Pacing, packing and sex-based differences in Olympic and IAAF World Championship marathons

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ABSTRACT

The aim of this study was to describe pacing profiles and packing behaviours of athletes in Olympic and World Championship marathons. Finishing and split times were collated for 673 men and 549 women across nine competitions. Mean speeds for each intermediate 5 km and end 2.2 km segments were calculated. Medallists of both sexes maintained even-paced running from 10 km onwards whereas slower finishers dropped off the lead pack at approximately half-distance. Athletes who ran with the same opponents throughout slowed the least in the second half ($P < .001$, men: ES ≥ 1.19; women: ES ≥ 1.06), whereas other strategies such as moving between packs or running alone were less successful. Overall, women slowed less ($P < .001$, ES = 0.44) and were more likely to run a negative split ($P < .001$), and their more conservative start meant fewer women dropped out ($P < .001$). This also meant that women medallists sped up in the final 2.2 km, which might have decided the medal positions. Marathon runners are advised to identify rivals with similar abilities and ambitions to run alongside provided they start conservatively. Coaches should note important sex-based differences in tactics adopted and design training programmes accordingly.

INTRODUCTION

The marathon is one of the most popular running events in terms of the number of participants and spectators. It is the longest of the running events at all major athletics championships, and the various physiological, psychological and biomechanical factors important to success make it an appealing event for research. These factors include glycogen depletion (Jeukendrup, 2011), muscle fibre distribution (Sjödin & Svedenhag, 1985), and changes in spatiotemporal variables with fatigue (Buckalew, Barlow, Fischer, & Richards, 1985). How marathon runners regulate their effort over the 42.2 km distance has been the subject of several studies on pacing profiles as there is typically a considerable decrease in speed after approximately 30 km (March, Vanderburgh, Titlebaum, & Hoops, 2011). Indeed, 30 km is often colloquially considered 'halfway' in a marathon (Martin & Coe, 1997) because the change in pace and strategy that typically occurs at this distance is so marked. Disadvantages of such positive pacing profiles, where athletes start races quickly and slow progressively thereafter, are that they result in increased oxygen uptake, greater accumulation of fatigue-related metabolites, and increased rating of perceived exertion (RPE) (Abbiss & Laursen, 2008). By contrast, starting slowly and speeding up towards the finish might avoid such problems but can prove difficult in practice given the easiest decision is to adopt an early fast pace when rewards are based on finishing position, such as in important championship marathons (Renfree & St Clair Gibson, 2013).

Different aspects of pacing in endurance events have been investigated, including the benefits of an even-paced profile (Padilla, Mujika, Angulo, & Goiriena, 2000) and the role of RPE (Tucker, 2009). With regard to elite-standard marathons, Angus (2014) examined the two most recent men's world record performances and concluded that both runners could have improved performance with more even-paced running. Renfree & St Clair Gibson

(2013) analysed the women's race at the 2009 World Championships and concluded that poorly performing athletes had started the race too quickly for their ability, possibly because they chose to follow the pace set by better athletes; similar findings were reported for men in World Cross Country Championships (Hanley, 2014). However, recent research on elite-standard half marathons showed that pack running has an important role in reducing decreases in speed, as those athletes who ran most of the race with others of similar ability experienced both the smallest decreases in pace and the best finishes (Hanley, 2015). These packs did not just comprise the best athletes but also packs of slower, matched-ability athletes, who might have benefitted from using rivals as external references for pacing (Renfree, Martin, Micklewright, & St Clair Gibson, 2014). Whether similar packing strategies have also been used in elite-standard marathons has not been examined to date, and could provide useful information to athletes and coaches about the value of such tactics in achieving an even pace.

Previous research on marathon running has also focussed on sex-based differences in pacing profiles, with some authors reporting that women decrease speed less in the second half of the marathon than men (e.g. Deaner, Carter, Joyner, & Hunter, 2015). It was suggested that these sex-based differences could be because of either physiological or psychological factors (or both) (Deaner et al., 2015). However, this and similar studies (e.g. Santos-Lozano, Collado, Foster, Lucia, & Garatachea, 2014; Trubee, Vanderburgh, Diestelkamp, & Jackson, 2014) analysed competitors in large-city marathons, which typically use pre-arranged pacemakers to aid the very best athletes (Erdmann & Lipinska, 2013) and, in some cases, the mass field, an advantage not afforded to competitors in championship races like the Olympic Games (Nerurkar, 2004). In addition, mass fields comprise men and women competitors running alongside each other, meaning women could get a pacing benefit from running with men, or vice versa. Indeed, the women's world record of 2:15:25 that was set by Paula Radcliffe in 2003 (IAAF, 2015a) was aided by two men pacemakers, and inadvertent pacing by men of women can also occur (Hanley, Smith, & Bissas, 2011). An analysis of the pacing profiles adopted by elite-standard competitors in separately-held races will demonstrate the possible pacing differences between men and women, and show if different tactical approaches are beneficial.

