Group 1 finishers to run at lower relative speeds than athletes in other groups in the initial 30 km of the race, this trend appeared to reverse as the race progressed. Group 1 athletes were running at significantly higher relative speeds than Group 4 athletes between 50 and 60 km ($P = 0.001$) and 90 and 100 km ($P = 0.0011$), and higher than Group 2 athletes between 70 and 80 km ($P = 0.04$; Figure 1). Variability in segment-to-segment running speed also increased as mean overall running decreased, with CVs over intermediate segments of 6.66% (95% CI = 2.51, 10.82) for Group 1, 10.41% (95% CI = 3.86, 16.95) for Group 2, 10.45% (95% CI = 3.88, 17.02) for Group 3 and 12.82% (95% CI = 4.70, 20, 93) for Group 4.

Despite similarities in pacing profiles displayed by individual age groups, there also appears to be some effect of finishing position relative to others in the same age group on overall strategy. Analysis of 'top' and 'bottom' finishers (determined by median split) within age groups reveals that higher performing athletes tend to display lower relative speeds in the early stages of the race. Top finishers displayed lower relative speeds in the first ($P < 0.01$), second ($P < 0.01$) and third ($P < 0.01$) 10-km segments in the SEN group, in the second ($P = 0.04$) in the V50 group, and in the first ($P < 0.01$) and second ($P = 0.01$) in the V60 group. Although not all differences were statistically significant, there appeared to be a consistent trend apparent in all age groups whereby athletes achieving superior overall finishing times displayed lower relative speeds in the initial stages of the race (Table II).

Table I. Overall characteristics of competitors in each age group

| Age category | *n* | Mean race speed (m $s^{-1}$) |
|---|---|---|
| SEN | 93 (34 female, 59 male) | 3.38 ± 0.43 |
| V40 | 52 (11 female, 41 male) | 3.28 ± 0.39 |
| V45 | 26 (9 female, 15 male) | 2.98 ± 0.32 |
| V50 | 13 (3 female, 10 male) | 2.91 ± 0.39 |
| V55 | 12 (3 female, 9 male) | 2.81 ± 0.29 |
| V60+ | 7 (0 female, 7 male) | 2.63 ± 2.11 |

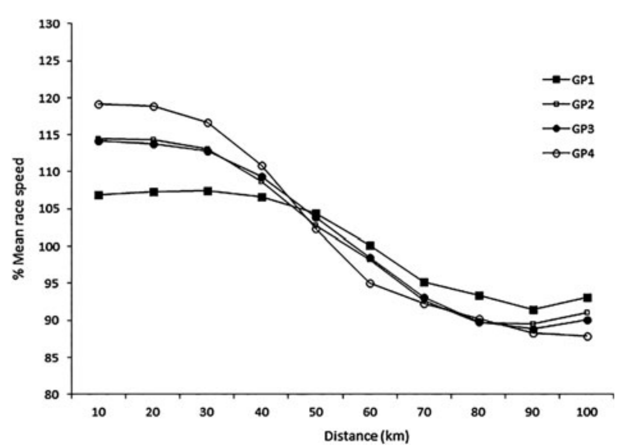


Figure 1. Relative speed in each intermediate segment for Groups 1–4 (error bars and statistical significance removed for clarity).

Table II. Relative speed in each 10-km segment within 'top' (T) and 'bottom' (B) performing competitors in each age group (difference between T and B).

