# Fast men slow more than fast women in a 10 kilometer road race (#10542)



First submission

Please read the **Important notes** below, and the **Review guidance** on the next page.
When ready **submit online**. The manuscript starts on page 3.

## Important notes

### Editor and deadline

Justin Keogh / 3 Jun 2016

| | |
|---|---|
| **Files** | 2 Figure file(s)<br>4 Table file(s)<br>1 Raw data file(s)<br>Please visit the overview page to **download and review** the files not included in this review pdf. |
| **Declarations** | **Involves the study of human participants/human tissue.** |

# Review guidelines



Please in full read before you begin

## How to review

When ready **submit your review online**. The review form is divided into 5 sections. Please consider these when composing your review:

1. **BASIC REPORTING**
2. **EXPERIMENTAL DESIGN**
3. **VALIDITY OF THE FINDINGS**
4. General comments
5. Confidential notes to the editor

You can also annotate this **pdf** and upload it as part of your review

To finish, enter your editorial recommendation (accept, revise or reject) and submit.

### BASIC REPORTING

- Clear, unambiguous, professional English language used throughout.
- Intro & background to show context. Literature well referenced & relevant.
- Structure conforms to **PeerJ standard**, discipline norm, or improved for clarity.
- Figures are relevant, high quality, well labelled & described.
- Raw data supplied (See **PeerJ policy**).

### EXPERIMENTAL DESIGN

- Original primary research within **Scope of the journal**.
- Research question well defined, relevant & meaningful. It is stated how research fills an identified knowledge gap.
- Rigorous investigation performed to a high technical & ethical standard.
- Methods described with sufficient detail & information to replicate.

### VALIDITY OF THE FINDINGS

- Impact and novelty not assessed. Negative/inconclusive results accepted. *Meaningful* replication encouraged where rationale & benefit to literature is clearly stated.
- Data is robust, statistically sound, & controlled.
- Conclusion well stated, linked to original research question & limited to supporting results.
- Speculation is welcome, but should be identified as such.

The above is the editorial criteria summary. To view in full visit **https://peerj.com/about/editorial-criteria/**

# Fast men slow more than fast women in a 10 kilometer road race

Robert Deaner, Vittorio Addona, Rickey E Carter, Michael J Joyner, Sandra K Hunter

**Background.** Previous studies have demonstrated that men are more likely than women to slow in the marathon. This study investigated whether the sex difference in pacing occurs for a shorter race distance. **Materials & Methods.** Data were acquired from the Bolder Boulder 10 km road race for the years 2008-2013, which encompassed 191,693 performances. There were two pacing measures, percentage change in pace of the first 3 miles relative to the final 3.2 miles and percentage change in pace of the first mile relative to the final 5.2 miles. Pacing was analyzed as a continuous variable and as two categorical variables, as follows: ‘‘maintain the pace,’’ defined as slowing < 5% and ‘‘marked slowing,’’ defined as slowing ≥ 10%. **Results.** Among the fastest (men < 48:40; women < 55:27) and second fastest (men < 53:54; women < 60:28) sex-specific finishing time sextiles, men slowed significantly more than women with both pacing measures, but there were no consistently significant sex differences in pacing among the slower four sextiles. For the fastest sextile, the odds for women were 1.96 (first pacing measure) and 1.36 (second measure) times greater than men to maintain the pace. For the fastest sextile, the odds for women were 0.46 (first measure) and 0.65 (second measure) times that of men to exhibit marked slowing. Multiple regression indicated that being older was associated with lesser slowing, but the sex difference among faster runners persisted when age was controlled. **Conclusions.** There was sex difference in pacing during a 10 km race where glycogen depletion is not typically relevant. These results support the hypothesis that the sex difference in pacing partly reflects a sex difference in decision making.

# Fast men slow more than fast women in a 10 kilometer road race

ROBERT O. DEANER[a, *]

VITTORIO ADDONA[b]

RICKEY E. CARTER[c]

MICHAEL J. JOYNER[d]

SANDRA K. HUNTER[e]

[a]Grand Valley State University, Department of Psychology, Allendale, MI, USA

[b]Macalester College, Department of Mathematics, Statistics, and Computer Science, Saint Paul, MN, USA

[c]Mayo Clinic, Department of Health Sciences Research, Rochester, MN, USA

[d]Mayo Clinic, Department of Anesthesiology, Rochester, MN, USA

[e]Marquette University, Exercise Science Program, Department of Physical Therapy, Milwaukee, WI, USA

*** Corresponding author**

Tel.: +1 616 331 2423; Fax: +1 616 331 2480; E-mail: robert.deaner@gmail.com

Address: Department of Psychology, Grand Valley State University, 1 Campus Drive, 1315 AuSable Hall, Allendale, 49401, MI, USA

**Short Title:** Fast men slow more than fast women

## Abstract

**Background.** Previous studies have demonstrated that men are more likely than women to slow in the marathon. This study investigated whether the sex difference in pacing occurs for a shorter race distance. **Materials & Methods.** Data were acquired from the Bolder Boulder 10 km road race for the years 2008-2013, which encompassed 191,693 performances. There were two pacing measures, percentage change in pace of the first 3 miles relative to the final 3.2 miles and percentage change in pace of the first mile relative to the final 5.2 miles. Pacing was analyzed as a continuous variable and as two categorical variables, as follows: ‘‘maintain the pace,’’ defined as slowing < 5% and ‘‘marked slowing,’’ defined as slowing ≥ 10%. **Results.** Among the fastest (men < 48:40; women < 55:27) and second fastest (men < 53:54; women < 60:28) sex-specific finishing time sextiles, men slowed significantly more than women with both pacing measures, but there were no consistently significant sex differences in pacing among the slower four sextiles. For the fastest sextile, the odds for women were 1.96 (first pacing measure) and 1.36 (second measure) times greater than men to maintain the pace. For the fastest sextile, the odds for women were 0.46 (first measure) and 0.65 (second measure) times that of men to exhibit marked slowing. Multiple regression indicated that being older was associated with lesser slowing, but the sex difference among faster runners persisted when age was controlled. **Conclusions.** There was sex difference in pacing during a 10 km race where glycogen depletion is not typically relevant. These results support the hypothesis that the sex difference in pacing partly reflects a sex difference in decision making.


**Keywords:** *gender; risk taking; endurance exercise; distance running; athletic performance*

## Introduction

Scientists have long been interested in pacing in endurance events. They have characterized successful pacing trajectories in races of varying lengths and also identified several physiological, energetic, and environmental factors that influence pacing (Abbiss & Laursen, 2008; Tucker & Noakes, 2009; Roelands et al., 2013). Recently, researchers discovered a robust pattern that suggests additional influences on pacing. The pattern is that men are more likely than women to slow their pace in the marathon (42.195 km) (March et al., 2011; Trubee et al., 2014; Deaner et al., 2015a; Krawczyk & Wilamowski, 2015; Hubble & Jinger, 2015; Hanley, 2016). For example, a study of 14 U.S. marathons, including more than 90,000 performances, found that, on average, men ran the second half of the marathon 15.6% slower than the first half, whereas women slowed by 11.7% (Deaner et al., 2015a). Furthermore, in that study, men were roughly three times as likely as women to slow by least 30%.

