Influence of Sex and Level on Marathon Pacing Strategy. Insights from the New York City Race

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Key words
- aerobic
- exercise performance
- sport physiology
- marathon
- pacing

Abstract

Different pacing profiles have been identified in the literature for endurance sporting events: the 'positive', 'negative', 'even', 'parabolic shaped' and 'variable pacing'. Most studies have focused on competitive or elite athletes (including winners) without considering more recreational runners, for many of whom the primary goal is simply to finish the event. The major city marathons provide a large heterogeneous sample to compare the pacing profiles of competitive vs. recreational runners, and thus to understand pacing more broadly. A total of 190 228 New York finishers' (69 316 women) marathon times (from 2006 to 2011) were assessed. Although all runners developed a positive pace profile, a lower variability of speed through the race was found in the top runners (coefficient of variation (CV) for speed during 5-km splits: 7.8% (men) and 6.6% (women)) compared with the less successful runners (CV ranging from 8.3 to 14.4%). Both men and women try to maintain an even pace profile along the marathon course, partly by avoiding an excessively fast start that might result in a pronounced decrease in the speed in the second half of the race.

Introduction

'Pacing', i.e., the actual distribution of speed, power output or energetic reserves during a given sporting event [34] is a fundamental determinant factor of competitive endurance performance [11]. 'Pacing strategy' is the self-selected strategy or tactic that the athletes adopt, basically from the beginning of an event [34]. Because the rate of fatigue development during a sporting event can influence athletes' pacing irrespective of their a priori self-selected 'strategy', we hereafter use the term 'pacing profile' (or 'pattern') instead of 'pacing strategy'. The pacing profiles adopted by athletes have been described in running [31,41], cycling [15,18], speed skating [27], rowing [12,28] and triathlon events [23]. The marathon footrace (42.2 km) is one of the most challenging endurance competitions. Despite the popularity of the event and despite the fact that pacing can contribute to optimizing performance and preventing unreasonably homeostatic disturbances during the race [6,40,41,43], available published data on pacing profiles over the 42.2-km distance are relatively scarce.

3 basic pacing profiles ('positive', 'negative' and 'even pacing') have been previously identified [1] in long distance events, and both even pace and varied pacing patterns have been positively associated with marathon performance [1,8,24,25, 33]. Foster et al. [10] and March et al. [24], showed that faster marathoners maintain a more consistent race speed throughout the race than slower marathoners. Renfree et al. [33] concluded that for competitive athletes participating in championships, those finishing the race in the top positions showed a more even pace pattern than the less successful contenders, primarily by slowing less during the terminal portion of the event. Although there is evidence that each athlete has his or her optimal pace pattern, many runners start shorter races quickly, slow through the intermediate stages, and produce a final acceleration or 'end-spurt' [10]. A common feature of most published studies is a focus on successful or winning athletes. Little information is available in the literature regarding patterns displayed by amateur/recreational runners [10,33]. On the other hand, to our knowledge only one previous study has investigated sex differences in marathon pacing, reporting that women tended to adopt a more even pace than men.

The major city marathons such as New York City (NYC) marathon provide a good opportunity for examining a large amount of data from both pro-

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fessional and amateur runners with different performance levels. Such large body of data allows the opportunity for gaining a better appreciation of the fundamental way in which humans approach pacing in endurance events. The aim of this study was to analyse the influence of performance level and sex in the pacing profiles adopted during the NYC marathon.

Methods

Experimental approach to the problem

This study involved the analysis of publicly available data so that individual informed consent was not necessary. The study was approved by the university's Human Ethics Committee. It was performed according to the declaration of Helsinki and it conformed to the Ethical Standards in Sport and Exercise Science Research [14]. Sex and time performance data for all finishers in the NYC marathon from 2006 to 2011 were obtained through the NYC marathon website: http://www.ingnycmarathon.org/. The race course or dates (November) have not been changed from 2006, minimizing the effects of some key confounders such as race profile and primary environmental conditions.