| | 0–10 km | 10–20 km | 20–30 km | 30–40 km | 40–50 km | 50–60 km | 60–70 km | 70–80 km | 80–90 km | 90–100 km |
|---|---|---|---|---|---|---|---|---|---|---|
| *SEN* | | | | | | | | | | |
| T | 107.27 ± 4.86** | 107.58 ± 4.60** | 107.57 ± 4.30** | 106.56 ± 3.86 | 104.50 ± 3.70 | 100.32 ± 4.60 | 95.50 ± 4.84 | 93.28 ± 4.19 | 91.18 ± 5.06 | 92.55 ± 5.45 |
| B | 114.54 ± 8.07 | 113.99 ± 8.03 | 113.32 ± 7.61 | 109.24 ± 7.30 | 103.14 ± 8.17 | 97.71 ± 6.71 | 93.53 ± 7.80 | 90.53 ± 6.60 | 89.72 ± 7.75 | 90.12 ± 9.22 |
| *V40* | | | | | | | | | | |
| T | 108.40 ± 4.99 | 108.82 ± 4.75 | 108.73 ± 4.77 | 107.46 ± 4.51 | 105.30 ± 4.32 | 101.59 ± 4.40 | 95.62 ± 5.15 | 92.16 ± 4.66 | 88.93 ± 6.78 | 91.87 ± 8.35 |
| B | 114.47 ± 8.95 | 114.39 ± 7.98 | 113.29 ± 7.34 | 110.04 ± 5.43 | 103.78 ± 5.98 | 98.60 ± 6.28 | 94.00 ± 6.90 | 90.30 ± 5.11 | 87.27 ± 6.63 | 89.34 ± 7.73 |
| *V45* | | | | | | | | | | |
| T | 112.69 ± 6.90 | 111.59 ± 6.69 | 110.45 ± 5.74 | 107.64 ± 3.88 | 102.10 ± 3.99 | 95.82 ± 6.04 | 94.71 ± 4.10 | 92.48 ± 5.10 | 90.86 ± 4.12 | 91.10 ± 5.02 |
| B | 116.42 ± 9.30 | 115.04 ± 9.75 | 112.68 ± 7.88 | 108.62 ± 5.80 | 102.21 ± 3.35 | 97.16 ± 4.50 | 91.00 ± 4.35 | 91.20 ± 5.48 | 89.13 ± 5.69 | 90.45 ± 5.43 |
| *V50* | | | | | | | | | | |
| T | 108.97 ± 2.74 | 109.26 ± 2.58* | 110.21 ± 1.94 | 109.69 ± 3.00 | 105.23 ± 3.20 | 99.77 ± 3.63 | 93.46 ± 4.05 | 89.77 ± 5.95 | 89.07 ± 2.77 | 93.5 ± 4.57 |
| B | 122.95 ± 13.50 | 124.36 ± 14.48 | 121.32 ± 14.36 | 116.63 ± 13.02 | 108.50 ± 12.61 | 95.94 ± 10.29 | 93.07 ± 7.49 | 85.28 ± 8.19 | 83.60 ± 11.27 | 85.65 ± 14.24 |
| *V55* | | | | | | | | | | |
| T | 115.89 ± 8.97 | 115.29 ± 8.20 | 113.43 ± 6.79 | 108.44 ± 3.52 | 100.64 ± 3.96 | 99.47 ± 10.20 | 91.07 ± 5.45 | 90.69 ± 3.66 | 87.94 ± 4.49 | 90.91 ± 4.27 |
| B | 114.96 ± 4.95 | 114.25 ± 5.20 | 113.57 ± 4.98 | 108.53 ± 3.90 | 104.78 ± 5.61 | 97.30 ± 4.14 | 91.00 ± 7.07 | 85.54 ± 10.26 | 91.12 ± 4.09 | 93.99 ± 10.39 |
| *V60+* | | | | | | | | | | |
| T | 108.88 ± 3.52** | 108.44 ± 4.76** | 107.37 ± 3.15 | 106.83 ± 4.02 | 101.74 ± 1.82 | 93.51 ± 8.57 | 96.53 ± 3.33 | 95.23 ± 4.09 | 94.72 ± 4.27 | 92.23 ± 4.08 |
| B | 123.84 ± 5.60 | 120.31 ± 0.31 | 117.20 ± 2.26 | 110.77 ± 3.59 | 98.52 ± 4.86 | 88.85 ± 4.75 | 91.24 ± 4.12 | 94.07 ± 4.01 | 89.06 ± 5.19 | 85.32 ± 2.41 |

$^*P < 0.05$, $^{**}P < 0.01$.

Analysis of performances achieved by each gender revealed that males achieved a higher overall race speed (3.24 ± 0.50 m p $s^{-1}$) than females (3.11 ± 0.32 m p $s^{-1}$; $P = 0.04$).