The sex difference in marathon pacing could be attributed to a sex difference in physiology. In particular, it was hypothesized that the sex difference is due to men's greater susceptibility to muscle glycogen depletion (March et al., 2011; Trubee et al., 2014), a major contributor to marathon slowing (Coyle, 2007; Rapoport, 2010). Supporting this hypothesis are studies indicating that, for any given intensity of endurance exercise, women are more likely than men to spare glycogen (Roepstorff et al., 2002; Tarnopolsky, 2008).

It was also hypothesized that the sex difference in marathon pacing reflects a sex difference in some aspect of decision making (Deaner et al., 2015a; Krawczyk & Wilamowski,

2015; Hubble & Jinger, 2015). Supporting this hypothesis are recent studies of the Warsaw marathon and the Houston marathon that examined the relation between runners' pacing and the discrepancy between their pre-race self-forecasts and their actual performances; in both marathons, pacing and forecasting discrepancy were substantially correlated, and men's greater slowing could be largely attributed to their more discrepant forecasting, which may, in turn, be caused by greater over-confidence or risk taking (Krawczyk & Wilamowski, 2015; Hubble & Jinger, 2015). Also consistent with the decision making hypothesis is the fact that, in non-sport domains, men generally perceive lesser risks than women do (Harris, Jenkins & Glaser, 2006), and laboratory studies indicate that individuals with lesser perceptions of risk are more likely to select ambitious initial paces (Micklewright et al., 2015).

The susceptibility to glycogen depletion hypothesis and the decision making hypothesis are mutually compatible because the decision to adopt an ambitious or risky pace relative to one's ability will impose physiological challenges. Nevertheless, it could be fruitful to attempt to differentiate these hypotheses in order to clarify the factors that contribute to group and individual variation in pacing. One approach to differentiating these hypotheses is to test for a sex difference in pacing in a distance running event where glycogen depletion should be irrelevant, generally an event shorter than 25 km (Coyle, 2007; Rapoport, 2010). If men's greater susceptibility to glycogen depletion is the main cause of the sex difference in pacing, then no sex difference should occur in a shorter race. However, if decision making contributes to the sex difference in pacing, then a sex difference, where men slow more than women, should occur in a shorter race.

Here we attempt to differentiate these hypotheses by examining pacing in the Bolder Boulder 10 km road race, which is one of the largest road races in the U.S. (Running USA, 2015) and one of the few large road races shorter than a marathon to record split times. For races occurring between 2008 and 2013, we obtained splits at each mile for 191,693 performances. In addition to testing for an overall sex difference in pacing, we will explore if finishing time and age modulate any sex difference; previous studies of marathon pacing have indicated the importance of these factors (March et al., 2011; Trubee et al., 2014; Santos-Lozano et al., 2014; Deaner et al., 2015a; Krawczyk & Wilamowski, 2015; Hubble & Jinger, 2015; Hanley, 2016).

In summary, the aim of this study is to provide the first test of whether the sex difference in pacing that has been documented for the marathon also occurs in a large 10 km road race.

## Materials & Methods

This study did not require formal approval by Grand Valley State's institutional review board (IRB) or the other IRBs (Macalester College, Marquette University, Mayo Clinic). The Grand Valley State University IRB determined that the protocol (reference number 756083-1) was exempt under federal category 45 CFR 46.101(b) (4) because all data were preexisting and public.

The Bolder Boulder website (bolderboulder.com/Page/Find/Results) publicly posts data on finishers' names, hometowns, sex, age, and finishing times for races beginning in 1980; beginning with the 2008 race, mile splits are also available. To speed data acquisition, we

115 requested that all data be sent to us as a single file. The race organizers and timing company
116 generously agreed to this request, although they first removed finishers' names. The data set
117 spanned 6 years (2008-2013) and initially included all finishers who had sex, age, finishing time,
118 and all splits recorded (n = 274,966). We excluded all finishers which we believe had one or
119 more data entry errors, according to the following rules: (i) one or more mile times less than 2
120 min 30 sec or (ii) mile times not consistent with their total finishing time (n = 9).
121
122 We also excluded all those who finished in 83 min 20 sec or greater (n = 83,264; 67.76%
123 women). We did this because the transition speed between walking and running typically occurs
124 around 2.0 m / sec (or 4.5 mph), so we assumed that runners whose overall speed was slower
125 than this (i.e., a finishing time ≥ 83 min and 20 sec) were likely walking a substantial portion of
126 the race. Although there is individual variability in the transition speed between walking and
127 running, this variation appears unrelated to oxygen consumption (Rotstein et al., 2005; Monteiro
128 et al., 2011). Thus, we used this same exclusion criterion for men and women of all ages. After
129 making these exclusions, the sample was comprised of 191,693 usable performances, including
130 48.85% women (n = 93,643).
131
132 **Statistical Analysis**
133 We considered two measures of pacing. For our first pacing measure, we calculated the
134 percentage change in the pace maintained over the first 3 miles relative to the final 3.2 miles.
135 That is, % change = (minutes per mile in final 3.2 miles – minutes per mile in first 3 miles) /
136 minutes per mile in first 3 miles. We used this measure because it is similar to comparing the
137 pace of the first half of the race to the second half of the race, which has been done in marathon

138 studies (Deaner et al., 2015a; Krawczyk & Wilamowski, 2015). (No 5 km split was available for
139 this race, preventing a more direct comparison with previous studies.) Our second pacing
140 measure was the percentage change in the pace of the first mile relative to the final 5.2 miles.
141 That is, % change = (minutes per mile in final 5.2 miles – minutes per mile in first mile) /
142 minutes per mile in first mile. We selected this measure because it should capture runners
143 beginning the race at a speed which is too fast to be sustainable.
144
145 We considered each of these two pacing measures as a continuous variable and as two
146 categorical variables. For the first categorization, percentage changes less than 5% were
147 considered ‘‘maintaining the pace.’’ For example, a runner who completed the first 3 miles of
148 the race in 6 minutes and 40 seconds per mile and the final 3.2 miles in 7 minutes per mile or
149 better maintained the pace; those who ran the final 3.2 miles in more than 7 minutes per mile
150 failed to maintain the pace. For the second categorization, percentage changes equal to or greater
151 than 10% were considered as ‘‘marked slowing.’’ For example, a runner who completed the first
152 3 miles of the race in 6 minutes and 40 seconds per mile and the final 3.2 miles in 7 minutes and
153 20 seconds per mile or worse showed marked slowing. Total finishing time and all mile split
154 times were determined from electronic chip times (i.e., based on when each individual crossed
155 the starting line).
156
157 To explore the impact of finishing time on our categorical pacing measures, we also
158 categorized male and female performances into sex-specific sextiles (i.e., dividing all
159 performances of one sex into six equivalent sized groups). The fastest male group consisted of
160 men finishing in 48:40 or faster, and the other sextile boundaries for men were 53:54, 58:30,

63:40, and 71:05. The corresponding boundaries for women were 55:27, 60:28, 64:58, 69:53, and 75:41.

When considering pacing as a continuous response (or dependent) variable, we estimated two multiple regression models for each of our two pacing measures. Model 1 used sex, age, and finishing time as explanatory (or independent) variables. Model 2 included sex, age, and finishing time, along with the pairwise interactions between these variables. For these models and some figures, we followed a previous study (Deaner et al., 2015a) in dividing women' times by 1.12 to account for men's greater maximal oxygen uptake (Joyner, 1993; Sparling, O'Donnell & Snow, 1998; Cheuvront et al., 2005).

