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Age-related Changes in Marathon and Half-Marathon Performances

Abstract

We examined age-related changes in endurance performance of marathon and half-marathon finishers. A total of 405 515 running times were separated into groups based on age, sex, and distance. After exclusion of repetitive running times, 300 757 runners were analyzed by ANOVA (factors: age, sex). For each age group (six decades, 20 – 79 years), mean running times for all finishers, as well as top-ten performers, were assessed. As expected, age and sex had significant influence on running times. Female running times were about 10% (marathon) and 13% (half-marathon) above the corresponding times of their age-matched peers. The main finding is that in our sample of trained subjects significant age-related losses in endurance performance did not occur before the age of 50 years. Mean marathon and half-marathon times were virtually identical for the age groups from 20 – 49 years. Moreover, age-related performance decreases ($p < 0.01$) of the 50 – 69-year-old subjects were only in the range of 2.6 – 4.4% per decade. These results suggest that the majority of older athletes are able to maintain a high degree of physical plasticity. The hypothesis that lifestyle factors have considerably stronger influences on functional capacity than the factor age is also supported by these findings from physically active and fit elderly.

Key words
Aging · gender · endurance · aerobic capacity · long-distance running

Introduction

The aging process in humans is characterized by significant decreases in physiological functions. The reduction in endurance performance has most commonly been characterized by changes in maximum oxygen uptake ($\dot{V}O_{2max}$). Numerous cross-sectional and a few longitudinal studies have shown that after 25 years of age $\dot{V}O_{2max}$ will significantly decline [10,13,15,19 – 21,29]. The age-related decline in $\dot{V}O_{2max}$ probably varies in rate, timing and extent between subjects and is largely related to differences in occupational or leisure physical activity, lifestyle, genetic profile, disease and other factors [2,17,27,30]. This might explain the inconsistent reports about the rate of the age-related reduction in $\dot{V}O_{2max}$ ranging from < 5% up to more than 15% per decade [6,8, 11,14,16,19].

Even though $\dot{V}O_{2max}$ is probably the most frequently used criterion to evaluate aerobic work capacity, it has to be taken into account that $\dot{V}O_{2max}$ is only one of the determinants explaining successful endurance performances [7,9,18,28]. It is not uncommon to see that e.g., master athletes with lower $\dot{V}O_{2max}$ are performing endurance competitions as good as or even better than younger

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Table **1** Absolute and relative number of finishers of 69 marathons and 65 half-marathons performed in Germany between 2003 and 2005

	Marathon				*Half-marathon*			
Age group	***Men (n)***	***%***	***Women (n)***	***%***	***Men (n)***	***%***	***Women (n)***	***%***
25	12151	9.35	3449	12.88	15550	14.95	7780	19.45
35	46040	35.43	10372	38.72	36489	35.07	15304	38.26
45	49551	38.14	9868	36.84	35664	34.28	13087	32.72
55	17731	13.65	2689	10.04	12778	12.28	3319	8.30
65	4146	3.19	394	1.47	3247	3.12	467	1.17
75	310	0.24	16	0.06	314	0.30	41	0.10
Total	129929	100	26788	100	104042	100	39998	100

individuals with higher $\dot{V}O_{2max}$ values [1,3,23,24]. Thus, studies investigating the age-related $\dot{V}O_{2max}$ decline may not inevitably mirror changes in endurance performances in long-distance running competitions.

However, in addition to $\dot{V}O_{2max}$-tests, marathon and half-marathon events could provide an excellent opportunity to study age-associated changes in endurance performance. Result lists of long-distance competitions (with running time, age, and sex of participants) can be utilised as large and epidemiologically relevant sample. Surprisingly, though these performance data include gender and age and are often publicly available, they are hardly used for scientific research so far. To the best of our knowledge, there is only the study of Jokl et al. [12], examining running times of the top 50 male and top 50 female finishers by age categories in the New York City Marathon from 1983 to 1999.

In the present cross-sectional study we did not only focus on the running performances of the top athletes. We analysed running times of some 400000 marathon and half-marathon finishers. Our purpose was to evaluate the age-related changes in endurance performance of men and women aged 20 to 79 years in a sample of epidemiological relevant size.

Methods

We examined 69 marathons and 65 half-marathons performed in Germany between 2003 and 2005. After receiving the informed consent of the event organisers we downloaded result lists via the Internet. Data collection and data processing were carried out in adherence to the directives of the Commissioner for Data Protection of the Federal State of North Rhine-Westphalia (Germany), who was informed about purpose and approach of the present study. Running time, age and sex of all finishers were stored in a database. Names of participants were aliased and not stored in the files.

