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Performance Analysis on Trained and Recreational Runners in the Venice Marathon Events from 2007 to 2019

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Featured Application: The Venice Marathon is a small recreational marathon that has gained fame and prestige over time. In terms of gender participation, the 13 editions from 2007 to 2019 have seen an increase in female participation over time in the 40-year age category. Recreational athletes showed a general decrease in running speed (performance); meanwhile, the analysis limited to trained athletes showed a performance improvement of runners in the 40-year age category in both sexes. This information could be useful for trainers and self-training to adjust physical activity to compensate for physiological decline. In fact, based on piecewise analysis, we found that the largest decline in running speed in males was found in 50- and 55-year age categories in recreational and trained athletes, respectively, showing that training ensures the maintenance of fitness. In females, the greatest decrease was found in the 55- and 45-year age categories in recreational and trained athletes, respectively, demonstrating that the physiological decline in trained athletes is related to the events of hormonal change, irrespective of training.

Abstract: The Venice Marathon (VM) has gained fame and prestige over time. It is part of a group of marathons that are recognized worldwide. The aims of this study were to describe the attractiveness of the event over the years according to the gender and age of participants, and to investigate their performances according to gender and age differences in the group of all finishers over 23 years old (AD), along with the best 10% performance (TOP) over a 13-year period. Methods: We conducted a retrospective analysis of VM race data from 2007 to 2019; the data were collected from the free Timing Data Service website and statistically analyzed. Results: In total, 82.3% of participants were male and 17.7% were female. A significant total increase in female participation was observed over the 13 editions of the VM. Linear regression analysis of AD speeds for each category showed a significant decrease in the youngest categories. Among the TOP athletes, the 40-year age category showed increased performance of both males and females. Analyzing the mean speed by age (AD13 and TOP13), there was a breakpoint in the speed decrease in AD13 in the age categories of 50 years in males and 55 years in females, while in TOP13 the breakpoints were in the 55- and 45-year age categories in males and females, respectively. Conclusion: The results obtained confirmed the reduction in running speed with age, as well as the definition of the VM as an example of a recreational marathon in which the participation of runners over 40 years will increase in the future, and for which specific adaptations will be required.

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1. Introduction

Evidence about the health benefits of physical activity and exercise to maintain optimal health and wellbeing has grown exponentially [1]. It is known that the practice of physical activity during aging can improve individuals' quality of life. In detail, endurance activity brings numerous benefits to the cardiovascular health of the individual—for example, by counteracting hypertension, hypercholesterolemia, and diabetes. In fact, it has been shown that the incidence of risk factors for these three cardiovascular diseases decreases in runners [1,2]. One of the parameters for evaluating athletic performance is running speed; it is known that it decreases with aging, and in long-distance runs—such as marathons—the decline in running speed is faster than in short-distance runs [3,4]. In detail, there appears to be a 1.2% loss of aerobic power each year between the ages of 40 and 80 [3], a decrease in skeletal muscle strength and power (a condition known as dynapenia) [5], a loss in skeletal muscle mass, an increase in muscle stiffness [6,7], and changes in the connective tissue within skeletal muscles [8]. However, the constant practice of aerobic exercise leads to an improvement in VO2max, reduces intramuscular lipid accumulation, and increases resting fascicle length, and higher-intensity workouts induce more marked adaptations than those of lower intensity [6,9]. Recreational marathons, whose total length is 42.195 km, are social motivators for the participation of adults in sports and are among the few sporting events in which elite and non-elite runners compete at the same time, although the performances can be very different between the two types of runners. Males and females participate in the event without distinction based on gender or age. The high number of runners of all ages in recreational marathons has stimulated numerous different analyses—especially on the most renowned races, such as the New York City, Boston, and Berlin marathons, which have large numbers of participants [10,11]. These events are successful for participants of all ages, and visiting a spectacular foreign country can be a good motivation to compete [12]. Several studies have described the significant improvements in marathon race times in elderly men, but studies on female performances have been published only recently [13]. Marathon data analysis studies are mainly focused on identifying the age of peak performance, performing analyses on elite runners [10,11], analyzing the limits [13] that elderly athletes can reach in marathons, analyses of world records [4], or evaluations of performance differences between the male and female categories [14]. Similarly, the Venice Marathon (VM), although it is an event with a relatively small number of participants compared to famous marathons such as the New York and Boston marathons, is an example to study the performance of runners. The obtained information can be added to the global knowledge aiming to encourage people to practice sports and, at the same time, to monitor changes in the physical state of the aging population. The VM is recognized worldwide and certified with a Bronze Label by the International Association of Athletics Federations (IAAF), and with a Gold Label by the Federazione Italiana di Atletica Leggera (Italian Federation of Athletics—FIDAL). The route of the race starts outside Venice and then enters the city and crosses floating bridges that are set up for the race [15]. It attracts athletes from all over the world, so it could serve as a good representative example of a recreational marathon to carry out a data analysis of the participation distribution and running speed among all participants. The aims of the present study were to analyze worldwide participation and running speed performance trends by category: first, considering all of the recreational runners (AD) and the best 10% of athletes (TOP) in 13 editions of the VM, from 2007 to 2019; second, by age; and third, to identify whether there was an evident point of decline in running speed by age. We found that participation increased throughout the 13 editions of the VM—particularly for female participants—and that the most interesting running speed to observe was that of 40-year-old runners, in both men and women.

