

Do older athletes reach limits in their performance during marathon running?

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Title: Do older athletes reach limits in their performance during marathon running?

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Abstract: In the last decades, the participation of elderly trained people in endurance events such as marathon running has dramatically increased. Previous studies suggested that the performance of master runners (> 40 yrs) during marathon running has improved. The aims of the study were : (i) to analyze the changes in participation and performance trends of master marathon runners between 1980 and 2009 and, ii) to compare the gender differences in performance as a function of age across the years. Running times of the best male and female runners between 20 and 79 yrs of age who competed in the New-York City marathon were analyzed. Gender differences in performance times were analysed for the top 10 male and female runners between 20 and 65 yrs of age. The participation of master runners increased during the 1980-2009 period, to a greater extent for females compared to males. During that period, running times of master runners significantly ($P<0.01$) decreased for males older than 64 yrs and for females older than 44 yrs, respectively. Gender differences in running times decreased over the last 3 decades but remained relatively stable across the ages during the last decade. These data suggest that male (65 yrs) and female (45 yrs) master runners have probably not yet reached their limits in marathon performance. The relative stability of gender differences in marathon running times across the different age groups over the last decade also suggests that age-related declines in physiological function do not differ between male and female marathoners.

Response to Reviewers: We are grateful to the reviewer for the critical comments and useful suggestions that have helped us to improve our paper. As indicated in the responses below, we have taken all these comments and suggestions into account in the revised version of our manuscript.

General comment
Reviewer:
The authors expand the analysis from Jokl et al. in Br J Sports Med 2004;38:408-412 of the New York City Marathon for the first decade of the new century. Since this marathon is one of the most known marathons, this is an important paper to see advances of master marathon runners in the first decade of the new century.
Regarding the paper of Jokl et al. 2004, the authors add the new data and make some substantial contributions.
Response: We thank the reviewer for his positive comments.

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Specific comments
Reviewer:
Abstract
- I would like to see an opening sentence as background, what is known and what has been done.
Response:
We added the following sentence: "In the last decades, the participation of elderly trained people in endurance events such as marathon running has dramatically increased. Previous studies suggested that the performance of master runners (> 40 yrs) during marathon running has improved."

- The last sentence, I would put 'marathoners' at the end since you have investigated marathoners for this specific finding.
Response:
Done, as requested.

Introduction
- First paragraph: It is a good idea to start the paper this way. I recommend using the references of Williams PT, for example Williams PT. Relationship of distance run per week to coronary heart disease risk factors in 8283 male runners. The National Runners' Health Study. Arch Intern Med. 1997 Jan 27;157(2):191-8. Williams PT. Incident hypercholesterolemia in relation to changes in vigorous physical activity. Med Sci Sports Exerc. 2009 Jan;41(1):74-80. Williams PT. Lower prevalence of hypertension, hypercholesterolemia, and diabetes in marathoners. Med Sci Sports Exerc. 2009 Mar;41(3):523-9. And similar articles of this author. So you can show how important marathon running is for health and minimizing health costs.
Response:
Thank you for the references. We have added the three references suggested by the reviewer in the manuscript (Williams 1997, Williams 2009a Williams 2009b, see references) and the following sentence in the introduction: "For example, it has been shown that prevalence of hypertension, hypercholesterolemia, and diabetes decreases with the frequency of marathon participation independent of annual running distance. This may be due to the inclusion of longer training runs in preparation for marathons or to genetic or other innate differences between marathon and nonmarathon runners (Williams 2009b)".

- Page 3, Line 44, the word 'chronic' sounds for me like a 'chronic disease leading to death'. I recommend using another expression.
Response:
The word "chronic" has been replaced by 'usual".

- Page 4, first line, I think you want to say 'world-wide'
Response:
The reviewer is right.

- Page 4, Lines 22-27. This is the most important aspect of your paper, you should emphasize more!
Response:
The following sentence has been added: "However, the changes in participation and performance of elderly athletes at the NYC marathon this last decade (i.e. from 2000 to 2009) have not been yet investigated and it is not known whether master's athletes still improved their marathon performance or whether they have reached their limits".

- End of Introduction: You need to express that to date, no data exist for the participation and performance in marathon running for master athletes in the first decade of the new century. And you

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want to expand the existing data from Jokl et al. 2004. This should be more clearly since this is the strength of your paper.
Response:
We have added the following sentence to the last paragraph of the introduction: "To date, no data exist regarding the participation and performance trends in marathon running for master athletes in the first decade of the new century. Accordingly, the first purpose of this large cross-sectional study was to expand the existing data from Jokl et al. (2004) by examining the changes in participation and performance of masters athletes at the NYC marathon over the last 30 years (from 1980 to 2009)."

