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Sex Differences in the Age of Peak Marathon Race Time

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Abstract

Recent studies showed that women were older than men when achieving their fastest marathon race time. These studies, however, investigated a limited sample of athletes. We investigated the age of peak marathon performance in a large sample of female and male marathon finishers by using data from all finishers. We analyzed the age of peak marathon performance in 1-year and 5-year age intervals of 451,637 runners (*i.e.* 168,702 women and 282,935 men) who finished the 'New York City Marathon' between 2006 and 2016, using analysis of variance and non-linear regression analysis. During these 11 years, men were faster and older than women, the participation of women increased disproportionately to that of men resulting in a decrease of the male-to-female ratio, and relatively more women participated in the younger age groups. Most women were in the age group 30-34 years and most men in the age group 40-44 years. The fastest race time was shown at 29.7 years in women and 34.8 years in men in the 1-year age intervals, and in age group 30-34 years in women and 35-39 years in men in the 5-year age intervals. In contrast to existing findings reporting a higher age of peak marathon performance in women compared to men, we found that women achieved their best marathon race time ~5 years earlier in life than men in both 1-year and 5-year age intervals. Female athletes and their coaches should plan to achieve their fastest marathon race time at the age of ~30 years.

Key Words: age, athlete, endurance, sex

Introduction

Marathon running is one of the most popular sports in the world with increased participation rates during the last decades (15). In sports, each discipline seems to have its specific age of peak performance. The knowledge of the age of peak athletic performance is important for athletes and coaches to plan a career (2). In marathon running, the age with the fastest race time has been investigated in different studies (13, 14, 17, 21, 30). These studies used different samples (*e.g.* top athletes, all finishers) and different methods (*e.g.* multiple linear regression models, non-linear regression analyses, mixed-effects regression analyses) (13, 14, 17, 21, 30). As a result, the age of peak marathon performance is assumed to be ~25-35 years, but a more precise age and the variation by sex remain inconclusive (13, 14, 17, 21, 30).

Regarding the sex difference in the age of peak marathon running, studies reported that women were older than men when achieving their fastest

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marathon race time (13, 17, 21, 30). This result was confirmed by using different samples of athletes and different statistical methods (13, 17, 21, 30). However, a recent study investigating female and male mountain and city marathoners found that the age of peak female marathon performance was younger compared to peak male marathon performance in both mountain and city marathon running when all female and male finishers were considered (14). Most likely, the sample size (*e.g.* including all female and male finishers) and the method (*e.g.* non-linear regression analysis) were responsible for this opposing result. For instance, considering the best runners (*e.g.*, top 10 or top 100) by age group may result in observing a younger age of peak performance than considering all runners. Thus, it would be interesting to combine these methodological approaches (*i.e.*, best versus all runners) in a single sample.

Although the abovementioned studies have improved our understanding of marathon performance variation by age, we have limited knowledge with regards to such variation in large sets of marathon runners, especially considering sex differences. Such knowledge would be of great practical application for coaches and fitness trainers working with marathon runners in order to set long-term performance goals. Since most studies investigating the age of peak marathon performance used a limited sample of athletes (13, 17, 21, 30), the aim of the present study was to determine the age of peak female and male marathon running performance in a large sample of female and male marathoners by including all official race finishers, not only the top athletes.

Materials and Methods

Ethics Approval

The institutional review board of St Gallen, Switzerland, approved this study. Since the study involved analysis of publicly available data, the requirement for informed consent was waived.

Methodology

Participants in the present study were 451,637 (women, n = 168,702; men, n = 282,935) runners, *i.e.* all those who finished the 'New York City Marathon' from 2006 to 2016. Data were obtained from the official race website www.tcsnycmarathon.org. Age, sex and finish time from each official finisher were considered for data analysis. Female and male athletes were sorted into 1-year and 5-year age intervals. The use of both 1- and 5-year age groups was qualified, because both approaches might have practical applications. According to the rules of the particular race, participants are classified in 5-year age groups; thus, it would be interesting to know which 5-year age group is the faster and whether this is the same for female and male participants. Furthermore, the chronological age of participants is available, which provides the opportunity to study the effect of age on performance in more details, *i.e.* to show at which age the peak of performance occurs.