Descriptive summaries are presented as mean ± standard deviation (SD). All analyses were conducted using the R programming language, version 3.1.1 (R Core Team). Data are reported as mean ± SD in the text. Two-sided P-values less than 0.05 were taken as statistically significant.

## Results

A total of 191,693 runners (48.85% women) were included in this analysis. The ages for men and women, respectively, were 35.54 ± 15.27 and 32.90 ± 12.41 years. Finishing times for men and women were 59:23 ± 10:51 and 65:10 ± 9:36 minutes, respectively, a difference in means of 8.9%.

184 The percentage changes in pace of the first 3 miles relative to the final 3.2 miles were
185 2.02 ± 6.69 and 1.71 ± 5.90% for men and women, respectively ($P < 0.0001$). The percentage
186 changes in pace of the first mile relative to the final 5.2 miles were 8.17 ± 9.38 and 8.04 ± 8.62%
187 for men and women, respectively ($P = 0.0024$).
188
189 **Pacing by sex and finishing time**
190 Table 1 reports the results for the two pacing measures (Measure 1: first 3 miles relative
191 to the final 3.2 miles; Measure 2: first mile relative to the final 5.2 miles) for each finishing time
192 sextile, separately for men and women. For both measures and both sexes, change in pace varied
193 significantly across sextiles ($P < 0.0001$ for both sexes and both measures), with slower runners
194 generally experiencing greater slowing. Among runners in the fastest two sextiles, men slowed
195 significantly more than women for both pacing measures. Among the other sextiles, women
196 sometimes slowed significantly more than men, men sometimes slowed significantly more than
197 women, and in some cases, there was no significant sex difference.
198
199 We next determined, for each pacing measure, the percentage of men and women in each
200 sextile that maintained the pace (< 5% slowing). Table 2 shows that, for both pacing measures,
201 maintaining the pace varied across sextiles, as faster runners were more likely than slower
202 runners to maintain the pace ($P < 0.0001$ for both sexes and both measures).
203
204 We calculated the common (pooled) OR for maintaining the pace for women compared
205 with men across the sextiles (Table 2). Overall, the odds that women maintained the pace were
206 1.16 times (95% confidence interval (CI), 1.13–1.18; $P < 0.0001$) greater compared to men for

the first pacing measure. For the second pacing measure, the odds that women maintained the pace were 0.97 times as great as the odds that men maintained the pace (95% CI, 0.95–0.99; P < 0.0001). For both measures, there were significant differences among the sextiles (P < 0.0001 for both measures, indicated by a Breslow–Day test for homogeneity). The largest sex differences occurred in the fastest sextile (first measure: OR, 1.96; 95% CI, 1.82–2.10; second measure: OR, 1.36; 95% CI, 1.30–1.42).

We conducted similar analyses of marked slowing (≥ 10% slowing). Table 3 shows that, for both measures, marked slowing varied across sextiles, as faster runners were less likely to exhibit marked slowing (P < 0.0001 for both sexes). Overall, the odds of exhibiting marked slowing were 0.79 (95% CI, 0.76-0.81; P < 0.0001) times as great for women compared with men for the first pacing measure, and 0.98 times (95% CI, 0.97–1.00; P = 0.10) as great for women compared with men for the second pacing measure (Table 3). There were significant differences among the sextiles (P < 0.0001 for both measures). The greatest sex differences occurred in the fastest sextile (first measure: OR, 0.46; 95% CI, 0.38–0.55; second measure: OR, 0.65; 95% CI, 0.61–0.68).

To further explore whether the relationship between finishing time and pacing differed for men and women, we plotted these relationships separately for each sex. In these plots, we adjusted (i.e., decreased) female finishing times by 12% (see Methods). Figure 1 illustrates the results, panel A for Pacing Measure 1, and Panel B for Pacing Measure 2. This figure indicates that, for both measures, slower finishers exhibited greater percentage slowing, although this trend was most prominent for those who finished in approximately 60 minutes or more. In

addition, this figure shows that, for both measures, men tended to slow more than women among the fastest runners (i.e. roughly those who finished in under 53 minutes, corresponding to a time of 59:36 for women). Among slower runners, there was no consistent sex difference in pacing for the first pacing measure (Fig. 1A). For the second pacing measure, among slower runners, women showed a consistent tendency to slow more than men (Fig. 1B). We also plotted these relationships without making a 12% adjustment to women' finishing times (Fig. 2). With these absolute finishing times, men slowed more than women among faster and slower runners, and this was true for both pacing measures.

**Regression modeling to control for runner's age**

The preceding results investigated the relationships among pacing, sex and finishing time through tabular and visual displays. In order to simultaneously address the potential impact of runner's age, we used multiple regression modeling. We fit two models for each of our two continuous pacing measures. Model 1 used sex, age, and finishing time as explanatory variables. Model 2 additionally included the pairwise interactions between sex, age, and finishing time. In these models, finishing time was measured in minutes (adjusted by 12% for women) and age was measured in years.

For Pacing Measure 1, older, faster, and female runners exhibited more even pacing (Model 1). With regards to sex differences, Model 2 indicated that the effect of sex was attenuated for slower finishers. That is, men generally showed greater slowing than women, but this difference weakened as finishing time increased.

For Pacing Measure 2, older and faster runners showed more even pacing, while males and females were not significantly different (Model 1). The lack of significance of the sex variable in Model 1 reflects a significant interaction between sex and finishing time (Model 2). That is, among fast runners, men showed greater slowing but, among slower finishers, women showed greater slowing.

These regression results corroborated the patterns illustrated in Figure 1. Complete information on the value of the coefficients and standard errors from these models are available in Table 4.

## Discussion

This study demonstrated that in the Bolder Boulder race, a large 10 km road race, there was a sex difference in pacing, specifically among faster runners. In particular, men and women in the fastest two sex-specific finishing time sextiles differed significantly in their pacing, with men generally slowing more than women. This was true whether pacing was defined as the change in pace of the first 3 miles relative to the final 3.2 miles (first pacing measure) or as the change in pace of the first mile relative to the final 5.2 miles (second measure). Moreover, categorical comparisons indicated that the magnitude of the sex difference was not trivial (Tables 2 and 3). Perhaps most notably, among the fastest sextile, the odds of women slowing by at least 10% was 0.46 (first pacing measure) and 0.65 (second pacing measure) times that of the corresponding value for men (Table 3). The sex difference in pacing among faster runners also occurred when comparisons were based on continuous finishing times, rather than sex-specific

finishing time sextiles, including when female finishing times were adjusted by 12% to account for men' greater maximal oxygen uptake (Joyner, 1993; Sparling, O'Donnell & Snow, 1998; Cheuvront et al., 2005). Finally, the sex difference in pacing persisted in multiple regression models that controlled for age (Table 4).