Methods
- The authors should explain why they took the top 10 finishers of each age group. Jokl et al. took the top 50 of each age group.
Response:
In contrast to Jokl et al (2004) that considered age groups of 10 years, we considered age groups of 5 years for males and females older than 40. In addition, the small participation of very old athletes especially for females with sometimes less than 20 finishers per age group, justified the necessity to consider only the top 10 finishers.
We have added the following sentence in the methods "The small participation of athletes older than 65 yrs, especially for females, during the first decade studied (1980-1989), with sometimes less than 20 finishers per age group, justified the necessity to consider only the top 10 finishers."
- Results
The authors should explain that the organizer sets a limit. This will influence the participation!
Response:
The reviewer is right. This point was already discussed in the paragraph "Increase in participation of master athletes" of the discussion: "It should be mentioned over the years, the race organisation has imposed limits to the number of entries accepted and this entry cap has increased over the years. However, if the field size limits to the NYC marathon would alter the number of allowable finishers, it would probably not change the relative proportions of males/females and ages."

Discussion
- Page 9, Line 49: How can you explain your statement 'There is no evidence that participation of women will reach those of men in the near future'?
Response:
We agree that this assumption is not justified according to the present results so we have deleted this sentence.

- Page 9, Line 54: You have inserted (2), this should probably be a reference?
Response:
The reviewer is right. The reference was: Burfoot (2007)

- Page 10, Line 17-22, I think you should insert there a reference
Response:
We have added the following reference: Lee MS, Tanaka K (1997) Significance of health fitness appraisal in an aging society. Appl Human Sci 16:123-131.

- Page 11, Line 24, how do you define 'older females'?
Response:
We have added to the sentence: "females older than 50 yrs".

- Can you explain about your female age group 44-44 years?
Response:

We have added the following sentence: "These results suggested that the youngest female master runners have already reached their limits in performance during marathon."

- Although you have a lot of data and good analysis, you should mention in the limitations that weather influences marathon performance times, see Int J Biometeorol. 2010 May;54(3):297-306. Jokl et al. mention in the second last paragraph the year 1983!
Response:
The possible effects of weather on the performance of marathon runners (Vihma 2010) have been evocated in the discussion.

- References
Page 14, Line 22. VO2max
Page 14, Line 36. The first letter of each word is capitalized
Response:
Done, as requested.

- Figures
In Figure 1, you have more age groups for males than for females. Could you arrange the figure to show that there were no participants in the age groups 70-74 and 75-79?
Response:
The figure 1 has been modified as requested.

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abstract
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Abstract

In the last decades, the participation of elderly trained people in endurance events such as marathon running has dramatically increased. Previous studies suggested that the performance of master runners (> 40 yrs) during marathon running has improved. The aims of the study were : (i) to analyze the changes in participation and performance trends of master marathon runners between 1980 and 2009 and, ii) to compare the gender differences in performance as a function of age across the years. Running times of the best male and female runners between 20 and 79 yrs of age who competed in the New-York City marathon were analyzed. Gender differences in performance times were analysed for the top 10 male and female runners between 20 and 65 yrs of age. The participation of master runners increased during the 1980-2009 period, to a greater extent for females compared to males. During that period, running times of master runners significantly (P<0.01) decreased for males older than 64 yrs and for females older than 44 yrs, respectively. Gender differences in running times decreased over the last 3 decades but remained relatively stable across the ages during the last decade. These data suggest that male (≥ 65 yrs) and female (≥ 45 yrs) master runners have probably not yet reached their limits in marathon performance. The relative stability of gender differences in marathon running times across the different age groups over the last decade also suggests that age-related declines in physiological function do not differ between male and female marathoners.

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Do older athletes reach limits in their performance during marathon running?

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Abstract

In the last decades, the participation of elderly trained people in endurance events such as marathon running has dramatically increased. Previous studies suggested that the performance of master runners (> 40 yrs) during marathon running has improved. The aims of the study were : (i) to analyze the changes in participation and performance trends of master marathon runners between 1980 and 2009 and, ii) to compare the gender differences in performance as a function of age across the years. Running times of the best male and female runners between 20 and 79 yrs of age who competed in the New-York City marathon were analyzed. Gender differences in performance times were analysed for the top 10 male and female runners between 20 and 65 yrs of age. The participation of master runners increased during the 1980-2009 period, to a greater extent for females compared to males. During that period, running times of master runners significantly (P<0.01) decreased for males older than 64 yrs and for females older than 44 yrs, respectively. Gender differences in running times decreased over the last 3 decades but remained relatively stable across the ages during the last decade. These data suggest that male (≥ 65 yrs) and female (≥ 45 yrs) master runners have probably not yet reached their limits in marathon performance. The relative stability of gender differences in marathon running times across the different age groups over the last decade also suggests that age-related declines in physiological function do not differ between male and female marathoners.

Keywords : Running, Aging, Master athletes, Endurance exercise, Gender differences.