Statistical and Data Analysis

Statistical analyses were performed using IBM SPSS v.20.0 (SPSS, Chicago, USA) and figures were created using GraphPad Prism (Version 5, GraphPad Software, La Jolla, USA). Data were expressed as mean and standard deviations of the mean (SD). The Kolmogorov-Smirnoff test of normality and visual inspection of normal Q-Q plots examined the normality of all variables. The test of normality and the visual inspection of the normal Q-Q plots showed that the data deviated from normality (Kolmogorov-Smirnov 0.059 in women and 0.053 in men, $P < 0.001$); however, we qualified the use of parametric statistics to have comparable analysis with previous studies (7, 24, 30). A two-way analysis of variance (ANOVA) examined the effects of sex, age group and calendar year on race speed and age. Subsequent comparisons among groups were carried out using *post-hoc* Bonferroni tests. The magnitude of the differences among groups was examined using effect size eta square (η^2) and was evaluated as following: small ($0.010 < \eta^2 \leq 0.059$), moderate ($0.059 < \eta^2 \leq 0.138$) and large ($\eta^2 > 0.138$) (6). A chi-square test (χ^2) examined the association between calendar year and sex, and between age group and sex. The magnitude of these associations was tested by Cramer's phi (φ). The age with the fastest race time considering age groups in 1-year and 5-year intervals was calculated using a non-linear regression model with a second order (quadratic) polynomial function ($y = ax^2 + bx + c$) that fitted the data. The vertex of the quadratic function was calculated as $p(x|y)=\left(-\frac{b}{2a}\middle|C-\frac{b^2}{4a}\right)$. We determined the the age with the fastest marathon race time for both the fastest women and men and all women and men in 1-year age intervals. The non-linear regression analysis was qualified instead of linear regression analysis, because it has been shown that the main physiological determinant of marathon performance, maximal oxygen uptake, increases with age during childhood and adolescence, but decreases during adulthood (12). Significance level was set at alpha = 0.05.

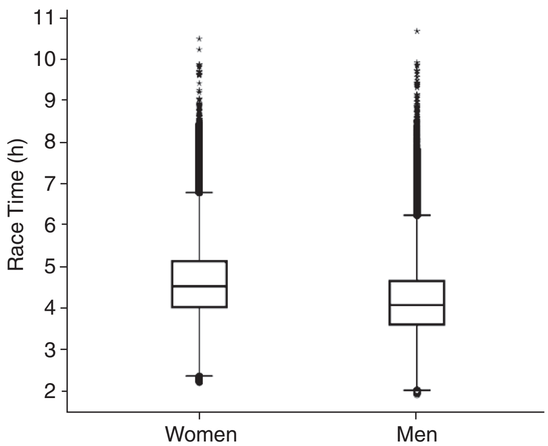

Fig. 1. Sex differences in race time. The dark line in middle of the boxes is the median of race time. The box shows the 25th-75th percentile values, whereas the T-bars include the 95% of the data. Cycles denote outliers and the asterisks show extreme outliers (values three times the height of the boxes). The race time refers to all finishers during 2006-2016.

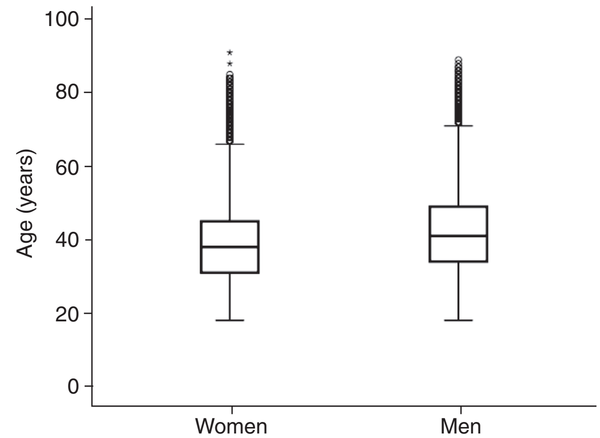

Fig. 3. Sex difference in age. The dark line in middle of the boxes is the median of age. The box shows the 25th-75th percentile values, whereas the T-bars include the 95% of the data. Cycles denote outliers and the asterisks show extreme outliers (values three times the height of the boxes). The age refers to all finishers during 2006-2016.