Subjects

190 228 NYC marathon times of all finishers from 2006 to 2011 were retrieved (women: 69 316; men: 120 912). The total marathon distance was divided into 5-km splits for the initial 40 km, and also into the last 2 195 km. All split times (5, 10, 15, 20, 25, 30, 35, 40 and 42 km) were required to include an individual record in the database. Subjects were divided into 4 groups dependent on their final net time: Group 1 [fastest runners, i.e., finishing time ≤219 min (men) and ≤245 min (women)], Group 2 [fast runners, i.e., 220–247 min (men) and 246–273 min (women)], Group 3 [medium runners, i.e., 248–280 min (men) and 274–307 min (women)], and Group 4 [slow runners, i.e., >281 min (men) and >308 min (women)], which comprised the first, second, third, and fourth quartile (25 %) of final net time of all finishers in each race edition, respectively.

The speed in each split was calculated dividing 5 km (or 2 195 km for the last split) by the time each runner needed to cover this distance. Total mean speed was also individually calculated for each runner by dividing total distance by his or her final net time. The pace was defined as the percentage of the variation in the speed during each split in relation to the total mean speed of each runner.

Statistical analysis

One-way ANOVA test was used to evaluate the influence of performance level (i.e., Groups 1–4) and sex in final net time, total mean speed and split times. The same test was also performed to study the influence of the performance level in the pace in each split time. When the assumptions of sphericity were violated, we applied the Greenhouse Geisser correction factor. A Bonferroni post hoc test was used in all pairwise comparisons when a significant result was found. Finally, the intra-class correlation coefficient (ICC) and the coefficient of variation (CV) between speed splits were calculated for each performance level and sex.

All statistical analyses were performed with PASW (Predictive Analytics Software for MAC, v. 20.0 SPSS Inc., Chicago, IL, USA). Descriptive data are presented as means ± standard deviation (SD), and significance was set at $P \leq 0.05$.

Results

The total net time and the split time by sex and performance level are shown in **Fig. 1**. The ANOVA analysis showed significant differences between men and women in the final total time, in the speed-split and in the pace in all splits ($P<0.05$). Significant differences between all performance levels were also found within each sex ($P<0.05$, **Fig. 1–3**).

The speed in each split by sex and group is showed in **Fig. 2** ($P<0.05$). In view of the difference in speed pattern in the last distance split (40–42 km) between the top runners (Group 1, who on average slowed down) and the rest of runners (who exhibited a final burst), and also to account for the potential heterogeneity in pacing profile within Group 1 (which included both professional runners and amateur runners), this group was divided into 10 subgroups (deciles), and comparisons between the 40 km and 42 km split within each sex decile were performed using a Student's *t*-test for paired data. The results (**Table 1**) showed that the speed and speed off-average were significantly different between 40 and 42 km split ($P<0.05$) in the top 4 (women) and top 3 deciles (men).

Fig. 3 shows the pace (relative to the overall average pace) in each split by sex and performance level group. It can be appreciated that the faster the runner overall, the more even the pace during the whole race. The ANOVA analysis showed a significant performance-group main effect and post hoc comparisons revealed differences between the speeds of all performance level groups in all splits ($P<0.05$).

The ICC and the CV are shown in **Table 2**. The highest (men and women: 0.96) and the lowest (men: 0.33, women: 0.19) ICC values corresponded to the fastest quartile and medium runners, respectively. Better performance levels were associated with the lower CV values.

Elevation race map is shown in **Fig. 4**.

Discussion

Overall, our main finding was that marathoners adopt a positive pacing pattern, decreasing the speed throughout the race independently of sex and performance level. Irrespective of sex, better runners maintain a more constant velocity than the slower runners. This is in accordance with previous reports by Maughan et al. [25] and Foster et al. [10], who found similar results in smaller data sets. Our data showed that faster runners run at a comparatively even velocity over the 42.2-km distance, yet slower runners start run significantly faster than their average velocity during the first 20–25 km, after which their running speed decreases to significantly below the average speed for the total race.