2. Materials and Methods

2.1. Participants and Race

The official results from the VM were collected from the Timing Data Service website [16]. This free-access dataset included participants' name, surname, sex, team, category, race time, position in the general ranking, and position in the category ranking. All participants were grouped by age category and by race time, according to the rules of the Italian Federation of Athletics. The categories analyzed (distinguishing males and females) included subjects aged 23 years and older; the first category (30 years old) included athletes from 23 to 34 years old. The categories from 35 years onwards included progressive age ranges of 5 years each (35 years = 35–39 years old; 40 years = 40–44 years old, and so on). Participants enrolled without a category were not included in the analyses; this led to the exclusion of 3% of women and 1.9% of men from the total male and female participants in the 13 VM editions.

Since 1994, a rule of this event was to enroll a limited number of participants [15]. Over the years, this rule changed, and the limit set by the organizers of the last event was about 8000 entries, with the aim of preserving their safety and the integrity of the city [15].

2.2. Analysis of Attendance

The number of participants was analyzed by gender and category from the 2007 to 2019 editions of the VM. To this end, the numbers of males and females per year and category were considered, and the corresponding female/male ratios were calculated (ratio-y and ratio-c, respectively). Linear regression analysis was then performed, and slope coefficients were estimated in order to describe the changes in the attendance parameters as a function of VM edition or category. In all of the following considerations, an alpha level of $p < 0.05$ was used to identify statistically significant results.

2.3. Speed Analysis by Category in the 13 VM Editions

The official race times in the rankings were converted from a traditional hour:minutes: seconds format to decimal numbers, and the speed in km/h was calculated and used in the analyses.

The performance analysis in the 13 editions of the VM was carried out by measuring the mean speed of each category for each edition over all finishers (all data—AD) and for the TOP performers. Linear regression analysis was then performed to analyze the trends exhibited by these parameters as a function of category and VM edition. The TOP performers were extracted from each year of competition and each category considering the best 10% of performances.

2.4. Speed Analysis between and within Genders

To analyze the running speed trends in terms of age and gender, the mean speed exhibited by males and females within each category was calculated by grouping the results from all editions of the marathon, with AD13 representing all finishers and TOP13 representing the best 10% of performances. To determine the age at which a more evident decline appears, we performed a piecewise linear regression analysis, run by fitting two linear models, to minimize the mean standard error [17]. The generalized model is as follows:

$$y \sim \sum_{i=1}^{\#B} (x \geq b_i \wedge x \leq b_{i+1})\, x$$

where $\#B$ is the cardinality of a set of sequential breakpoint pairs.

The differences between the categories and the trends by gender were evaluated by t-test analysis.