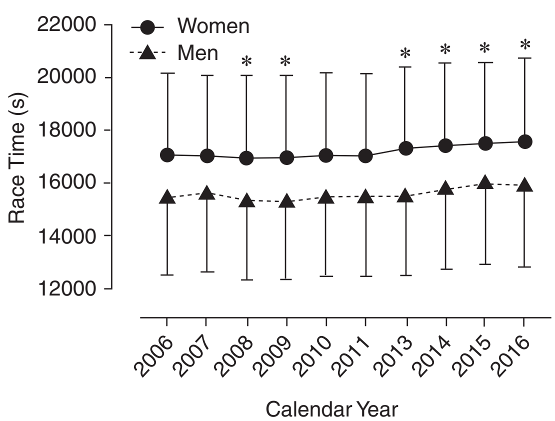

Fig. 2. Changes in race time by sex and calendar year; * = different to 2006. The asterisks represent differences in race time of all finishers among calendar years.

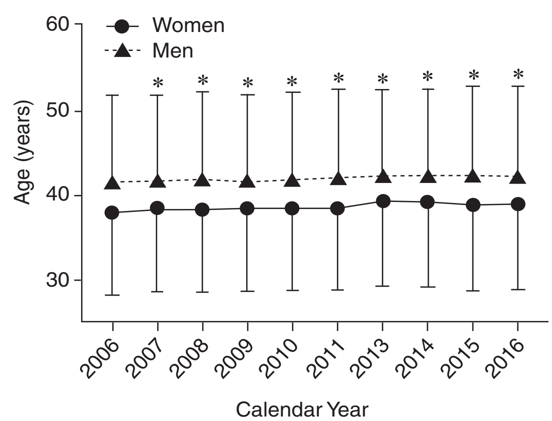

Fig. 4. Changes in age by sex and calendar year; * = different to 2006. The asterisks represent differences in age of all finishers among calendar years.

Results

The Effect of Sex and Calendar Year on Race Time and Age

A small effect of sex on race time was observed ($F_{(1)} = 27,785.63$, $P < 0.001$, $\eta^2 = 0.058$), where men were faster than women by 0:27:06 h:min:s (4:20:40 versus 4:47:47 h:min:s, respectively; Fig. 1). A trivial effect of calendar year on race time was shown ($F_{(9)} = 253.32$, $P < 0.001$, $\eta^2 = 0.005$), where the race time in the recent races was slower than in previous races with the fastest time found in 2009 (4:25:22 h:min:s) and the slowest in 2015 (4:37:52 h:min:s; Fig. 2). Also, a trivial sex × calendar year interaction on race time was observed ($F_{(9)} = 13.59$, $P < 0.001$, $\eta^2 < 0.001$), where the sex difference in race time was the smallest in 2007 (-0:23:20 h:min:s) and the largest in 2013 (-0:30:20 h:min:s).

A small effect of sex on age was observed ($F_{(1)} = 11,324.57$, $P < 0.001$, $\eta^2 = 0.024$), where women were younger than men by -3.3 years (38.8 ± 9.8 versus 42.0 ± 10.2 years, respectively; Fig. 3). A trivial effect of calendar year on age was shown ($F_{(9)} = 45.95$, $P < 0.001$, $\eta^2 = 0.001$), where the age in the recent races was older than in previous races with the youngest age found in 2006 (40.4 ± 10.1 years) and the oldest in 2013 (41.1 ± 10.1

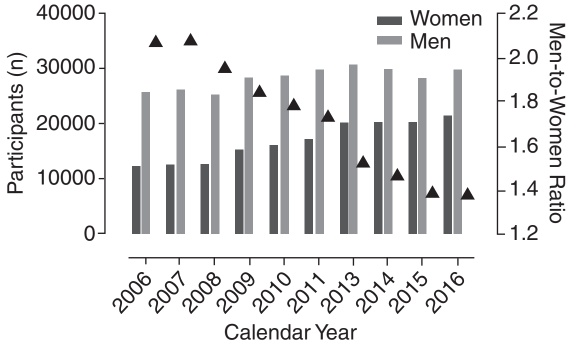

Fig. 5. Participation and men-to-women ratio (▲) by calendar year.

