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Athletes' origin trends in participation and performance of master runners in the New York City marathon (1999–2024): a sex- and age-group analysis

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It is well known that the fastest elite marathon runners come from East African countries such as Ethiopia and Kenya. However, to date, there is no information available on the origin of the fastest age group (master) marathoners. This study aimed to determine the countries of origin of the fastest age group marathoners who have participated in the 'New York City Marathon' over the past several decades. Race data from 1,009,839 runners (626,183 male and 383,656 female finishers) who completed the 'New York City Marathon' between 1999 and 2024 were analyzed. Participants were categorized into five-year age groups: <20, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, and 75 + years. The data were stratified by sex (male and female) and country of origin. The dataset was organized into five performance-based subgroups: (i) the entire dataset, including all finishers by age group and nationality; (ii) the top 100 finishers per age group; (iii) the top 30 finishers per age group; (iv) the top 10 finishers per age group; and (v) the top individual from each country within each age group. Regression analyses were conducted to explore demographic predictors of marathon performance. Participation generally increased over the study period, with temporary declines during the COVID-19 pandemic; male participation consistently outnumbered female participation, the 40–44 years age group was the most represented for both sexes, and participation was lowest in the youngest (< 20 years) and oldest (75 + years) age groups. Crucially, analyses focusing on the fastest age-group marathoners revealed clear nationality-based performance patterns. In younger adult age groups (20–39 years), the fastest average race times were predominantly achieved by female and male runners from Kenya and Ethiopia. The < 20 years age category showed comparatively stronger performances from European runners, including those from Poland, Switzerland and Italy. In the 50 years and older age groups, the best average times were increasingly recorded by runners from the United States of America, Japan, Germany and Switzerland. This shift highlights a regional transition in peak marathon performance with increasing age, from East African to European, North American, and East Asian dominance.

Keywords Endurance, Performance, Age group, Nationality

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Marathon running is becoming increasingly popular worldwide, with a substantial rise in participation among master (age group) athletes over recent decades[1]. The expansion of the marathon running universe has been so significant that the traditional list of six marathons that are considered components of the Abbott World Marathon Majors (WMM) circuit (Tokyo Marathon, Boston Marathon, London Marathon, Berlin Marathon, Chicago Marathon and New York City Marathon) was recently expanded to include the Sydney Marathon[2–4]. In addition, the WMM organization has already indicated that its goal is to expand the circle to nine marathons in the near future[5]. The growing popularity among master athletes has thus been demonstrated in recent decades at events such as the 'New York City Marathon' and the 'Berlin Marathon'[2,4]. These studies show substantial increases in both participation and performance levels among runners aged ≥ 40 years, reflecting broader demographic and recreational fitness trends. However, it remains unknown which nationalities consistently produce the fastest master runners across age groups, and how these patterns differ when examining progressively higher competitive tiers.

Considering marathon running performance, the fastest marathoners typically come from East-African countries such as Ethiopia and Kenya[6,7]. In terms of the age of the fastest marathon runners, Ethiopian and Kenyan runners were the fastest and youngest among both women and men[2], with the age of the fastest runners being 25–30 years old[7,8].

Most master marathon runners (i.e. age group runners aged 40 years and above) predominantly originate from Europe and North America, where participation has significantly increased due to aging populations and a strong cultural emphasis on health and fitness[8–10]. While Africa, particularly Kenya and Ethiopia, excels in producing outstanding elite marathoners, the number of master (age group) runners is relatively small but characterized by exceptional performance levels[11–13]. Europe and North America therefore lead the way in terms of master athlete participation, whereas Africa leads the way in terms of elite-level performance. However, little is known about the most popular competitions, justifying the importance of knowing the fastest athletes in events such as the 'New York City Marathon' and 'Berlin Marathon'.

East African runners have historically dominated global marathon performance, pattern attributed to both environmental and population-level factors[14–17]. However, major marathons are not just for professional competitors. The inclusion of master athletes serves many other goals and benefits, such as promoting physical, psychological, social and cognitive well-being, and we have to date no knowledge where the fastest age group marathoners come from[13]. The 'New York City Marathon' is one of the most important marathons in the world regarding its unique global participation, historical importance and potential impact on the training and health programs of master runners[2].

Although previous research has explored long-term participation and performance trends in the 'New York City Marathon', including analyses conducted by our group, no study has comprehensively examined how performance varies by nationality across the full spectrum of masters age groups. Furthermore, earlier analyses did not incorporate multiple layers of competitive depth to determine whether geographical patterns differ among all finishers, top-100 performers, and top-10 performers. To address these gaps, the present study evaluates a 26-year period (1999–2024), providing the most up-to-date and detailed overview of nationality-specific performance ageing in a major global marathon. This approach extends the broader literature on master's endurance performance and age-related decline[18] and positions our study within a wider conceptual framework linking ageing, demographic patterns, and competitive depth in distance running.

To provide a conceptual foundation for interpreting nationality- and age-related differences in marathon performance, this study is framed within contemporary biopsychosocial models of ageing, which view endurance capacity as the result of interacting biological, psychological, and social factors across the lifespan[19,20]. Complementing this, life-course and social-ecological perspectives highlight how long-term sport participation is influenced by broader cultural, economic, and environmental conditions, including national running traditions, accessibility of training environments, and societal support for lifelong physical activity[21,22]. These frameworks provide a basis for understanding why performance trajectories may differ between nations and across masters age groups, beyond simply documenting descriptive trends. From a practical perspective, understanding age- and nationality-specific participation and performance patterns may help race organizers, such as those of the New York City Marathon, to more effectively target marketing strategies, tailor international outreach, and anticipate future participation trends across demographic groups.

Therefore, the aim of the present study was to investigate the origins of the fastest age group marathoners who have completed the 'New York City Marathon' in recent decades. We hypothesized that, within each sex, runners from East African countries would demonstrate faster mean finish times than runners from other regions in younger age groups (25–29 years and 30–34 years), whereas in older masters age groups, runners from other countries would achieve the fastest times, particularly among the top finishers. Given that the strongest demographic effects were expected among higher-performing athletes, the hypothesis specifically pertains to the top finishers, while analyses of the wider field are treated as descriptive and exploratory.

Methods

Ethical approval

The study received ethical clearance from the Institutional Review Board of Kanton St. Gallen, Switzerland (EKSG 01/06/2010). As the analysis was based solely on publicly accessible race records, individual informed consent was not required. All procedures conformed to the ethical standards of the 1964 Helsinki Declaration and its subsequent revisions.

Data collection

Athlete data was downloaded from the official New York Road Runners website (https://results.nyrr.org) using a Python script to make API calls. All finishers were obtained in JSON format by querying each event in blocks of

100 athletes (e.g., 1–100 placed finishers, then 101–200 placed finishers, etc.) until no more data was available. This data included most notably a unique identifier (runnerId), name, gender, age, country and race time. An additional API request was then made for each race result using the unique identifier (runnerId) to obtain all available split times. Notably, data for 2012 and 2020 were unavailable due to race cancellations linked to Hurricane Sandy and the COVID-19 pandemic, respectively.

Dataset and data preparation

The dataset comprised information on the year of participation, official finish time, age, sex, and nationality of each athlete who competed in the 'New York City Marathon' during the study period. Only runners who successfully completed the full marathon distance of 42.195 km were included. Records with missing demographic data, duplicated entries within the same year, or disqualifications were excluded to ensure the accuracy and integrity of the analysis. Additionally, implausible finish times (e.g., clear timing errors) were identified and removed during data cleaning to maintain dataset accuracy. Participants were categorized into five-year age groups: <20 years, 20–24 years, 25–29 years, 30–34 years, 35–39 years, 40–44 years, 45–49 years, 50–54 years, 55–59 years, 60–64 years, 65–69 years, 70–74 years, and 75 + years. The data were stratified by sex (male and female) and by country of origin. To ensure consistency across the dataset, country names and abbreviations were standardized (harmonized to a single ISO-style label), especially for entries between 2006 and 2016, where inconsistencies in national identifiers were present. Age group classifications were verified to ensure accurate group assignments, and all finish times were converted to total minutes to enable consistent computational analysis. Despite its minimal participation numbers and limited analytical influence, the < 20 years age group was retained for completeness and to maintain consistency across all age categories. For analytical purposes, the dataset was organized into five performance-based subgroups: (1) the entire dataset, including all finishers by age group and nationality; (2) the top 100 finishers per age group; (3) the top 30 finishers per age group; (4) the top 10 finishers per age group; and (5) the top individual from each country within each age group. These subgroupings were created solely for comparative and exploratory purposes to identify whether patterns differed by competitive depth.