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Introduction

Although longevity continues to increase, some lifestyle risks might have a sufficiently large impact on mortality to halt the present upward trends in life expectancy. The lifestyle risks found in most of the populations of the world's most affluent countries are cigarette smoking, obesity, an unhealthy diet, lack of exercise, alcohol consumption and general sedentary behavior (Harper and Howse 2008). It has been shown that regular physical activity can reduce the risk of all causes of mortality and increase life expectancy (Williams 1997, Williams 2009a). Despite the benefits of exercise, the percentage of a populations physical inactivity increases with advancing age and according to the U. S. Department of Health and Human Services, approximately one-third of persons aged 65 or older lead a sedentary lifestyle (http://aspe.hhs.gov/health/reports/physicalactivity/).

The aging process in humans is characterized by significant decreases in physiological functions, but numerous studies have demonstrated that continued exercising such as running late into life, attenuates sarcopenia and is beneficial for cardiovascular health (Trappe 2007; Faulkner et al. 2008). Careful studies of people who age successfully from a physical performance standpoint may elucidate methods and mechanisms that doctors can apply to all patients to develop a more uniform healthcare approach. Older (or Masters) endurance athletes represent an ideal model to determine successful aging due to their usual participation in high intensity exercise (Hawkins et al. 2003). They are a positive example of exceptional aging and are a rich source of insight into a person's ability to maintain peak physical performance and physiological function with advancing age (Tanaka and Seals 2008). For example, it has been shown that prevalence of hypertension, hypercholesterolemia, and diabetes decreases with the frequency of marathon participation independent of annual running distance. This may be due to the inclusion of longer training runs in preparation for

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marathons or to genetic or other innate differences between marathon and nonmarathon runners (Williams 2009b).

Since the early 1980's, participation in distance running events such as marathon has skyrocketed with hundreds of marathons world-wide and several events having more than 40 000 participants (Burfoot 2007). The marathon has become a world-wide social and fitness phenomenon, and therefore represents an interesting model to analyze the participation and performances trends of athletes across the ages over a long period of time.

To the best of our knowledge, few studies have focused on the participation and performance trends of masters athletes at the marathon distance since the early 1980's (Jokl et al. 2004, Leyk et al. 2009). Jokl et al. (2004) showed that participation in the New York City (NYC) Marathon over the 1983-1999 period increased at a higher rate in athletes above 50 years old than in younger athletes, for both men and women. In addition, over the same 1983-1999 period, the best male and female athletes older than 50 improved their running times at a greater rate than the younger athletes, whose performance levels have plateaued. However, the changes in participation and performance of elderly athletes at the NYC marathon this last decade (i.e. from 2000 to 2009) have not been yet investigated, and it is not known whether master's athletes still improved their marathon performance or whether they have reached their limits.

Gender differences in running have been well investigated for elite athletes (Pate and O'Neil 2007; Sparkling et al. 1998; Baker and Tang 2010; Hunter et al. 2011). However, there is paucity of data related to the combined interaction of age and gender on running performance (Leyk et al. 2007; Ransdell et al. 2009). Knowing that the physiological (e.g. muscle strength, oxygen carrying capacity) and morphological (e.g. percentage of body fat, muscle mass) functional characteristics change with advancing age, gender differences in endurance running performance may also change with advancing age. For example, some

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studies have suggested that elderly females may lose muscle mass more rapidly than do their male counterparts (Phillips et al. 1993; Samson et al. 2000); but it is not a general finding. An increase in 10-km running time with advancing age has been found to be greater in females compared to males (Tanaka and Seals 2003). Jokl et al. (2004) found that the time improvement were substantially greater for older female athletes compared to their male counterparts at the NYC marathon over the 1983-1999 period. These findings suggest that gender differences in marathon running performances for master's athletes may have decreased during last 3 decades. However, the possibility of an increased gender difference in endurance running with advanced age needs to be examined.

To date, no data exist regarding the participation and performance trends in marathon running for master athletes in the first decade of the new century. Accordingly, the first purpose of this large cross-sectional study was to expand the existing data from Jokl et al. (2004) by examining the changes in participation and performance of masters athletes at the NYC marathon over the last 30 years (from 1980 to 2009). A secondary purpose was to analyze the gender differences in running performance as a function of age across the same 1980-2009 period.

Methods

Approval for the project was obtained from the Burgundy University Committee on Human Research. This study involved the analysis of publicly available data so content was waived. Age and time performance data for all runners completing the NYC marathon from 1980 to 2009 were obtained through the NYC marathon web site: http://www.ingnycmarathon.org/. Although there is no consensus in the literature about the definition of a masters athlete, we defined masters athletes in the present study as those equal to or older than 40 yrs. For male

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and female athletes younger than 40 yrs, we considered two age groups of 10 years: 20-29 yrs, 30-39 yrs. To focus more on changes in participation and performance in masters athletes, we considered age groups of 5 years for males and females older than 40, as follows: 40-44 yrs, 45-49 yrs, 50-54 yrs, 55-59 yrs, 60-64 yrs, 65-69, 70-74 yrs, and 75-79 yrs. The small participation of athletes older than 65 yrs, especially for females, during the first decade studied (1980-1989), with sometimes less than 20 finishers per age group, justified the necessity to consider only the top 10 finishers. Averaged running time performances of the top 10 finishers of each age group for both females and males were analyzed from 1980 to 2009. If there were less than 10 finishers in an age group, the data were not considered. The magnitude of gender differences was examined by calculating the percent difference for running times between the top 10 males versus females of each age group. In order to simplify the analysis over the 30 years studied period (1980-2009), we pooled data into three decades: 1980-89, 1990-99 and 2000-09.

