Successful pacing profiles of Olympic and IAAF World Championship middle-distance runners across qualifying rounds and finals

Brian Hanley [a]*, Trent Stellingwerff [b,c,d] and Florentina J. Hettinga [e]

a. Carnegie School of Sport, Leeds Beckett University, Leeds, United Kingdom
b. Canadian Sport Institute - Pacific, Victoria, British Columbia, Canada
c. Athletics Canada – Ottawa, Ontario, Canada
d. Department of Exercise Science, Physical & Health Education, University of Victoria, British Columbia, Canada
e. School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Colchester, United Kingdom

* Correspondence author contact information:
Brian Hanley,
Fairfax Hall,
Headingley Campus,
Leeds Beckett University,
LS6 3QS,
United Kingdom.
Telephone: +44 113 812 3577
Fax: +44 113 283 3170
Email: b.hanley@leedsbeckett.ac.uk

Abstract

Purpose: This was the first study to analyze high-resolution pacing data from multiple global championships, allowing for deeper and rigorous analysis of pacing and tactical profiles in elite-standard middle-distance racing. The aim of this study was to analyze successful and unsuccessful middle-distance pacing profiles and variability across qualifying rounds and finals. *Methods*: Finishing and 100-m split speeds and season's best times (SB) were collected for 265 men and 218 women competing in 800 m and 1500 m races, with pace variability expressed using coefficient of variation (CV). *Results*: In both events, successful athletes generally separated themselves from slower athletes in the final 200 m, not by speeding up, but by avoiding slowing compared with competitors. This was despite different pacing profiles between events in the earlier part of the race preceding the endspurt. Approximately 10% of athletes ran SBs, showing a tactical approach to elite-standard middle-distance racing, and possible fatigue across rounds. Men's and women's pacing profiles were remarkably similar within each event, but the previously undescribed seahorse-shaped profile in the 800 m (predominantly positive pacing) differed from the J-shaped negative pacing of the 1500 m. Pacing variability was high compared with world records, especially in the finals (CV: 5.2 – 9.1%), showing that athletes need to be able to vary pace and cope with surges. *Conclusions*: Previous studies have focussed more on athletes in finals, but the present study showed that the best athletes had the physiological capacity to vary pace and respond to surges through successive competition rounds.

Keywords: elite-standard athletes, endurance, fatigue, race tactics, track and field

Introduction

The 800 m and 1500 m are middle-distance running events contested at all global athletics championships. Competitors qualify for the final via a series of rounds in a process that usually comprises heats and semi-finals, from which the highest-placed athletes in each race, and a smaller number of "fastest losers" across all races, qualify.[1] Middle-distance competition features head-to-head racing that creates unique tactical considerations such as drafting and attempting to run the shortest distance ("on the rail"), but which increases the likelihood of getting "boxed in".[2] The necessity for athletes to finish high enough in earlier rounds to advance to subsequent rounds, while conserving energy for the final, suggests that well-planned short- and long-term competition strategies might be crucial, although this tactical hypothesis has not been definitively investigated in elite-standard middle-distance runners. It was recently found that Olympic and World Championship middle-distance finalists were racers, rather than pacers,[3] in that, regardless of time, finalists approached the heats and semi-finals with a strategy of winning, and might not have optimized energy conservation. Accordingly, a novel comprehensive analysis of pacing profiles, using high-resolution 100-m split times, adopted throughout major championships will better inform coaches about successful approaches to middle-distance racing, and including an analysis of variability will indicate the importance of responding to (or instigating) pace changes throughout all rounds of competition.

Previous studies on middle-distance pacing have not always been able to access electronic split times. Therefore, many researchers have conducted their own calculations using video footage from broadcasters[4,5] with the limitation that these broadcasts typically restrict coverage to the leaders and identifying when each split is reached can be difficult because of obscured athletes, and usually only every 200 m or 400 m. By contrast, Thiel et al.[6] benefitted from official split times for each 100-m segment across Olympic distance running finals (in 2008) and stated that the traditional resolution of splits (i.e., every 200 m or 400 m) is inadequate in revealing pacing behaviors in middle-distance events. Consequently, lap splits do not allow for an appreciation of when the top athletes separate themselves from their opponents, or how variable pace is. That athletes vary pace is normal in distance running, and coefficient of variation (CV)[6] is a good indicator of the range of speeds experienced during racing that should be practiced. However, even with 100-m split data, the small sample available to Thiel et al.[6] precluded any statistical analysis and, like other studies,[5] limited the analysis to finals. Accordingly, this study analyzed a greater volume of high-resolution data, allowing for deeper analysis of pacing profiles in elite-standard middle-distance championship racing, not only during finals but also during qualifying toward the final. This allows for contemporary and robust recommendations regarding competitive strategies. Therefore, the aim of this study was to analyze successful and unsuccessful pacing profiles of men and women across qualifying rounds and finals in Olympic and World Championship middle-distance events using official 100-m split times.