Running times of all finishers were split into groups based on running distance, sex and age. The individual age of the participants was assigned to age groups (code 25 = 20 – 29 years, code 35 = 30 – 39 years, code 45 = 40 – 49 years, code 55 = 50 – 59 years, code 65 = 60 – 69 years, and code 75 = 70 – 79 years). For each data set, the running times for all finishers, as well as the top ten performers, were analysed. Subjects with more than one marathon or half-marathon competition (potential "repeaters") have been identified by means of the variables alias code, age, and sex. To eliminate a potential bias due to persons participating in several races, all "repetitive" running times were excluded from the analysis.

Statistical analyses were performed using SPSS 12.1 and STATISTICA 7.1. Data are given as means and standard error (SE; Figures) or standard deviation (SD, Tables and text). Additionally, medians, interquartiles and 5th and 95th percentiles are given in Figs. **2** and **3**. Running times were investigated by two-way ANOVA (factors: age and sex). The Newman-Keuls-test was used for post hoc comparisons. Significance level was chosen as $p < 0.01$.

Results

Participation

A total of 405515 running times (210898 marathon and 194617 half-marathon times) were collected. After the exclusion of the repetitive running times, it turned out that 156717 (marathon) and 144040 (half-marathon) subjects finished the endurance events. The ratios of male and female finishers are 4.85 : 1 (marathon) and 2.60 : 1 (half-marathon). Table **1** lists the absolute number and relative portion of the male and female finishers in the different age groups. Irrespective of gender, the age group 35 and age group 45 have the greatest number of finishers (both 36%) surpassing the age segment 25 (12.9%) and age segment 55 (12.1%) by more than factor two. The analysis of the 405515 running times revealed that about 38% (marathon) and 32% (half-marathon) of the subjects were "repeaters" (Table **2**).

Running performance of the top-ten athletes

The mean marathon and half-marathon running times of the top-ten athletes are given in Fig. **1**. Compared to their male peers the running times of the female elite athletes are on average 20% (marathon) and 22.5% (half-marathon) higher. Both sexes show significant age-related increases in running times beyond the age group of 35 years ($p < 0.01$): marathon running times of top-ten finishers increase almost linearly by 10.5% per decade (men) and 14.8% per decade (women) from the age group 45 to the age group 65. The corresponding half-marathon data are 8%

Table **2** Percentage distribution of marathon and half-marathon repeaters of male (m) and female (f) finishers. Subjects with more than 4 competitions (marathon 2.6%; half-marathon 1.7%) are not listed

Age group	*Participants with 1 competition*			*Repeaters with 2 competitions*			*Repeaters with 3 competitions*			*Repeaters with 4 competitions*		
	All	*M*	*F*	*All*	*M*	*F*	*All*	*M*	*F*	*All*	*M*	*F*
Marathon												
25	79.7	78.6	84.1	15.6	16.1	13.5	3.2	3.5	2.0	0.9	1.1	0.3
35	65.2	63.4	73.8	23.1	23.7	19.9	7.1	7.6	4.7	2.4	2.7	1.1
45	58.3	56.4	68.5	26.2	26.8	22.9	9.0	9.6	5.9	3.3	3.6	1.7
55	59.2	58.1	67.4	26.2	26.7	22.3	8.7	9.0	6.8	3.1	3.2	1.9
65	53.9	53.0	63.7	28.3	28.8	23.2	9.6	9.9	6.3	4.0	4.1	2.7
75	52.9	52.5	61.5	28.7	28.3	38.5	9.4	9.7		4.8	5.0	
Total	62.4	60.6	72.0	24.3	25.5	20.7	7.9	8.4	5.1	2.8	3.1	1.4
Half-marathon												
25	79.1	78.1	81.2	15.9	16.3	15.1	3.5	3.8	2.9	0.9	1.1	0.5
35	68.6	67.0	72.7	21.4	22.0	19.8	6.1	6.4	5.3	1.9	2.1	1.4
45	64.3	62.8	68.7	23.8	24.2	22.5	7.5	7.8	6.4	2.4	2.6	1.8
55	66.4	65.9	68.3	23.4	23.7	22.1	7.0	7.0	6.6	1.9	1.9	1.8
65	63.9	63.9	64.3	25.1	25.2	24.3	7.8	7.6	9.1	2.0	2.1	1.7
75	67.1	66.5	71.7	22.1	22.7	17.4	8.0	8.0	8.7	2.0	2.0	2.2
Total	68.4	66.9	72.5	21.7	22.3	20.1	6.3	6.7	5.4	1.9	2.1	1.4