Two-way ANOVAs (age group x decade) with repeated measures on decade were used to compare percent of finishers and running times between the decades across ages, for both males and females. Two-way ANOVAs (age group x decade) with repeated measures on decade were also used to compare gender differences in running times between the decades across ages. Tukey's post hoc analyses were used to test differences within the ANOVAs when appropriate. A significance level of $P < 0.05$ was used to identify statistical significance.

Results

Participation of masters athletes

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Table 1 shows that the number of total finishers increased by 65% between decade 1980-89 and decade 1990-99 and by only 25% between decade 1990-99 and decade 2000-09. The number of finishers increased more for females than for males: 145% *vs.* 49% between 1980-89 and 1990-99 and 68% *vs.* 11% between 1990-99 and 2000-09. The ratio of male and female finishers decreased over the three decades, and was equal to 5.1, 3.1 and 2.1, respectively. The relative increase of finishers was greater for the masters athletes > 40 yrs than for younger athletes for both males and females, and was greater for female masters athletes than for the males (Table 1). The distribution of finishers per age group over the three decades studied is shown in Fig. 1. Over the three decades, the percent of finishers younger than 40 yrs significantly decreased ($P < 0.05$), while the percent of masters finishers significantly increased ($P < 0.05$), for both males and females. Over the 3 decades 1980-89, 1990-99 and 2000-09, male masters athletes represented 36%, 45% and 53% of total male finishers, respectively; while female masters athletes represented 24%, 34% and 40% of total female finishers, respectively.

Performances of masters athletes

The mean finish times for the top 10 of each male and female age group over the three studied decades are shown in Fig. 2. For males, ANOVA revealed that mean finish times did not change over the three decades for age groups < 60-64 yrs. In contrast, running times significantly decreased ($P < 0.01$) over the three decades for age groups ≥ 60-64 yr. For example, average running times of males within the 65-69 yrs age range significantly decreased ($P < 0.01$) by ~8 min (3.7%) between 1980-89 and 1990-99, and by ~7 min (3.2%) between 1990-99 and 2000-09. Average running time of males within the 70-74 yrs age range significantly decreased ($P < 0.01$) by ~13 min (4.9%) between 1980-89 and 1990-99, and by

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~4 min (1.6%) between 1990-99 and 2000-09. For females, mean finish times did not change over the three decades for age groups < 45-49 yrs, except the time of the 30-39 yrs group that was lower in 2000-09 decade compared to previous decades. Female running times significantly decreased (P <0.01) over the three decades for age groups ≥ 45-49 yr. For example, average running time of females within the 55-59 yrs age range significantly decreased (P < 0.01) by ~33 min (14.5%) between 1980-89 and 1990-99, and by ~8 min (3.5%) between 1990-99 and 2000-09. Average running times of females within the 60-64 yrs age range significantly decreased (P < 0.01) by ~16 min (6.8%) between 1990-99 and 2000-09.

Gender differences in running times with age

Independently of age, gender differences in running times were significantly (P < 0.001) lower for decade 2000-2009 compared to both previous decades 1980-89 and 1990-99. Mean gender differences in running times were equal to 28.4 ± 10.3 %, 25.8 ± 6.9%, and 19.7 ± 4.2 % for decades 1980-1989, 1990-1999, and 2000-2009, respectively. There was a significant age group x decade interaction for gender differences in performance times (F = 8.7; P < 0.001), (Fig. 3). Gender differences at age groups > 45-49 yrs decreased over the three decades. During decade 1980-89, gender differences were significantly (P<0.01) greater for age groups 55-59 yrs and 60-64 yrs compared to all younger age groups comprised between 20-29 yrs and 50-54 yrs. Interestingly, gender differences did not differ across the ages for the last two decades 1990-99 and 2000-09.

Discussion

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The main findings of the present study were first that the participation of masters athletes at the NYC Marathon increased during the 1980-2009 period, but to a greater extent for females than for males. Second, during that period, running times of masters runners has significantly decreased for males older than 64 yrs and for females older than 44 yrs, respectively. Third, gender differences in running time decreased over the last 3 decades but remained relatively stable across the different ages during the last decade.

Although it lacked some data about physiological (e.g. aerobic capacity) and anthropometric (e.g. body weight, lean body mass) parameters, as well as training volume (Knechtle et al. 2009) and environmental conditions of the race (Vihma 2010), the present study has provided valuable data concerning masters athletes performances at the marathon distance during the last 30 years. Indeed, masters athletes represent an ideal model to determine successful aging due to their sustained participation in exercise. While numerous research has been conducted describing the age-related declines in aerobic capacity (Harper and Howse 2008), the influence of chronic exercise on physiological capacity has been less investigated. The approach that consists of examining the changes in endurance performance with age in highly trained and competitive athletes represents an effective experimental model because changes observed with advancing age are thought to be mainly the results of primary (physiological) aging (Tanaka and Seals 2008). It is likely that the athletes finishing in the top 10 of their age group in a competitive event such the NYC Marathon, performed to their maximal physical capacity.

