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# Age and Performance from 10 Seconds to a 6-Days Race

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**Abstract**

**Purpose:** An increasing amount of people are turning to new challenges such as the completion of an ultra-marathon and choose to continue to train intensively despite advanced age. As a result, numerous epidemiological data are available and constitute an experimental model for the research community that studies the effects of aging on physiological functions.

The objective of the study is to measure the relationships between age and performance over the entire athletic spectrum from 100 m up to the 6-day ultra-marathon event for men and women.

**Method:** The Top 50 male and female ages and race speed races of all time were compiled with 12 events ranging from 100 m to 6-day races (N=1200). A second database made up of record race-speeds by age (N=1682) was created for all 12 events and for both genders.

**Results:** For both genders, a very significant increase (p<0.01) in age for the Top 50 based on race distance is noticeable from the 100 m sprint to the 6-day race, with an even higher climb starting at the marathon. On the other hand, the age range also increases with the running distance for both genders. The area under the curve (AUC) decreases significantly (p<0.01) with the race distance for both genders.

**Conclusion:** This study measured the impact of aging on the world's best performances ranging from sprints to ultra-endurance events in a context where peak-age performance increases with the distance of the event for both genders.

**Keywords**

Ultra marathon; Track and field; Performance peak; Age

## Introduction

The impact which age has on physical and athletic performances is a widely-recognized axis in scientific literature. Many studies have attempted to identify several events' peak performance age including athletics [1-3] running [3-5] swimming [3], Ultra-triathlon [6,7] or even sports with non-measurable performance indicators such as tennis, baseball or golf [3,8].

Relationships between age and performance were modeled for the first time in 1975 by Moore based on a simple inverted U-shaped function [9]. This relationship characterizes the capacities of many physical and physiological parameters as a function of time such as maximum oxygen consumption, force [10] respiratory volume [11] pulmonary capillary volume [12] and cognitive performance [13]. It is clearly demonstrated that maximal oxygen uptake and heart rate reserve are the most common physiological measurements in endurance [14,15] and that they quickly deteriorate during aging [16-21]. As a result, age-related performance impairment appears to be expected in long-distance events. However, several studies have shown that the best ultra-marathon performances were had by runners between 30 and 45 years old [22-26].

Depending on the event's specificity, environmental conditions, physiological, psychological and technical components it generates, as well as the starting age of training, the optimal performance age may be modified.

For Ultra Marathon events, it has already been shown that the peak performance age of the top ten runners of all time increased with the duration of the race from 35 ± 6 years for the 6 h event to 48 ± 6 years for the 10-day event [27].

However, the evolutionary peak age pattern will evolve with the popularity of the discipline which, has only increased since the beginning of the seventies with a very strong exponential popularization since 1995, on all of the male and female events [27]. An increasing number of people are turning to new challenges and are choosing to continue to train intensively despite their advanced age. As a result, numerous epidemiological data are available and provide an experimental model for the research community that studies the effects of aging on physiological functions. To our knowledge, no scientific study has analyzed the impact of age on such a wide range of race distances and on both sexes.

The goal of this study is to measure the relationships between age and performance across the full running spectrum from the 100 m sprint up to the 6-day ultra-marathon event for men and women.

## Materials and Methods

### Data collection

This study needed two databases to be completed. The first is the age and performance of the top 50 male and female runners of all time for the following 12 events: 100 m, 400 m, 800 m, 3000 m, 10,000 m, marathon, 50 km, 100 km, 12 h, 24 h, 48 h and 6-day, which adds up to 1200 performers.

The second database incorporates both sexes in all 12 events, the all-time race record speed by age, which equals 1682 performers per age. These data have been compiled on several websites [http://statistik.duv.org] [http://www.arrs.net] [http://www.iaaf.org] [http://tilastopaja.org] then, only the record performance per age was retained for the rest of the analysis. This method was performed for both sexes and for each of the 12 events.

### Statistical analysis

For both genders and every event, all performances were converted into $km.h^{-1}$ for speed to be able to compare them with one another.

### Top 50: Age and performance relationship

For this initial part of the analysis, a non-parametric Anova test by Kruskall-Wallis was used to observe an existing significant correlation

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between age and speed for the top 50 best male and female runners from the 100 m sprint to the 6-day race.