Statistical analysis

Descriptive statistics, including both mean and median finish times, were calculated for each country across all age groups and both sexes within each performance tier (entire dataset, top 100, top 30 and top 10 finishers). As the differences between the means and medians were minimal and did not affect interpretation, subsequent analyses were performed based on mean values only. This approach follows previous marathon performance analyses and ensures consistency across comparisons, as mean values are more sensitive to performance differences at the top end, which are central to the study focus. This tiered approach allowed for a comprehensive examination of overall participation patterns as well as elite-level performance, while maintaining sufficient sample sizes within each age group and sex to allow stable comparisons of nationality patterns. Data visualization was employed to illustrate distributional differences and temporal trends across demographic subgroups. Multiple linear regression analyses were performed to further investigate the influence of age group and nationality on performance outcomes. The regression model was applied primarily to the top 100 finishers, as this subset provides clearer performance distributions than the entire dataset; analyses using the full dataset were treated descriptively. Separate models were created for the entire dataset and for the top 100 performers in each age group. In both cases, finish time (in minutes) served as the dependent variable, while nationality and age group were included as categorical predictors. These models facilitated the identification of demographic effects on performance but were interpreted cautiously and not as causal estimates. Where appropriate, linear or polynomial trend lines were applied to highlight performance trajectories across age categories. All analyses were conducted using a combination of custom Python scripts, IBM SPSS Statistics (version 29) and Microsoft Excel. Statistical significance was defined as $p < 0.05$.

Results

Figures 1, 2, 3, 4, 5, 6 present the visualizations most directly aligned with the study hypotheses, while the remaining performance-stratified plots (Figs. 7, 8, 9, 10, 11, 12) are included to provide a comprehensive description of nationality patterns and depth of representation across competitive tiers.

A total of 1,009,839 runners completed the 'New York City Marathon' between 1999 and 2024, comprising 626,183 male and 383,656 female finishers. Participation showed a general upward trend over the 25-year period, with a notable decline in 2020 and 2021 attributed to the COVID-19 pandemic (Fig. 1). Overall, male participation consistently outnumbered female participation across all years. In terms of age distribution, the 40–44 years age group emerged as the most represented for both sexes, while the youngest (< 20 years) and oldest (75 + years) categories had considerably lower participation (Fig. 2).

The United States consistently represented the largest share of participants across all age groups (Table 1). Initially, countries such as France, Germany, the United Kingdom and Italy followed the United States in terms of participant numbers. However, from the mid-2000s, Italy became the second most represented nation, with other countries like Canada, Mexico, and Japan maintaining steady participation. In recent years, nations from Latin America and East Asia, including Mexico and Japan, have gradually increased their presence, reflecting the marathon's global appeal.

Analysis of performance trends revealed that the fastest average finishing times in the younger age groups (20–39 years) were predominantly achieved by runners from Kenya and Ethiopia. This pattern was observed in both male and female competitors (Figs. 3 and 4). In contrast, the under 20 years age group was marked by stronger performances of European runners, including those from Poland, Switzerland and Italy. With increasing age, particularly in the 50 + years age groups, the best average times were increasingly achieved by

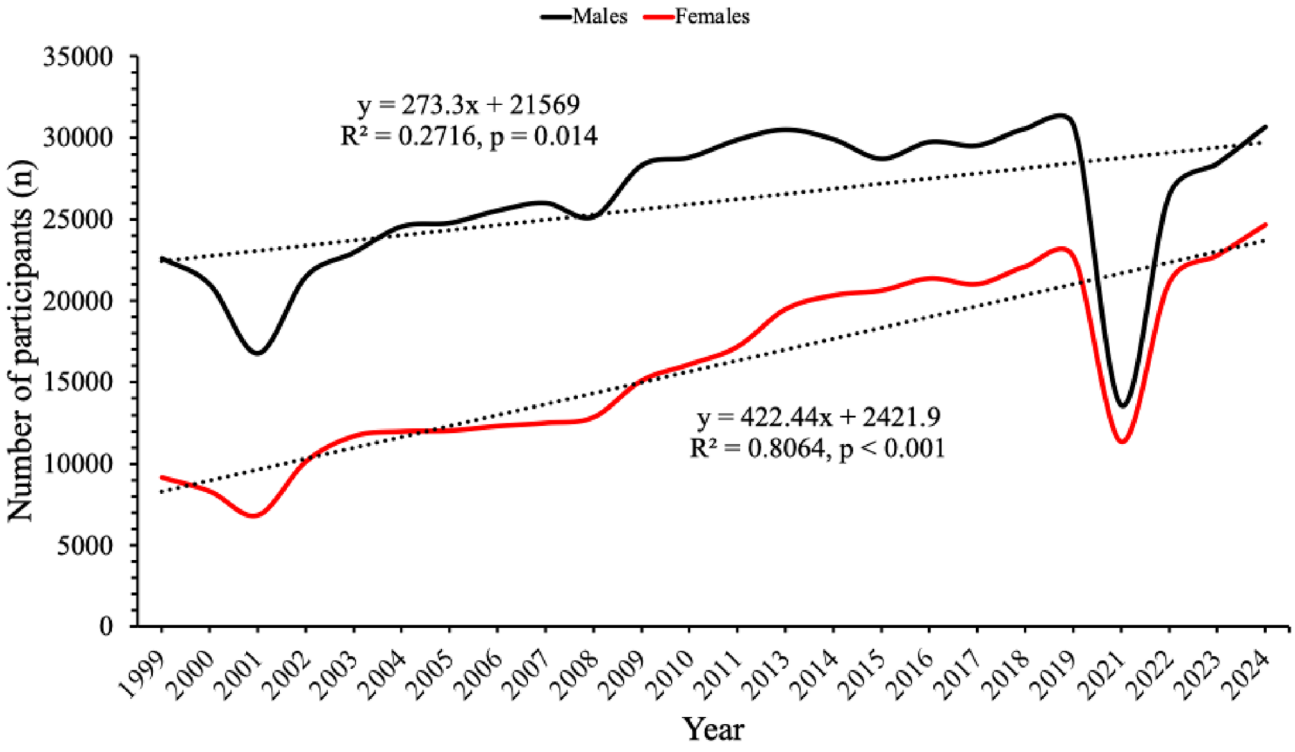

Fig. 1. Number of male and female participants in the 'New York City Marathon' from 1999 to 2024.

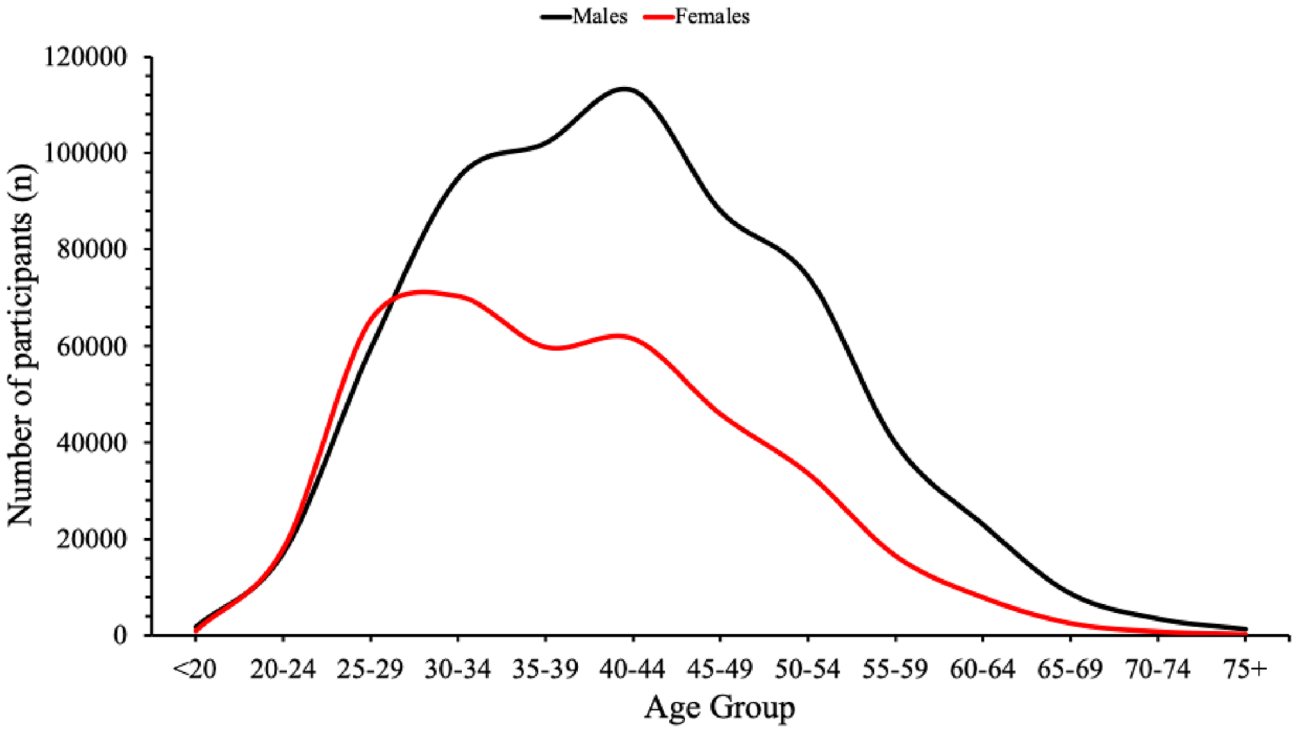

Fig. 2. Total number of male and female participants in the 'New York City Marathon' by age group.

runners from the United States, Japan, Germany and Switzerland. This shift highlights a regional transition in peak performance with age, from East African to European, North American, and East Asian dominance.