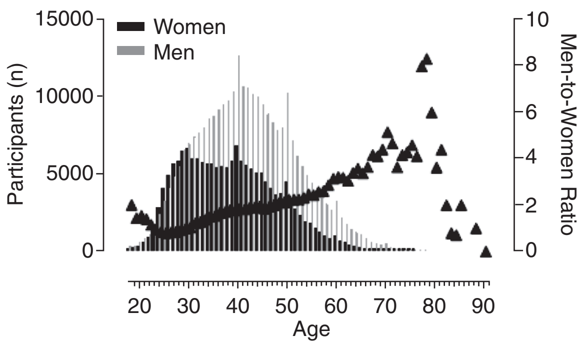

Fig. 6. Participation and men-to-women ratio (▲) by 1-year age group.

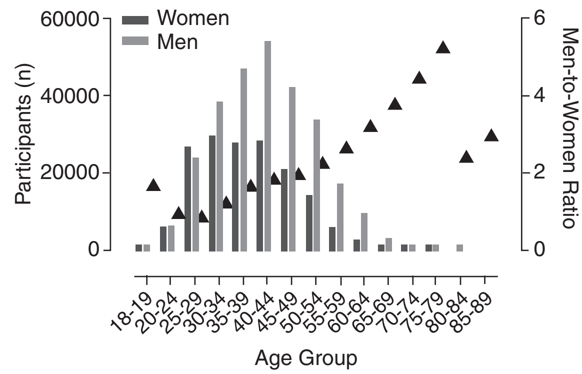

Fig. 7. Participation and men-to-women ratio (▲) by 5-year age group.

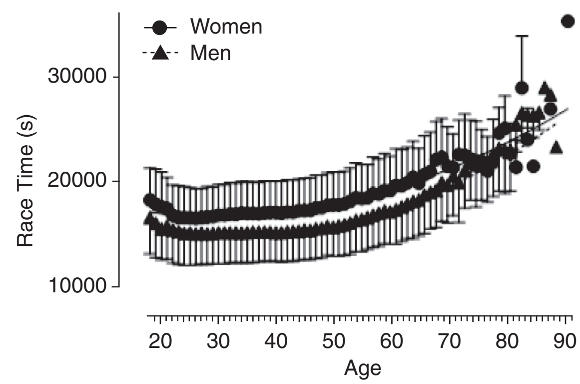

Fig. 8. Race time in 1-year age group intervals by sex. The race time refers to all finishers during 2006-2016.

years; Fig. 4). Also, a trivial sex × calendar year interaction on age was observed ($F_{(9)} = 5.52$, $P < 0.001$, $\eta^2 < 0.001$), where the sex difference in age was smaller in 2016 (-3.3 years) than in 2006 (-3.6 years).

The Men-to-Women Ratio

The total men-to-women ratio was 1.68. Compared to 2006 (n = 12,321), 21,441 women participated in 2016, *i.e.* an increase of +74.0%, whereas the corresponding scores in men were 25,558, 29,829 and +16.7%, and in both women and men 37,879, 51,270 and +35.4%. A sex × calendar year association was shown ($\chi^2 = 2285.59$, $P < 0.001$, $\varphi = 0.071$; Fig. 5), where the men-to-women ratio was the smallest in 2016 (1.39) and the largest in 2007 (2.08). A sex × age association was observed, either when age groups were considered in 1-year ($\chi^2 = 12752.48$, $P < 0.001$, $\varphi = 0.168$; Fig. 6) or 5-year intervals ($\chi^2 = 12081.90$, $P < 0.001$, $\varphi = 0.164$; Fig. 7), where the men-to-women ratio was larger in the older than in the younger age groups. When the age groups were considered in 1-year intervals, most women and men were in the 40 year age group. When the age groups were considered in 5-year intervals, most women were in the age group 30-34 years, whereas most men were in the age group 40-44 years.