Although these results indicate that the sex difference in pacing that has been documented in the marathon (March et al., 2011; Trubee et al., 2014; Deaner et al., 2015a; Krawczyk & Wilamowski, 2015; Hubble & Jinger, 2015; Hanley, 2016) also occurs in shorter race distances, there were some notable differences between pacing at these distances. First, the magnitude of slowing in this 10 km race was substantially less than has been found in marathons. In this 10-km race, the mean slowing for the first 3 miles relative to the final 3.2 miles was 2.0% for women and 1.7% for men, whereas, in a sample of 14 marathons, the mean slowing for the first half of the marathon relative to the second half was 11.7% for women and 15.6% for men (Deaner et al., 2015a). A second important difference is that, in this 10 km race, the pattern of men slowing more than women was limited to relatively fast runners (Tables 1-3; Fig. 1). Among slower runners there was no consistent sex difference and, in some analyses, women slowed significantly more than men did. In the 14 marathons, by contrast, men slowed substantially more than women among faster runners, and this sex difference became larger among slower runners (Deaner et al., 2015a). Third, among faster runners, men were consistently more likely than women to slow in this 10 km race, but the magnitude of this sex difference was less than that reported in the 14 marathons. Although ability groupings and categorical definitions of slowing differed in these studies, it is reasonable to conclude there is a difference

because odds ratios indicating sex differences were consistently smaller in this 10 km race, even for faster runners, (Tables 2 and 3) than reported in the 14 marathons (Deaner et al., 2015a).

**Susceptibility to glycogen depletion hypothesis**

The documentation of a sex difference in pacing in a 10 km road race challenges the hypothesis that the sex difference in pacing is due to men's greater susceptibility to glycogen depletion (March et al., 2011; Trubee et al., 2014). According to that hypothesis, no sex difference in pacing should have occurred for a 10 km race because glycogen depletion is irrelevant for events of this duration (Coyle, 2007; Rapoport, 2010). Nevertheless, it is premature to completely reject the susceptibility to glycogen depletion hypothesis because the present study of a 10 km race cannot discount that men's apparently greater susceptibility to glycogen depletion contributes to the sex difference in pacing in marathons. The fact that the sex difference in pacing in this 10 km race was limited to faster runners and was smaller in magnitude than the sex difference in marathon pacing is consistent with this possibility.

**Decision making hypothesis**

This study's results support, albeit indirectly, the hypothesis that the sex difference in pacing in distance running reflects, at least in part, some kind of sex difference in decision making (Allen & Dechow, 2013; Deaner et al., 2015a; Krawczyk & Wilamowski, 2015; Hubble & Jinger, 2015). For example, men may be more likely than women to begin a race with an ambitious or risky pace relative to their ability, and this would increase their likelihood of slowing later.

The decision making hypothesis is supported by several lines of evidence besides the present study's results. First, men's greater slowing in the Warsaw and Houston marathons was substantially associated with their more discrepant forecasting, indicating men were typically more ambitious or over-confident than were women (Krawczyk & Wilamowski, 2015; Hubble & Jinger, 2015). Second, a study of the Chicago marathon showed that performances among non-elite runners clustered at round numbers (e.g., just under 4 h) because some runners accelerated in the final 2.2 km of the race; although women were more likely than men to have accelerated in the final 2.2 km, men were more likely to have done so in order to achieve round numbers, indicating that the men were more likely to modify their pace to pursue external goals (2). Third, in non-sport domains, men generally take greater risks, partly due to their lesser perceptions of risk (Harris, Jenkins & Glaser, 2006), and laboratory studies of running and cycling indicate that individuals with lesser perceptions of risk are more likely to adopt ambitious initial paces (Micklewright et al., 2015). Finally, risk taking and competitiveness are believed to be closely related (Croson & Gneezy, 2009), and there is mounting evidence that male distance runners are typically more competitive than their female counterparts (Deaner, 2013; Deaner, Addona & Mead, 2014; Deaner et al., 2015b).

Other physiological factor(s) besides glycogen depletion may contributes to the sex difference in pacing. The only suggestion of which we are aware is that the sex difference in pacing might be due to men's (putatively) greater susceptibility to hyperthermia (Trubee et al., 2014), a frequent contributor to slowing in distance running (Maughan, Watson & Shirreffs, 2007; Gonzalez-Alonso, Crandall & Johnson, 2008; El Helou et al., 2012). This hypothesis was suggested by the fact that the sex difference in marathon pacing increases with warmer ambient

344 temperatures (Trubee et al., 2014; Krawczyk & Wilamowski, 2015). The present study's results
345 from the Bolder Boulder 10 km race do not address the susceptibility to hyperthermia
346 hypothesis. We note, however, that this hypothesis is weakened by the fact that, compared to
347 women, men are generally believed to have advantages in thermoregulation (Gagnon & Kenny,
348 2012). Moreover, the sex difference in pacing has been documented in marathons (March et al.,
349 2011; Trubee et al., 2014; Krawczyk & Wilamowski, 2015) that occurred at temperatures
350 sufficiently cool (e.g., < 10 ºC) that hyperthermia would have been irrelevant (El Helou et al.,
351 2012).
352
353 Another crucial point is that although there is, at present, no compelling evidence that a
354 physiological difference between men and women can explain the sex difference in pacing, the
355 decision making hypothesis is not at odds with physiology contributing to individual and group
356 variation in pacing. This is because the decision to adopt an ambitious or risky pace will
357 undoubtedly impose physiological challenges (Coyle, 2007; Abbiss & Laursen, 2008; Tucker &
358 Noakes, 2009).
359
360 **Why men's greater slowing was limited to faster runners**
361 An interesting question is why the greater slowing by men than women in this 10 km
362 road race was limited to relatively fast runners, roughly men who finished in less than 53
363 minutes and women who finished in less than 60 minutes. By contrast, the sex difference in
364 marathon pacing occurs for runners of widely ranging abilities (March et al., 2011; Trubee et al.,
365 2014; Deaner et al., 2015a; Krawczyk & Wilamowski, 2015). Furthermore, research on sex
366 differences in risk taking in non-sports domains (e.g., driving) generally indicate that sex

differences occur across broad populations (Harris, Jenkins & Glaser, 2006; Croson & Gneezy, 2009) or, if they vary across populations, the sex differences tend to be smaller or non-existent among more selective sub-populations (Croson & Gneezy, 2009 but see Deaner et al., 2015b). The sex difference in financial risk taking, for instance, apparently weakens or disappears among professional investors (Croson & Gneezy, 2009).

Although we cannot definitively explain why the sex difference in pacing was limited to relatively fast runners, we can offer a suggestion, based on two points. First, although pacing in distance running can involve risk taking, it often may not. For instance, an evenly paced performance may not indicate a runner whose gamble with an ambitious risky pace paid off; it may simply indicate a runner who adopted a pace that was easy for them. Conversely, a performance with dramatic slowing may not indicate a runner who began the race with an ambitious pace but, despite great effort, failed to hold it; it may merely indicate a runner who did not prioritize achieving an outstanding performance and was content to slow when their initial pace became uncomfortable. Second, although any particular running performance may or may not involve substantial risk taking, it can be expected that faster runners generally will be more likely than slower runners to select an ambitious pace and to exert themselves in maintaining it. This is supported by surveys showing that faster runners are more likely than are slower runners to endorse competitiveness and goal achievement items (e.g., “to push myself beyond my current limits”) (Masters, Ogles & Jolton, 1993; Deaner et al., 2015b). If these points are correct, then variation in pacing among fast runners may provide important insights about risk taking, whereas variation in pacing among slower runners may be less informative.