### Maximal performance, age and area under the curve (AUC)

Initially, the external studentized residue formula was used to verify the existence of outliers in the initial data sets. After passing this test, the data were fitted with the following mathematical model which describes the performance according to age:

$$P(t) = N_0 \beta_0 \, e^{\frac{\alpha_0}{\alpha_r}\left(1-e^{-\alpha_r t}\right)} \left(1-e^{\beta_r (t-t_d)}\right)$$

Then the fit's error margin is calculated using a 95% confidence interval. This allows determining the margin of error when calculating the surface under the curve between the first and the last point.

Statistical analyzes were performed with R v2.14.0 and Mathematica v10.2 software. Statistical significance was considered at P<0.05.

## Results

### Top 50: Age and performance

For both genders, there is a very significant correlation (p<0.01) between age and race distance when considering the 50 fastest runner in the 100 m to the 6-day race. For men, the average age for the 50 fastest runners is 25.6 years ± 3.3 years for the 100 m, 24.6 years ± 2.9 years for the 400 m, 24.3 years ± 3.2 years for the 800 m, 24.8 years ± 3.9 years for the 3000 m, 23.8 ± 3.7 years for the 10 000 m, 27.1 years ± 4.1 years for the marathon, 31.6 years ± 4.9 years for the 50 km, 33.9 years ± 5.5 years for the 100 km, 36.3 years ± 6.2 years for the 12 h, 39.5 years ± 6.3 years for the 24 h, 43.8 years ± 5.7 years for the 48 h and 44.8 years ± 7.7 years for the 6 day (Figures 1a and 1b).

For women, the average age of the top 50 runners is 25.6 years ± 3.5 years for the 100 m, 25.8 years ± 3.2 years for the 400 m, 25.5 years ± 3.9 years for the 800 m, 25.5 years ± 3.9 years for the 3000 m, 26.1 years ± 4.5 years for the 10,000 m, 28.5 years ± 3.8 years for the marathon, 33.6 years ± 5.1 years for the 50 km, 34.1 years ± 5.1 years for the 100 km, 39.9 years ± 6.1 years for the 12 h , 39.7 years ± 6.5 years for the 24 h, 45.1 years ± 6.6 years for the 48 h and 41.9 years ± 8.5 years for the 6 day.

From the 100 m sprint to the marathon, no significant variation in age is visible between the top 50 male and female world runners. On the other hand, for both genders, the average age of the top 50 runners for the Ultra marathon events is significantly higher than the overall number of runners participating in the other athletic events (Figures 2a and 2b).

The age range also increases with the running distance for both genders. For the men's 100 m sprint, the age of the 50 best sprinters of all time ranges from 21 to 33 years old, while it fluctuates from 19 to 37 years old for the marathon and from 29 to 60 years old for the 6-day race. For women, the age of the top 50 varies from 19 to 36 years old for the 100 m sprint, from 29 to 38 years old for the marathon and from 23 to 57 years old for the 6-day race.

### Maximum performance by age

For both genders, the overall age-related performance increases progressively with race distance with a peak of performance at 24.7 years old for the 100 m, 26.3 years old for the marathon, 35.9 years old for the 12 h, 42.2 years old for the 48 h and 38.1 years old for the 6-day for men (Figure 3). For women, this trend is confirmed with an age at peak maximum performance of 25 years old for the 100 m, 27.2 years old for the marathon, 33.6 years old for the 12 h, 45.2 years old for the 48 h and 43 years old for the 6-day (Figures 3a and 3b).