2.5. Data Analysis and Statistics

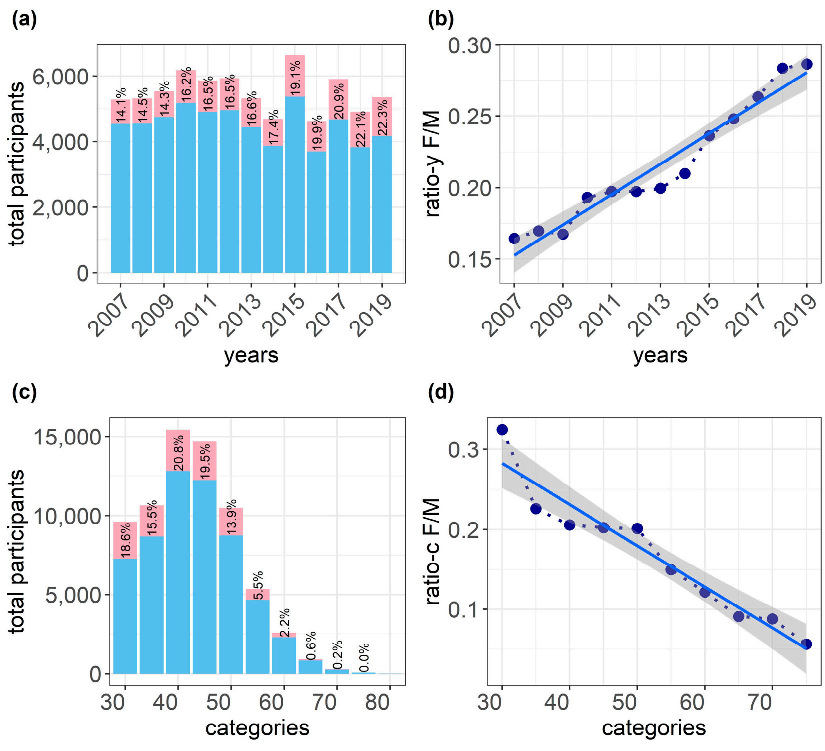
The construction of the display boards and the extrapolation of groups, means, standard deviations, and pie charts were carried out using Microsoft Excel, while statistical analyses such as ANOVA, linear regression, descriptive statistics, and *t*-tests were performed using GraphPad Prism 5.0 software (GraphPad software, La Jolla, CA, USA) and GNU R statistical software [18]. Plots were created with R [18].

3. Results

3.1. Analysis of Attendance

The total number of athletes registered in the 13 VM editions between 2007 and 2019 (the year of the last edition before the lockdown due to the COVID-19 pandemic) was 71,575 finishers, with 59,819 males (82.3%) and 12,656 females (17.7%).

Figure 1a shows the numbers of participants in the 13 editions, with a significant increase ($p < 0.001$) in the female participation, which increased from 14% in 2007 to 22.3% in 2019, and a non-significant decrease ($p = 0.132$) in the number of men. The greatest number of female participants (n = 1270) was in the 2015 edition, with an increase of 70% in comparison to the 2007 edition; this year also had the greatest number of male participants in the 13 events analyzed.



(e)

	30	35	40	45	50	55	60	65	70	75	80
slope M	-28.47	-41.64	-29.91	-2.85	10.98	4.12	4.29	2.13	0.8	0.15	0.12
p-value M	<0.0001	<0.0001	0.013	0.808	0.142	0.238	0.054	0.047	0.035	0.444	0.166
slope F	-1.17	-0.7	2.91	9.55	8.21	3.01	1.58	0.49	0.13		
p-value F	0.639	0.628	0.34	0.001	0	0.003	0.001	0.039	0.252		

Figure 1. Distribution of participants in the 2007–2019 editions of the VM: (**a**) Total number of participants in each year from 2007 to 2019; males are represented in blue and females in pink; the percentage of female participants with respect to the total participants by year is reported in the pink bars. (**b**) Linear regression of female vs. male ratios by year (ratio-y F/M). The confidence interval is shaded in gray. Real data are plotted as points connected with dotted lines. (**c**) Total numbers of

participants by category; males in blue and females in pink; the percentage of female participants with respect to the total number of participants per year is reported in the pink bars. (**d**) Linear regression of female vs. male ratios by age category (ratio-c F/M); the dotted line shows the trend of the female vs. male ratio for each category. Real data are plotted as points connected with dotted lines. (**e**) Slope coefficients computed by linear regression on the number of participants of each age category and gender in the 13 editions of VM. M = male, F = female; p-values < 0.05 are considered statistically significant, and p-values < 0.001 are considered highly significant.

The ratio (ratio-y F/M) between female and male participants by year, obtained as the number of female participants over the number of males, showed a linear and significant increase (Figure 1b), from a minimum value in 2007 (ratio-y = 0.16) to a maximum in 2019 (ratio-y = 0.29) ($p < 0.001$).