Increase in participation of master athletes

The number of male and female finishers increased over the last three decades. It should be mentioned over the years, the race organisation has imposed limits to the number of

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entries accepted and this entry cap has increased over the years. However, if the field size limits to the NYC marathon would alter the number of allowable finishers, it would probably not change the relative proportions of males/females and ages. Based on extrapolation, Jokl et al. (2004) suggested that the male/female ratio of participation would approach 1 in 2007. Our findings did not confirm that assumption. Indeed, the relative participation of females at the NYC Marathon increased over the last 30 years (from ~17% of the total field for the 1980-89 period to ~33% for the 2000-09 period), but remained lower than participation of the males.

The growth of female and masters age groups in worldwide marathon racing has been particularly startling over the last 30 years (Burfoot 2007). Present data confirm previous observations as the total participation of master runners at the NYC Marathon has increased during the last three decades and to a greater extent for female than for males. Throughout the 2000-09 decade, masters runners represented more than 50% of male finishers and 40% of female finishers, respectively. In addition, the relative proportion of masters runners in the total field has also increased for both males and females over the last three decades while those of runners younger than 40 yrs of age decreased during the same period. Similarly, Jokl et al. (2004) found that the number of participants at the NYC Marathon (older than 50 yrs of age) increased at a greater rate than their younger counterparts during the 1983-1999 period. The reasons for such an increase in participation of masters runners especially in the female field are not clear but may be related to sociological phenomena. Increases in life expectancy and good health combined with a better consideration by older people of the positive effects of physical activity upon health with advancing age, i.e. “better aging” may explain this finding (Lee & Tanaka 1997). However, among the masters category, the distinction between people who started training in running late in life (i.e. after 40 yrs age) and people who used to had participated in running younger age is not known. The exponential increase in participation of masters athletes especially in the female field in sporting events such as a

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marathon running should lead to a re-evaluation of the aging process and how it relates to athletic performance.

Performances of masters athletes

Accordingly, the present results show that the running performance times of men within the 40-64 yrs age range have plateaued during the last two decades, while running times decreased for males older than 65 yrs. Several reasons may explain the improved performance of males older than 65 yrs over these 20 years, such as a greater participation of the older age groups, which would increase the probability of finding better runners in these age groups, increase training facilities for older people, and increase the competitive spirit in these older groups. In addition, if masters athletes performed at such a high-level for so long, it is reasonable to expect that those destined to maintain that intensity could do so because they remained largely injury-free (Knobloch et al. 2008). In contrary, the relative stability of running performances for males within the 40-64 yrs age range, suggest that this category of "young' men masters athletes has nowadays approached the limits of their marathon performance.

In contrast to males, the running performance times of female masters athletes decreased during the last two decades for all age groups except for the 40-44 yrs one. These results suggested that the youngest female master runners have already reached their limits in performance during marathon. Improvements of masters running performance have been much greater for females than for males as it has already been observed by Jokl et al. (2004). For example, female running times with the 60-64 yrs age range decreased by ~7% over the last two decades, while it remained stable for their male counterparts. These data suggest that females older than 50 yrs may still improve their marathon performance in the future as the

new generation of well-trained young female athletes will move into the older age group competitions. In addition to better performances for older female athletes, an increase of density such the top 10 spreads of each age group may also be expected in the future.

Gender difference in running time

The gender gap between male and female world best marathon performances has narrowed during the last 30 years. In 1980, the world record for males was 2:08:34 and for females 2:25:41, corresponding to a differential of 13.3%. The current world marathon record is 2:15:25 for females and 2:03:59 for males (Joyner et al. 2011), corresponding to a gender gap of 9.2%. The present results showed that independently of age, the gender differences in running performance times decreased over the last three decades, suggesting that females have reduced the gap to males. During the last decade, gender differences in running times ranged from ~12 % for the 30-40 yrs age group to ~26 % for the 65-69 yrs age group. This finding corroborates the results of Hunter et al. (2011) and Randsell et al. (2009) who examined gender differences in elite and age group runners over several marathons. During the decade 1980-89, the difference between males and females in their performance times increased significantly with advancing age from 55 yrs up to ~40%. However, since the 1990-99 decade differences between female and male running times decreased for older age groups, therefore gender differences did not significantly differ across the age. Recently, Lepers & Maffiuletti (2011) have shown that during the 2006-2008 period gender differences in an ultraendurance event (Ironman triathlon) performance times increased with advancing age from 55 yrs. Ironman triathlon is a newer endurance event (the first even held in 1982) with less participants (~ 2000), compared to NYC Marathon (Lepers 2008), and that maybe explain

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why gender differences across the age in Ironman triathlon are currently similar with to those that were observed for NYC Marathon 30 yrs ago.