Methods

***Subjects*.** The study was approved by the School Research Ethics Committee. Official electronic finishing and 100-m split times of the men's and women's 800 m and 1500 m at the 2008 Olympic Games and IAAF World Championships in 2013 and 2017 were obtained from the open-access IAAF website.[7,8] For the 1500 m, data from the 2016 Olympic Games were also obtained.[9] The total complement of splits was not available because of disqualification, athletes dropping out, or faults in the timing system for 28 performances in the men's 800 m, 4 in the women's 800 m, 29 in the men's 1500 m, and 15 in the women's 1500 m. Overall, the performances of 483 athletes were analyzed. No semi-finals were held for the women's 1500 m in 2008, and so this particular edition has been excluded (i.e., all rounds). The competitors' season's best (SB) times before the championships in each analysis year were also obtained,[8] although SBs were not available for 4 men in the 800 m, and 2 men and 2 women in the 1500 m.

***Design and Methodology*.** The study was designed as observational research in describing pacing profiles in elite-standard modern middle-distance events. Competitors were divided into groups based on their highest round achieved. These groups comprised those who reached the final ("finalists"), those who only reached the semi-final ("semi-finalists"), and those who did not qualify from the heats ("heats runners"); the number of athletes allocated to each group is shown in Tables 1 and 2. These 3 groups were analyzed for each round they appeared in, so that the finalists had finishing times recorded separately for the final, semi-finals and heats, respectively; the semi-finalists for the semi-finals and heats; and the heats runners for the heats only. The finalists were further separated into medalists and non-medalists; semi-finalists into athletes who qualified for the finals ("finalists") and those who did not qualify ("semi-finalists"); and athletes in the heats into "qualifiers" (to the semi-finals) and "non-qualifiers". Athletes' split times were used to calculate mean speed during each 100-m segment before the given split (e.g., 0 – 100 m was termed the 100-m segment). To calculate whether athletes ran a positive or negative split (i.e., slowed or sped up, respectively) in the 1500 m, the 700 – 800-m split time was divided by 2 and this halved time added to the first and second 700-m segments. To compare men's and women's pacing profiles, individuals' speeds for each 100-m segment were expressed as a percentage of their mean speed for the whole race. The split times included for this sex-based comparison comprised each athlete's highest performance, i.e., the finalists' performances in the final, the semi-finalists' performances in the semi-finals, and the heats runners' performances in the heats. Pace variability was measured using CV of all 100-m segments. The CV was calculated as a percentage (CV%) for each athlete's performance.

***Statistical analysis*.** One-way repeated measures ANOVA was conducted on the segment speeds, with repeated contrast tests conducted to identify changes between successive 100-m segments; groups were considered to have separated from one another when a difference was found between cumulative split times. Greenhouse-Geisser corrections were used if Mauchly's test for sphericity was significant. The mean speed percentage data for men and women were arcsine transformed[10] and compared using independent *t*-tests. One-way ANOVA with Tukey's post-hoc tests were conducted to compare mean segment speeds and cumulative times between multiple groups, with differences between 2 groups compared using independent *t*-tests where appropriate. Statistical significance was accepted as $P < 0.05$. Effect sizes (ES) for differences between successive segments, between groups for each segment and for CV%, were calculated using Cohen's *d*[11] and considered to be either trivial (ES < 0.20), small (0.21 – 0.60), moderate (0.61 – 1.20), or large (1.21 – 2.00).[12]

Results

The mean finishing times and finishing times as a percentage of SB for each group in each round are shown in Table 1 (men) and Table 2 (women). The mean speeds for each 100-m split for each group of 800 m men are shown in Figure 1. In all figures and tables (and the text below), differences between successive splits have been annotated only when the ES was moderate or larger. The distances at which groups first separated have also been annotated;

these are the distances at which cumulative times, rather than individual split times, were different. Across all men's 800 m races, 86% of the fastest 100-m splits were run within the opening 200 m, and 63% of races run were with a positive split. Only 13 of the 134 competitors recorded new SB times. The medalists' mean finishing times were 1.1% faster than the non-medalists' times ($P = 0.005$, ES = 1.33); similarly, in the semi-finals, the finalists were also 1.1% faster than the semi-finalists ($P < 0.001$, ES = 1.63).