The marathon is an endurance event where choosing the correct pacing strategy can be crucial to achieve the best possible performance. Previous research on pacing profiles in the marathon has focussed mostly on large-city races where men and women ran together. In terms of major championships, it would be useful for coaches of elite-standard athletes to know if particular packing strategies are beneficial in the absence of official pacemakers. Hence, the aim of this study was to describe and compare pacing profiles used by elite-standard men and women in IAAF World Championship and Olympic marathons, with regard both to competition performance and packing behaviour.

METHODS

Participants

The Faculty Research Ethics Committee approved the study. Finishing and split times were obtained from the open-access IAAF website (IAAF, 2015b) for competitors in the men's and women's marathon races at the eight IAAF World Championships held between 2001 and 2015 and the Olympic Games in 2012. The 2007 men's and the 2011 women's World Championship races were not included as all 5 km splits were not available (and 5 km splits were not recorded at Olympic Games marathons before 2012). A total of 673 men and 549 women were analysed across all nine competitions (including athletes competing more than once). The performances of seven men and 20 women considered very slow (i.e. with a finishing time more than 25% greater than the winner's time) were omitted based on being highlighted as outliers using SPSS Statistics 22 (IBM SPSS, Inc., Chicago, IL), where an outlier was more than 1.5 times the interquartile range (IQR) from the median of the scores. Athletes who did not finish (179 men, 84 women) or who were disqualified (either at the time of competition or subsequently: four men, three women) were included when identifying packs but not in the main analysis.

Data Analysis

The study was designed as observational research in describing pacing profiles. Race split times were obtained for each 5 km, halfway (21.098 km) and the finish (42.195 km), and the mean speed for each of these 10 segments calculated. For convenience, the final segment distance is described as 2.2 km. Competitors in each race were first divided into five groups based on finishing times, and each athlete placed in one group only. These groups were medallists (a total of 24 men and 24 women); non-medallists whose finishing times were within 5% of the winner's time in their respective races (the 5% group: 109 men; 136 women); athletes whose finishing times were between 6% and 10% slower than the winner's time (the 6–10% group: 189 men; 146 women); athletes whose finishing times were between 11% and 15% greater (the 11–15% group: 101 men; 101 women); and athletes whose finishing times were between 16% and 25% greater (the 16–25% group: 67 men; 58 women). All finishing time percentages were rounded to the nearest integer before athletes were allocated to a group.

The second part of the analysis investigated the pacing profiles of athletes identified as running alone or in a pack. Athletes were considered to be in a pack when the split time difference between consecutive athletes was 1 s or less (at the nine intermediate splits, but not the finish). Six types of pack were defined, similar to previous research (Hanley, 2015): ever-present packs – where all pack members were together for at least eight of the nine splits up to 40 km (53 men; 51 women); halfway packs – where all athletes ran together in the same pack until halfway, but were then isolated after at least 30 km (87 men; 92 women); nomadic packs – where all athletes were in packs for at least seven of the nine splits, but not always with the same competitors (78 men; 65 women); semi-nomadic packs – where all athletes were in packs for at least five of the seven splits up to 30 km, but were isolated after that distance (90 men; 40 women); regrouping packs – where athletes were in different packs for more than half of the nine splits, and regrouped having had two splits where they were not in any pack (68 men; 56 women); and short-lived packs – where athletes were in a pack for fewer than half of the nine splits (114 men; 161 women). The very few athletes (two men and eight women) who were never in any pack were included in the short-lived pack. The percentage of athletes from each group (e.g. medallists) in each type of pack is shown in Table 1. To compare the pacing profiles of the packs with one another, each athlete's mean speed for the first 5 km was expressed as 100% and each subsequent mean segment speed expressed as a percentage of their initial 5 km speed.

**** Table 1 near here ****

Statistical analysis

One-way within-groups ANOVA compared mean speeds of each group with repeated contrast tests conducted to identify changes between successive race segments (Field, 2009). In addition, one-way ANOVA with Tukey's post-hoc tests compared mean segment speeds between groups and mean percentages between packs (Field, 2009). Percentage data were arcsine transformed for the purposes of statistical analysis (Hanley, 2014; Hanley, 2015). The percentage change in pace between the first and second halves for men and women was compared using an independent *t*-test; a positive split was considered to occur when an athlete ran the second half of the race in a longer time than the first, and a negative split occurred when the first half was longer. Pearson's chi-squared test of association (χ^2) compared observed counts of categorical data (e.g. percentages of athletes who did not finish) between men and women. Statistical significance was accepted as $P < .05$. Effect sizes (ES) for differences between successive segments, and between groups during each segment, were calculated using Cohen's *d* (Cohen, 1988) and considered to be either trivial (ES: < 0.20), small (0.21 – 0.60), moderate (0.61 – 1.20), large (1.21 – 2.00), or very large (2.01 – 4.00) (Hopkins, Marshall, Batterham, & Hanin, 2009).