Our suggestion for why the sex difference in pacing was limited to faster runners in this 10 km race does raise the question of why the sex difference in pacing in marathons held even among slower runners (March et al., 2011; Trubee et al., 2014; Deaner et al., 2015a; Krawczyk & Wilamowski, 2015). Although we cannot provide a definitive answer to this question, we can suggest that 10 km races and marathons may differ in ways that make marathon races more likely to reveal individual and group variation in decision making. One difference is that somewhat different kinds of individuals may participate; marathoners tend to be more motivated by competition (Ogles, Masters & Richardson, 1995). A second difference involves the demands of maintaining an even pace, a reliable correlate of performance in distance running (Abbiss & Laursen, 2008; Tucker & Noakes, 2009; March et al., 2011; Trubee et al., 2014; Santos-Lozano et al., 2014; Deaner et al., 2015a; Krawczyk & Wilamowski, 2015; Hubble & Jinger, 2015; Hanley, 2016). Because fatigue in a marathon generally reflects slowly cumulating processes, such as glycogen depletion (Coyle, 2007; Rapoport, 2010), hyperthermia (Maughan, Watson & Shirreffs, 2007; Gonzalez-Alonso, Crandall & Johnson, 2008; El Helou et al., 2012), and muscle damage (Del Coso et al., 2013), coaching handbooks advise that achieving an evenly paced marathon requires running the first half of the race at a pace that seems sufficiently comfortable that the runner is frequently tempted to accelerate in order to "bank some minutes" and get ahead of their time goal; resisting this temptation may be crucial for avoiding dramatic slowing late in the race (Humphrey, Hanson & Hanson, 2012; Magness, 2014). By contrast, in shorter races, such conservatism seems less important, apparently because immediate feelings of discomfort are generally sufficient to inform the runner that they should reduce their speed to avoid severe distress. Underscoring the unusual pacing demands in the marathon is that the mean percentage slowing in marathons (Deaner et al., 2015a) is far greater than documented in this 10 km race.

413

414 **Future work on decision making and pacing**

415 Although the present study's results, in conjunction with previous research, indicate that
416 decision making contributes to the sex difference in pacing, additional research must be
417 conducted to make strong tests of this hypothesis. Ideally, this work will investigate when and
418 how runners establish their pre-race goals, including their target pace(s); runners' estimates of
419 the benefits, costs, and likelihoods of various race outcomes (e.g., dramatic slowing, setting a
420 personal best, winning age group); runners' psychological and physiological experiences during
421 the race as they adjust their pace and modify their goals; and how these factors vary according to
422 sex, age, experience, risk taking, training, ability, coaching, course difficulty, and race distance.
423 Besides allowing a strong test of whether decision making contributes to the sex difference in
424 pacing, this research may reveal unexpected and interesting interactions among physiological
425 and psychological factors.

426

427 **Limitations**

428 The current study has several limitations. First, we evaluated pacing by comparing the
429 pace of the first 3 miles to the final 3.2 miles and by comparing the pace of the first mile
430 relative to the final 5.2 miles. Although these two pacing measures produced roughly similar
431 outcomes with respect to sex differences among faster runners, other pacing measures could be
432 explored and might yield different results. Second, although we succeeded in identifying sex,
433 finishing time, and age as contributors to pacing variation, other factors must also be important.
434 For example, in the study of 14 U.S. marathons, greater race experience was associated with
435 lesser slowing, although the effect was modest and did not eliminate the sex difference in

pacing (Deaner et al., 2015a). As noted above, other relevant factors might include risk taking, training, and coaching. Third, although our sample size was large in terms of runners, the sample was drawn entirely from six years of the same race, the Bolder Boulder 10 km road race. This may limit the generalizability of our conclusions. Finally, many runners participated in more than one year of the race, and we did not cluster performances by runner. This could have led to p-values being smaller than they would have been if clustering was modeled explicitly.

## Conclusions

This study demonstrates that the sex difference in pacing that has been documented in marathons also occurs in a large 10 km road race, although the magnitude of the sex difference was smaller and limited to relatively fast runners, roughly men who finished in less than 53 minutes and women who finished in less than 60 minutes. This sex difference was robust in several respects, including that it occurred with two measures of pacing, with continuous and categorical specifications of the pacing measures, and when age was statistically controlled. These results suggest that the sex difference in pacing partly reflects a sex difference in some aspect of decision making. To make a strong test of this hypothesis, future research must directly address runners' decision making and relate it to their pacing.

## Acknowledgments

We thank Josh Drew (Online Race Results) for assistance with data acquisition.

458 **References**

459

460 Abbiss CR., Laursen PB. 2008. Describing and understanding pacing strategies during athletic
461 competition. *Sports Medicine* 38:239–252.
462 Allen EJ., Dechow PM. 2013. *The "rationality" of the long distance runner: Prospect theory*
463 *and the marathon*. Rochester, NY: Social Science Research Network.
464 Cheuvront SN., Carter R., DeRuisseau KC., Moffatt RJ. 2005. Running performance differences
465 between men and women: An update. *Sports Medicine* 35:1017–1024. DOI:
466 10.2165/00007256-200535120-00002.
467 Coyle EF. 2007. Physiological regulation of marathon performance. *Sports Medicine* 37:306–
468 311. DOI: 10.2165/00007256-200737040-00009.
469 Croson R., Gneezy U. 2009. Gender differences in preferences. *Journal of Economic Literature*
470 47:448–474. DOI: 10.1257/jel.47.2.448.
471 Deaner RO. 2013. Distance running as an ideal domain for showing a sex difference in
472 competitiveness. *Archives of Sexual Behavior* 42:413–428. DOI: 10.1007/s10508-012-
473 9965-z.
474 Deaner RO., Carter RE., Joyner MJ., Hunter SK. 2015a. Men are more likely than women to
475 slow in the marathon. *Medicine and Science in Sports and Exercise* 47:607–616. DOI:
476 10.1249/MSS.0000000000000432.
477 Deaner RO., Lowen A., Rogers W., Saksa E. 2015b. Does the sex difference in competitiveness
478 decrease in selective sub-populations? A test with intercollegiate distance runners. *PeerJ*
479 3:e884. DOI: https://dx.doi.org/10.7717/peerj.884.

480 Deaner RO., Addona V., Mead MP. 2014. U.S. masters track participation reveals a stable sex
481 difference in competitiveness. *Evolutionary Psychology* 12:848–877.
482 Del Coso J., Fernández D., Abián-Vicen J., Salinero JJ., González-Millán C., Areces F., Ruiz D.,
483 Gallo C., Calleja-González J., Pérez-González B. 2013. Running pace decrease during a
484 marathon is positively related to blood markers of muscle damage. *PLoS ONE* 8:e57602.
485 DOI: 10.1371/journal.pone.0057602.
486 El Helou N., Tafflet M., Berthelot G., Tolaini J., Marc A., Guillaume M., Hausswirth C.,
487 Toussaint J-F. 2012. Impact of environmental parameters on marathon running
488 performance. *Plos One* 7. DOI: 10.1371/journal.pone.0037407.
489 Gagnon D., Kenny GP. 2012. Does sex have an independent effect on thermoeffector responses
490 during exercise in the heat? *Journal of Physiology-London* 590:5963–5973. DOI:
491 10.1113/jphysiol.2012.240739.
492 Gonzalez-Alonso J., Crandall CG., Johnson JA. 2008. The cardiovascular challenge of
493 exercising in the heat. *Journal of Physiology-London* 586:45–53. DOI:
494 10.1113/jphysiol.2007.142158.
495 Hanley B. 2016. Pacing, packing and sex-based differences in Olympic and IAAF World
496 Championship marathons. *Journal of Sports Sciences*. DOI:
497 10.1080/02640414.2015.1132841.
498 Harris CR., Jenkins M., Glaser D. 2006. Gender differences in risk assessment: Why do women
499 take fewer risks than men? *Judgment and Decision Making Journal* 1:48–63.
500 Hubble C., Jinger Z. 2015. Gender differences in marathon pacing and performance prediction.
501 *Journal of Sports Analytics* Preprint. DOI: 10.3233/JSA-150008.