There were also differences in the pacing strategy displayed by each gender. Whereas males displayed significantly higher relative speeds in the first ($P = 0.03$), second and third (both $P < 0.01$) 10-km segments, females displayed significantly higher relative speeds in the ninth segment ($P = 0.01$; Figure 3). There was less variability in pace in females than males. CVs over intermediate segments were 7.39% (95% CI = 2.77, 12.00) for females and 10.33% (95% CI = 3.83, 16.83) for males.

Analysis of the influence of performance level on pacing indicated differences between genders. Although no significant differences were found between top and bottom finishing female participants, top performing males displayed significantly lower relative speeds in the first, second, third (all $P < 0.0001$) and fourth (all $P = 0.0090$) 10-km segments, whereas they displayed significantly higher relative speeds in the sixth ($P = 0.0023$) and tenth ($P = 0.0004$) segments.

## Discussion

The results of this study indicated that although pacing during a 100-km ultramarathon remained consistent across age categories, it differed with level of performance within athletes of differing performance levels within each age category. The strategies adopted also differed between genders, with males displaying more variability in pace than females. However, although there were differences found between males of differing performance levels, this was not the case with females.

The observed age-related reductions in average race speed (Figure 1) were not unexpected given the changes in physiological parameters associated with endurance performance capacity that typically occur with ageing (Santos-Lozano et al., 2015). Despite the fact that this was a 100-km event, mean speeds achieved in all age categories were above the marathon running speeds required for inclusion in the study by March et al. (2011), suggesting the participants studied in this analysis were more highly trained.

Analysis of absolute performance level (regardless of age or gender) on pacing strategy adopted (Figure 3) concur with previous findings that athletes who finish towards the front of competitive endurance events display more even pacing than less successful competitors in both cross country (Esteve-Lanao et al., 2014; Hanley, 2014) and marathon running (March et al., 2011; Renfree & St Clair Gibson, 2013; Santos-Lozano et al., 2015). This finding suggests

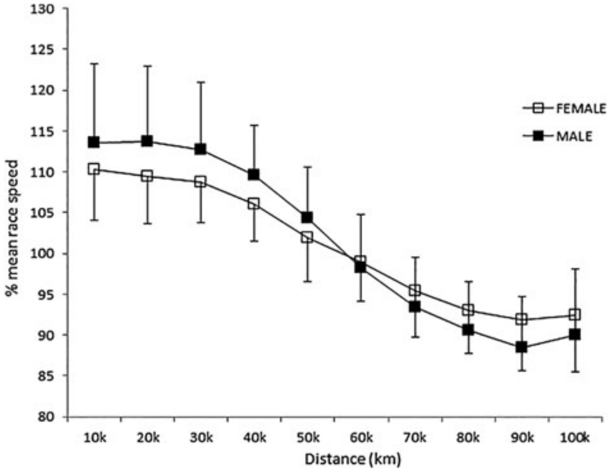


Figure 2. Relative speed in each intermediate segment for males and females (*$P < 0.05$).

that even though the precise nature of the physiological determinants of performance ability may vary between events of different durations, similar mechanisms pertaining to regulation of work-rate influence the strategy adopted in disparate competitive endurance activities.

Although levels of absolute performance differed between competitors in the various age categories, the similarities in pacing strategies adopted are remarkable, with no significant differences between any two groups found in any individual 10-km segment (Figure 2). It has been previously proposed that pacing is regulated via reference to a 'template' of power outputs, which is developed partly as a result of experience and a learned ability to associate levels of emotions with the ability to maintain muscular work rates for specific durations (Baron, Moullan, Deruelle, & Noakes, 2011). However, it is worth emphasising that the present study analysed pacing strategy in a rather 'extreme' event (100-km race). Although we do not have access to information regarding all participants' previous competitive experience, it would seem highly likely that such ultra-endurance athletes are not able to compete as regularly as shorter distance specialists. This may mean that their ability to develop a pacing 'template' is somewhat limited. Despite this, the findings of this study suggest that regardless of whether age-related decrements in performance ability are mediated by physiological or motivational factors, the pacing template is robust and regulation of work rates during endurance activities is achieved in a similar manner as athletes age. Exactly how athletes learn to pace themselves in events they are not able to complete regularly warrants further investigation. Furthermore, it would also be of interest to explore an individual athletes pacing profile as they age, as although this analysis compares different age groups, we know little about the competitive experience of athletes within each group.