In the women's 800 m, the semi-finalists ran closer to their SB time in the heats than the finalists did ($P = 0.002$, ES = 0.87; Table 2), with 25 of the 100 athletes running new SB times. The mean speeds for each 100-m split for each group of 800 m women are shown in Figure 1. Across all women's 800 m races, 97% of the fastest 100-m splits were run within the opening 200 m, with 79% of races run with a positive split. The medalists' mean finishing times were 1.9% faster than the non-medalists' times ($P = 0.001$, ES = 1.66), and in the semi-finals, the finalists were 1.4% faster than the semi-finalists ($P < 0.001$, ES = 1.30).

The mean speeds for each 100-m split for each group of 1500 m men are shown in Figure 2. Across all men's 1500 m races, 73% of the fastest 100-m splits were run within the last 300 m, with 93% of races run with a negative split. Only 3 of the 131 men recorded new SB times. The medalists' mean finishing times were not significantly faster than the non-medalists' times; however, in the semi-finals, the finalists were 1.0% faster than the semi-finalists ($P < 0.001$, ES = 0.94).

The mean speeds for each 100-m split for each group of 1500 m women runners are shown in Figure 2. Across all women's 1500 m races, 69% of the fastest 100-m splits were run within the last 300 m; 94% of races were run with a negative split. Eleven of the 118 women recorded new SB times. The medalists' mean finishing times were not significantly faster than the non-medalists' times, whereas in the semi-finals, the finalists were 1.7% faster than the semi-finalists ($P < 0.001$, ES = 1.81).

The mean CV% results are shown in Table 3. When all CV% values were grouped for each event, the CV% in the men's 1500 m (7.0 ± 2.8%) was larger than in both the men's 800 m (4.8 ± 1.5%) and women's 800 m (5.3 ± 1.5%) (both $P < 0.001$, ES = 0.92 and 0.71, respectively). There was no overall difference for CV% between the men's and women's 800 m, or between any event and the women's 1500 m (5.6 ± 2.4%).

With regard to sex-based differences, the mean speeds (as a percentage) for each 100-m segment for men and women are shown in Figure 3. The only difference found in either event was that women ran the first 100-m segment of the 800 m quicker relative to mean race pace ($P < 0.001$, ES = 0.94).

Discussion

The aim of this study was to analyze and compare successful and unsuccessful pacing profiles of elite-standard middle-distance runners across major championship qualifying rounds and finals. There were no statistical differences in finishing times between winning a medal and not winning one in the 1500 m, and relatively small differences (≤ 1.7%) between qualifying from the semi-finals and missing out (as in the 800 m). This shows that success does not only result from running quickly, but highlights the importance of being tactically astute to achieve an automatic qualifying position and the miniscule time differences between qualifying and not. Where separation between groups was found in both events, it occurred mostly in the final 200 m, and showed the importance of the endspurt in successful racing. It was noteworthy that endspurt success was not demonstrated by an increase in speed during the last 200 m, but rather by avoiding slowing too much compared with one's opponents in both events. This similarity between events occurred despite different pacing profiles adopted before reaching this distance, and highlighted the importance of training specifically for the endspurt. Given the importance of tactical positioning in middle-distance racing,[13] the late separation of faster runners from slower ones also indicates that the best runners took a tactically risky decision to run with the pack regardless of pace (and risking getting boxed in), before breaking away over the last phases of the race. In championship racing, where multiple rounds are negotiated and finishing position is more important than time taken,[6,13] successful pacing in qualifying is not about using all possible energy stores by the finish line,[14] but where resources are preserved[15] and psychological efforts managed effectively.[16] However, previous research,[3] supported by this novel study that incorporated analyses of qualifying rounds, suggests athletes do not necessarily adopt championship-specific pacing strategies where achieving qualification is as untaxing as possible, but appear to be primarily dictated by group tactical dynamics.

The pacing patterns across all groups analyzed in the 800 m were similar: the fastest speeds were achieved over the first 200 m followed by a considerable decrease in pace to 300 m, with pace maintained to 500 m. However, once athletes reached the back straight again, there was a very consistent pattern with an increase in pace from 500 m to 600 m; athletes then either maintained their speed to the finish, allowing them to qualify and/or win medals, or slowed. The pacing profile was therefore largely U-shaped[17] although the slower 'tail' meant it had a seahorse-shaped appearance, a profile that appears unique to championship 800 m racing. Aside from the opening 100 m of the 800 m, the increase in pace from 500 m to 600 m was the only increase found in any group in any round; this re-acceleration occurred as athletes tried to obtain a good position before the last bend, with the fast opening 200 m on the first lap possibly serving the same purpose.