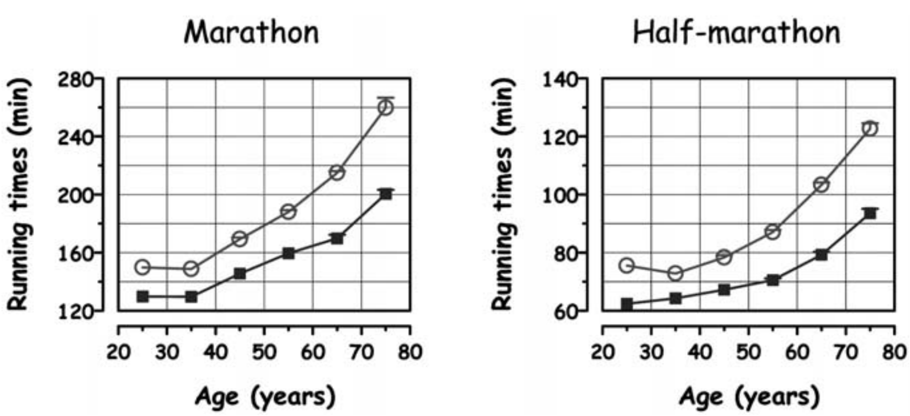

Fig. **1** Mean running times of the top-ten male (closed squares) and top-ten female (open circles) athletes in 69 marathon (left panel) and 65 half-marathon (right panel) competitions (men: n = 120; women: n = 120). Values are means ± SE.

(men) and 14% (women). In addition, Fig. **1** shows acceleration in the reduction in marathon performance in the seventh decade of life.

Running times analyses for all finishers

As expected, ANOVA revealed significant influence of the main factor "gender" on running times ($p < 0.001$). Female finishers required only about 10% (marathon) and 13% (half-marathon) more time than their male counterparts. The gender-related differences are only half of the corresponding differences between the male and female top-ten runners.

With regard to the results of the top-ten athletes, running times analyses for all finishers reveal marked differences in the age-related changes in endurance performance. Running times of the marathon and half-marathon finishers remain almost stationary from 20 to 50 years (Fig. **2**, Fig. **3**). The mean marathon performances of the age groups 35 and 45 were even better than the corresponding performances of the age groups 25 (Fig. **2**). The analyses of the half-marathon competitions revealed similar findings (Fig. **3**). With the exception of the small difference in mean running times (Δ 1%) between the male age group 25 and the male age group 45 ($p < 0.01$), all other comparisons between age groups 25, 35 and 45 provide no significant differences. It can also be taken from Fig. **2** and Fig. **3** that interquartiles as well as the 5th and 95th percentiles of the running times are almost identical for age groups 25, 35, and 45.

Mean running times of all finishers significantly increase per decade after the age of 50 years ($p < 0.001$). Moreover, in contrast to the age groups of top-ten finishers, the age-related decreases in endurance performance are considerably smaller: Marathon performances of men and women aged 50–79 years drop annually only by about 0.45% (men) and by 0.24% (women). The analogous half-marathon values are 0.47% (men) and 0.36% (women).

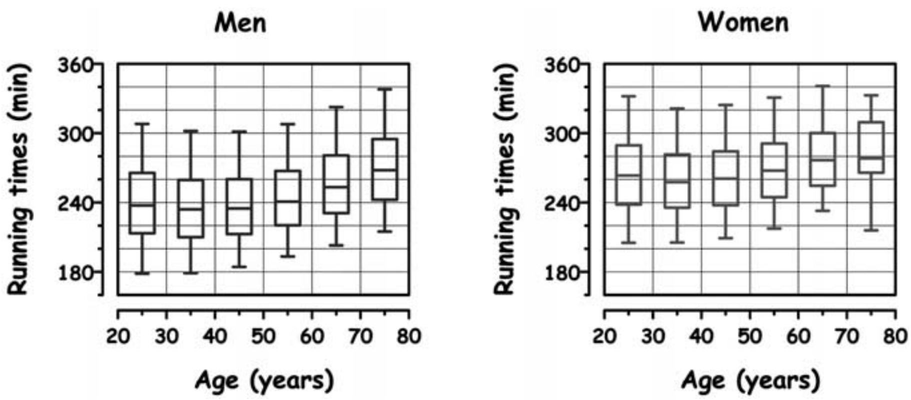

Fig. **2** Running times of male (left panel) and female (right panel) finishers in 69 marathon competitions (men: n = 129 929; women: n = 26 788). Values are medians; 25th and 75th percentile; 5th and 95th percentile.