RESULTS

Mean segment speeds for each group of men are shown in Figure 1. As in other figures, differences between successive splits have been annotated only where the ES was moderate or larger. There was no difference between the medallists and the 5% or 6–10% groups for mean speed over the first 5 km, although the medallists were already faster than the other two groups by this distance by 0.31 $km \cdot h^{-1}$ and 0.62 $km \cdot h^{-1}$ respectively (11–15% group: $P = .020$, ES = 0.69; 16–25% group: $P < .001$, ES = 1.25). By 10 km, the medallists were 0.37 $km \cdot h^{-1}$ faster than the 6–10% group ($P = .005$, ES = 0.83), but were not faster than the 5% group until 25 km ($P = .038$, ES = 0.86), when they were 0.36 $km \cdot h^{-1}$ faster. Fourteen of the 24 medallists and 4.7% of all men ran a negative split. The margin between gold and silver medallists at the finish was 39 s (± 48). Overall, men covered the second half of the race in 109.4% (± 7.1) of the time it took to complete the first half.

**** Figure 1 near here ****

Mean segment speeds for each group of women are shown in Figure 2. As with the men, there was no difference between the medallists and the 5% or 6–10% groups for mean speed over the first 5 km, although the medallists were already faster than the other two groups by this distance by 0.51 $km{\cdot}h^{-1}$ and 0.80 $km{\cdot}h^{-1}$ respectively (11–15% group: P = .001, ES = 0.76; 16–25% group: P < .001, ES = 1.00). By 10 km, the medallists were 0.56 $km{\cdot}h^{-1}$ faster than the 6–10% group (P < .001, ES = 1.03), but were not faster than the 5% group until 30 km (P = .015, ES = 0.65), when they were 0.42 $km{\cdot}h^{-1}$ faster. Nineteen medallists and 12.9% of all women ran a negative split. The margin between gold and silver medallists at the finish was 16 s (± 20). Overall, women covered the second half of the race in 106.4% (± 6.6) of the time it took to complete the first half. The women's second half percentage was lower than the men's (P < .001, ES = 0.44) and they were also more likely to run a negative split (χ^2 = 20.3, P < .001).

**** Figure 2 near here ****

The percentage of athletes forming packs and the number of packs at each 10 km split in each race is shown in Table 2. The lead pack at 10 km in the eight men's races comprised 39, 49, 38, 31, 40, 35, 35, and 36 athletes respectively. The time gaps between the first and last members of these packs at 10 km were 7 s, 4 s, 4 s, 5 s, 4 s, 3 s, 10 s, and 5 s respectively. Differences in segment pace relative to the opening 5 km pace for men are shown in Figure 3. The ever-present packs completed the second half of the race in a time that was 102% (± 2) of the first half; the halfway (109 ± 8%), nomadic (108 ± 6%), semi-nomadic (111 ± 6%), regrouping (111 ± 7%) and short-lived packs (112 ± 6%) all experienced larger positive splits than the ever-present packs (all $P < .001$, ES = 1.19, 1.27, 1.77, 1.62, and 2.01 respectively). The only other differences between packs were that the short-lived packs had larger positive splits than the halfway ($P = .007$, ES = 0.39) and nomadic packs ($P < .001$, ES = 0.64).

**** Table 2 near here ****

**** Figure 3 near here ****

The lead pack at 10 km in the women's races comprised 27, 23, 3, 25, 30, 41, 7, and 18 athletes respectively; the percentage of women forming the lead pack at 10 km was less than in men's races ($\chi^2 = 22.6$, $P < .001$). The time gaps between the first and last members of these packs at 10 km were 4 s, 4 s, 0 s, 2 s, 4 s, 4 s, 2 s, and 3 s respectively. Differences in segment pace relative to the opening 5 km pace for women are shown in Figure 4. The ever-present packs completed the second half of the race in a time that was 99% (± 3) of the first half; as with the men, the halfway (106 ± 7%), nomadic (104 ± 5%), semi-nomadic (108 ± 6%), regrouping (108 ± 5%) and short-lived packs (109 ± 6%) all experienced larger positive splits (all $P < .001$, ES = 1.06, 1.07, 1.88, 2.04, and 1.78 respectively). The other differences between packs were that the short-lived packs had larger positive splits than the halfway ($P < .001$, ES = 0.42) and nomadic packs ($P < .001$, ES = 0.91), and the nomadic group had smaller positive splits than the semi-nomadic ($P < .001$, ES = 0.94) and regrouping packs ($P < .001$, ES = 0.88).

