AGE, SEX, AND FINISH TIME AS DETERMINANTS OF PACING IN THE MARATHON

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ABSTRACT

March, DS, Vanderburgh, PM, Titlebaum, PJ, and Hoops, ML. Age, sex, and finish time as determinants of pacing in the marathon. *J Strength Cond Res* 25(2): 386–391, 2011—Previous researchers have suggested that faster marathoners tend to run at a more consistent pace compared with slower runners. None has examined the influence of sex and age on pacing. Therefore, the purpose of this study was to determine the simultaneous influences of age, sex, and run time on marathon pacing. Pacing was defined as the mean velocity of the last 9.7 km divided by that of the first 32.5 km (closer to 1.0 indicates better pacing). Subjects were 186 men and 133 women marathoners from the 2005, 2006, and 2007 races of a midwestern U.S. marathon. The course was a 1.6 km (1 mile) loop with pace markers throughout, thus facilitating pacing strategy. Each 1.6-km split time was measured electronically by way of shoe chip. The ambient temperature (never above 5°C) ensured that hyperthermia, a condition known to substantially slow marathon times and affect pacing, was not likely a factor. Multiple regression analysis indicated that age, sex, and run time ($p < 0.01$ for each) were simultaneously independent determinants of pacing. The lack of any 2- or 3-way interactions ($p > 0.05$ for each) suggests that the effects of 1 independent variable is not dependent upon the levels of others. We conclude that older, women, and faster are better pacers than younger, men, and slower marathoners, respectively. Coaches can use these findings to overcome such tendencies and increase the odds of more optimal pacing.

KEY WORDS distance run, velocity, gender

INTRODUCTION

Although the physiologic demands of marathon running have been well studied (6,15,24,25), less is known about pacing during this event. More specifically, although a more consistent running speed, or even pace strategy, has been associated with better marathon performance (1,7,22), little is known about the determinants of optimal pacing. Indeed, most of the previous studies investigating pacing on athletic events have focused on events of a much shorter duration than the marathon, such as cycling (9), kayaking (3), rowing (16), and 5-km running time trial (10).

Earlier investigations on 2-km cycling (9) and 1.5-km skating (8) suggest that an even pace strategy or a fast start produced the fastest finish time. A fast start has also been attributed to faster finish times for 2-minute kayak performance (3). For longer races, however, there exist no data suggesting that faster starts contribute to faster times. In fact, Jones (13) has suggested that a faster start for longer races would negatively affect performance, a notion that has been supported empirically for a 20-km cycle time trial (21). In that study, researchers found that accumulation of blood lactate, characteristic of a fast start, was inversely associated with race performance. Padilla et al. (23) reported that an even pace strategy has been demonstrated to be optimal for a 1-hour cycling track world record attempt.

In a study of pacing in the 5-km run, a strategy of faster early run speed than overall run speed resulted in the fastest finish time for 8 of 11 subjects (10). The fast start, however, resulted in runners slowing their run speed during the latter stages of the time trial, whereas an even run speed start resulted in an increase in run speed during the latter stages of the race. This suggests that an even run speed might be more effective for races of longer distance. Indeed, an uneven distribution of effort during a 30-minute self-paced treadmill run has been reported to result in a greater overall physiologic demand for runners (26). There appear to be 2 important mechanisms by which an even pacing strategy may improve long-distance run performance: muscle glycogen depletion leading to hypoglycemia and hyperthermia (2,4,6,24). The depletion of muscle glycogen and hypoglycemia, often termed "hitting the wall," tends to result in a dramatic reduction in running velocity and may well be the result of improper pacing (6).

The even run speed has been shown to be effective in a 100-km ultramarathon (17). Ten kilometer spilt times were analyzed for 67 male competitors to investigate the changes in running speed throughout the race. Results suggested that the faster runners ran at a more constant run speed and were

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able to maintain the pace established in the first half of the race for a longer distance compared with the slower runners. They speculated that the inability to maintain running speed in the slower runners may be attributed to physiologic mechanisms such as exercise economy, glycogen depletion, neuromuscular changes, variations in training habits, pacing practice, or genotype of the runners. Clearly, this distance is much longer than the 42.2-km marathon to which the effect of a similar pacing strategy is difficult to infer.