Figure 1c shows the distribution of participants by age category over the 13 editions of VM. The numbers of male and female participants rose sharply at 40 years old and then showed a gradual decrease in the older categories. The 40- and 45-year age categories were the most numerous (representing 43% of males and 40% of females), followed by the 50-year age category (15% of males and 14% of females). The percentages were greatly reduced in the 60-year age category (4% of males and 2% of females), and participation was reduced even further in the older categories. The higher female vs. male ratio by category (ratio-c F/M) was most evident in the younger categories—the female vs. male ratio was almost constant in the ages between 35 and 50 years, and then there was a major decrease in the 55-year and older categories (Figure 1d).

The analysis of the slope coefficients computed by linear regression on the mean participation by category in all 13 editions showed a significant reduction in male participants in the age categories from 30 to 40 years old ($p < 0.0001$ and $p = 0.013$, respectively) (Figure 1e), followed by an increase that started from 50 years old and became significant only in the 65- and 70-year age categories ($p < 0.05$). In women, there was a non-significant reduction in the 30- and 35-year age categories, followed by an increase that became significant from 45 to 65 years old ($p < 0.05$).

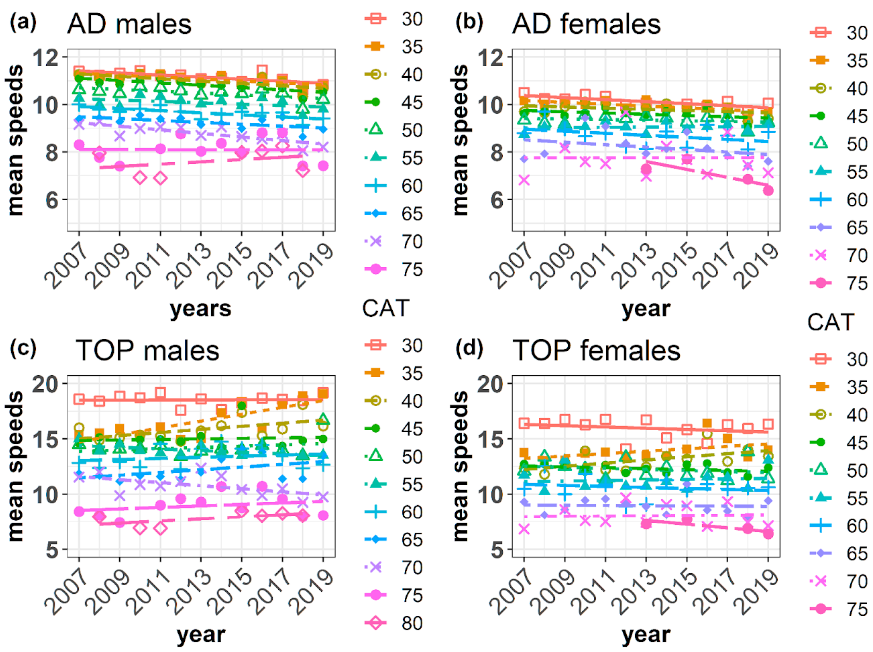
3.2. Speed Analysis by Category in the 13 VM Editions

The mean speed values observed over the 13 editions were analyzed either by including all speeds (AD) or by limiting the analysis to the TOP performers reported in each category according to gender (Figure 2).

The regression analysis of AD speeds in the 13 years of the VM showed a significant decline in almost all male categories (Figure 2a,e), while in women the decline in almost all categories was significant only up to 35 years old (Figure 2b,e). The overall analysis of the TOP performances during the 13 editions showed an increase in almost all age categories in males, which was significant in the 35- and 40-year age groups; a significant decrease was observed only in the 55- and 70-year age categories (Figure 2c,e). In women, a significant increase was observed in 40-year-olds (as in men), and no significant changes were observed in the other categories (Figure 2d,e). There were no significant changes in running speed in the TOP performers even in the youngest male and female categories, which included subjects aged 23 to 34 years old (30-year age category).