It has become more common to have dominant front-runners amongst medalists in the men's 800 m because of a recently dominant front-runner,[5] and this previously undescribed "seahorse" pacing also appears in the women's 800 m. When dominant front running occurs, many elite-standard endurance athletes follow the leaders from the start, regardless of their fitness, in a more time- (or distance-) to-exhaustion approach.[10,18,19] Aggressive front running can be a sensible tactic to stay out of trouble, dictate the pace, run on the rail, and be at the front where the odds of winning improve.[20] The importance to overall time and tactical positioning by front running on the rail is underappreciated by many athletes and coaches.[21] Completing one lap in lane 2, instead of lane 1, results in an extra 7.67 m per lap. Therefore, an 800 m athlete running in lane 2 for the entire race runs approximately 15 m farther, increasing time by about 2 s. However, front running needs to be weighed up against the greater oxygen cost in overcoming air resistance, as even in still conditions there is roughly a 7.5% increase in oxygen uptake when running at 6 m/s to overcome air resistance.[22]

In tactical races, parabolic-shaped pacing often results, either in the form of U-shaped (the start and finish are quickest), J-shaped (greater finishing pace), or reverse J-shaped pacing (greater starting pace),[17] compared with even-paced world records.[23] In this novel high-resolution pacing analysis of championship 1500 m races, the quicker finishes resulted in J-shaped pacing, with athletes gradually increasing speed from between 500 m and 700 m until 1300 m before either maintaining speed to the finish or slowing. Unlike the 800 m runners, most 1500 m athletes ran negative splits and this difference should be noted by middle-distance coaches when planning race-specific training. Of the 41 increases in speed recorded across all groups and rounds of the 1500 m, 37 occurred on either the home straight or back straight. As noted for the 800 m, the increase in distance when running out of the inside lane discourages athletes from overtaking around the bends. Indeed, an athlete might increase pace on the straight sections because it compels rivals to cover more ground on the upcoming bend if overtaking,[24] and is a useful tactic to consider.

Across all 1500 m rounds, what separated qualifiers or medalists from the rest occurred only over the last 15 to 20% of the race, as shown by previous research on pace variability.[5,6] Successful athletes have potentially superior maximal oxygen uptake, as well as the technical abilities to change pace and limit deceleration, in that they experience less physiological disturbance and are better able to draw upon their anaerobic capacity and speed.[21] This supports an emerging middle-distance mechanical construct with bioenergetics implications called anaerobic speed reserve (ASR).[25] ASR is the difference between an athlete's maximal sprint speed (MSS) and speed at maximal oxygen uptake ($v\mathrm{VO}_{2max}$). Therefore, 2 athletes with the same $v\mathrm{VO}_{2max}$, but differing MSS, will present a very different proportion of their ASR as the endspurt begins, and the athlete with higher MSS (and same $v\mathrm{VO}_{2max}$) will be superior. However, one also needs a world-class $v\mathrm{VO2}_{max}$ (or aerobic capacity and power) to be in contention in the first place. It should be noted that world-class aerobic physiology is most relevant to performances over 1500 m given the aerobic dominance of this event.[26-28] Conversely, depending on the individual's fiber type, the 800 m is at the crossroads of metabolism, with energy source production between 50 and 70% aerobic,[26] with the rest coming from anaerobic metabolism.[28] Therefore, 800 m tactical success is bio-energetic, biomechanical and structural in nature.[29]

When comparing athletes using percentage of SB time, no differences were found between those who qualified from the heats and those who did not, confirming previous findings that those with better SBs were more likely to qualify.[13] The best athletes were able to run slower than SB time and still qualify as the slower runners would have had to get closer to their SB times to beat them. This suggests the qualifiers experienced less physiological disturbance by the beginning of their endspurt,[4] and theoretically took advantage of a superior aerobic component of the ASR. Additionally, by running at similar percentages of SB, they took a tactical approach to winning (or finishing highly) that focussed less on time achieved.[3] That only approximately 10% ran SB times across all races suggests tactical racing amongst the elite, fatigue accumulation across rounds, and an absence of pacemakers to set even pace or help with drafting, as occurs in Diamond League events.[30] Interestingly, the pacing profiles found in the present study differed from those found in Diamond League events[30] as their analyses showed a more even pace was adopted after the first 200 m (especially for women). This contrast might reflect not only potential differences in pacing, but also the smaller resolution available to that study (200-m splits), the subjective nature of analysing video, and the broadcasters' focus on leading athletes. Therefore, a strength of this new study is its depth and quality of official electronic 100-m split times across all competitors in 800-m and 1500-m championship racing to explain pacing patterns.