Humphrey L., Hanson K., Hanson K. 2012. *Hansons marathon method: A renegade path to your fastest marathon*. Boulder, Colo: Velo Press.

Joyner MJ. 1993. Physiological limiting factors and distance running: influence of gender and age on record performance. *Exercise and Sport Sciences Reviews* 21:103–133.

Krawczyk M., Wilamowski M. 2015. Are we all overconfident in the long run? Evidence from one million marathon participants. *Working Papers, Faculty of Economic Sciences, University of Warsaw*.

Magness S. 2014. *The science of running: How to find your limit and train to maximize your performance*. Origin Press.

March DS., Vanderburgh PM., Titlebaum PJ., Hoops ML. 2011. Age, sex, and finish time as determinants of pacing in the marathon. *Journal of Strength and Conditioning Research* 25:386–391. DOI: 10.1519/JSC.0b013e3181bffd0f.

Masters KS., Ogles BM., Jolton JA. 1993. The development of an instrument to measure motivation for marathon running: The Motivations of Marathoners Scales (MOMS). *Research Quarterly for Exercise and Sport* 64:134–143.

Maughan RJ., Watson P., Shirreffs SM. 2007. Heat and cold: What does the environment do to the marathon runner? *Sports Medicine* 37:396–399. DOI: 10.2165/00007256-200737040-00032.

Micklewright D., Parry D., Robinson T., Deacon G., Renfree A., Gibson ASC., Matthews WJ. 2015. Risk perception influences athletic pacing strategy. *Medicine and Science in Sports and Exercise* 47:1026–1037. DOI: 10.1249/MSS.0000000000000500.

Monteiro WD., Farinatti PTV., de Oliveira CG., Araujo CGS. 2011. Variability of cardio-respiratory, electromyographic, and perceived exertion responses at the walk-run

transition in a sample of young men controlled for anthropometric and fitness characteristics. *European Journal of Applied Physiology* 111:1017–1026. DOI: 10.1007/s00421-010-1720-3.

Ogles BM., Masters KS., Richardson SA. 1995. Obligatory running and gender: An analysis of participative motives and training habits. *International Journal of Sport Psychology* 26:233–248.

R Core Team *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rapoport BI. 2010. Metabolic factors limiting performance in marathon runners. *PLoS Computational Biology* 6:e1000960. DOI: 10.1371/journal.pcbi.1000960.

Roelands B., de Koning J., Foster C., Hettinga F., Meeusen R. 2013. Neurophysiological determinants of theoretical concepts and mechanisms involved in pacing. *Sports Medicine* 43:301–311. DOI: 10.1007/s40279-013-0030-4.

Roepstorff C., Steffensen CH., Madsen M., Stallknecht B., Kanstrup IL., Richter EA., Kiens B. 2002. Gender differences in substrate utilization during submaximal exercise in endurance-trained subjects. *American Journal of Physiology-Endocrinology and Metabolism* 282:E435–E447.

Rotstein A., Inbar O., Berginsky T., Meckel Y. 2005. Preferred transition speed between walking and running: Effects of training status. *Medicine and Science in Sports and Exercise* 37:1864–1870. DOI: 10.1249/01.mss.0000177217.12977.2f.

Running USA 2015.Statistics. *Available at http://www.runningusa.org/statistics* (accessed October 5, 2015).

547 Santos-Lozano A., Collado PS., Foster C., Lucia A., Garatachea N. 2014. Influence of sex and
548 level on marathon pacing strategy: Insights from the New York City race. *International*
549 *Journal of Sports Medicine* 35:933–938. DOI: 10.1055/s-0034-1367048.
550 Sparling PB., O'Donnell EM., Snow TK. 1998. The gender difference in distance running
551 performance has plateaued: An analysis of world rankings from 1980 to 1996. *Medicine*
552 *and Science in Sports and Exercise* 30:1725–1729. DOI: 10.1097/00005768-199812000-
553 00011.
554 Tarnopolsky MA. 2008. Sex differences in exercise metabolism and the role of 17-beta estradiol.
555 *Medicine and Science in Sports and Exercise* 40:648–654. DOI:
556 10.1249/MSS.0b013e31816212ff.
557 Trubee NW., Vanderburgh PM., Diestelkamp WS., Jackson KJ. 2014. Effects of heat stress and
558 sex on pacing in marathon runners. *Journal of Strength and Conditioning Research*
559 28:1673–1678.
560 Tucker R., Noakes TD. 2009. The physiological regulation of pacing strategy during exercise: A
561 critical review. *British Journal of Sports Medicine* 43:e1. DOI:
562 10.1136/bjsm.2009.057562.
563

## Table 1(on next page)

Pacing by sex and finishing time sextile.

Pacing Measure 1 indicates percentage change in pace of the first 3 miles relative to the final 3.2 miles. Pacing Measure 2 indicates percentage change in pace of the first mile relative to the final 5.2 miles.

1

| | Pacing Measure 1 | | | Pacing Measure 2 | | |
|---|---|---|---|---|---|---|
| | Women | Men | | Women | Men | |
| Sextile (# of Women, # of Men) | Mean (SD) | Mean (SD) | P-value | Mean (SD) | Mean (SD) | P-value |
| Fastest sextile (15649,16344) | 0.62 (3.61) | 1.62 (3.88) | < 0.0001 | 4.82 (5.39) | 6.08 (5.77) | < 0.0001 |
| Second sextile (15607,16352) | 0.46 (4.50) | 1.17 (4.97) | < 0.0001 | 4.91 (6.41) | 5.84 (7.12) | < 0.0001 |
| Third sextile (15585,16334) | 1.09 (5.09) | 1.25 (5.76) | 0.0071 | 6.04 (7.10) | 6.14 (8.04) | 0.23 |
| Fourth sextile (15606,16342) | 1.96 (5.89) | 1.48 (6.56) | < 0.0001 | 8.05 (8.02) | 7.01 (9.00) | < 0.0001 |
| Fifth sextile (15608,16341) | 2.79 (6.85) | 2.75 (7.56) | 0.62 | 10.69 (9.35) | 9.72 (9.99) | < 0.0001 |
| Slowest sextile (15588,16337) | 3.35 (7.83) | 3.83 (9.48) | < 0.0001 | 13.78 (10.47) | 14.24 (12.00) | 0.00027 |

2

3

## Table 2(on next page)

Percentage of runners who maintained the pace (< 5% slowing) by sex and finishing time sextile.

Pacing Measure 1 indicates percentage change in pace of the first 3 miles relative to the final 3.2 miles. Pacing Measure 2 indicates percentage change in pace of the first mile relative to the final 5.2 miles. The odds ratio (OR) compares the odds of maintaining the pace for women compared with men.