3.3. Speed Analysis between and within Genders

The overall mean speeds of the 13 VM editions obtained by age category (AD13 and TOP13) showed a downward trend with increasing age in both genders (Figure 3a,b). The age categories of males included runners up to 80 years old, while those of females included runners up to 75 years old. In all age categories, females showed lower values than males. The mean speeds of AD13 men ranged from 11.16 to 7.62 km/h, while those of AD13 women ranged from 10.13 to 7.06 km/h. The mean speeds of men in TOP13 ranged from 18.51 km/h to 7.94 km/h, while those of women ranged from 16.01 km/h to 7.06 km/h.



(e)

		30	35	40	45	50	55	60	65	70	75	80
AD	slope M	-0.043	-0.041	-0.05	-0.049	-0.038	-0.029	-0.044	-0.04	-0.075	0	0.048
	p-value M	0.007	0.004	0.003	0.001	0.032	0.109	0.005	0.028	0.001	0.993	0.479
AD	slope F	-0.043	-0.039	-0.025	-0.027	-0.013	0.005	-0.043	-0.052	0.001	-0.167	
	p-value F	0.003	0.008	0.164	0.091	0.405	0.72	0.215	0.261	0.987	0.192	
TOP	slope M	0.004	0.308	0.14	0.024	0.059	-0.075	0.05	0.123	-0.137	0.068	0.099
	p-value M	0.912	0.001	0.043	0.748	0.346	0.027	0.495	0.113	0.044	0.428	0.153
TOP	slope F	-0.057	0.108	0.142	-0.041	-0.047	0.024	-0.046	-0.01	0.014	-0.167	
	p-value F	0.385	0.114	0.048	0.168	0.473	0.739	0.552	0.879	0.87	0.192	

Figure 2. Analysis of the running speed of participants in the 2007–2019 VM editions: (**a**–**d**) Regression lines for athletes' mean speeds by year in each age category. (**a**,**c**) Regression lines for AD and TOP male athletes, respectively. (**b**,**d**) Regression lines for AD and TOP female athletes, respectively. (**e**) Slope coefficients and p-values computed by linear regression on speeds by age category and gender in the 2007–2019 VM editions. CAT = age category, M = male, F = female, 30–80 = age category. The p-values < 0.05 are considered statistically significant, and p values < 0.001 are considered highly significant.

The curve patterns were not significantly different between males and females in both groups (AD13 and TOP13; t-test $p = 0.266$ and $p = 0.404$, respectively) (Figure 3a,b), although in TOP13 there were greater differences between males and females.

The mean speed differences calculated within genders (Figure 3c,d) showed that in AD13 the difference between nearby age categories tended to increase, albeit not significantly, in both males and females ($p > 0.05$).

Analyzing these differences within all trained athletes (TOP13) of both sexes, a sharp decline in performance was detected between the individuals younger than 34 years and the upper category (i.e., the 30- and 35-year age categories, respectively), with a lower peak for 40-year-old males ($p < 0.001$) and 45-year-old females ($p < 0.001$). Later, the differences tended to increase, with an interruption at 55 years old in males ($p < 0.001$) and 70 years old in females ($p = 0.115$).

Considering the cumulative differences represented by the lines in Figure 3c,d, the gender trends appeared similar. By applying a t-test between the cumulative trends, the p-values were found to be statistically non-significant ($p = 0.950$ and $p = 0.959$ for

AD13 and TOP13, respectively). This result could be considered a "regression to the mean" phenomenon, in which performances between men and women tend to uniformly decrease.

The piecewise linear regression analysis highlighted the age categories that suffered the greatest decline. Considering AD13, men showed a breakpoint at 50 years old, while women had a sharp decline at 55 years old (Figure 3e). The same analyses performed on TOP13 showed a shift in the breakpoint to 55 years old in males, while in women it occurred earlier, at 45 years old (Figure 3f).