**** Figure 4 near here ****

Approximately 65% of the 179 men who did not finish the race dropped out after halfway, with the largest single percentage of dropouts occurring between 25 and 30 km (27%). Those who dropped out between these distances had slowed to 88.2% (± 12.4) of their starting 5 km pace in their previous 5 km segment, with 65% of these athletes running alone at 25 km. With regard to the women, 70% of those who did not finish dropped out after halfway, with most dropouts occurring between 25 and 30 km and between 30 and 35 km (both 23%). Those who dropped out between 25 and 30 km had slowed to 87.1% (± 9.3) of their starting 5 km pace (84% of these athletes were running alone at 25 km), while those who dropped out between 30 and 35 km had slowed to 83.5% (± 8.5) (89% were running alone at 30 km). 78% of men and 29% of women who eventually dropped out were in the lead pack after 5 km, and overall women were less likely to drop out than men ($\chi^2 = 23.4$, $P < .001$). Only five men and two women who dropped out were never in a pack.

DISCUSSION

The aim of this study was to describe and compare men's and women's pacing profiles in world-class championship marathons. Approximately 95% of men and 87% of women ran the second half of the race slower than the first (positive pacing). This was unsurprising given the typical increase in dependence on lipids (O'Brien, Viguie, Mazzeo, & Brooks, 1993) and other sources of fatigue. This study further emphasised how the 25 to 35 km section was critical for final placing: it was when both sets of men and women medallists first separated themselves from those in the 5% group; it was when the numbers running in packs fell sharply (Table 2); and it was when the highest percentages of dropouts occurred. While Martin and Coe (1997) highlighted this part of the race as when pace and strategy change, decreases in running speed did not occur in medallists (or in the women's 5% group) and thus it appeared the best strategy was to maintain an even pace and wait for rivals to slow down or drop out. For medallists this meant maintaining the pace adopted by 10 km (the first 5 km segment having being slower) and resulted in 33 negative splits amongst the 48 medallists. Slower finishers also adopted even pacing for the first 20 to 25 km but were unable to maintain it and slowed to more sustainable speeds that allowed them to finish (Thiel, Foster, Banzer, & de Koning, 2012); it is possible this deceleration occurred because they started too quickly relative to ability (Renfree & St Clair Gibson, 2013). Unlike in the half marathon (Hanley, 2015), there was no evidence of athletes running below their critical speed in the last quarter to save metabolic reserves for a fast endspurt (Burnley & Jones, 2010), although women medallists sped up in the final 2.2 km (Figure 2). World-class athletes should therefore note that the most successful approach is the early adoption of a fast but maintainable pace that less able athletes will drop off from, or results in them dropping out.

Pack running was a noticeable aspect of these world-class marathons; most athletes ran in a pack until halfway after which the packs fragmented (Table 2). The negative effect of this fragmentation occurred in particular in the men's races where there was considerable deceleration in all packs after 25 km apart from the ever-present packs. Athletes running with others of similar ability and ambition in these ever-present packs achieved more even-paced running (Figures 3 and 4). Most medallists adopted this form of packing behaviour, whereas many athletes finishing within 5% of the winner's time ran with others up to 30 km. Deciding to run with competitors of known ability (such as those from the same nation) means they can be used as external references (Renfree et al., 2014) and can therefore be useful in achieving an even pace, even if the intention is to ultimately beat those opponents. Although other packing strategies did not achieve even pacing, there was evidence from the women's races that running in a nomadic fashion (by dropping back to other packs or speeding up to join others) was better than running most of the race alone. However, running in a pack to halfway only (either with the same athletes or in a semi-nomadic manner), regrouping having lost contact, and running most of the race alone were no different in terms of overall pacing profiles (Figures 3 and 4) and so athletes should choose the strategy that best suits their immediate needs. Of course, athletes cannot know that they will be unable to run alongside others throughout the race and many are still in the lead pack after 10 km. The inability of most athletes to maintain contact with the leaders means they quickly lose speed and suffer positive splits. In addition, given that 78% of men who eventually dropped out had been in the lead pack after 5 km, it is possible that many had started too quickly (given how slow they had become just before dropping out) and would have been better off identifying a more conservatively-paced pack from the beginning, as seems to have occurred in the women's races (other very likely reasons for dropping out include injury or illness). A practical recommendation for marathon runners is to identify competitors of similar ability to run with for most of the race if possible; this form of symbiotic pacing helps all athletes in that pack to achieve even-paced running and potentially better performances.