There were practically no differences between the pacing patterns of men and women in either event, similar to research on other elite-standard distance races,[10] or between groups of athletes. The pacing patterns within each event were so similar, but also sufficiently different from the other, that an "800 m pacing profile" and a "1500 m pacing profile" could be identified. The differences in anaerobic energy contribution between the events[27] is one probable cause, although the rule requiring 800 m athletes to run the first bend in staggered lanes means they cannot pace themselves as easily, and might have contributed to the very quick opening 200 m when aiming for the best positions within the pack. Although most 800 m runners ran positive splits, many did not (37% of men and 21% of women) and coaches should include training sessions that replicate situations where either type of split is run. From a purely physiological stand-point athletes would aspire for even-paced races, as even-pacing has a lower energy cost than running with acceleration and deceleration spurts throughout.[15] Smooth race accelerations in the 1500 m, rather than aggressive ones, should result in less mid-race usage of finite anaerobic energy reserves, which could be used during the endspurt.[21] However, the CV% data were crucial in highlighting the necessity for top athletes to cope with varied pace, and most importantly when higher speeds were required. This was especially true in the 1500 m, where most athletes (93% of men and 94% of women) ran negative splits. Additionally, the increased CV% amongst finalists in the men's 800 m and women's 1500 m showed that the best athletes in these events could run more evenly in the earlier rounds and save their higher running speeds for the final.

Practical applications

This study analyzed men's and women's middle-distance pacing profiles, and found distinct pacing profiles for the 800 m (seahorse-shaped) and 1500 m (J-shaped). Coaches should note that different tactical approaches, such as negative and positive pacing, are required for each event, but that men's and women's pacing profiles within each event were remarkably similar and do not require sex-specific training. It should be noted that these pacing profiles are unique to championship racing, as world-record and/or paced Diamond League races tend to feature a much smoother pacing profile.[23,30] Accordingly, many elite-standard athletes are more comfortable with "rabbited" high-speed race tactics presented at Diamond League-type events compared with the unique, and rare, pace tactics demonstrated at major championships. Consequently, this study provides unique insights into these varied paces that coaches and athletes can use in training situations to mimic championship racing.

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Table 1 Mean (± SD) finishing times / finishing times as a percentage of SB for each group of men athletes in each round.

	Finalists	Semi-finalists	Heats runners
		Men	
800 m	N = 24	N = 48	N = 62
Heats	1:46.31 (± 0.82) / 102.0% (± 1.2)	1:46.41 (± 0.70) / 101.4% (± 1.4)	1:48.13 (± 1.19) [1] / 101.9% (± 1.3)
Semi-finals	1:45.62 (± 0.52) / 101.2% (± 1.0)	1:46.83 (± 0.83) / 101.9% (± 1.4)	
Final	1:45.14 (± 1.04) [a] / 100.9% (± 1.1)		
1500 m	N = 42	N = 40	N = 49
Heats	3:39.98 (± 3.39) / 103.0% (± 2.0)	3:40.75 (± 3.58) / 103.0% (± 1.8)	3:44.75 (± 3.72) [1] / 102.8% (± 2.5)
Semi-finals	3:39.06 (± 2.05) / 102.7% (± 1.4)	3:41.29 (± 2.68) / 103.3% (± 1.3)	
Final	3:40.51 (± 6.96) / 103.3% (± 3.2)		

[a] Faster than the heats ($P < 0.001$)
[1] Slower than the finalists and semi-finalists in this round ($P < 0.001$)

Table 2 Mean (± SD) finishing times / finishing times as a percentage of SB for each group of women athletes in each round.