For the marathon, an even pacing strategy has also been shown to optimize performance in 2 investigations. In the first (22), with a sample of 62 male runners competing in cool climatic conditions, researchers measured rectal temperature directly after the completion of the marathon to gauge the relationship between pacing strategy and postrace rectal temperature. Pacing strategy was based on 8-km split times throughout the race. Results indicated that, compared with their slower counterparts, the faster runners maintained a more even running pace throughout the race with slightly reduced velocities in the latter stages. Slower finishers exhibited the largest velocity decreases near the finish. Interestingly, postrace rectal temperature was positively correlated with time taken to complete the last 6.2 miles.

Ely and colleagues (7) investigated the influence of air temperature on the pacing of women marathoners. In a sample of 219 women across 62 years for 3 Japanese marathons, data included 5-km split times, finish times, and corresponding weather conditions. Consistent with previous studies (17,22), their results suggested that the fastest runners ran at a more even run speed throughout the race, whereas runners of slower finish times slowed as the race progressed, particularly after 20 to 25 km. They also reported that higher race temperatures were associated with a more pronounced decrease in running velocity among the faster runners compared with the slower runners, who tended to start the race at a slower running velocity under those environmental conditions. In cooler race conditions, however, faster runners maintained a more constant running velocity than their slower counterparts.

To our knowledge, no previous study has investigated sex differences in marathon pacing. Hopkins and Hewson (12) reported that women had less variability in finish time in consecutive races in a series within a competitive season. This dependent variable, perhaps more associated with recovery and training intensity, is not the same as pace strategy within the same race. Regarding the latter, although no sex-effect empirical data exist, some evidence suggests that women marathoners may have physiologic advantages over men in maintaining an even pace strategy. Specifically, women compared with equally trained men have a lower respiratory exchange ratio (RER) during endurance exercise, suggesting that women use proportionately more fat and less carbohydrate (5,18,27) at a given relative intensity. Such a glycogen-sparing effect could delay the onset of glycogen depletion (4,6,24), a notable determinant of marked run velocity decreases in the late stages of the marathon.

Although marathon performance is well known to decline with age (19), no evidence exists, to our knowledge, that links age with marathon pacing. World class marathoners are, however, often older than runners of shorter distances (24). This suggests that experience may be an intervening factor. In the aforementioned study (12), Hopkins and Hewson reported that marathon finish times tended to be less variable for older runners competing in consecutive races within a competitive season. Their explanations included the following for older runners: a more even pace strategy in consecutive races as a result of their memory of run speed from the previous races, competitive experience, and attitudes toward competing. Indeed, Young (28) stated that "expert pacing skill is likely acquired via voluminous training across many years in the sport."

Therefore, the purpose of this study was to investigate the simultaneous influences of age, sex, and run time on marathon pacing in nonelite marathoners. This population was chosen given the likelihood of heterogeneity in these independent variables. On the basis of existing data, we hypothesized that women, older, and faster would demonstrate more even pacing than men, younger, and slower marathoners, respectively.

METHODS

Experimental Approach to the Problem

All data for this study were obtained from the Last Chance for Boston Marathon website (http://www.premierraces.com/lastchance/lastchance.html), which included subject sex, finish time, and each 1.6-km (1-mile) split time ($n = 26$ for each runner). This particular race, with its very cool race temperature, flat topography, and readily displayed split times minimized the effects of some key confounders such as heat, humidity, grade, and lack of pacing information. Stepwise multiple regression was used to determine the influences of sex, age, and finish time on pacing. Analyses included all possible interactions to examine the possibility that the influence of 1 independent variable on pacing might be dependent on the level of another independent variable.

TABLE 1. Subject descriptive statistics (mean ± *SD*).

	Men ($n = 186$)	Women ($n = 133$)
Age (yr)	41 ± 12	37 ± 10
Finish time (min)	228.3 ± 34.3	252.5 ± 33.1

Subjects

Subjects were 185 male and 134 female marathoners whose descriptive data are shown in Table 1. Institutional review board (IRB) approval was granted for this study, and, because of the readily available nature of all race data (age, run time, split times, and sex) by way of the internet, the IRB approved the waiver of informed consent. All completed the same midwestern US marathon during the years 2005 to 2007 in a finish time of less than 5 hours. This would correspond to a minimum average run speed of at least 2.33 $m \cdot s^{-1}$, a pace that would be very difficult to walk (approximately 11:30 $min \cdot mile^{-1}$, or 5.2 mph). Because some runners competed in consecutive years of this race, only the most recent run time was used. This accommodated the necessary assumption of independence among subjects required for multiple regression analysis. Because the data were archived and retrieved from a public access internet site, we could not ascertain the training level of marathon experience of subjects.