This study found strong evidence that women are better at evenly pacing marathons than men: women ran the second half of the race closer to the pace of the first half; they were more likely to achieve negative splits; and fewer dropped out. That women achieve more even-paced running has been reported for mixed, mass field competitions of runners who were not elite-standard (Deaner et al., 2015; Santos-Lozano et al., 2014; Trubee et al., 2014) but this novel study has shown that there are sex-based differences in pacing in world-class championship marathons where men and women compete separately. While there might be physiological reasons for this difference, such as women's larger proportional areas of Type I muscle fibres (Hunter, 2014) or men's greater likelihood of glycogen depletion

(Tarnopolsky, 2008), it is also possible that men have an evolutionary predisposition to be over-ambitious (Deaner, 2012) and by contrast women start more conservatively. The benefit to women of such a start (with fewer athletes in the lead pack than in men's races, even though the percentages forming packs were similar) was that more even-paced running was achieved with fewer dropouts. Because the women medallists started slowly and sped up, slower athletes who followed the lead pace in the early stages also benefitted from a more conservative start and suffered smaller decreases in pace later on. A slower start by the best women was therefore beneficial to the whole field, although one other consequence was that the medallists had enough metabolic reserves to increase pace in the final 2.2 km and the endspurt might be more important in deciding the winner of women's marathons than in men's. Coaches of women should therefore note that while a conservative start is beneficial to achieving a more even pace, there could be a disadvantage to those lacking a fast finish and those athletes might be better off adopting a quicker start similar to men and that requires suitable prior training.

CONCLUSIONS

This study analysed pacing profiles of elite-standard men and women competing in the marathon from the viewpoint of final performance, packing behaviour and sex-based differences. Medallists of both sexes maintained an even pace throughout the race, although the more conservative start by women meant the medallists could (or needed to) speed up during the final 2.2 km. Slower athletes had similar pacing profiles until about halfway, when they started to slow and record positive splits. Running with the same athletes throughout the race was conducive to achieving even pacing, although other packing tactics did not differ in terms of reducing decreases in speed in the second half. Women were better at pacing than men, with fewer dropouts, less deceleration in the second half, and more negative splits. This might have been because they adopted a more conservative start and because fewer kept up with the lead pack at the beginning. World-class athletes are advised to consider carefully their speed in the opening stages (neither too fast nor too slow depending on ability and ambition), identify other athletes who would be suitable, if unwitting, pacemakers and to note the different approaches by men and women that might require sex-specific training.

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Table 1. Percentage of athletes from the performance groups in each type of pack.

	Ever-present (%)	Halfway (%)	Nomadic (%)	Semi-nomadic (%)	Regroupers (%)	Short-lived (%)
			Men			
Medallists	71	17	8	4	0	0
5%	24	29	14	13	13	7
6–10%	6	18	24	20	19	13
11–15%	0	12	13	30	10	36
16–25%	0	7	4	12	12	65
			Women			
Medallists	58	17	17	4	0	4
5%	21	32	24	4	6	13
6–10%	3	21	13	13	21	30
11–15%	3	11	7	13	16	50
16–25%	0	8	3	3	3	83

Table 2. Percentage of athletes running in packs (and the number of packs) at each 10 km split.

Year	Total (N)	10 km (%)	20 km (%)	30 km (%)	40 km (%)
			Men		
2001	95	74 (9 packs)	78 (14 packs)	35 (11 packs)	19 (7 packs)
2003	89	94 (9)	88 (9)	71 (15)	29 (9)
2005	98	91 (12)	70 (14)	39 (13)	10 (3)
2009	87	92 (8)	72 (14)	46 (10)	21 (5)
2011	67	94 (8)	74 (11)	41 (10)	14 (3)
2012	102	85 (9)	73 (19)	43 (12)	13 (4)
2013	68	93 (7)	72 (9)	59 (10)	25 (5)
2015	67	89 (6)	72 (7)	49 (7)	19 (4)
All races	**673**	**89**	**75**	**47**	**19**
			Women		
2001	54	86 (7 packs)	68 (7 packs)	33 (3 packs)	23 (4 packs)
2003	65	81 (6)	61 (8)	48 (6)	35 (9)
2005	55	84 (8)	48 (7)	33 (5)	18 (2)
2007	61	83 (7)	71 (6)	48 (8)	35 (6)
2009	68	74 (9)	66 (9)	46 (9)	20 (5)
2012	114	91 (19)	81 (21)	56 (21)	40 (17)
2013	67	72 (15)	39 (7)	30 (6)	15 (2)
2015	65	83 (11)	57 (8)	54 (8)	12 (2)
All races	**549**	**82**	**63**	**45**	**26**