	Finalists	Semi-finalists	Heats runners
	Women		
800 m	N = 24	N = 39	N = 37
Heats	2:00.63 (± 1.21) / 102.2% (± 2.1)	2:00.77 (± 1.07) / 100.9% (± 1.2)	2:02.27 (± 0.93) [1] / 101.4% (± 0.9)
Semi-finals	1:59.14 (± 1.12) / 101.0% (± 1.6)	2:00.75 (± 1.31) / 100.9% (± 1.1)	
Final	1:57.86 (± 1.67) [a b] / 100.2% (± 1.5)		
1500 m	N = 32	N = 31	N = 55
Heats	4:06.67 (± 2.17) / 102.1% (± 1.9)	4:07.50 (± 2.76) / 101.2% (± 1.3)	4:11.60 (± 3.27) [1] / 102.1% (± 1.6)
Semi-finals	4:04.88 (± 0.96) / 101.6% (± 1.1)	4:08.99 (± 3.09) / 101.7% (± 1.6)	
Final	4:07.63 (± 4.20) [c] / 102.7% (± 1.9)		

[a] Faster than the heats ($P < 0.001$)
[b] Faster than the semi-finals ($P < 0.01$)
[c] Slower than the semi-finals ($P < 0.01$)
[1] Slower than the finalists and semi-finalists in this round ($P < 0.001$)

Table 3. Mean (± SD) CV% values for each group of athletes in each round, calculated for each athlete's performance using the mean and standard deviation of all their 100 m segment speeds.

	Finalists	Semi-finalists	Heats runners
		Men	
800 m			
Heats	4.2 (± 0.9)	4.1 (± 1.5)	4.8 (± 1.8)
Semi-finals	5.3 (± 0.7)	5.5 (± 1.2) [b]	
Final	5.8 (± 1.3) [a]		
1500 m			
Heats	6.5 (± 2.4)	6.7 (± 2.7)	6.1 (± 3.0)
Semi-finals	7.5 (± 1.5)	7.0 (± 1.2)	
Final	8.2 (± 4.1)		
		Women	
800 m			
Heats	5.3 (± 1.9)	5.0 (± 1.4)	5.7 (± 1.5)
Semi-finals	5.3 (± 0.9)	5.5 (± 1.3)	
Final	5.2 (± 1.6)		
1500 m			
Heats	4.9 (± 1.2)	4.4 (± 1.5) [1]	4.8 (± 2.2) [1]
Semi-finals	5.9 (± 1.4)	5.1 (± 1.1) [1]	
Final	9.1 (± 3.0) [b c]		

[a] Higher than the heats ($P < 0.01$)
[b] Higher than the heats ($P < 0.001$)
[c] Higher than the semi-finals ($P < 0.001$)
[1] Lower than the finalists' value in the final ($P < 0.001$)