As expected, running speed was higher in men than in women for the same performance level in all splits. As a result, the final and partial times also differed between sexes. However, in spite of these normally expected sex differences [16,17], marathon pace profile appears to depend less on sex than on the performance level. Similar results have been found in triathlons in which elite women and men triathletes adopted similar positive pacing patterns during the swimming, cycling and running phases [23]. Our results showed differences between performance levels when both women and men were analysed separately. Although, all performance level groups selected a positive pacing profile (**Fig. 3**), a more constant pace was performed by the better

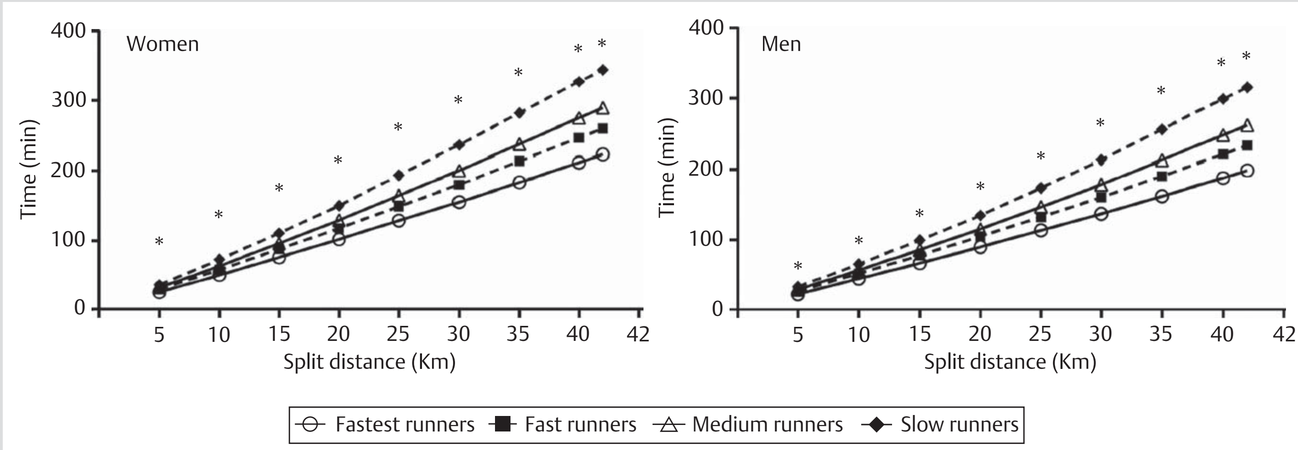

Fig. 1 Total final and split time by sex. *denotes a significant difference between all performance group levels of the same sex, same split ($P<0.05$).

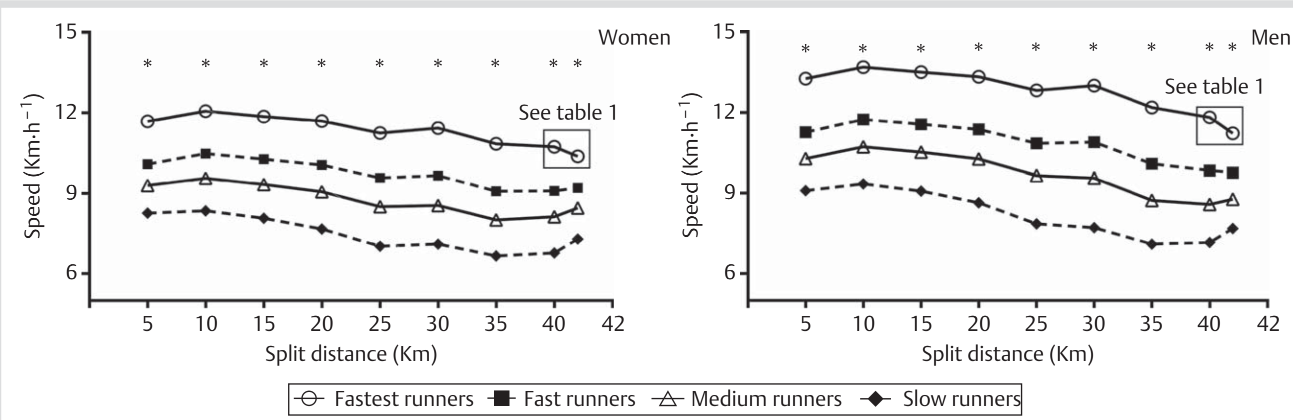

Fig. 2 Split speed by sex. *denotes a significant difference between all performance group levels of the same sex, same split ($P<0.05$).