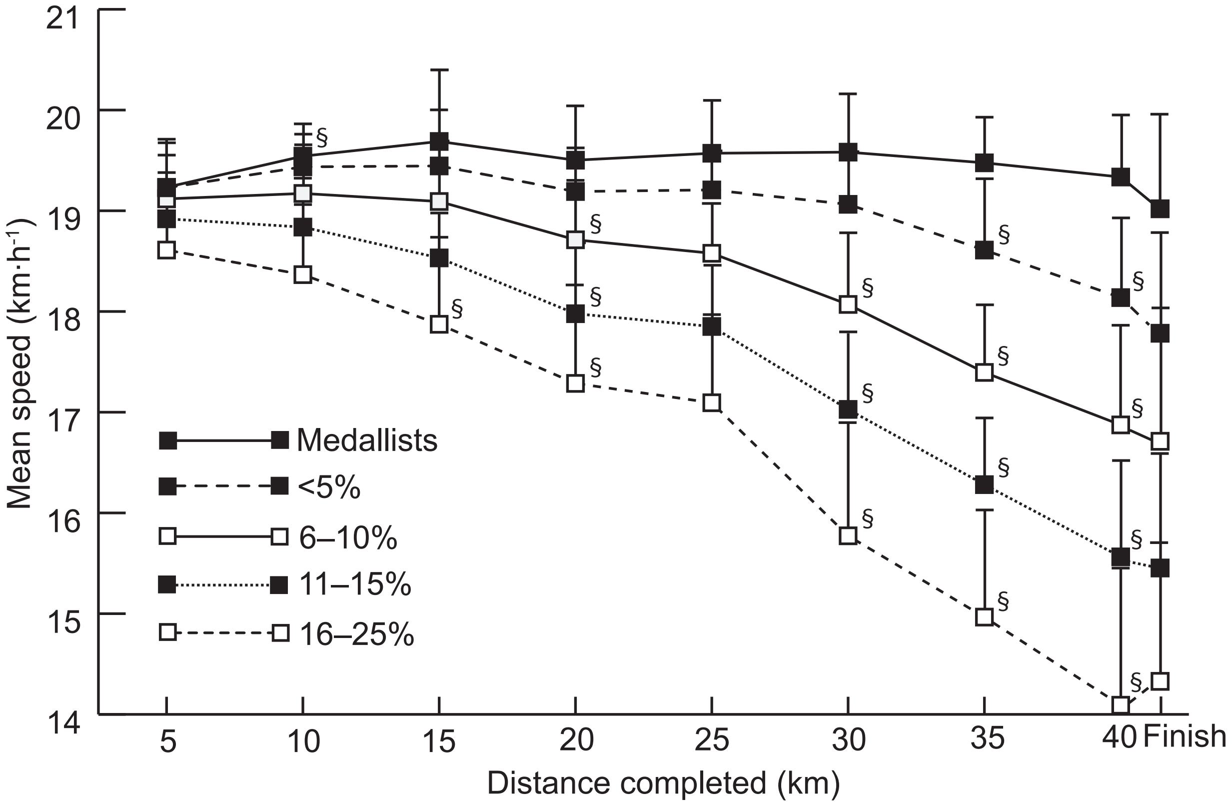
Figure captions

Figure 1. Mean (+ SD) speed for each segment for each group of athletes competing in the men's races. Differences between successive segments with a moderate or larger effect size are shown as $P < .001$ (§).

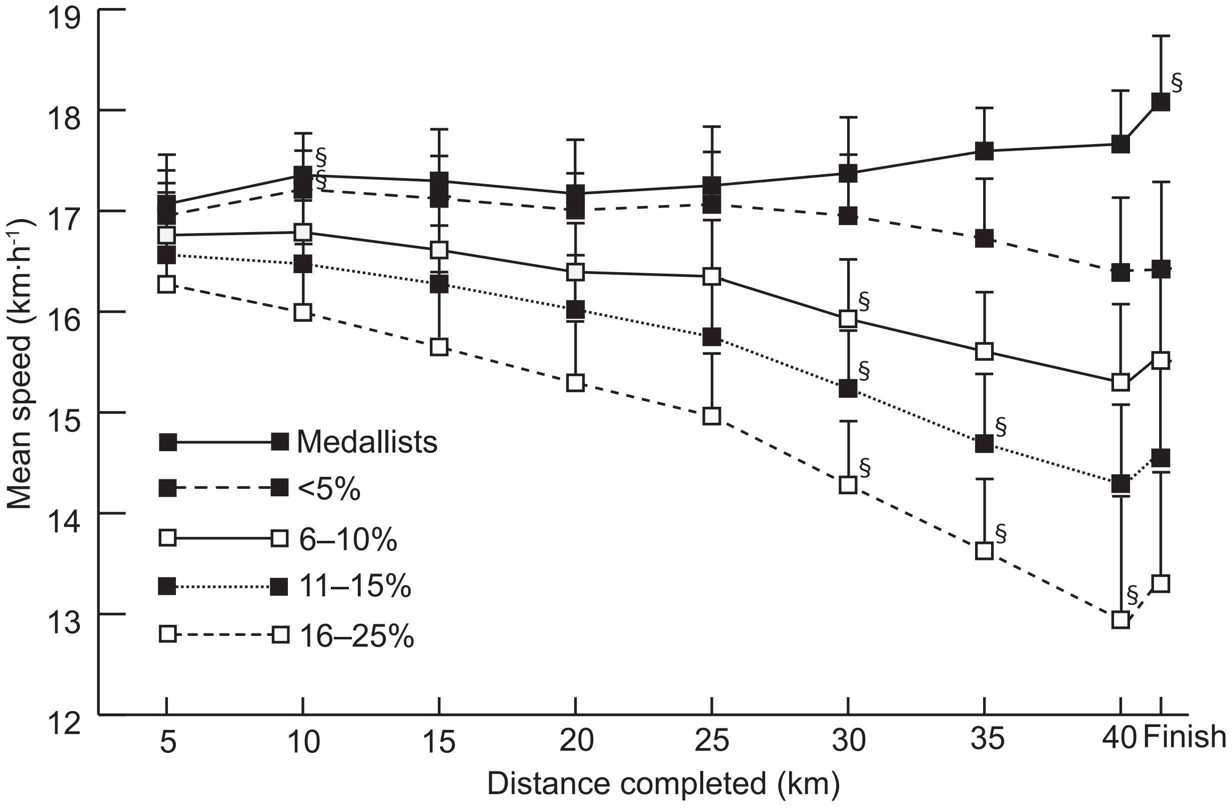
Figure 2. Mean (+ SD) speed for each segment for each group of athletes competing in the women's races. Differences between successive segments with a moderate or larger effect size are shown as $P < .001$ (§).