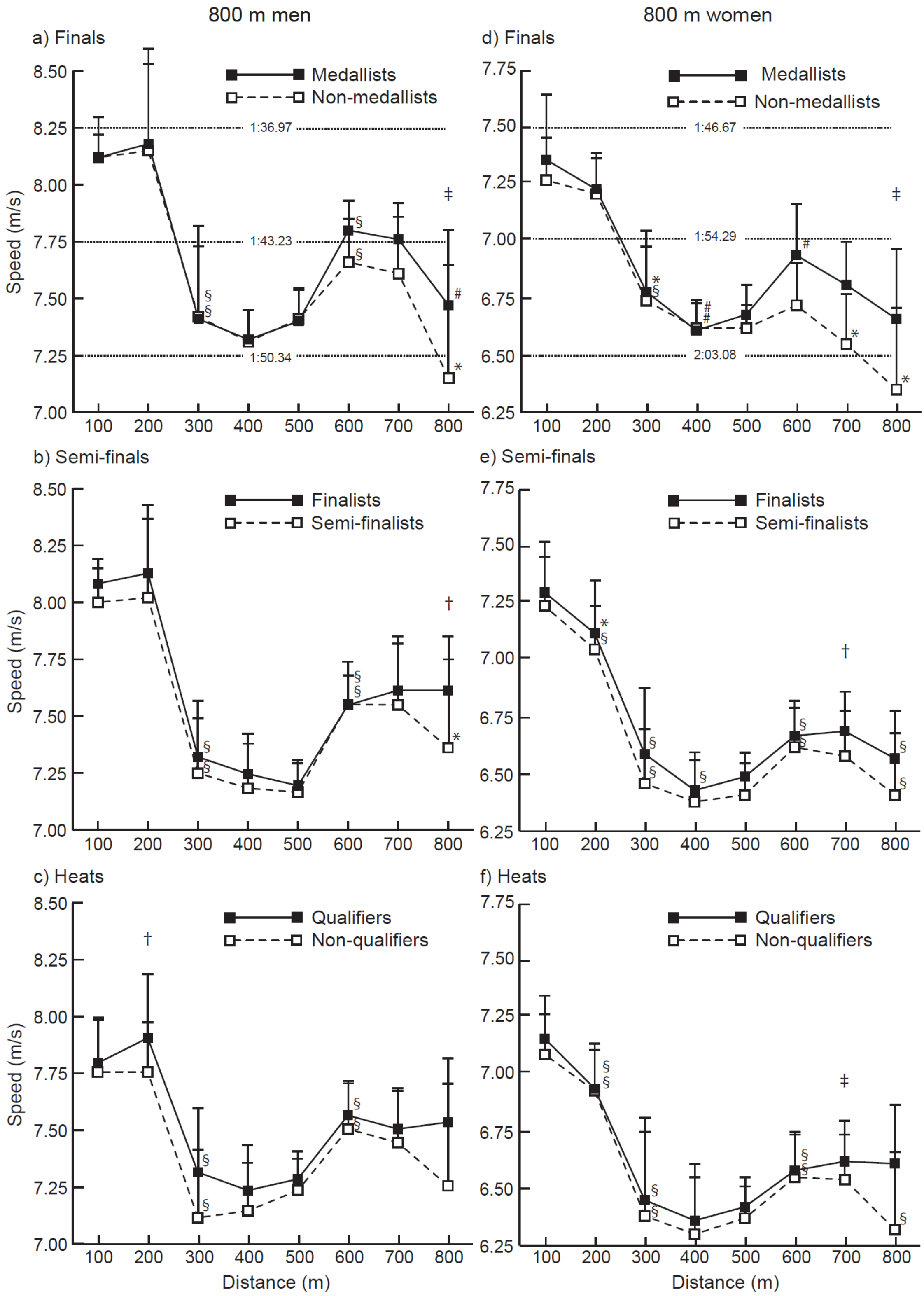

Figure 1. The mean (+ SD) 100-m segment speed for each group of men and women 800 m athletes for all three rounds. Differences between successive segments with a moderate or larger effect size are shown as either *P* < 0.001 (§), *P* < 0.01 (*) or *P* < 0.05 (#). Where separations between groups first occurred, these are indicated as either *P* < 0.001 (†) or *P* < 0.01 (‡). The dashed horizontal lines and annotated race times indicate the race pace achieved at those speeds.