The relative stability of gender differences in marathon running times across the ages observed during the last decade suggests that the age-related declines in physiological function did not differ between males and females. Age-related changes in the physiological determinants of endurance performance (e.g. maximal oxygen uptake, lactate threshold, and running economy) between males and females have not received considerable attention. For example, Holloszy and Kohrt (1995) suggested that the relative rates of decline in maximal oxygen consumption with age are similar between the sexes. However, further investigations are required in order to analyse the age-related declines in other physiological parameters such lactate threshold and running economy in males and females.

Conclusion

The participation of masters runners at the NYC Marathon increased over the last 30 yrs and it will probably still grow in the future in the New-York and other marathons worldwide. Interestingly, the last two decades the master runner's performances have plateaued within the 40-64 yrs age range for males, but only within the 40-44 yrs range for females. The present data suggest that male (≥ 65 yrs) and female (≥ 45 yrs) master runners have probably not yet reached their limits in marathon performances. The relative stability of gender differences in marathon running times across the age these last decades also suggests that the age-related declines in physiological functions did not differ between males and females. Literature on the masters athletes improvements in performance has already and, should still stimulate further research on the understanding of age related physiological changes and the potential slowing of some of the aging processes through athletic training.

Further investigations are required in order to analyse participation and performance trends of masters athletes for other sporting endurance events such as swimming, cycling or triathlon, to see if present findings on NYC Marathon are similar for other endurance events.

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The authors have non conflict of interests to report.

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Figure captions

Fig. 1

Percentages of finishers within the different age groups at the New York City marathon over the three studied decades for both males (Panel A) and females (Panel B). Values are mean ± SD.

*: Significantly different from the decade 1980-1989, $P < 0.05$.

$: Significantly different from the decade 1990-1999, $P < 0.05$

Fig. 2

Mean finish running times for the top 10 males (Panel A) and females (Panel B) in each age group at the New York City marathon over the three studied decades. Values are mean ± SD.

* : Significantly different from the decade 1980-1989 for the same age group, $P < 0.01$.

$: Significantly different from the decade 1990-1999 for the same age group, $P < 0.01$

Fig. 3

Averaged gender differences in running times at the New York City marathon over the three decades studied. Values are means ± SE.

** : Significantly different from decade 1980-1989 for the same age group, $P < 0.01$

$: Significantly different from decade 1990-1999 for the same age group, $P < 0.05$

table
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Age group (yrs)	Sex	Number of finishers D1 1980-1989	D2 1990-1999	D3 2000-2009	Changes D2-D1 (%)	Changes D3-D2 (%)
20-29	M	28152	34729	28072	23	-19
	F	8165	19115	25680	134	34
30-39	M	58410	77269	80582	32	4
	F	12037	25939	43005	115	66
40-44	M	25314	36855	45618	46	24
	F	3971	9834	19213	148	95
45-49	M	15601	27739	31411	78	13
	F	2122	6502	12145	206	87
50-54	M	8913	20065	26050	125	30
	F	922	4034	8308	338	106
55-59	M	3921	9435	13209	141	40
	F	325	1630	3920	402	140
60-64	M	1604	4510	7527	181	67
	F	167	694	1701	316	145
65-69	M	541	1712	2650	216	55
	F	61	238	542	290	128
70-74	M	243	623	1012	156	62
	F	17	98	157	476	60
75-79	M	54	186	274	244	47
	F	4	29	60	625	107
Total	M	142753	213123	236405	49	11
	F	27770	67986	114514	145	68

Table 1

Number of finishers of each sex (M: male, F: female) per age group at the New York City marathon over the three decades: D1: 1980-1989, D2: 1990-1999 and D3: 2000-2009 ; and relative changes between the decades D2 and D1 and between the decades D3 and D2