Perhaps the most interesting finding resulting from these analyses is that athletes achieving different levels of performance within each age category display different pacing strategies. Although not all differences between the top and bottom performing groups of competitors were statistically significant, it was consistently found that the top half of finishers in each age category ran at lower percentages of their mean race speed than the bottom half of finishers in the initial stages of the race (Figure 4). The fact that this phenomenon occurred was still apparent in the older age groups is perhaps surprising given that even the leading finishers within these groups finished in relatively low absolute positions in the overall race. For example, there were significant differences between athletes comprising the top and bottom half of finishers in the first and second 10-km segments within the V60 group, even though the outright winner of this age group only finished in 138th position out of the 196 total finishers. This observation could suggest that athletes are using other athletes within their age groups as 'anchors' upon which their own pacing strategy is based. Tversky and Kahneman (1974) proposed that individuals display a form of cognitive bias, whereby they rely heavily (or anchor) on initially presented sources of information when decision-making. In the context of the event being analysed then, it could be proposed that individuals may be using the starting pace selected by other athletes within their own age category as the anchor which informs their own starting speeds, and, therefore, subsequently the pacing profile displayed over the entire race. If this is the explanation for these findings, and age category of each athlete is not clearly identifiable through, for example, the use of different coloured competition numbers, it is as yet unclear how identification of these anchors is achieved in a mass start event such as this. A possible alternative explanation for the observation that top and bottom performing athletes display differing strategies is simply that the top athletes achieve superior performances partly as a result of a better ability to pace themselves appropriately in order to maximise their physiological capacities. However, previous analysis of a World Championship marathon race (Renfree & St Clair Gibson, 2013) suggests that less successful competitors 'underperformed' relative to their absolute performance capacities due to the selection of unsustainable starting speeds that were similar to those adopted by the leading runners. Although information relating to the absolute performance capabilities of participants in the race being analysed is unavailable, it would seem likely that the large decrements in speed displayed by the bottom performing runners are not optimal for performance in events of this duration (Lambert, Dugas, Kirkman, Mokone, & Waldeck, 2004).

The results of this analysis also suggest that gender may have an impact on pacing strategy during competitive endurance events. The finding that females displayed a more even strategy than males (Figure 4) concurs with previous findings during marathon running by March et al. (2011), but not Santos-Lozano, Collado, Foster, Lucia, and Garatachea (2014) who demonstrated similar overall strategies in both genders in a large analysis of six successive occurrences of the New York City marathon. The reason for these differences is at present unclear, although it may be possible that the athletes in the present study were more highly trained than those in the study by Santos-Lozano et al. which deliberately studied strategies adopted by more recreational runners who aimed simply to finish the event. Perhaps more significant is the findings that the strategy displayed appears to differ between competitors of different performance level in males, but not in females. This may provide further evidence for previous suggestions that gender differences in competitiveness and win orientation (Gill, 1988) may result in differences in strategy adopted (Renfree & St Clair Gibson, 2013). Attitudes to risk-taking have also recently been demonstrated to influence pacing during ultra-marathon running (Micklewright et al., 2014), and it also seems that males typically are more apt to engage in risky behaviour (Byrne, Miller, & Schafer, 1999), another potential explanation for the gender differences observed.

## Conclusions

Results of the analyses presented in this paper concur with previous findings that absolute performance level achieved is associated with the pacing strategy adopted during competitive endurance events. Furthermore, the strategies adopted remain stable across differing age categories, the top half of finishers in each category consistently display a more even strategy than the bottom half, regardless of overall position in the race. Pacing strategy also appears to vary with gender and varies between athletes of differing performance level in males but not females. Taken together, the results suggest that direct competitors within the same age category may act as more important anchors in informing decisions taken with regards to selection of initial speeds than athletes in other age categories who happen to be in close proximity. Given that, in this event, female athletes display a more even strategy than males, and appear to be less influenced by absolute performance level, it would seem possible that the nature of the anchors informing this decision-making process may differ between genders. Further research is required to test the relationships between these variables experimentally.

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