1

| | Pacing Measure 1 | | | Pacing Measure 2 | | |
|---|---|---|---|---|---|---|
| | Women | Men | | Women | Men | |
| Sextile (# of Women, # of Men) | % maintained pace | % maintained pace | OR (95% CI) | % maintained pace | % maintained pace | OR(95% CI) |
| Fastest sextile (15649,16344) | 91.29 | 84.28 | 1.96 (1.82,2.10) | 52.43 | 44.78 | 1.36 (1.30,1.42) |
| Second sextile (15607,16352) | 87.22 | 82.29 | 1.47 (1.38,1.56) | 51.49 | 46.46 | 1.22 (1.17,1.28) |
| Third sextile (15585,16334) | 81.07 | 78.64 | 1.16 (1.10,1.23) | 45.17 | 45.40 | 0.99 (0.95,1.04) |
| Fourth sextile (15606,16342) | 73.27 | 74.45 | 0.94 (0.90,0.99) | 35.47 | 42.71 | 0.74 (0.71,0.77) |
| Fifth sextile (15608,16341) | 65.91 | 65.85 | 1.00 (0.96,1.05) | 24.72 | 32.08 | 0.70 (0.66,0.73) |
| Slowest sextile (15588,16337) | 61.96 | 59.17 | 1.12 (1.08,1.18) | 16.37 | 18.74 | 0.85 (0.80,0.90) |
| Overall (93643,98050) | 76.80 | 74.12 | 1.16 (1.13,1.18) | 37.62 | 38.36 | 0.97 (0.95,0.99) |

2

## Table 3(on next page)

Percentage of runners who exhibited marked slowing (≥ 10% slowing) by sex and finishing time sextile.

Pacing Measure 1 indicates percentage change in pace of the first 3 miles relative to the final 3.2 miles. Pacing Measure 2 indicates percentage change in pace of the first mile relative to the final 5.2 miles. The odds ratio (OR) compares the odds of experiencing marked slowing for women compared with men.

1

| | Pacing Measure 1 | | | Pacing Measure 2 | | |
|---|---|---|---|---|---|---|
| | Women | Men | | Women | Men | |
| Sextile (# of Women, # of Men) | % marked slowing | % marked slowing | OR (95% CI) | % marked slowing | % marked slowing | OR(95% CI) |
| Fastest sextile (15649,16344) | 0.97 | 2.10 | 0.46 (0.38,0.55) | 15.37 | 21.97 | 0.65 (0.61,0.68) |
| Second sextile (15607,16352) | 1.97 | 3.27 | 0.59 (0.52,0.68) | 19.39 | 24.74 | 0.73 (0.69,0.77) |
| Third sextile (15585,16334) | 3.70 | 5.19 | 0.70 (0.63,0.78) | 26.08 | 27.89 | 0.91 (0.87,0.96) |
| Fourth sextile (15606,16342) | 7.11 | 7.39 | 0.96 (0.88,1.05) | 36.82 | 32.52 | 1.21 (1.16,1.27) |
| Fifth sextile (15608,16341) | 11.15 | 13.29 | 0.82 (0.77,0.88) | 50.95 | 45.15 | 1.26 (1.21,1.32) |
| Slowest sextile (15588,16337) | 15.04 | 18.69 | 0.77 (0.73,0.82) | 65.23 | 63.67 | 1.07 (1.02,1.12) |
| Overall (93643,98050) | 6.65 | 8.32 | 0.79 (0.76,0.81) | 35.63 | 35.99 | 0.98 (0.97,1.00) |

2

## Table 4(on next page)

Summary of regression models of pacing (coefficients, with standard errors in parentheses).

Pacing Measure 1 indicates percentage change in pace of the first 3 miles relative to the final 3.2 miles. Pacing Measure 2 indicates percentage change in pace of the first mile relative to the final 5.2 miles. See text for descriptions of Model 1 and Model 2. A p-value < 0.0001 is indicated by ***.

1

| | Pacing Measure 1 | | Pacing Measure 2 | |
|---|---|---|---|---|
| Explanatory Variable | Model 1 | Model 2 | Model 1 | Model 2 |
| (Intercept) | -3.37 (0.092) *** | -3.99 (0.25) *** | -6.89 (0.13) *** | -13.48 (0.34) *** |
| Sex Male | 0.21 (0.029) *** | 2.76 (0.19) *** | -0.029 (0.039) | 5.42 (0.26) *** |
| Finishing Time (adjusted) | 0.092 (0.0015) *** | 0.10 (0.0041) *** | 0.30 (0.002) *** | 0.42 (0.0055) *** |
| Age | -0.0073 (0.001) *** | -0.038 (0.0063) *** | -0.078 (0.0014) *** | 0.0044 (0.0086) |
| Sex Male:Finishing Time | --- | -0.045 (0.0030) *** | --- | -0.11 (0.0041) *** |
| Sex Male:Age | --- | 0.0030 (0.0021) | --- | 0.021 (0.0029) *** |
| Finishing Time:Age | --- | 0.00048 (0.0001) *** | --- | -0.0015 (0.0001) *** |