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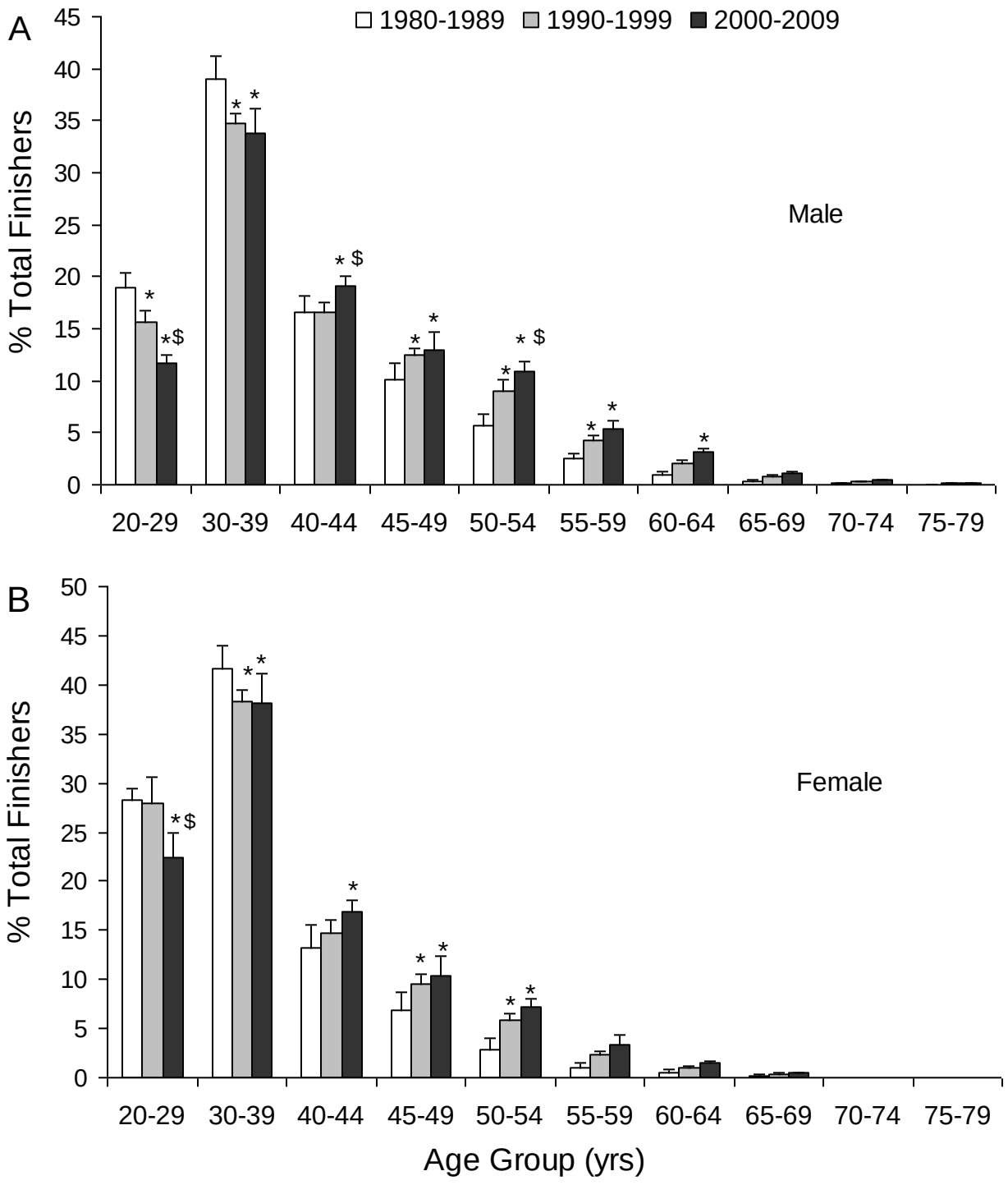


Figure 1

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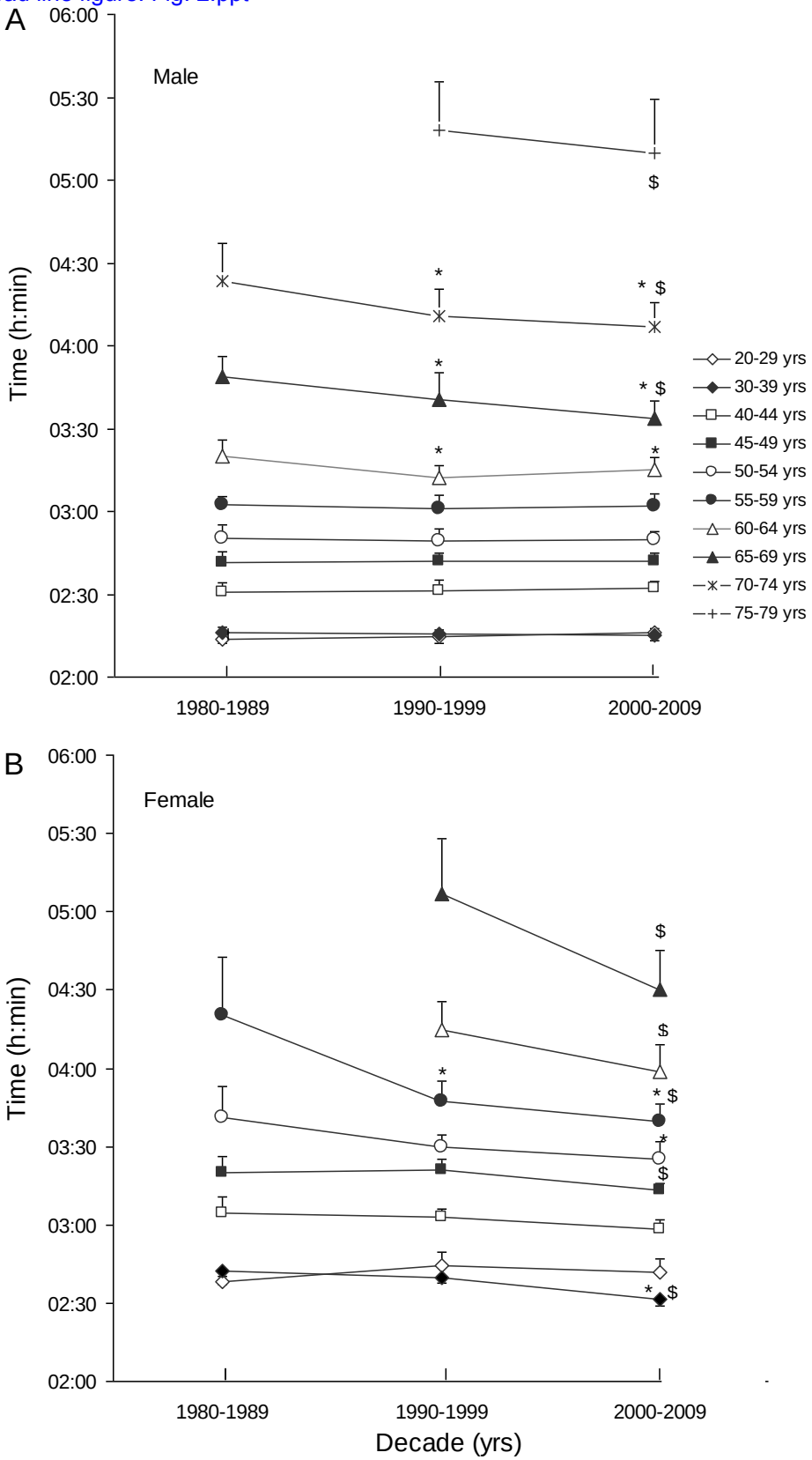