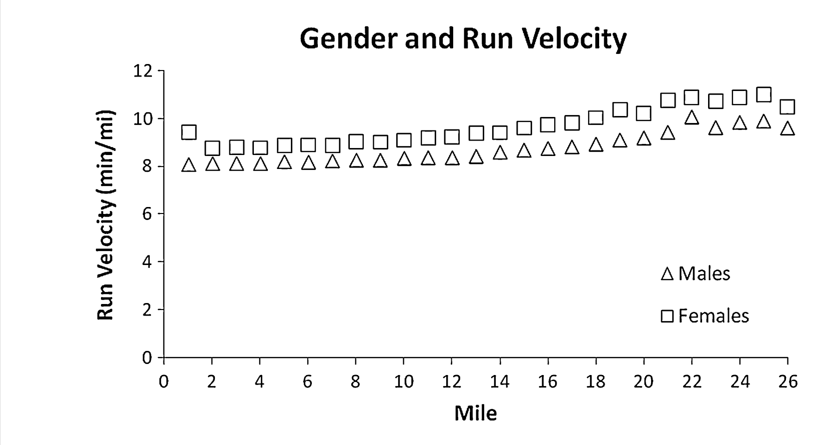

Figure 1. Mean running velocity by mile and sex.

Procedures

The course, a United States Association of Track and Field certified route (certification number OH03006PR) is 26.2 laps of a 1.6-km (1-mile) loop with no more than 1.2 m of elevation change at an average of 277 m above sea level. The course was marked every 0.40 km (1/4 mile) to facilitate self-pacing. Computer shoe-mounted chip timing technology (IPICO Sports, Sportag, Peoria, IL, USA) was used to count laps and provide net and split times. In the second half of the marathon, race officials informed runners by name of laps completed. According to official weather data, the range of indices of climatic conditions on race day for the 3 years were temperature between −10.1 and 1.4°C, humidity 46% to 65%, and wind speed 13 to 19.4 km/h (http://www.tutiempo.net/en/Climate). The flat course removed the influence of grade as a confounder. The cold race temperatures significantly reduced the likelihood that hyperthermia would confound pacing results and, unlike hot conditions (25°C+), could be accommodated by wearing an amount of additional clothing proportional to the temperature. Inclusion of only those runners who ran, not walked, nearly the entire race probably reduced the extent to which hypothermia would affect pacing. These combined with the precise split measurements for each runner and the small number of competitors on the course (total number of runners on the course at one time never exceeded 250) contributed to beneficial conditions for this study.

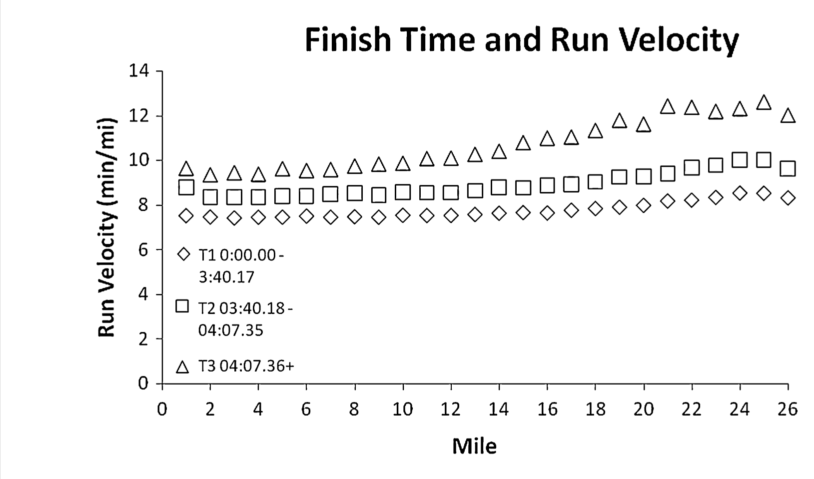

Figure 2. Mean running velocity by mile and finish time tertile (T1, T2, T3).

Pacing was defined as mean velocity during the last 9.7 km (6.0 mile) divided by that of the first 32.5 km (20.2 mile). Although not used in other pacing research, this index of pacing was chosen because of its empirical and physiologic bases. Specifically, glycogen depletion during the marathon