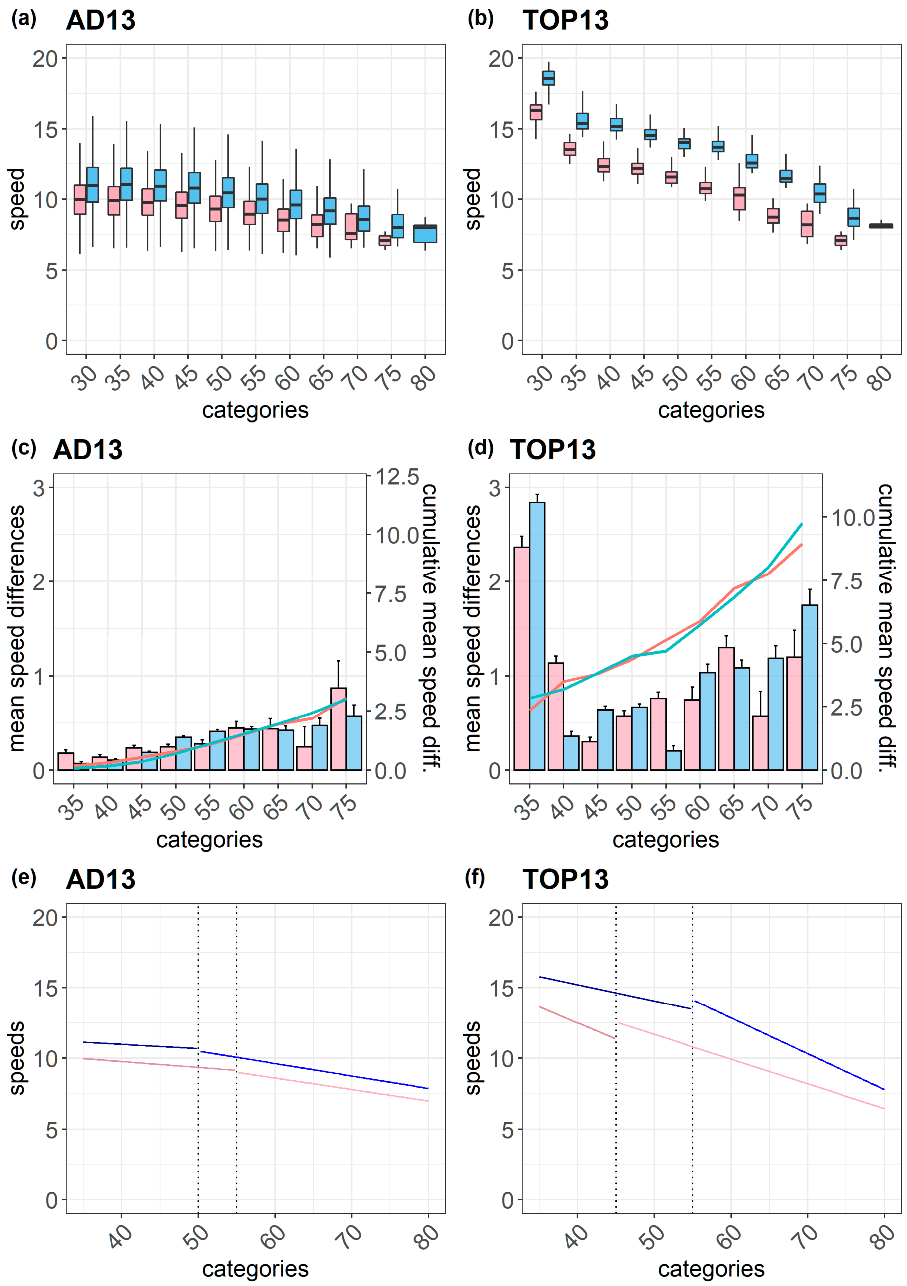


Figure 3. General analysis of speeds among participants in all 13 VM editions: Mean speed distributions grouping the 13 editions of the VM by age category among (**a**) AD13 and (**b**) TOP13. Differential (histograms) and cumulative (lines) differences in mean speeds by category among (**c**) AD13 and (**d**) TOP13. Piecewise regression lines for median speeds of (**e**) AD13 and (**f**) TOP13 athletes; the category 30 (24–34 years) in (**e**,**f**) has been removed. Males are represented by blue histograms or dotted lines, and females by pink histograms or continuous lines.

4. Discussion

This study aimed to test an example of active aging by evaluating all age categories of runners over a period of 13 years in the 2007–2019 editions of the Venice Marathon (VM). In the VM, most participants were from Italy [19], and the total number of participants was lower than that of other marathons, such as those of New York (USA) and Berlin (Germany) [10,11]. Despite this, analyzing a time span of 13 years of VM editions, the gender distribution and the increased participation of females were consistent with those shown in the Marathon Statistics 2019 worldwide report [20], which assessed the distribution of participants and marathon performances in 30 countries around the world by examining over 30,000 races held between 2008 and 2018 [20].