Figure 2

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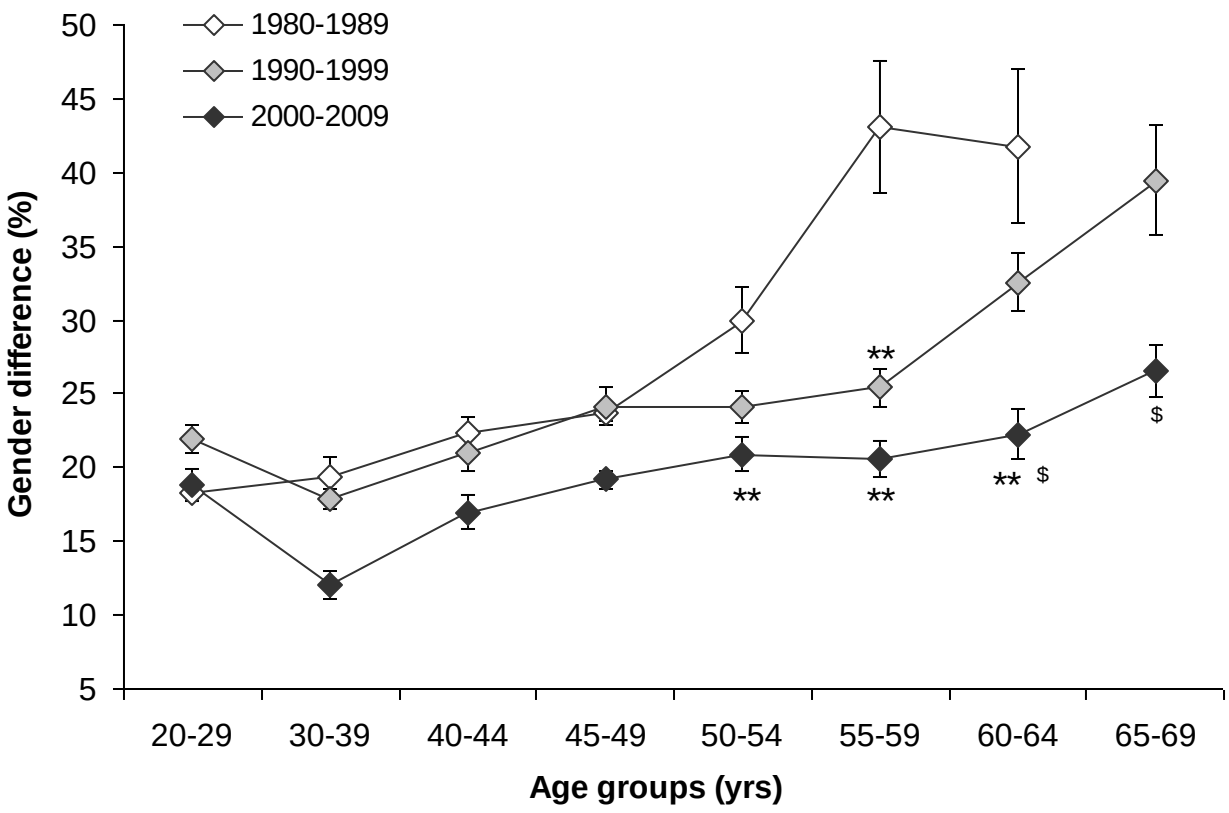


Figure 3

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