Figure 3. Mean (+ SD) segment pace relative to initial 5 km pace for each type of pack competing in the men's races. Differences between successive segments with a moderate or larger effect size are shown as $P < .01$ (*) or $P < .001$ (§).

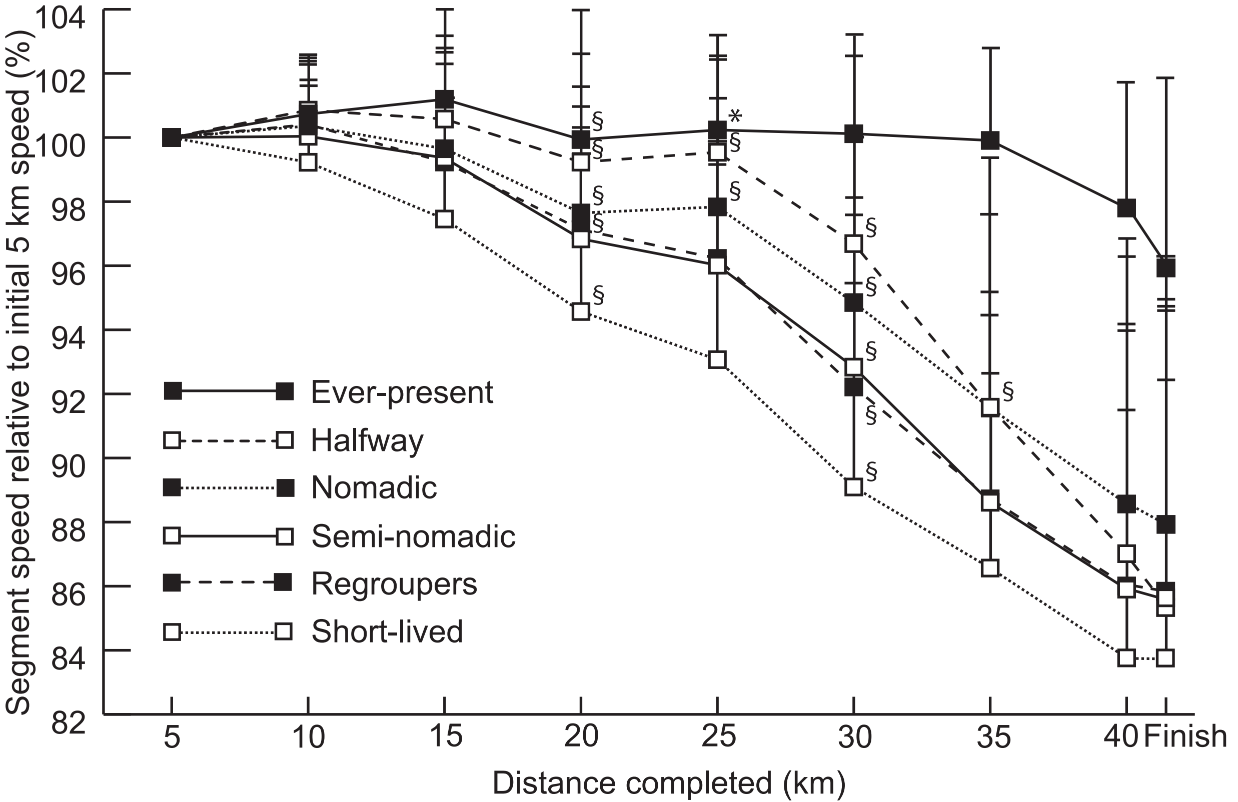
Figure 4. Mean (+ SD) segment pace relative to initial 5 km pace for each type of pack competing in the women's races. Differences between successive segments with a moderate or larger effect size are shown as $P < .01$ (*) or $P < .001$ (§).