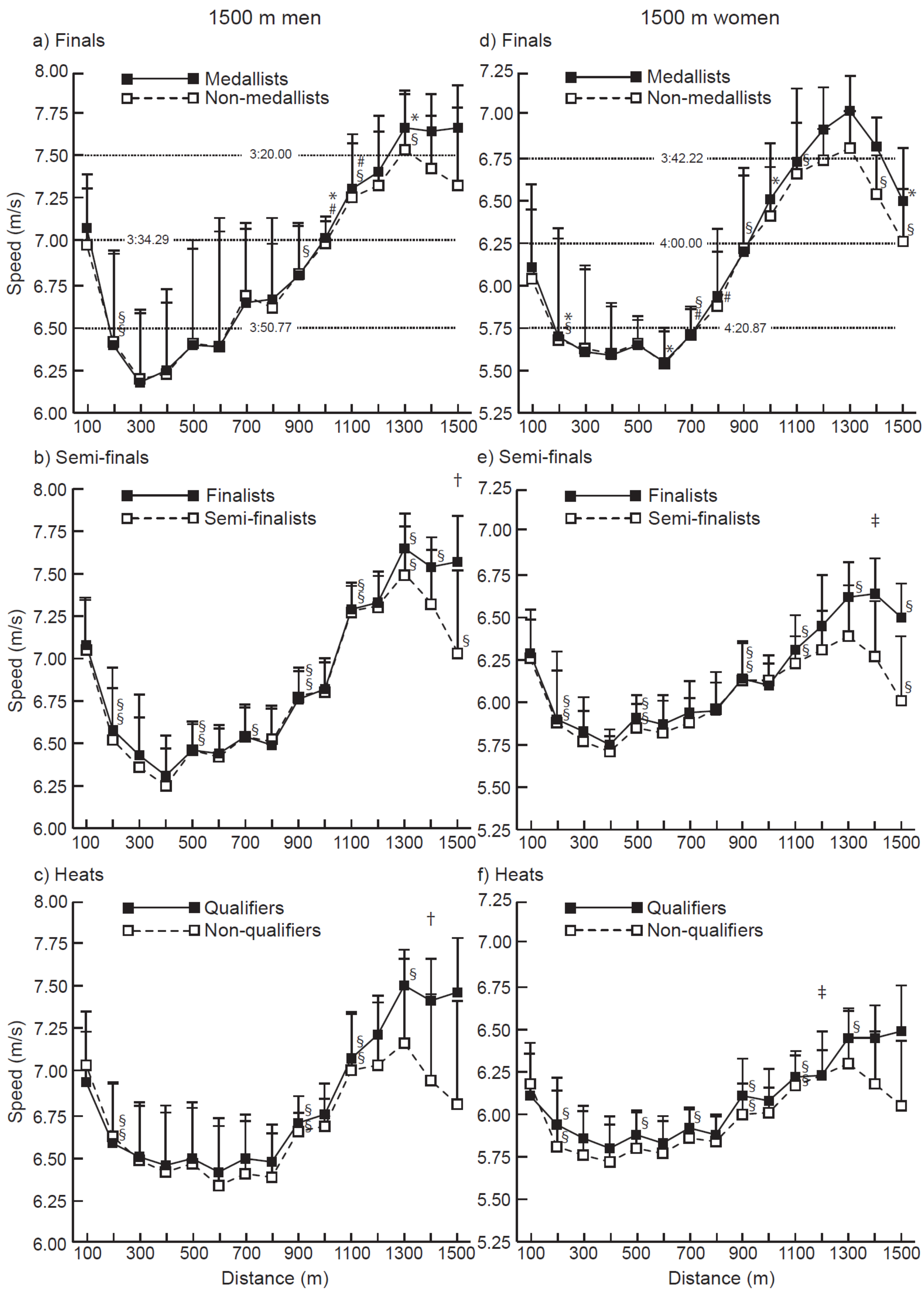

Figure 2. The mean (+ SD) 100-m segment speed for each group of men and women 1500 m athletes for all three rounds. Differences between successive segments with a moderate or larger effect size are shown as either *P* < 0.001 (§), *P* < 0.01 (*) or *P* < 0.05 (#). Where separations between groups first occurred, these are indicated as either *P* < 0.001 (†) or *P* < 0.01 (‡). The dashed horizontal lines and annotated race times indicate the race pace achieved at those speeds.

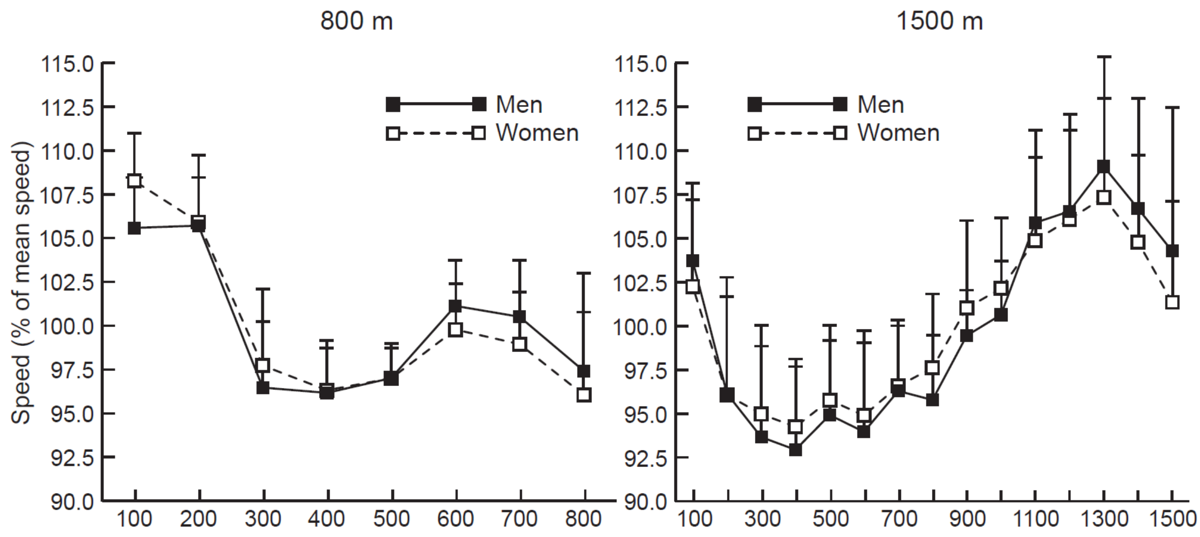

Figure 3. The mean (+ SD) 100-m segment speed expressed as a percentage of mean speed for men and women in each event.