When looking at the top individual performances per age group, similar trends were evident. Kenyan and Ethiopian runners consistently achieved the best individual times in the 20–39 years age group, underscoring

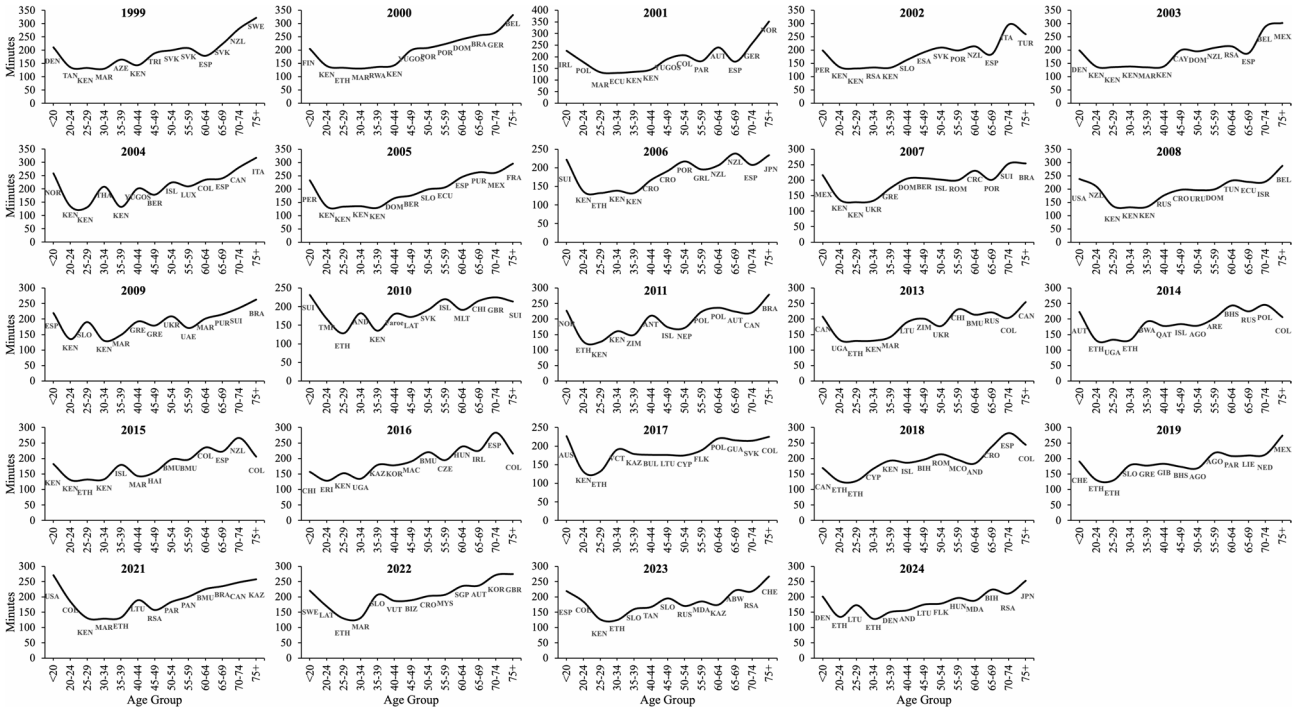

Fig. 3. Best average finishing times by male runners from the same country across age groups in the 'New York City Marathon' from 1999 to 2024. Best average times were calculated using all finishers within each age group and nationality from the entire dataset.

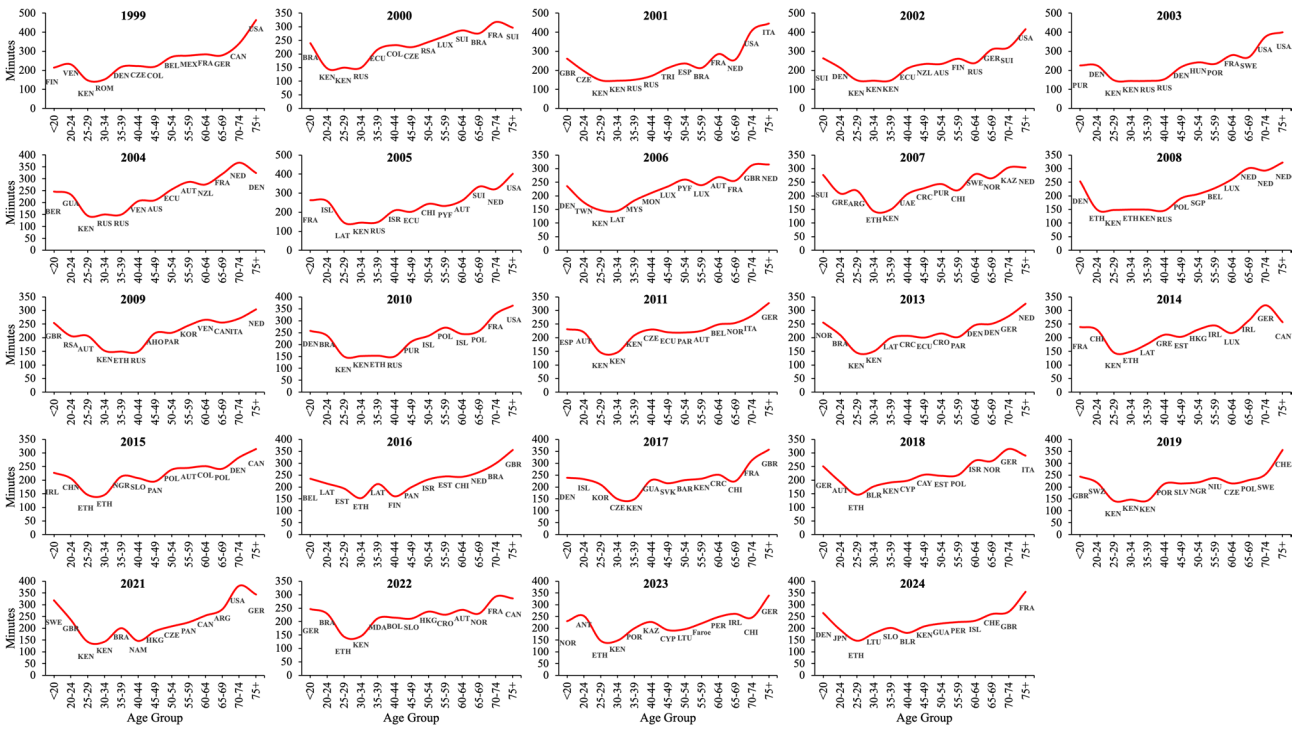

Fig. 4. Best average finishing times by female runners from the same country across age groups in the 'New York City Marathon' from 1999 to 2024. Best average times were calculated using all finishers within each age group and nationality from the entire dataset.

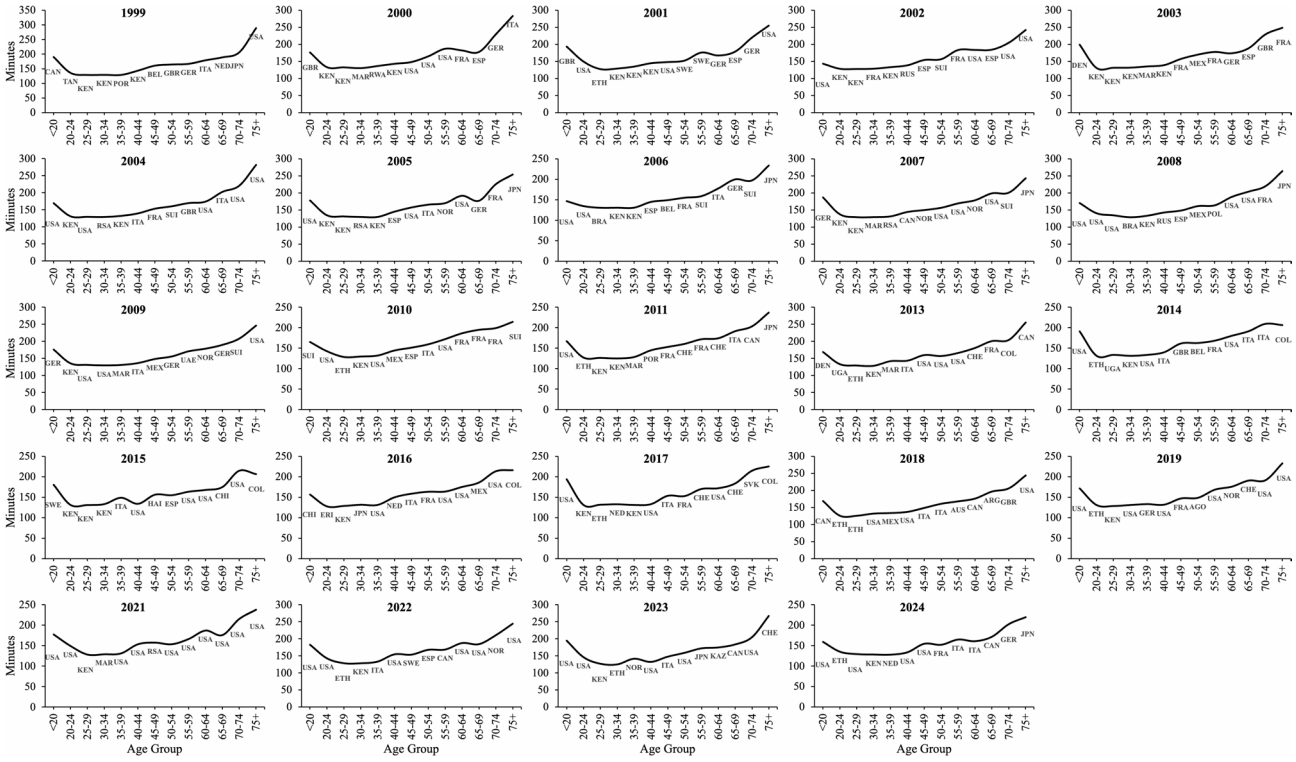

Fig. 5. Fastest individual male finishers by age group in the 'New York City Marathon' from 1999 to 2024.