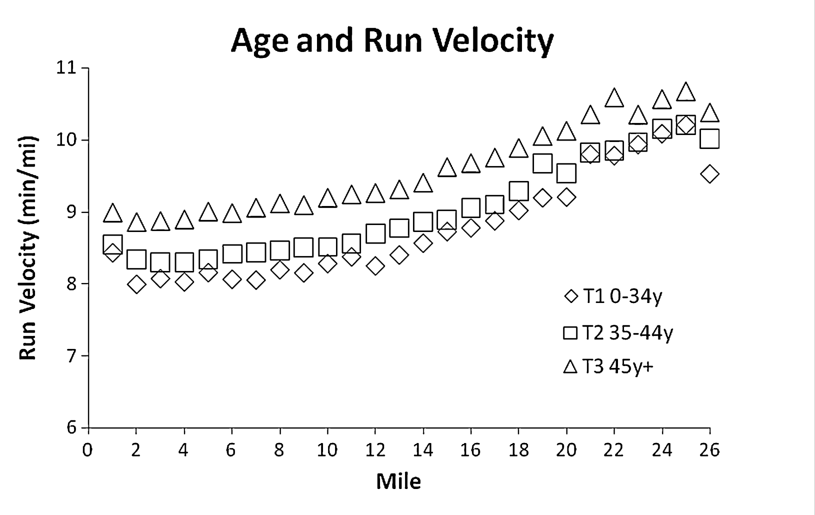

Figure 3. Mean running velocity by mile and age tertile (T1, T2, T3).

often occurs at or near approximately 3 hours or 30 km of the event (4,6,24), often leading to a leading to a marked decrease in running velocity. Our intent, then, was to focus on this influence of pacing change and not pacing variability throughout the race. In the other recent marathon pacing study, Ely and colleagues (7) defined pacing as the difference between runners' actual 5-km split time and their mean 5-km time calculated as their initial 40 km divided by 8. This allowed them to concentrate on pacing in multiple splits for accomplished women runners.

Statistical Analyses

Stepwise multiple regression analysis was used to assess the influences of age, sex, and finish time on pacing. To account for the possibilities that the effect of an independent variable on pacing might depend on the level of another independent variable, all 2- and 3-way interactions were also evaluated. Because multiple tests of significance were used, we chose $\alpha = 0.01$ for each.

RESULTS

Age, sex, and finish time were each statistically significant factors ($p < 0.01$) with all 3 in the model. There were no 2- or 3-way interactions ($p > 0.05$): age x sex, sex x finish time, age × finish time, or age × sex × finish time. No sex × age interaction means, for example, that the effect of sex on pacing was not dependent on age. The lack of the 3-way interaction similarly can be interpreted as: the effect of finish time on pacing was consistent regardless of age and sex. Figures 1 to 3 graphically depict the effects of sex, finish time, and age (finish time and age shown by tertiles) on pacing by split times. A marked slope increase within the last 6 splits would suggest a large decrease in pacing. In Figure 1, the sex pacing difference appears slight but shows that the men have a more distinctive drop in velocity over the last 10 km than women. In Figures 2 and 3, for finish time and age, respectively, these differences are quite apparent in that faster and older runners show less of the run velocity decrease later in the race.

The prediction equation that results from the multiple regression analysis can be useful to interpret the magnitude of these effects. Therefore, we calculated each term (coefficient × independent variable difference) for the following independent variables differences: male versus female, 25 versus 55 years of age, and 3 hours versus 4.5 hours finish time. For example, because 25 versus 55 years of age represents a 30-year difference, we multiplied 30 by the age coefficient of 0.00243 to yield an effect of 0.073, or 7.3% on pacing. In other words, the effect of being 30 years older, on average, translates to a 7.3% increase in pacing. Likewise, the effect of being female and faster (3 hr vs. 4.5 hr finish time) translated to 4.06% and 10.71% increases in pacing, respectively. We should point out that although each of these coefficients has a 99% confidence interval that does not include 0, one should not use this equation for prediction because the multiple R was 0.42, indicating that age, sex, and finish time accounted for only 18% of the differences in pacing.

DISCUSSION

Although these results do not imply causation, there are several key findings of this study. First, the negative coefficient for run time in the multiple regression equation suggests that a larger pacing factor is associated with faster run time, even when age and sex are considered. Said differently, small differences between the mean running velocities of the last 9.7 km and first 32.5 km are associated with faster finish times. Second, women appear to be more optimal pacers than men, even when the effects of finish time and age are controlled for. Third, the finding that age, sex, and run time each contribute without interactions (with each other) suggests that each has an independent and consistent effect on pacing, regardless of the level(s) of the other independent variables.

Interestingly, Figures 1 to 3 show that runners, regardless of age, sex, or fitness, tended not to adopt a fast start strategy. In fact, run speed was generally slower in the first 1.6 km (1.0 mile) than in the subsequent first half of the race. Furthermore, the designation of the average running velocity of the last 9.7 km (6 mile) as the numerator of the pacing factor appears to be warranted given that the distance versus running velocity slope change appears to occur at approximately that point.