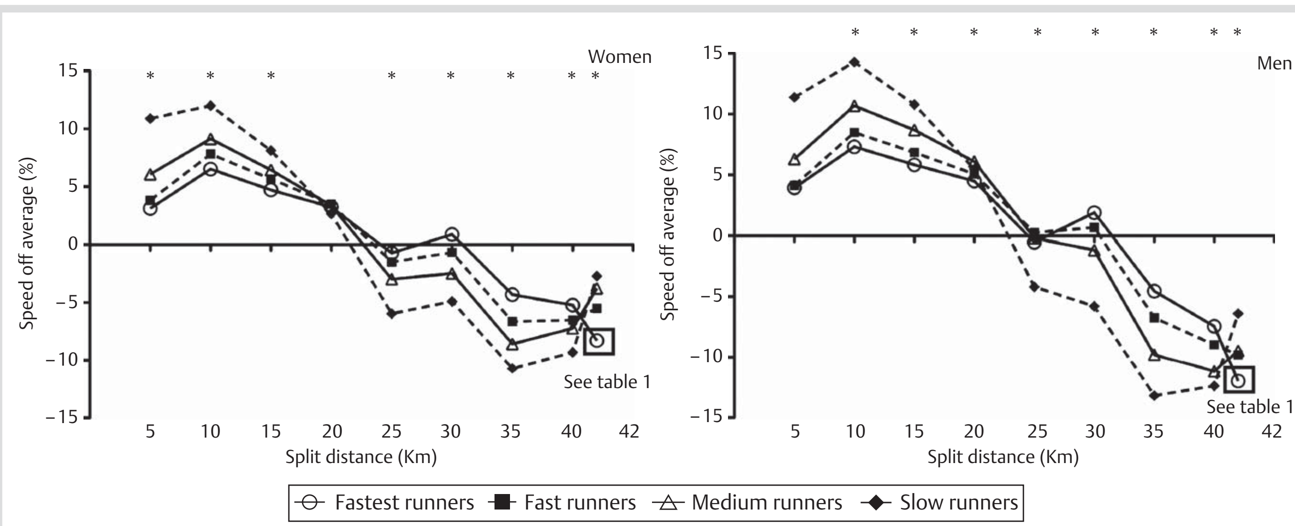

Fig. 3 The marathon pace by sex. *denotes a significant difference between all performance group levels, same split ($P<0.05$).

runners whose mean CV was 6.56% for women and 7.78% for men, respectively. The slowest group showed more variation in the pacing pattern (i.e., CV of 13.1 and 14.41% for women and men, respectively). Renfree et al. in 2012 [33] studied 60 women in the Women's Marathon event at the 2009 IAAF World Athletic Championship and found differences in that the most successful athletes adopted a more consistent speed pattern during the entire race than less successful athletes. Additionally, Lambert et al. [22] found that the faster ultra-marathoners regulated their speed more effectively compared to the slower participants, i.e.,

Table 1 Decile values for fastest runners (Group 1).

	Women					Men				
		40 km split		42 km Split			40 km split		42 km split	
Decile	Final net time (min)	Speed (km·h⁻¹)	Speed off average (%)	Speed (km·h⁻¹)	Speed off average (%)	Final net time (min)	Speed (km·h⁻¹)	Speed off average (%)	Speed (km·h⁻¹)	Speed off average (%)
1	188.80	12.80*	−0.55*	11.98	−1.35	165.36	14.40*	−0.82*	13.30	−1.92
2	206.24	11.59*	−0.59*	10.99	−1.18	179.70	13.17*	−0.80*	12.37	−1.60
3	213.80	11.17*	−0.59*	10.66	−1.09	187.80	12.35*	−1.03*	11.80	−1.58
4	219.66	10.84*	−0.62*	10.60	−0.86	194.32	11.92	−1.06	11.85	−1.14
5	224.86	10.57	−0.64	10.47	−0.73	199.63	11.61	−1.02*	11.38	−1.24
6	229.36	10.36	−0.64	10.40	−0.59	204.29	11.34	−1.05	11.64	−0.75
7	233.24	10.19	−0.64	10.34	−0.49	208.14	11.22	−0.97	11.89	−0.30
8	236.62	10.08	−0.62	10.42	−0.27	211.44	11.00	−1.14	12.90	0.75
9	239.52	10.00	−0.74	11.88	1.15	215.07	10.74	−1.04	11.12	−0.66
10	242.74	9.83	−0.70	11.11	0.58	218.38	10.54	−1.19	12.12	0.39

*Significantly different between splits 40 and 42, for same sex and decile, $P<0.05$

Table 2 Intra-class correlation coefficient (ICC) and coefficient of variation (CV) in the speed between split times.