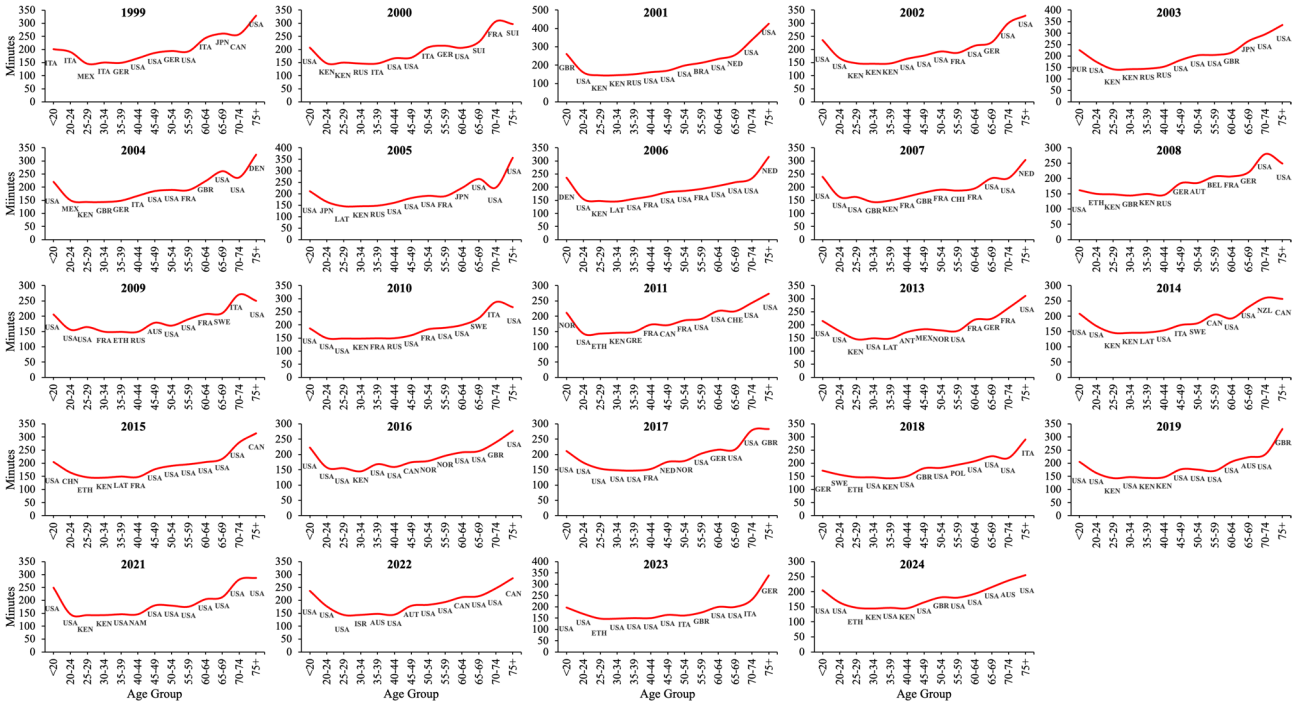

Fig. 6. Fastest individual female finishers by age group in the 'New York City Marathon' from 1999 to 2024.

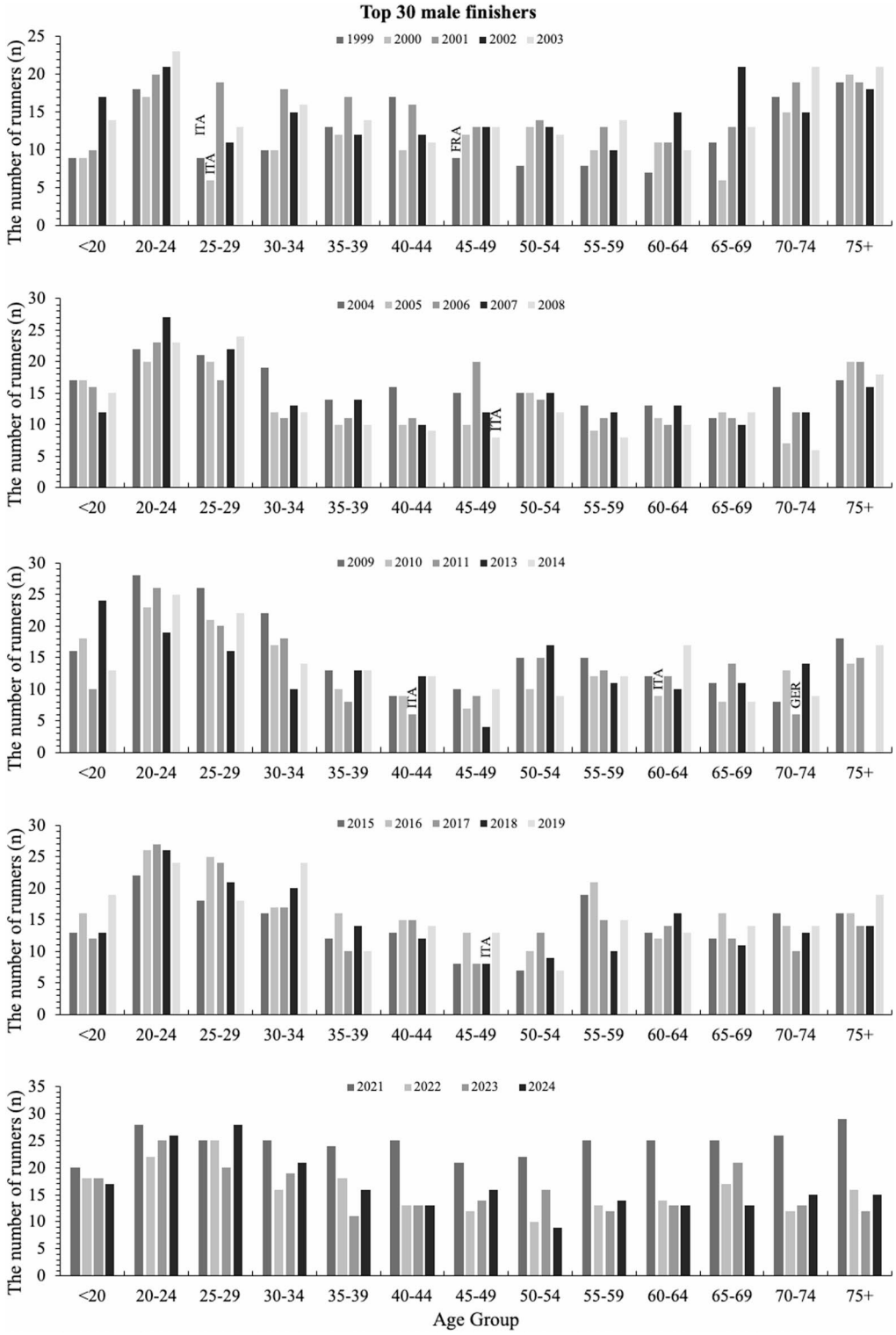

Fig. 7. Countries with the highest representation among the top 30 male finishers in each age group in the 'New York City Marathon' (1999–2024). Note: In cases where multiple countries had the same number of top 30 finishers in a given age group, the country with the faster average finish time was ranked higher.

their sustained excellence at the elite level (Figs. 5 and 6). However, in master (50 + years) age groups, the top performances shifted to runners from the United States, Switzerland and Japan, indicating a redistribution of elite capability among older age groups.