Moreover, the area under the curve (AUC) also decreases significantly with the distance traveled (p<0.01) for both genders. For men, the area under the curve is 7397 ± 76 IU for the 100 m, 6801 ± 105 for the marathon, 5479 ± 116 for the 12 h, 4974 ± 160 for the 48 h and 4864 ± 229 for the 6-day (a 34% decrease between the 100 m and the 6-day race). For women, the area under the curve is 6872 ± 82 for the 100 m, 6461 ± 79 for the marathon, 5496 ± 90 for the 12 h, 4779 ± 157 for the 48 h and 4606 ± 177 for the 6-day (a 33% decrease between the 100 m and the 6-day race).

| | 100 | 400 | 800 | 3000 | 10000 | Marathon | 50km | 100km | 12h | 24h | 48h | 6d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | | | | | | | | | | | | |
| 400 | NS | | | | | | | | | | | |
| 800 | NS | NS | | | | | | | | | | |
| 3000 | NS | NS | NS | | | | | | | | | |
| 10000 | NS | NS | NS | | | | | | | | | |
| Marathon | NS | NS | NS | NS | NS | | | | | | | |
| 50km | ** | *** | *** | *** | *** | *** | | | | | | |
| 100km | *** | *** | *** | *** | *** | *** | NS | | | | | |
| 12h | *** | *** | *** | *** | *** | *** | NS | NS | | | | |
| 24h | *** | *** | *** | *** | *** | *** | * | NS | NS | | | |
| 48h | *** | *** | *** | *** | *** | *** | *** | ** | NS | NS | | |
| 6d | *** | *** | *** | *** | *** | *** | *** | ** | NS | NS | NS | |

(A)

| | 100 | 400 | 800 | 3000 | 10000 | Marathon | 50km | 100km | 12h | 24h | 48h | 6d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | | | | | | | | | | | | |
| 400 | NS | | | | | | | | | | | |
| 800 | NS | NS | | | | | | | | | | |
| 3000 | NS | NS | NS | | | | | | | | | |
| 10000 | NS | NS | NS | NS | | | | | | | | |
| Marathon | NS | NS | NS | NS | NS | | | | | | | |
| 50km | *** | *** | *** | *** | *** | NS | | | | | | |
| 100km | *** | *** | *** | *** | *** | * | NS | | | | | |
| 12h | *** | *** | *** | *** | *** | *** | NS | NS | | | | |
| 24h | *** | *** | *** | *** | *** | *** | NS | NS | NS | | | |
| 48h | *** | *** | *** | *** | *** | *** | *** | *** | NS | NS | | |
| 6d | *** | *** | *** | *** | *** | *** | * | NS | NS | NS | NS | |

(B)

**Figure 1:** Ages and race speeds of the top 50 male (A) and female (B) athletes of all time in the 100 m to the 6-day race.

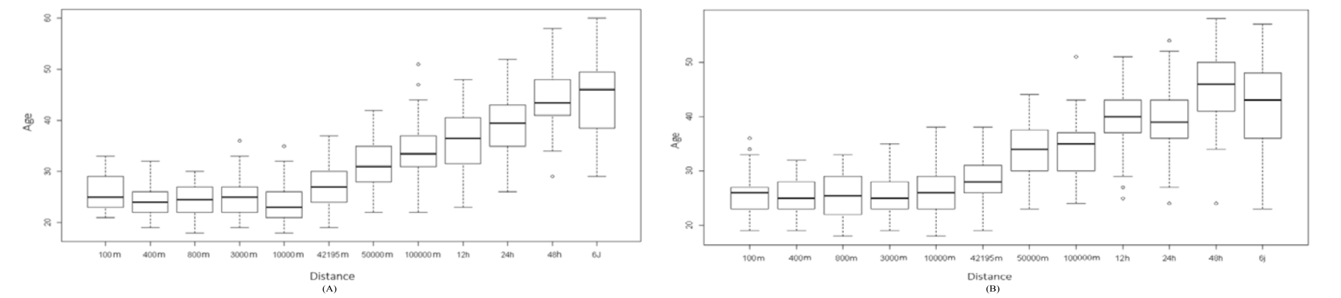
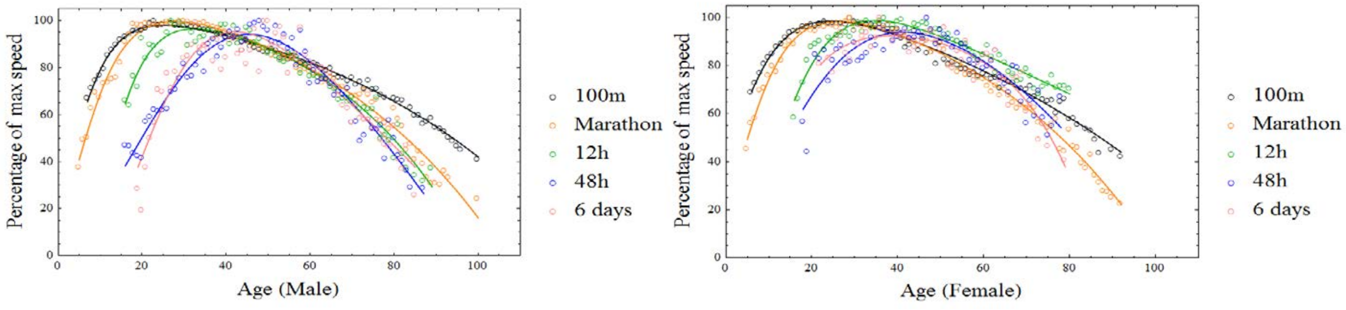