		Fastest runners	Fast runners	Medium runners	Slow runners
women	ICC	0.96	0.46	0.19	0.78
	CV	6.56 (±3.10)	8.28 (±4.02)	9.87 (±5.00)	13.1 (±6.30)
men	ICC	0.96	0.40	0.33	0.81
	CV	7.78 (±3.82)	9.16 (±4.46)	11.31 (±5.13)	14.41 (±6.38)

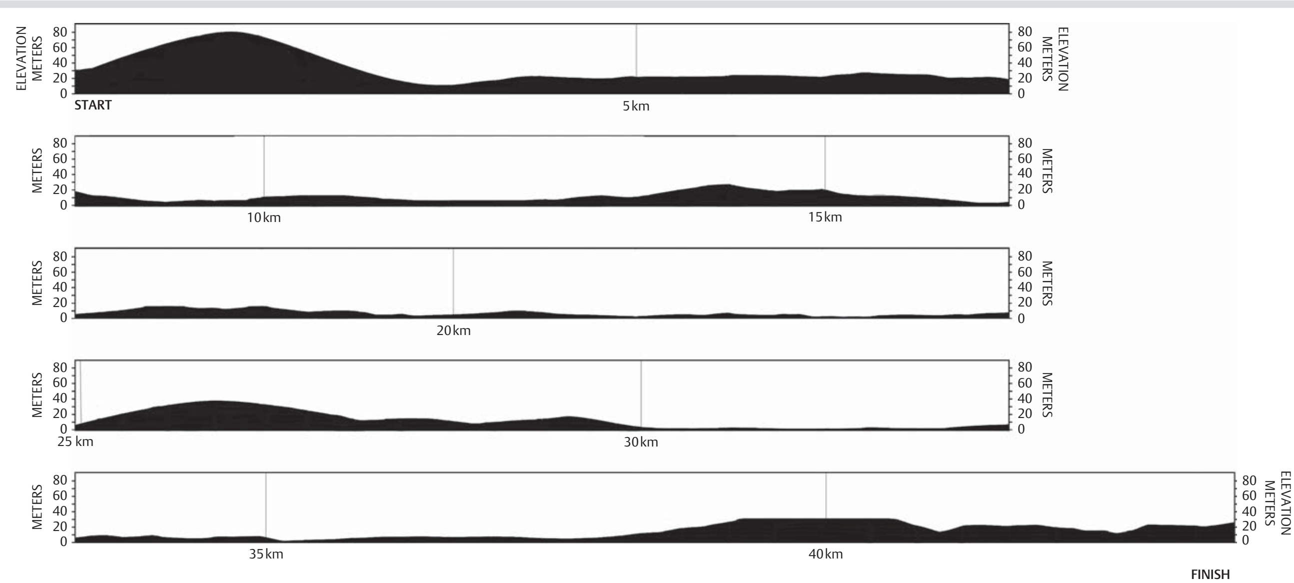

Fig. 4 Race elevation chart.

with a more delayed decrease in running speed, which did not occur until roughly the second half of the race [22]. The regulation of pace is largely dictated by the ability to resist fatigue [5], the influence of direct competitors to ensure the best finishing position [33] and the learning process [22,39]. It is also possible that a relative faster starting in the less competitive/experienced runners might simply reflect performance goals that are rather unrealistic and too ambitious [8,11].