To characterize the dominance patterns within the top-performing cohorts, we present the distribution of nationalities among the top 30 and top 10 male and female finishers. These descriptive figures illustrate which

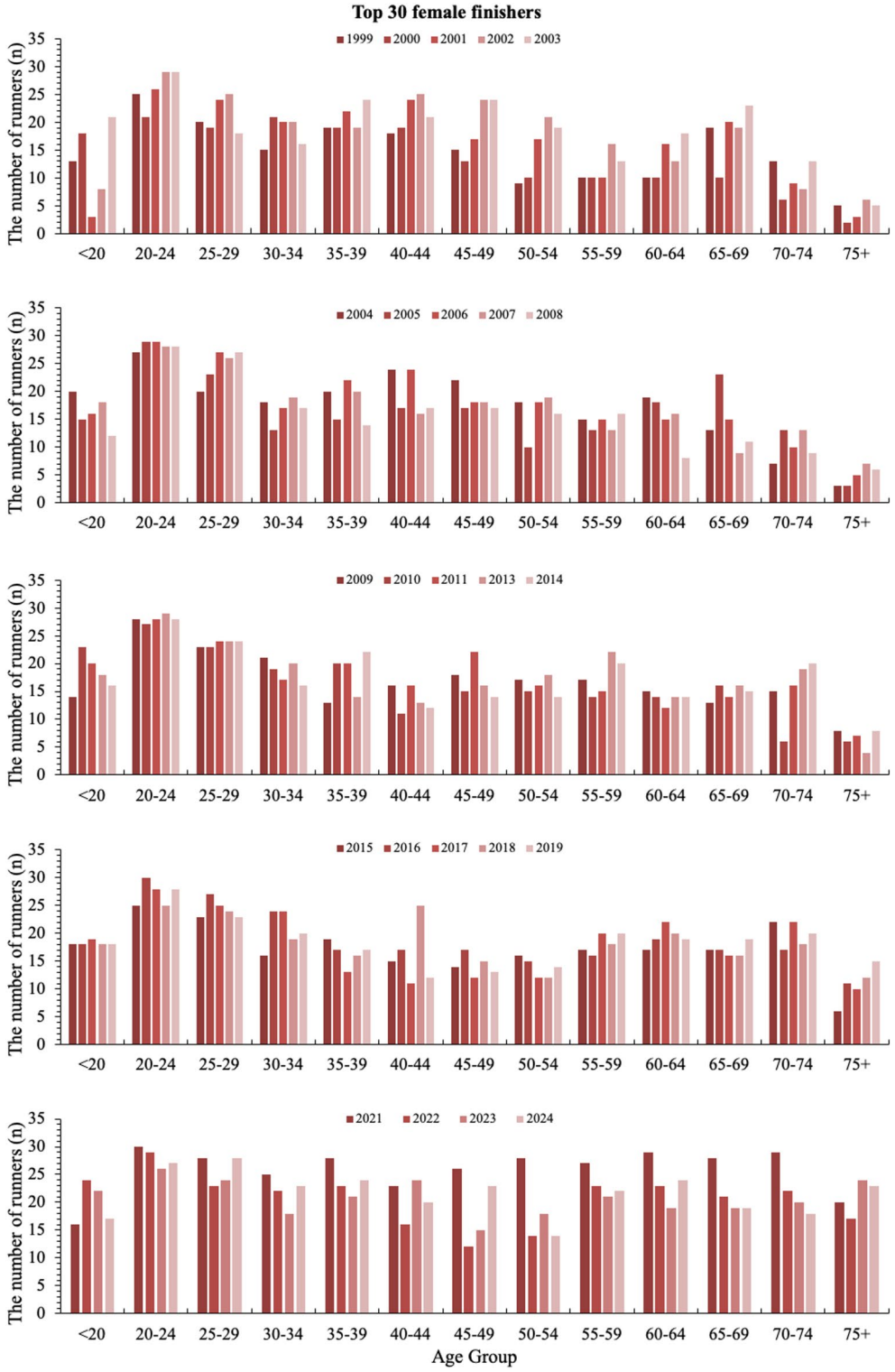

Fig. 8. Countries with the highest representation among the top 30 female finishers in each age group in the 'New York City Marathon' (1999–2024). Note: In cases where multiple countries had the same number of top 30 finishers in a given age group, the country with the faster average finish time was ranked higher.

countries consistently appear at the highest competitive levels. Further insights were derived from the analysis of the top 30 and top 10 performers by nationality (Figs. 7 and 8). In the top 30 rankings, the younger age categories remained dominated by East African countries, while the older categories were increasingly led by runners from Western nations, particularly the United States, Switzerland and Germany. Japan was also prominently represented in several senior categories.

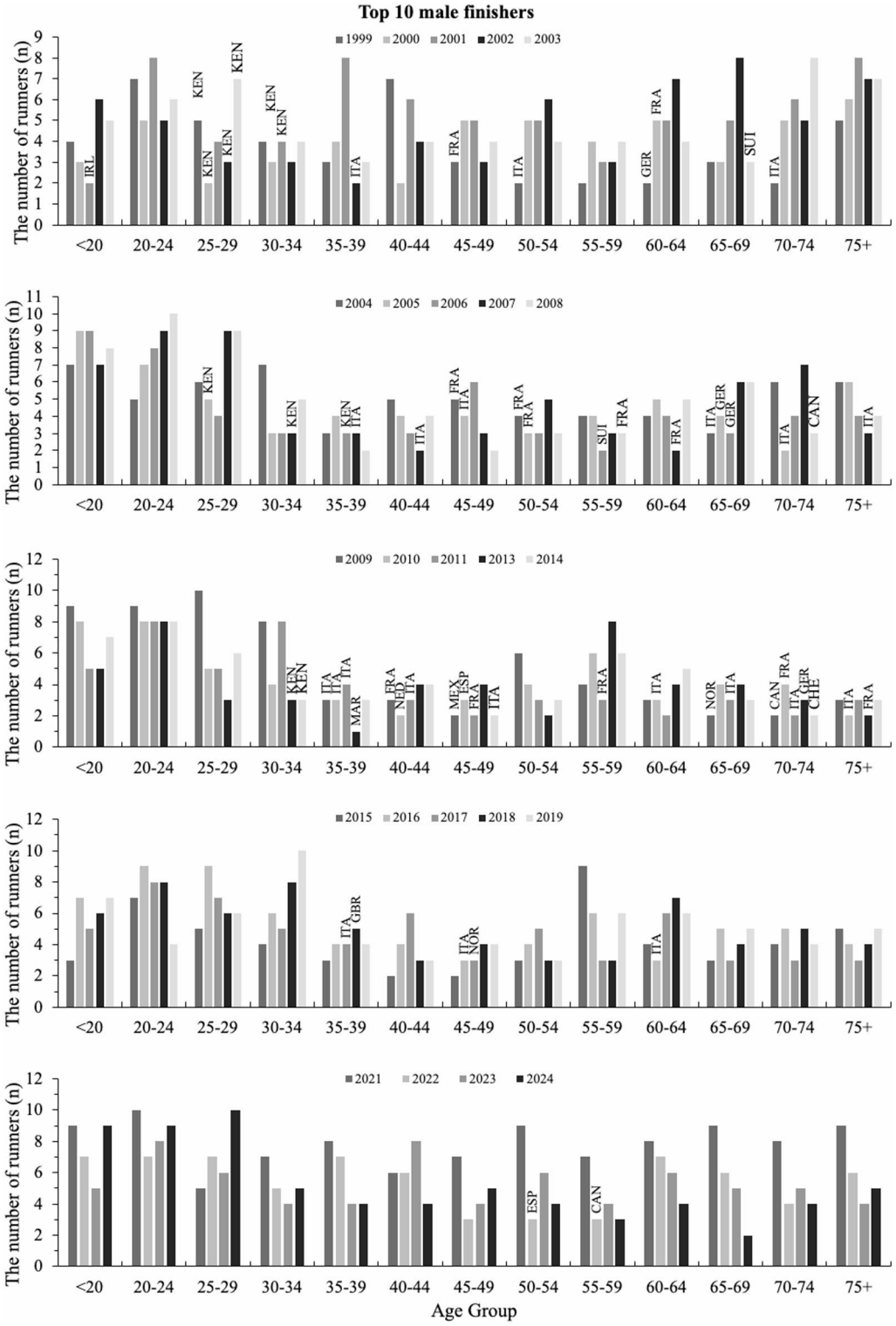

Fig. 9. Countries with the highest representation among the top 10 male finishers in each age group in the 'New York City Marathon' (1999–2024). Note: In cases where multiple countries had the same number of top 30 finishers in a given age group, the country with the faster average finish time was ranked higher.

Analysis of the top 10 offered even sharper contrasts (Figs. 9 and 10). While Kenya and Ethiopia dominated among the youngest runners, the older age groups—particularly among women—were heavily populated by athletes from the United States, Japan and Switzerland, suggesting strong support for lifelong competitive running in these nations.