**Figure 2:** Multiple age-comparison tests between the different events from a 100 m to a 6-day race for men (A) and women (B).




(A) (B)

**Figure 3:** Maximal performances by age expressed in percentage of best times for men (A) and women (B) in the 100 m, marathon, 12 h, 48 h, and 6-day races.

## Discussion

This study is to our knowledge, the first to show an increase in the age of the 50 best male and female runners of all time as well as a decrease of the areas under the curve (capacity of performance) for the race distances of 100 m up to the six-day event.

As a reminder, the average age for the 50 fastest runners is 25.6 years ± 3.3 years for men and 25.6 years ± 3.5 years for women for the 100 m, while this average goes from 27.1 years ± 4.1 years for men and 28.5 years ± 3.8 years for women to reach 44.8 years ± 7.7 years for men and 41.9 years ± 8.5 years for women for the 6 day race.

Several studies have attempted to identify the reasons for this variation in peak-age performance with race distance.

It is clearly demonstrated in the scientific literature that there is a growing popularity of all ultra-endurance events with an increasing participation of master's athletes [5,22,25]. Previous studies have looked at the various causes that would drive older racers to engage in sports [28-30]. According to the authors, the main reasons are pleasure, competition, fitness, health benefits, social interactions and self-transcendence.

These same authors argue that the increasing popularity of long distance trials, coupled with increased life quality and expectancy, increases the likelihood of finding top-level master's athletes, which consequently increases peak-age performance for the event duration.

Similarly, Zaryski states that the qualities and skills required for ultra-endurance, such as race management, movement economy and nutrition, are factors that are gradually learned with training experience, thus age [31].

It is clear that the aging process also involves physiological and psychological changes to the athlete whether they are structural or functional. In the scientific literature, it is widely recognized that the number of muscle cells decreases strongly with age as well as the number of motor units [2,32,33]. However, fast type II fibers appear to be much more altered than slow type I fibers which are favorably used for endurance racing. Lexell even demonstrated that with aging, a change in muscle typology was evident with a relative and progressive increase in the number of type I fibers. One reason for the increase in peak performance with race distance could therefore reside in this explanation.

In addition, the perception of pain may also partially explain this phenomenon. According to Gibson, a meta-analysis of some forty scientific articles showed a decrease in the perception of pain with age [34]. Although the reasons for these changes with age may vary according to the protocols, aging affects the internal treatment and more specifically the afferent fibers of the peripheral nerves. Indeed, an increase in amyelinic fibers C with age would delay the onset of pain [35].

Concomitantly, with the increase in peak performance and the duration of the event for the top 50 male and female runners in the world, the study also shows an increase in the interquartile range for both genders. This statistical indicator showing the dispersion around the mean highlights the age selection which is much more restrictive for short distances and open for long distances. For the 6-day race, runners aged 29 to 60 years old for men and 23 to 57 years old for women, achieved performances allowing them to enter the world's Top 50, which is far from being the case for sprint races.

The reasons for the variation of this interquartile interval with race distance reside in the difficulty and the popularity of the events. It seems much less traumatic for the athlete to overcome a 100 m sprint than to run for 6 days.

A meta-analysis on athletic injury epidemiology has been carried out, but the methodological differences (definitions, design, population, collection methods, calculation of incidences and/or percentages) sometimes make it difficult to compare results [36].