Fig. 3 showed the differences between levels in pace along the race. Irrespective of runner's sex or performance level, speeds progressively decreased during the second half of the marathon as previously reported [8]. The speed of the fastest runners displayed the smallest decrement within 15 and 25-km splits, while the slow runners exhibited the more marked decrease in speed during these splits. These findings agree with those reported by Renfree and St Clair Gibson [33], who also showed that the slower runners exhibited a more marked decrease in running speed compared to top runners. A possible explanation for this finding could lie in a higher prevalence in the less trained/experienced runners of muscle glycogen depletion, hypoglycaemia or hyperthermia, often termed "hitting the wall", a phenomenon that tends to result in a dramatic reduction of running velocity and may well be the result of improper pacing as previously reported [2,4,24,35]. Foster et al. [10], showed that the slowdown in the marathon is closely related to the quantity and quality of pre-race training. In contrast, the high running economy of the top runners might delay glycogen depletion and decrease metabolic heat production, thereby reducing the risk of hyperthermia [19] and thus "hitting the wall".

It is in the second part of the race where homeostasis (especially in the slow runners) can be more severely compromised, and the brain might subconsciously coordinate a 'down-regulating' response to ensure that the exercise intensity does not exceed the body's physiological limits, i.e., the so-called 'teleoanticipation' phenomenon [7,9]. This is in line with the 'central governor model' (which has also been applied to the marathon event) [30], according to which neural control systems in the brain and spinal cord determine the number of motor units that are activated in the working muscles [21,32,36]. This ensures that homeostasis is maintained throughout the entire sporting event (e.g., the marathon), with sensory information from the periphery being integrated by the brain to ensure that the effort being done does not compromise bodily homeostasis and that exercise is terminated (or intensity is decreased) before homeostasis fails [29,42]. In fact, recent research has shown that fatal events typically occur during the last quartile of marathon races, and almost exclusively in slow runners with very little training background in distances above half-marathons (and thus with lesser possibility of establishing an effective 'teleoanticipation') and having occult cardiovascular disease [20]. Additionally, the rating of perceived exertion in top runners could be lower because of their greater experience in 'suffering' the unpleasant symptoms associated with exertion, which might explain a lower decrease in speed in the second part of the race [9].

A consistent finding in athletic events lasting more than 2 min is that athletes tend to start at high speeds, slow at middle stages of the race and end with a final acceleration or "end-spurt" [33,37,38]. The latter usually occurs when the task is perceived to be ~90% completed, at least in 5000 to 10000-m races [3,8,41]. In our large sample of marathon runners, the top runners did not increase the speed in the last 2-km split, while the others 3 groups did. This pacing profile was actually exhibited in the fastest runners' subgroups in both sexes (▶ **Table 1**), with the best runners not showing a final acceleration, but rather a more marked decrease in the speed during the last 2 km of the race. The lack of the final end-spurt in the top runners is difficult to explain but may be due to different reasons. First, the more competitive runners might not reserve any energy for the very end. On the other hand, the final marathon outcome (in terms of top finishing positions) is usually not defined in the last 2 km. As such, the top runners would try to maintain their position while amateur runners, whose aims are rather to finish the race in the shortest possible time or improve their best personal record, would try to "sprint" in the last part of the race. Finally, the head group gradually decreases in number and only the top positioned are capable of maintaining the pacing profile.

The variation of speed is related to fitness (faster men and women runners run at a more consistent speed than less competitive runners) or fatigue (if the wrong pace is selected). As a result, the less competitive runners are more likely to decrease their speed or to be unable to finish the distance event [13]. To obtain the best final results, men and women runners, especially the most experienced, try to maintain an even pace profile as long as possible during the marathon race by avoiding an excessively intensive start to prevent a high decrease in the speed at the middle stages of the marathon event.

The present study analysed the influence of sex and performance level on marathon pace during 6 race seasons, from 2006 to 2011. Since the NYC marathon is one of the most popular races in the world and we analysed a large sample of subjects, we believe our results might be illustrative of the actual pace developed during marathoners of both sexes depending of their performance level. Nevertheless, our study has some methodological limitations. First, environmental temperature could affect the final time. It has been estimated that a 1 °C increase in temperature slows the winning time for men by 20 s ($P < 0.001$) and 21 s for women ($P < 0.001$) in the Boston marathon [26]. Second, the elevation profile could affect split times, i.e., there is 40 m gradient along Queensboro Bridge (from ~24 to 25.5 km) (▶ **Fig. 4**). Maintaining a consistent marathon pace has been shown to be an effective race profile for maximizing performance. According to the data of this study, coaches could advise marathoners to adopt specific race patterns depending on sex and performance level to resist fatigue and consequently to obtain the highest possible performance.

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