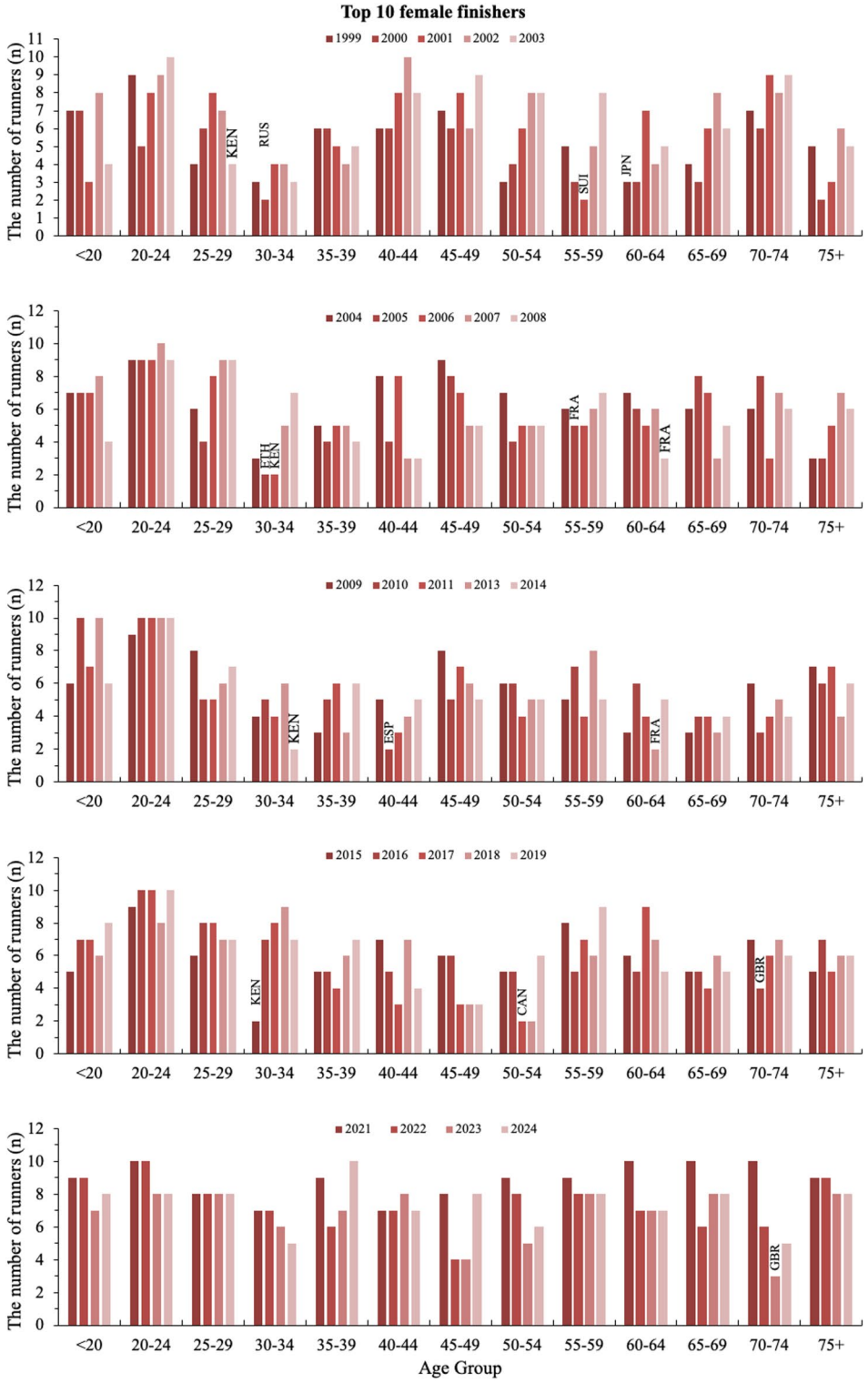

Fig. 10. Countries with the highest representation among the top 10 female finishers in each age group in the 'New York City Marathon' (1999–2024). Note: In cases where multiple countries had the same number of top 30 finishers in a given age group, the country with the faster average finish time was ranked higher.

Given the overwhelming representation of the United States across the years, a focused analysis of American runners was conducted (Figs. 11 and 12).

Among American males, participation increased steadily in nearly all age groups, especially in the 45–64 years age group. While average times remained relatively stable, individual best times improved in the 30–59 years categories, indicating enhanced competitive performance among midlife runners. In contrast, performances in

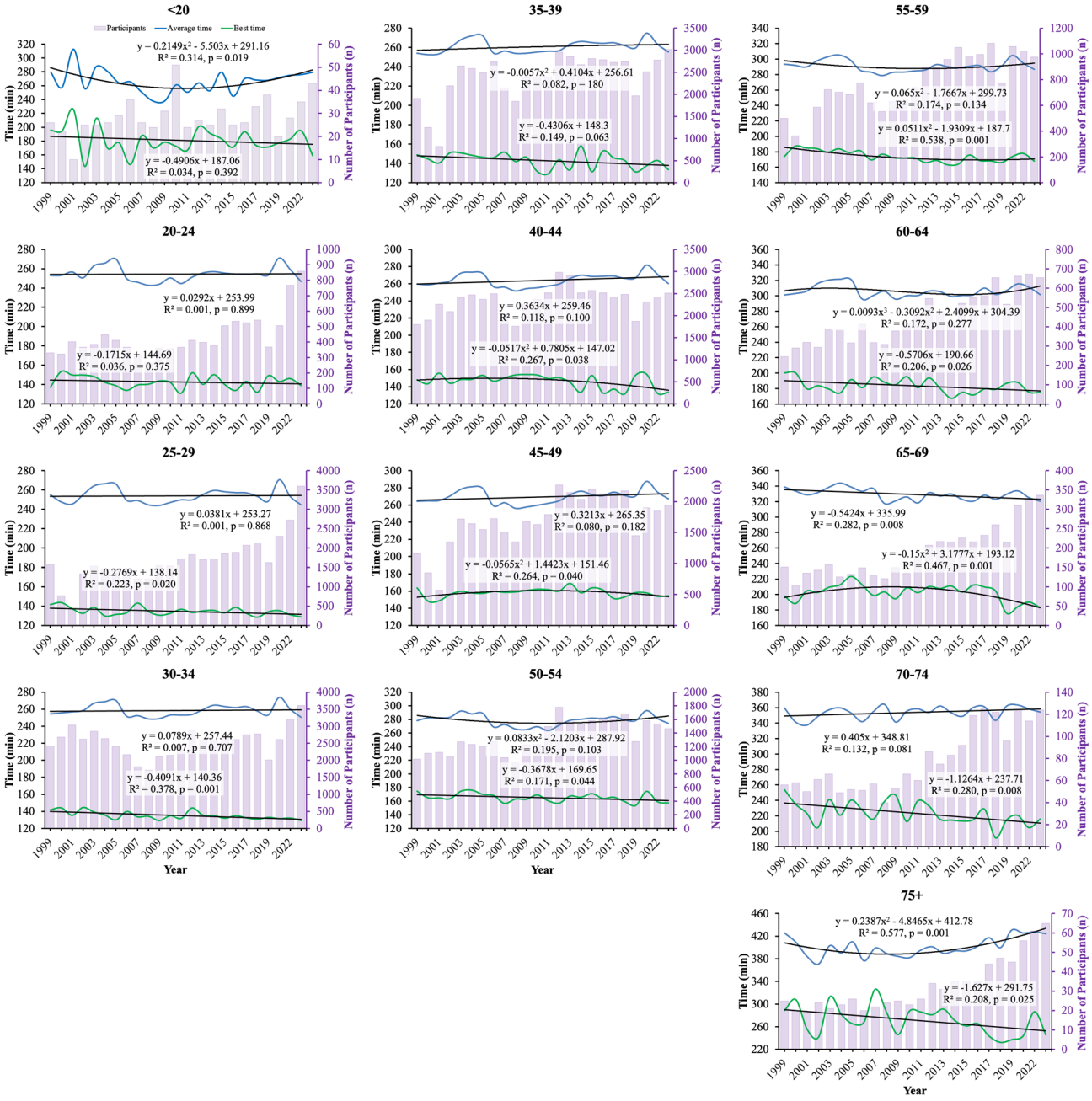

Fig. 11. Average and best finishing times, and number of American male participants per age group in the 'New York City Marathon' from 1999 to 2024.

the < 20 years age group stagnated or declined slightly. Among American women, participation was highest in the 50 + years categories, and notable improvements in best times were observed, particularly from age 45 years onwards. These trends indicate an increasing depth and quality of performance in older female age groups.