The increased participation in marathons resulted from a raised awareness of the importance of physical activity in adults, since it has been shown that regular physical activity at medium–high intensity improves health and facilitates bone remodeling [2].

Running is a relatively simple and easy physical activity to perform, either alone or in a group. Over time, the most important event in athletics—the marathon—has also become popular among amateurs, leading to the organization of recreational races that are open to professionals as well as to amateur or passionate athletes. In line with the findings of other authors [10], our analyses showed that the age categories of 40 and 45 years old were the most numerous among the participants, and the largest increases in participation were among women over 45 and men aged 65–70 years.

As expected and previously reported, the analyses of performance showed a decline with increasing age [14,21]. The best performances were always observed for both men and women in the 30-year age category, while the worst were observed in the oldest age categories—80 years old for men and 75 years old for women. The females generally performed worse in each age category, but the differences between genders were very small considering the mean speeds of AD13.

Since the analyses in each age category included the running speeds of both winners and the last classified participants (who kept a walking pace), these results are more of social and cultural relevance than of sporting interest, as reported by Reusser and collaborators [22]. The details of the analysis of AD during the 13 VM editions showed a trend towards a decline in men's performance almost in every age category, from 30 years old onwards, while in women this decline was limited to the 30–35-year age category.

The high number of recreational marathons in Italy and around the world has probably led to a greater selection of events in which to participate over time, and the VM could be less attractive for the younger amateurs.

However, the analysis of the TOP performers showed a speed improvement in several categories, which was significant for the 35–40-year-old males and 40-year-old females. This may suggest that the marathon attracts mature men and women who continue to see improvements in their performance.

The trends by gender observed in the AD13 and TOP13 analyses confirm that the age factor is a determinant in the performance decline.

As reported in other studies [2,23], eliminating all confounding characteristics—such as lifestyles that negatively affect running performance—our analysis shows that performance decline in trained athletes could be due to physiological changes that occur with aging. Even considering the interindividual variability, a heterogeneity of muscle size and strength responses was observed in trained individuals, with similarities between men and women in the same age groups [24]. This could suggest a homogeneous decrease in performance with age, until other factors such as the influence of hormones in women and different training regimens take over. Estrogens ensure the maintenance of trained muscles, fluid balance [25], nutrition, and energy intake [26]—all factors that change with age, especially in women [27–29].

Aged athletes have provided a variety of physiological, psychological, and scientific insights into the true aging process [2,3,21], but steadiness, regularity, and correctness in training gradually become more important over the years [27], and good motivation is also relevant for competing in recreational marathons [30].

As for the 70% increase in women's participation over the 13 years of the VM, and the maintenance of their performance over time, it could be related to the fact that women train and participate for a personal challenge even if they seem less inclined to competition [30]. Many of them took up running at a mature age (as our analysis has shown) and, therefore, for their own wellbeing, so obtaining athletic results is not as important to them, but their performance is regular up to the age of 55 years, beyond which physical change becomes more pronounced. On the other hand, the analysis of the TOP performers showed that training guarantees a much better performance in younger age categories and, generally, in men, who are able to maintain a constant performance up to the age of 55 years. Performance in women declines at an earlier age, after 45 years old, probably because despite careful muscle training, the initial hormonal changes are crucial [27–29]. While noting that there are some limitations to this work—such as the consideration of subjects aged 23–34 years in a single category, the consideration of all of the runners with no speed limit, or having also included the data of a VM event held on a "high tide day" in Venice—the analysis of the data has nevertheless allowed us to analyze the participation and performance in a small recreational marathon.

5. Conclusions

Notwithstanding the limitations of our study, the VM can be seen as an interesting model representative of small recreational marathons. Recreational marathons suffered a complete halt from spring 2020 following the COVID-19 pandemic, which blocked all kinds of sporting and cultural events worldwide. The restart has certainly brought relevant changes in many aspects of life that will be reflected in various sporting events [31]. In conclusion, the overall VM data showed that recreational marathons increasingly attract older people. The group of participants aged from 40 to 55 years were the most numerous, indicating that training for and completing a marathon after 40 years of age is not only possible, but is a goal achieved by many, and with a great motivational impact. These issues, together with the data obtained from the analysis of breakpoints in relation to age, should be considered by coaches or physiotherapists in order to adapt training programs to ensure continuity and safe participation from the point of view of physical effort.

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