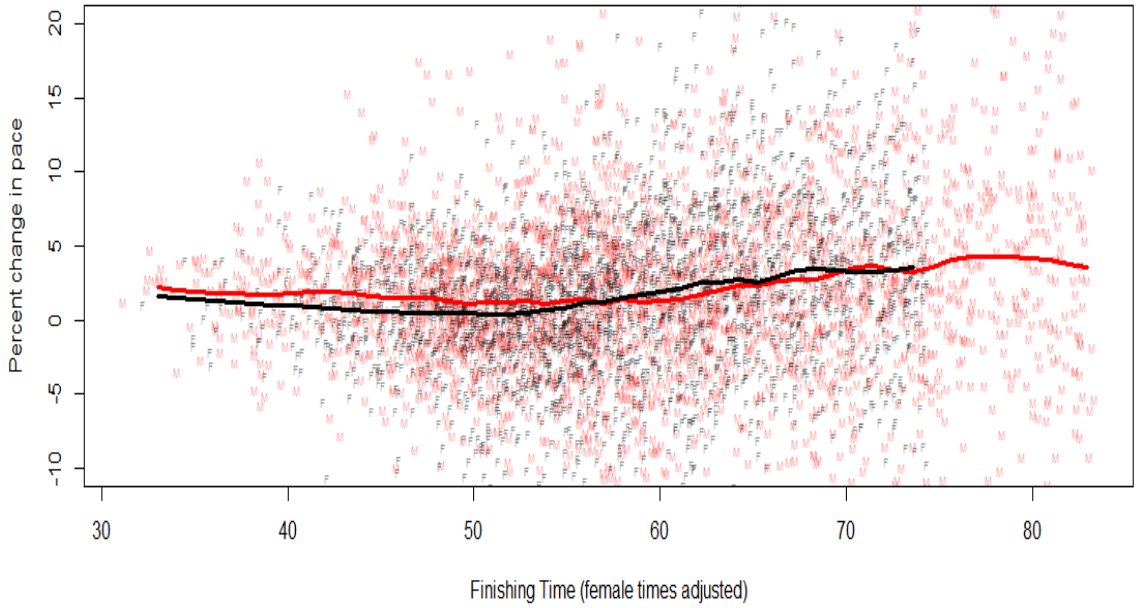
2
3

## Figure 1(on next page)

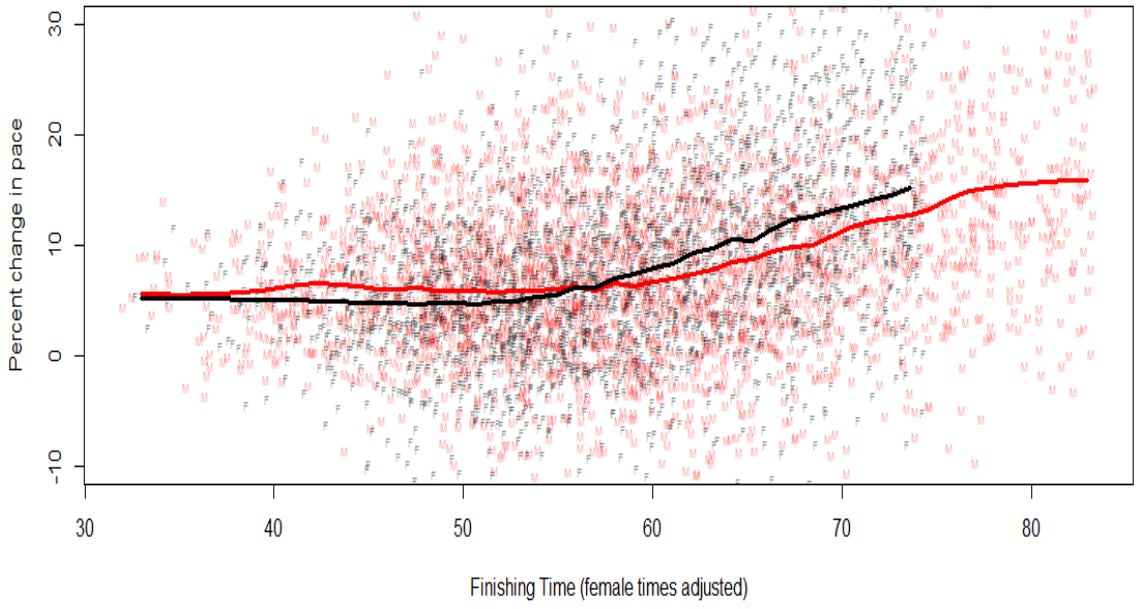
Pacing as a function of finishing time for men and women.

A random subset of 5000 data points are plotted, along with a loess smoother (obtained using all of the data) separately for men (red) and women (black). Women's finishing times presented on the x-axis have been adjusted (i.e., decreased) by 12%. A. Pacing Measure 1: Percentage change in pace of the first 3 miles relative to the final 3.2 miles. B. Pacing Measure 2: Percentage change in pace of the first mile relative to the final 5.2 miles.

A.


Percent change in pace
20
15
10
5
0
-5
-10
30
40
50
60
70
80
Finishing Time (female times adjusted)

B.

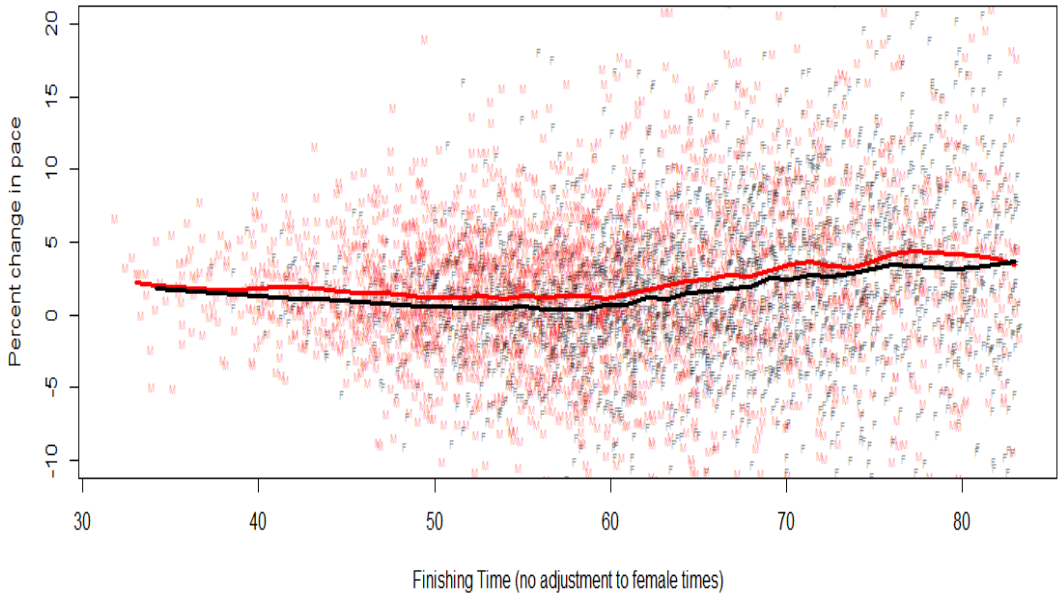

Percent change in pace
30
20
10
0
-10
30
40
50
60
70
80
Finishing Time (female times adjusted)

## Figure 2(on next page)

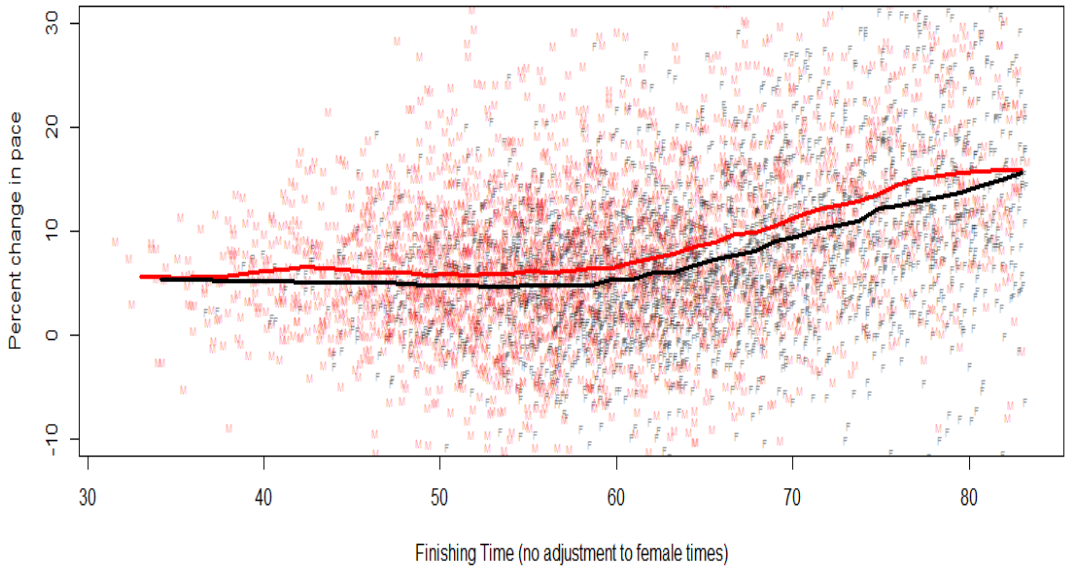
Pacing as a function of finishing time for men and women without 12% adjustment to women's times.

A random subset of 5000 data points are plotted, along with a loess smoother (obtained using all of the data) separately for men (red) and women (black). Women's finishing times presented on the x-axis have not been adjusted by 12%. A. Pacing Measure 1: Percentage change in pace of the first 3 miles relative to the final 3.2 miles. B. Pacing Measure 2: Percentage change in pace of the first mile relative to the final 5.2 miles.

A.


Percent change in pace
20
15
10
5
0
-5
-10
30
40
50
60
70
80
Finishing Time (no adjustment to female times)

B.


Percent change in pace
30
20
10
0
-10
30
40
50
60
70
80
Finishing Time (no adjustment to female times)