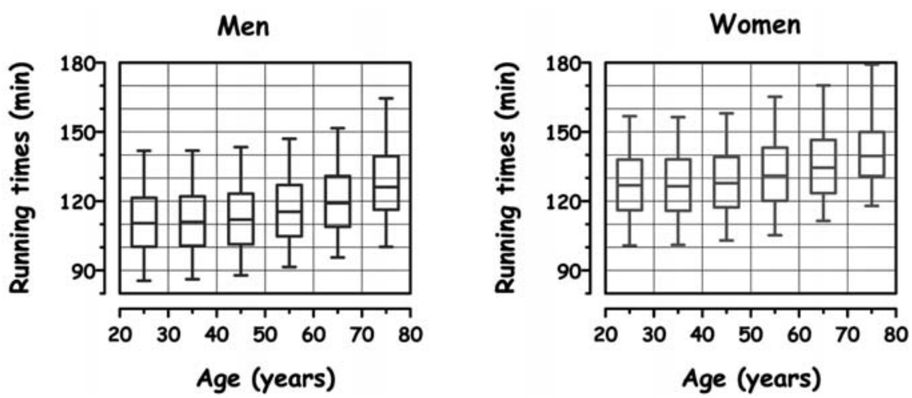

Fig. **3** Running times of male (left panel) and female (right panel) finishers in 65 half-marathon competitions (men: n = 104 042; women: n = 39 998). Values are medians; 25th and 75th percentile; 5th and 95th percentile.

Discussion

This study presents performance data of a large sample of endurance-trained subjects aged 20 to 79 years. We recognize that the marathon and half-marathon running times in the groups of "all finishers" do not reflect the maximal performance level attainable. Notwithstanding, these figures are not only powerful measures for endurance performance but, considering the sample volume, they may also be relevant for some inferences to public health and permit the generalizability of these data.

Our main finding is that there are virtually no relevant differences in marathon and half-marathon running times of subjects aging from 20 to 50 years. Moreover, the age-related performance declines of 50 – 69-year-old participants are just in the range of 2.6 – 4.4% per decade. We can not rule out that there are no age-associated differences between marathon and half-marathon performance since we found small, but significant half-marathon running time differences comparing the results of the male age group 25 and the male age group 45 (Fig. **3**). However, our results are consistent with some other studies showing only small declines in $\dot{V}O_{2max}$ of endurance trained subjects before 50 years of age but enhanced rates of decline thereafter [14,19,20]. Both the moderate decline in running performance and the large number of successful master athletes suggest that older athletes are able to maintain a high degree of physiological plasticity late into life [32]. The present results also indicate that this is equally valid for endurance trained men and women and confirm the observed gender difference in distance running performance [12,25].

It is quite evident from various studies that maintenance of training is of paramount importance for preserving endurance performance over longer periods of time [2,7,15,26,31]. With regard to top-class athletes, however, it has been suggested that maintaining extremely high levels of training appears to be difficult for more than 10 years in athletes, irrespective of age [4,5,13,21,22]. Moreover, studies of older endurance athletes have indicated that the training volumes of master athletes often are up to 50% lower compared to their younger peers [5,13,21, 31]. These circumstances could explain the pronounced influence of age on running performances of our top-ten athletes showing significant and marked performance losses already after the age of 39 years (Fig. **1**). A reduction in training intensity also may contribute to the larger declines in endurance performance of the elderly top-ten finishers [27].

A clear limitation of the present study is that only running times, age, and sex of the marathon and half-marathon finishers were available. It was not possible to collect other performance related factors like years of training, training volumes, body weight, lean body mass, etc. Thus, these factors had to be more or less ignored in this study.

Conclusions

Though limited by its cross-sectional design and the lack of further determinants of endurance performance, we believe that this study presents valuable data. We found no significant differences in the marathon running times of subjects aged 20 – 50 years and only moderate deteriorations thereafter. The results of our epidemiological relevant sample provide further evidence that, with the exception of elite athletes, there are no inevitable losses in endurance performance after 25 years of age. The present findings from physically active and fit elderly also support the hypothesis that lifestyle factors have considerably stronger influences on functional capacity than the factor age.

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