We chose this particular race because of its race characteristics and its February date, with the associated likelihood that hyperthermia would not confound study effects. As Maughan et al. (22) reported post race rectal temperature was positively correlated with time taken to complete the last 6.2 miles. As shown in Figure 2, and as the multiple regression analyses indicate, slower runners did exhibit a more marked decrease in running velocity. With race temperatures as low as −10°C, we could not rule out the possibility that hypothermia was a confounding factor. By excluding all runners whose finish time was greater than 5 hours and therefore ensuring that walking during the race was minimized, we hoped to reduce this influence.

There are some other important limitations of this study as well. First, we could not ascertain whether subjects gave their best effort. By limiting the sample to those whose finish time indicated that they must have run, not walked, nearly the entire distance, we could only ensure that at least the effort required for running was attained. We did not measure running experience, which could clearly have been the intervening factor more so than age. In other words, the extent to which older runners tend to be more optimal pacers may be explained more by experience than biological age. Furthermore, no information about caloric or fluid intake was available, either of which could have contributed to glycogen-sparing differences. Finally, because of the cross-sectional nature of this study's design, we could not conclude that if a subject with a low pacing factor in this race were to use a more optimal pacing strategy in a subsequent race that his or her race performance would improve.

The fact that race conditions for this study were otherwise nearly ideal, low elevation (277 m above sea level), flat course, aid stations at every 1.6 km (1 mile), relatively few runners, and pacing markers throughout, contributed to the generalizability of these findings. The ambient air temperatures, ranging from −10°C to 1°C, although quite cold compared with most U.S. marathons, could be matched by donning more clothing. Furthermore, the frequency with which the split times were recorded (i.e., 26 evenly spaced splits throughout) exceeds that of any other pacing study. Last, the subject pool was also favorable for this research question: a large enough sample of men and women marathoners in a race commonly used to attain qualifying times for a popular northeastern U.S. marathon.

The results are also congruent with the body of research regarding physiologic mechanisms of pacing. Because the 2 primary causes of "hitting the wall" in the marathon have been reported to be hyperthermia and glycogen depletion accompanied by hypoglycemia (2,4,6,24), and hyperthermia was not likely a factor in this study, then glycogen depletion may have been the primary intervening factor. In the aforementioned 100-km ultramarathon study (17), researchers found that more consistent pacing contributed to faster finish times. Such a pace would likely contribute to glycogen sparing that would mitigate the precipitous running velocity change that often accompanies too fast a start. Also, the authors' conjecture that pacing practice, which would result from running experience, may help explain the favorable effect of age on pacing in the present study. Training experience (perhaps associated with age) over very long distances also improves the muscle's ability to oxidize fat preferentially at the same percentage of maximum effort (11,14,24).

The observed sex effect such that women tended to be better pacers than men also has some physiologic support associated with glycogen sparing. At the same relative intensity, women typically have a lower RER during endurance exercise than males. As a result, they tend to oxidize more fat and less carbohydrate, thus sparing glycogen (5,18,27). Furthermore, women tend to have a higher percentage of type I (slow-twitch oxidative) fibers (27).

In conclusion, this study, the first that has examined the effects of age, sex, and finish time on marathon pacing, suggests that women, older, and faster marathoners maintain a more consistent race velocity throughout the race than younger, men, and slower marathoners, respectively. Although these findings cannot imply causation, they do suggest physiologically plausible relationships. Future studies on this topic should (1) elucidate the mechanisms by which these and other factors may contribute independently, (2) factor out running experience independent of age, and (3) assess the effectiveness within the same subjects of changing pacing strategy on race performance. With the increased abundance of online marathon race data, future research could also examine the stability of zthese findings over multiple variations of environmental and topographical race conditions with much larger data sets.

PRACTICAL APPLICATIONS

Maintaining a consistent marathon pace has been shown to be an effective race strategy to maximize performance. This study is the first to examine the effects of age, sex, and finish time on marathon pacing. Pacing was defined as the mean run speed during the last 6 miles divided by the mean run speed of the first 20.2 miles. We examined this measure in 319 men and women marathoners and found that older, women, and faster runners were better pacers than younger, men, and slower runners, respectively. We could not determine whether the age effect was really a result of experience or the inevitable age-related decline in run speed. Coaches could use these findings, for example, to advise younger novice male marathoners to pay particular attention to pacing training given their tendencies to be display a greater drop-off in run speed during the last 10 km of the race than their female counterparts.

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