To assess the extent to which demographic variables could predict marathon performance, linear regression models were constructed using age group and nationality as independent variables and finish time as the dependent variable. In the model that included all finishers, age group and nationality explained only 5.9% of the variance in finish times for men ($R^2 = 0.059$, $p < 0.001$) and 4.7% for women ($R^2 = 0.047$, $p < 0.001$), indicating limited explanatory power across the general population. These low R^2 values indicate that age and nationality have very limited explanatory power among the broader recreational field, and the demographic effects in this dataset should therefore be interpreted as weak associations rather than strong predictors. However, when the analysis was limited to the top 100 finishers per age group, the explanatory power increased substantially. In this elite subset, the model accounted for 55.0% of the variance in men's finish times ($R^2 = 0.550$, $p < 0.001$) and 49.5% in women's finish times ($R^2 = 0.495$, $p < 0.001$). These findings indicate that demographic characteristics become far more predictive at the elite age group level, where runners are likely to share more homogeneous training

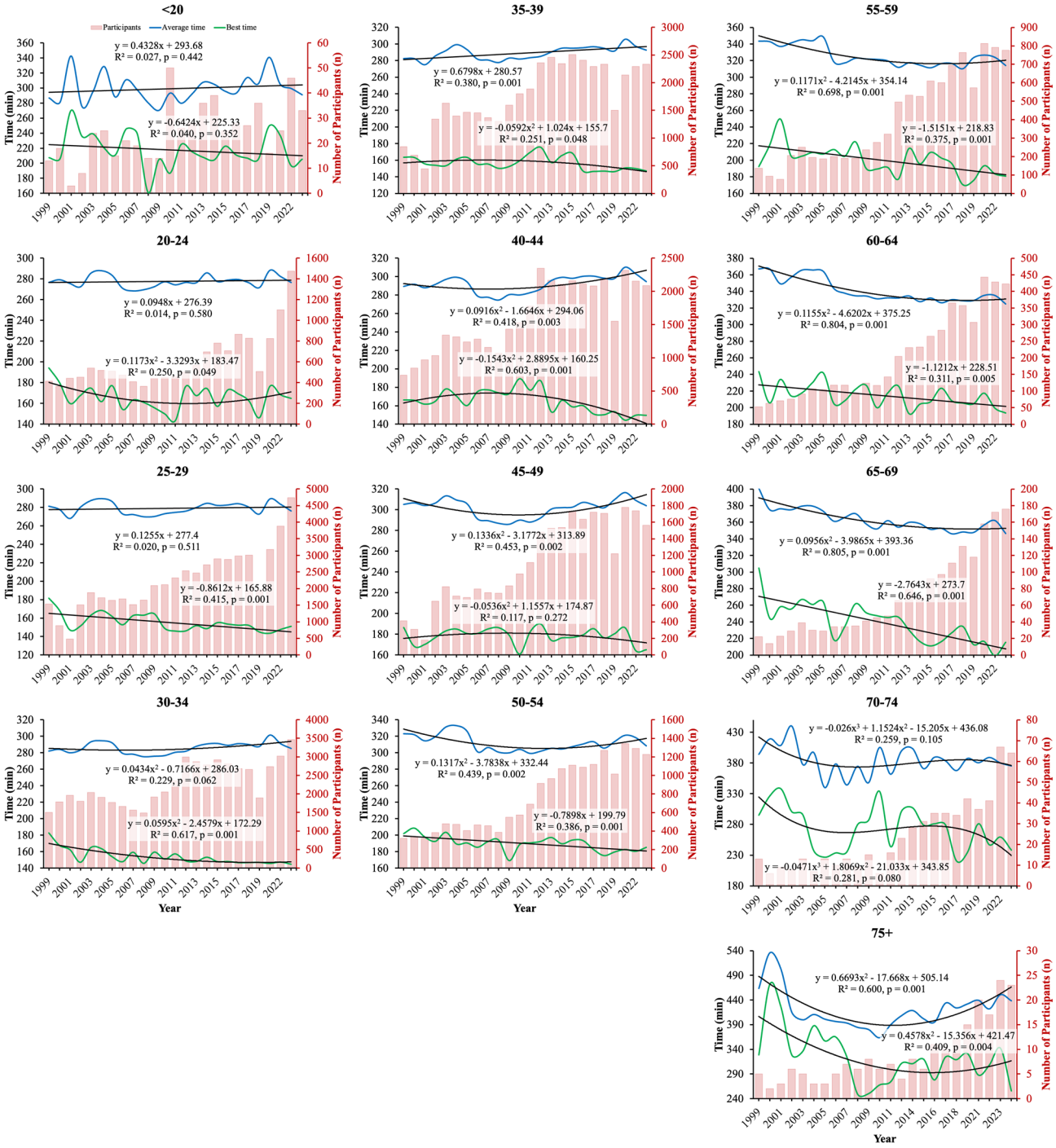

Fig. 12. Average and best finishing times, and number of American female participants per age group in the 'New York City Marathon' from 1999 to 2024.

habits, access to coaching and national sport infrastructure. However, as the model explained only a moderate proportion of variance, the effects of age and nationality should be interpreted cautiously, as these predictors capture only part of the variability in finishing times.

Discussion

The aim of this study was to investigate the origin of the fastest age group marathoners competing in the 'New York City Marathon' over the past 25 years. The main findings showed that East African runners, particularly from Kenya and Ethiopia, dominated the younger age groups (20–39 years), while athletes from the United States, Western Europe (especially Germany and Switzerland) and East Asia (notably Japan) were the top performers in the older age categories. These results also highlighted the importance of performance stratification when

Year	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Other
1999	USA	FRA	GBR	ITA	GER	NED	SUI	CAN	MEX	JPN	2862
	17,231	2715	2089	1767	1529	1203	704	657	578	400	
2000	USA	FRA	GBR	GER	ITA	NED	SUI	MEX	CAN	JPN	2971
	15,160	2769	2003	1594	1537	1181	679	494	456	431	
2001	USA	GBR	FRA	GER	NED	ITA	SUI	MEX	CAN	JPN	1575
	14,416	1829	1768	1049	966	749	380	351	252	251	
2002	USA	GBR	FRA	GER	NED	ITA	SUI	CAN	MEX	JPN	2302
	19,660	2401	2083	1302	1053	1016	605	463	363	323	
2003	USA	GBR	FRA	GER	ITA	NED	CAN	SUI	MEX	JPN	2116
	23,356	2267	1882	1306	1090	892	639	402	358	321	
2004	USA	GBR	FRA	GER	NED	ITA	CAN	MEX	JPN	SUI	2463
	22,215	2387	2024	1902	1720	1612	792	489	466	431	
2005	USA	GBR	ITA	GER	FRA	NED	CAN	SUI	MEX	JPN	2670
	21,231	2526	2338	2308	2190	1558	620	489	477	373	
2006	USA	GBR	FRA	GER	ITA	NED	CAN	SUI	MEX	SWE	2888
	21,860	2745	2519	2445	2119	1285	645	516	437	349	
2007	USA	ITA	GBR	FRA	GER	NED	CAN	SUI	ESP	IRL	4372
	18,858	3144	2908	2687	2523	1688	710	640	512	427	
2008	USA	ITA	GBR	FRA	GER	NED	CAN	ESP	SUI	IRL	4523
	17,513	3175	3042	2800	2571	1686	951	651	603	472	
2009	USA	ITA	FRA	GER	GBR	NED	CAN	SUI	ESP	MEX	5662
	22,146	3100	2919	2302	2263	1660	1206	747	734	642	
2010	USA	ITA	FRA	GBR	GER	NED	CAN	ESP	SUI	MEX	6284
	22,981	3443	3018	2153	2091	1440	1226	885	708	644	
2011	USA	ITA	FRA	GER	GRE	NED	CAN	ESP	MEX	CHE	6320
	25,258	3344	3116	1987	1805	1601	1209	894	766	741	
2013	USA	FRA	GER	ITA	NED	GBR	CAN	CHE	SWE	AUS	6196
	30,865	2955	1745	1719	1432	1382	1286	856	779	740	
2014	USA	FRA	ITA	GER	GBR	CAN	NED	MEX	AUS	SWE	6719
	29,836	2966	1881	1756	1532	1339	1182	1055	1035	909	
2015	USA	FRA	ITA	GER	GBR	NED	CAN	AUS	ESP	MEX	6956
	29,365	2557	2094	1601	1520	1354	1062	1057	884	869	
2016	USA	ITA	FRA	GBR	NED	GER	AUS	ESP	MEX	CAN	6935
	31,363	2602	2282	1586	1328	1328	1017	939	865	857	
2017	USA	ITA	FRA	GBR	GER	NED	ESP	AUS	CAN	MEX	7333
	30,717	2778	2297	1518	1279	1144	1031	859	793	783	
2018	USA	ITA	FRA	GBR	GER	NED	AUS	ESP	CAN	MEX	7758
	31,210	2994	2314	1828	1416	1330	1023	962	906	895	
2019	USA	ITA	FRA	GBR	GER	NED	CAN	MEX	ESP	AUS	8096
	32,051	2652	2413	1848	1529	1255	1067	882	828	824	
2021	USA	MEX	CAN	GER	ARG	COL	CRC	CHI	PER	GUA	563
	22,970	544	225	203	105	74	72	59	52	50	
2022	USA	ITA	FRA	GBR	GER	CAN	NED	ESP	MEX	BRA	5225
	31,833	2057	1828	1675	1183	898	825	813	792	531	
2023	USA	ITA	FRA	GBR	GER	MEX	CAN	NED	ESP	AUS	5910
	34,600	2255	1789	1658	1066	922	897	839	699	628	
2024	USA	ITA	FRA	GBR	GER	MEX	NED	CAN	AUS	BRA	6347
	37,680	2343	1961	1721	1235	1058	875	823	708	675	

Table 1. Top 10 most participating countries in the 'New York City marathon' from 1999 to 2024.

assessing the influence of age and nationality on marathon outcomes. Interpreting the present findings through a biopsychosocial and life-course lens suggests that the observed nationality- and age-related performance differences likely reflect a combination of physiological ageing, varying participation depth across countries, and broader sociocultural factors shaping lifelong endurance training. These frameworks help explain why performance gaps between nations narrow or widen at different ages: biological ageing trajectories are universal,

but exposure to endurance running, training culture, and structural support differ substantially between populations.