However, although the results might sometimes be contradictory between studies, they did not help determine which disciplines are more at risk than others in terms of frequency and incidence. It appears that the injury incidence rate was higher along with the duration of the events, ranging from 8.4% for the sprints to 67.2% for the longer distance events [36].

The influence of the level of performance on the incidence of injuries is also discussed. A high level of practice can be a risk factor for injuries due to the volume and intensity of training and competition. But at the same time, a low level of practice can also be considered a risk factor for injury as these athletes may have poor technical skills and less knowledge of their bodies. This idea is reflected in a meta-analysis of epidemiology for ultra-marathon injuries that shows 17.8 injuries in trained runners and 7.7 injuries in recreational runners per 1000 h of practice. This has a strong impact on the number of participants, which is only decreasing with race distance [27] starting in 2014 with 4000 annual runners for the 6-h race to about thirty athletes for the 10-h race.

### Area under the curve (AUC) and performance

Although our study demonstrates an increase in the age of performance with race distance, the impact of aging on performance remains highly visible on each event for both genders.

Several studies [22,23,37] and Ironman triathlons [38] have already demonstrated the impact of age on performance among ultra-endurance events such as the ultra-marathon or the triathlon. Overall, racing times seem to be maintained until about 35-40 years old, followed by a progressive decrease in performance up to 50 years old to then achieve strong alterations starting at 70 years old. The effect of aging results in a physiological rule, which is strongly visible in our study for both genders as well as for the entire race spectrum (100 m up to the 6-day trial). These decreases in performance with age are due to both internal physiological factors such as decreased maximum heart rate and systolic ejection volume, as well as superficial factors related to the alteration of mass and muscle composition, capillarization and enzymatic activity [39].

Although the impact of age on performance has been widely supported in the scientific literature on most of the events measured, to the best of our knowledge, no study has grouped the latter in order to compare the impact of aging. The study showed that a decrease in the area under the curve (AUC) was visible with the increase in distance for both genders between the 100 m and the 6-day race, (34% less for men and 33% less for women). In general, the area under the curve makes it possible to measure the surface area under the tracing of a mathematical function. In pharmacokinetics, AUC is used to represent the plasma concentration of a drug over time. This indicator is also used in medicine to refine physiological or morphological predictions. In their study, Cook et al. used the area under the curve to better predict blood pressure and body mass index in young adults from early childhood measurements [40]. However, to our knowledge, the AUC is not used to study the evolution of physical abilities during aging based on performance data related to athletic competition. In our study, this decrease in AUC with age as a function of the duration of the events seems to indicate the increasing difficulty and the physical and psychological skills required for these events. Therefore, this area under the curve has several virtues. It represents the pool of athletes according to their age in a physiological and psychological capacity, and regroups all the parameters necessary for the realization of this type of event. Use of the AUC on sports data may reveal other uses. These areas under the curves could prove useful in predicting the number of athletes able to get closer or improve records. Depending on the sporting event, it could be used to assess either the difficulty of an event, to estimate the popularity of an event or the capacity to remain at the highest level of performance according to age [41].

### Limitation of the study

As stated in the introduction to the study, the change in age at peak performance depending on the event's specificity; namely the environmental conditions, physiological, psychological and technical components it generates, as well as the starting age of training. However, none of these factors were considered in this analysis and could lead to future research questions.

## Conclusion

The investment of the various studies and research within high-performance sports level combined with the accessibility of international competitions increasingly ties the conditions for performance optimization. Proceeding in this direction, the impact of age on overall physiological, psychological, and social capacities is a very recognized limiting factor in scientific literature, which shows that most of the parameters follow a phase of progression, a peak, and then a regression. However, even though this living rule is visible on all running distances from the 100 m sprint to the 6-day race, the peak-age performance observed in the World's Top 50 male and female runners declines as the race distance increases. However, although there are addressed factors such as experience, race management, knowledge of one's own athlete or other physiological fluctuations, the study also shows that it is the whole of human capacities represented by the potential under the curve that shifts with time. The mathematical modeling of this human envelope must continue to be invested in to better understand all the characteristics that englobe a sporting event.

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