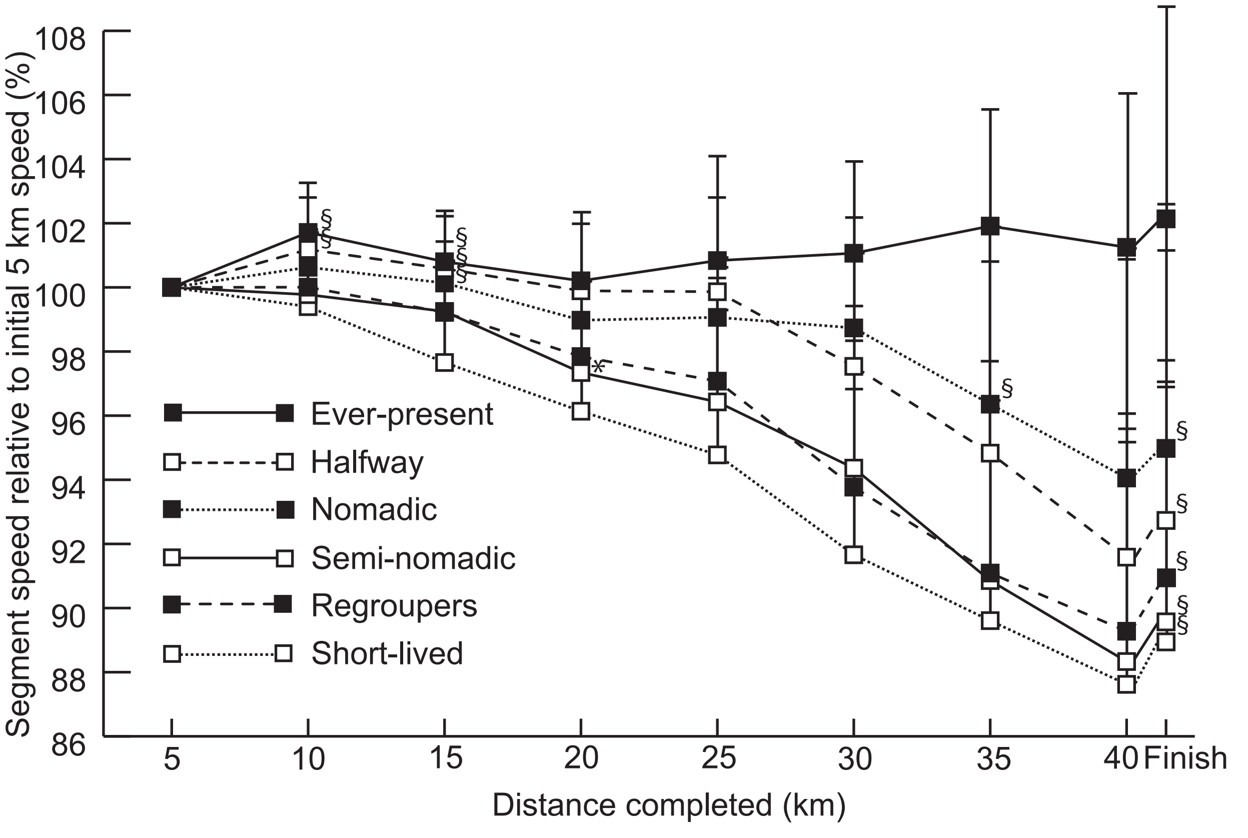
Mean speed (km·h-1)
21
20
19
18
17
16
15
14
5
10
15
20
25
30
35
40
Finish
Distance completed (km)
Medallists
<5%
6–10%
11–15%
16–25%
§



Mean speed (km·h-1)
19
18
17
16
15
14
13
12
5
10
15
20
25
30
35
40
Finish
Distance completed (km)
Medallists
<5%
6–10%
11–15%
16–25%
§



Segment speed relative to initial 5 km speed (%)
104
102
100
98
96
94
92
90
88
86
84
82
5
10
15
20
25
30
35
40
Finish
Distance completed (km)
Ever-present
Halfway
Nomadic
Semi-nomadic
Regroupers
Short-lived
§
*


Segment speed relative to initial 5 km speed (%)
108
106
104
102
100
98
96
94
92
90
88
86
5
10
15
20
25
30
35
40
Finish
Distance completed (km)
Ever-present
Halfway
Nomadic
Semi-nomadic
Regroupers
Short-lived
§
*