The Age with the Fastest Race Time

When the age was considered in 1-year age intervals, the fastest race time was shown at 29.7 years in women and 34.8 years in men (Table 1, Fig. 8). When the age was considered in 5-year age intervals, the fastest race time was achieved in age group 30-34 years in women and in age group 35-39 years in men (Fig. 9).

Discussion

The main findings of the present study were that (i) men were faster and older than women; (ii) the participation of women during the last decade increased disproportionately to that of men, resulting in a decrease of the men-to-women ratio; (iii) relatively

Table 1. Parameters in the second-order polynomial regression race time (s) = a + bx + cx^2 using the race time of all runners in 1-year age and 5-year age groups by sex.

	1-year age groups		5-year age groups	
Parameter	Women	Men	Women	Men
a (s)	19174	19424	17544	16809
b (s/year)	-161.6	-250.0	-442.6	-766.5
c (s/year^2)	2.725	3.595	64.07	85.03
Age (years)	29.7	34.8	30-34	35-39
Race time (s)	16778	15078	16780	15082

The parameters a, b and c are coefficients in the polynomial equation that shows the relationship between race time and age. Based on the regression analysis, we calculated the parameters Age (the age or age group of peak performance) and Race time (the performance of the corresponding Age).

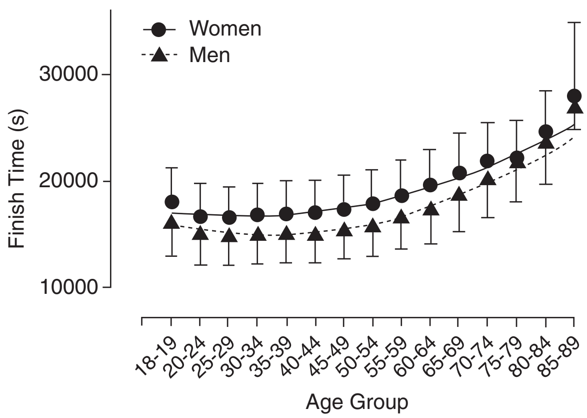

Fig. 9. Race time in 5-year age group intervals by sex. The race time refers to all finishers during 2006-2016.

more women participated in the younger age groups; (iv) most women were in the age group 30-34 years and most men in the age group 40-44 years; and (v) the fastest race time was shown at 29.7 years in women and 34.8 years in men, and in age group 30-34 years in women and age group 35-39 years in men.

The most important result was that, independently from the approach of age intervals (*i.e.* 1-year versus 5-year interval), the age with the fastest race time was younger in women than in men. Both methodological approaches offered information about the age of peak performance of practical value for marathon runners and their coaches. When the age groups were considered in 1-year intervals, this difference was ~5 years (*i.e.* 29.7 years in women and 34.8 years in men). Similarly, when 5-year intervals were considered, the difference was again ~5 years (*i.e.* age group 30-34 years in women and age group 35-39 years in men). This result contrasts existing findings where women were older than men when achieving their fastest marathon race time (13, 17, 21, 30).

A probable explanation of this difference might be the sex difference in the age of all participants. It was shown that women were younger than men by 3.3 years; therefore, a corresponding difference in the age of fastest race time should be expected. Further explanations are that the participation of women during the last decade increased disproportionately to that of men, resulting in a decrease of the men-to-women ratio; relatively more women participated in the younger age groups and they were competing between 23 and 28 years more often than men; more women were in age group 30-34 years and more men were in age group 40-44 years. An increase in female participation in running races in the last decades has also been reported for other distances (9, 11). In 10-km road races held in the United States between 2002-2005 and 2011, there was a significant annual decrease in the men-to-women ratio of finishers, indicating that increasingly more women competed in these races compared to men (9).

For other running distances such as 100 km (5) and 100 miles (23), the results were different for the age of peak running performance between women and men. In 100-km ultra-marathons held between 1960 and 2012 worldwide, the age of peak running performance remained unchanged at 34.9 ± 3.2 and 34.5 ± 2.5 years for the annual 10 fastest women and men, respectively (5). In 100-mile ultra-marathons held worldwide between 1998 and 2011, the age of peak running performance remained the same between women (39.2 ± 6.2 years) and men (37.2 ± 6.1 years) and showed no changes across the years (23). In Ironman triathletes competing in Ironman Switzerland - a qualifier for Ironman Hawaii -between 1995 and 2010, the age of peak Ironman performance of the annual top ten female and male finishers was 32.2 ± 1.5 years for men and 33.0 ± 1.6 years for women with no sex difference (25). The most likely explanation for these differences is the fact that these studies used a limited sample of athletes such as the top ten per year while we used no limitations in the present investigation.

Based on the above mentioned analysis, it was concluded that the younger age of peak performance in women than in men should be attributed mostly to the younger age of women participants compared to men. Particularly, relatively fewer women than men participated in the older age groups, which could be explained by women engaging in regular training and sport more recently compared to men. We observed that the men-to-women ratio was higher in the older than in the younger age groups, and particularly it was higher than 2 in age groups older than 50 years old, *i.e.* in those runners born before 1968. A greater participation of women in sports across years might be due to changes in laws and rules (22). For instance, after the passage of Title IX in 1972, an increased participation of women in sports was observed (27). In addition, the women's marathon was introduced in the Olympic Games for the first time in 1984, which should foster the popularity of this sport especially in female children and adolescent athletes.

Moreover, the variation in participation in marathon running by age group, which was in agreement with previous research (1), might be associated to the overall participation in sports activities. A study of a large database from 11 European countries showed that men were more active than women and that retirement increased the likelihood of participating in sport club activities only in men (3). A Greek study also showed that more men were participating in sports than in women (28). In 77 year-old Germans, men participated more than women in sport activities by 50% (18). Also, fewer opportunities to train have been identified for women compared to men (10). Therefore, it was assumed that the lower participation of women in the older age groups might be due to their lower level of their participation in sports.

Also, the sex differences in participation in marathon running reflect sex differences in psychological aspects, such as motivation. It has been suggested that women set goals in task-oriented categories, such us to win, to compete, to have fun and remain healthy after the race (16). Compared to men, women have reported greater benefits in terms of opportunities to meet people, relief from depression and feeling less shy (26). It has been suggested that women might differ in motivation to participate in a marathon run from men (4). The participation of women in an endurance race has been described as 'challenge' in a study that showed that the participation, *per se*, facilitated previously inactive women into sufficient levels of physical activity (8). Another barrier to the participation of relatively few older women in marathon might be a social discrimination, *e.g.* in the case of medical cautions which were more strict for women than for men (29).

A limitation of the present study is that since the 'New York City Marathon' has unique topographical and environmental characteristics, *e.g.* it is considered as a "flat" marathon, caution would be needed to generalize the findings in other marathon races. For instance, we would expect an increased muscular effort during less "flat" marathons, which in turn might result in observing younger age of peak performance (considering the age of peak of muscle strength). On the other hand, the race under examination is the largest marathon in the world which explains the recent increased scientific interest for this race (7, 19, 20, 24); thus, its analysis would have a relatively larger impact than other races. Accordingly, our findings would be of great theoretical and practical value. From a theoretical perspective, exercise physiologists focusing on the variation of human performance across life span would benefit from the results regarding the age of peak performance in race marathon, which was observed in older age than that of biological parameters associated with endurance performance, such as maximal oxygen uptake. From a practical perspective, the knowledge of the age of peak performance might help coaches and fitness trainers working with marathon runners setting long-term sex- and age-tailored performance goals.

In summary, in contrast to existing findings reporting an older age of peak marathon performance in women compared to men, we found that women achieved their best marathon race time ~5 years earlier in life compared to men. This sex difference might be associated with the overall younger age of female finishers.

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Conflict of Interest

We declare no conflict of interest.

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