Shifting geography of performance with age

The data clearly showed that East African runners, particularly from Kenya and Ethiopia, continue to dominate in the 20–39 years age range, which is consistent with existing literature reporting the dominance of these two nationalities and in particular two ethnic groups, the Kalenjin from Kenya and the Oromo from Ethiopia[16]. This finding is also consistent with previous research that has identified genetic predispositions, living at high altitudes, cultural factors and structured early-life running habits as key contributors to their elite performance[17], although these factors should be interpreted as possible influences rather than definitive causes. In addition, similar results were observed previously in an analysis of over one million performances in 50 km races[23].

However, this dominance declines significantly in the master age groups (40 years and older), where athletes from the United States, Germany, Switzerland and Japan lead the way. This geographic shift may indicate that while early-life physiological advantages play a role in performance at younger ages, long-term competitive success is likely shaped by systemic factors such as training opportunities, healthcare access, social support and lifestyle stability—features more prominent in high-income nations[24].

Notably, Japan displayed consistent excellence in male runners aged 60–69 years and Switzerland showed significant representation among high-performing female runners aged 45 years and above. These findings may reflect deeply ingrained culture of recreational running and community-based athletic infrastructures in these countries[25]. Germany's success, observed in both male and female master athletes, is similarly likely tied to institutional sport systems and long-standing participation norms[26]. Countries that invest in age-inclusive training infrastructure are able to maintain higher levels of athletic performance into old age[27].

The geographical shift observed with advancing age likely reflects an interaction of biological, social, and systemic influences. Biologically, age-related declines in aerobic capacity, muscle mass, and recovery ability affect all runners[28,29], but the extent to which these changes are mitigated depends on long-term training continuity and lifestyle factors. Social and cultural contexts, such as sustained recreational running traditions, high participation rates among older adults, and community-based support structures, may help maintain performance into later life in countries like Japan, Switzerland, and Germany[30]. Systemic factors, including access to organized training environments, healthcare, and age-inclusive sport infrastructure, also play an important role[31]. While the relative contribution of these domains cannot be quantified with the available data, the convergence of these influences offers a plausible explanation for the shift in nationality representation among faster master runners.

Comparable analyses from other major international marathons provide useful context for interpreting these findings. Studies of the Berlin Marathon and Boston Marathon have similarly reported strong East African dominance among younger age groups and more geographically diverse performance patterns in older runners, consistent with our observations in the New York City Marathon[32,33]. Although methodological differences and varying race profiles limit direct comparisons, the available evidence suggests that the age-related shift in nationality representation may be a broader phenomenon across major running road races.

It is important to note that nationality, as recorded in mass-participation events, is an imperfect categorical indicator. Nationality does not necessarily reflect ethnicity, lifetime training environment, migration history, socioeconomic background, or within-country regional differences. Consequently, the nationality-based patterns observed here should not be interpreted as direct genetic or environmental determinants but rather as population-level associations shaped by a complex mix of social, cultural, and structural factors[34].

High participation as a driver of performance depth

The United States was by far the most represented country in terms of total participation. Contrary to concerns that mass participation might dilute competitive performance; the findings indicate the opposite. American runners were not only well represented but also consistently ranked among the top finishers in the older age groups. This trend supports the hypothesis that widespread engagement in running creates a large and diverse talent pool that can foster the emergence of high-performing age group athletes[35]. This pattern has also been observed in other endurance events, highlighting the importance of community access and inclusivity in cultivating performance excellence at scale[36].

In contrast, countries with moderate participation rates, such as Switzerland and Japan, still achieved top-tier results in selected age groups. This indicates that while participation rates contribute to depth, they are not a prerequisite for excellence[37]. Rather, the quality of the sport culture, coaching and athlete support systems play a crucial role in maintaining elite performance, particularly as athletes age[38].

Sex-specific trends in aging and endurance performance

The performance trajectories of female runners followed a somewhat different pattern than those of their male counterparts. East African women dominated in younger age groups but showed declining representation in older cohorts. This decline could be due to either lower overall participation among East African women in marathons or to reduced access to long-term support structures for female athletes[39].

In contrast, American, Swiss and German women showed significant improvements in both participation and performance from age 40 years onwards. The rise of American women was particularly pronounced in the 45–64 years age groups. This may reflect shifting cultural attitudes toward female sports participation, increasing opportunities for lifelong athletic involvement, and generational effects from women who began running during the fitness boom of the late 20th century[40,41]. These trends underline the importance of gender equality in sport policy and programming, especially in promoting physical activity across the lifespan[42].

The sex-specific patterns observed in this study align with established literature on endurance aging. Women and men show comparable performance trajectories until middle age, after which declines in VO_2max, muscle

mass, and neuromuscular function typically progress more rapidly in men[43], whereas women often show more gradual declines relative to their individual peak[18]. These physiological differences, combined with sex-specific participation trends, such as the later and more sustained growth of female master's participation, may help explain the age-related patterns observed in our results. The greater heterogeneity among recreational female runners in younger age groups and the increasingly competitive profile of older female participants have both been noted in previous master's athletics research[44]. These dynamics provide context for the sex-specific nationality trends identified in the present study.

The predictive role of demographic variables

The regression analysis revealed that age group and nationality were weak predictors of marathon performance when applied to the entire dataset, explaining only a small fraction of the variance in finish times and underscoring that demographic influences are minimal among recreational runners, with any observed patterns in this group requiring considerable caution in interpretation. This outcome is not unexpected given the broad heterogeneity among recreational runners, who differ greatly in terms of their training backgrounds, motivations, physiological traits and pacing strategies[45,46]. However, when the analysis was limited to the top 100 finishers per age group, a cohort more likely to be uniformly trained and competitively focused, the explanatory power of age and nationality increased markedly, accounting for more than half of the variance in performance. These findings reflect the study's a priori focus on higher-performing athletes, consistent with the hypothesis that nationality- and age-related effects are most pronounced among top finishers rather than across the entire recreational field. Although the model showed moderate explanatory power, the influence of age and nationality on marathon performance should still be interpreted with caution, as these variables account for only part of the observed variability. This reinforces those demographic predictors, while meaningful, do not capture the full complexity of marathon performance. This highlights that additional factors, such as training background, socioeconomic differences, environmental exposure, and individual motivation, also might contribute importantly to performance outcomes among master runners. In this context, the observed nationality-specific patterns likely reflect the interplay of physiological ageing trajectories with broader social, cultural, and environmental determinants of long-term endurance participation[47,48].

These findings emphasize the importance of performance stratification in endurance sports research. Aggregated analyses that include all finishers may obscure meaningful patterns that are only apparent in elite or semi-elite populations. The stronger predictive value of demographic variables in these high-performing subgroups may reflect the alignment of athlete characteristics with national training systems, genetic predispositions, and access to elite-level coaching and competition[49].

Strengths and limitations

This study provides a robust dataset and applies a multi-layered analytical framework to dissect global performance trends. By including both average and best times as well as national representation across several performance strata, it provides a detailed picture of how age, sex and nationality intersect in marathon running. However, some limitations should be acknowledged. The analysis was limited to publicly available data, which did not include training history, socioeconomic status, altitude of residence or race-day conditions—factors that can significantly affect performance. Public datasets might overrepresent certain regions due to the availability of online results or underreport finishers with incomplete data. The categorical treatment of nationality also fails to account for within-country variability or cases of athlete migration and naturalization. Although the dataset included runners' first and last names, gender, and a runner ID, these identifiers were not stable or unique across years and therefore did not allow reliable tracking of individuals over time. As a result, each finisher–year record was treated as an independent observation, which precluded the application of multilevel or repeated-measures models. Finally, while restricting the regression models to the top 100 finishers improves model fit, it reduces the generalizability of the findings to the broader marathon population. Future research directions could include physiological and psychosocial aspects[50,51]. Cross-marathon comparisons (e.g., Boston, Berlin) should also be considered. Future areas could include cross-marathon comparisons, detailed longitudinal training data or examining factors behind the success of specific countries in older age groups.

Conclusions

In summary, the fastest average finishing times in the younger age categories (20–39 years) were predominantly achieved by both female and male runners from Kenya and Ethiopia. In contrast, the under-20 age category was marked by stronger performances by European runners, particularly from Poland, Switzerland and Italy. Among master athletes in the 50 + age groups, the best average times were increasingly achieved by runners from the United States, Japan, Germany and Switzerland. These results highlight a geographical transition in peak marathon performance with increasing age—from the dominance of East Africa in younger groups to the dominance of West and East Asia among older age groups.

Data availability

Athlete data was downloaded from the official New York Road Runners website (https://results.nyrr.org).

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Sasa Duric performed the statistical analyses, Beat Knechtle and Sasa Duric and drafted the manuscript, Elias Villiger obtained the data, Marilia Santos Andrade, Luciano Bernardes Leite, Pedro Forte, Daniela Chlíbková, Pantelis T. Nikolaidis, Katja Weiss, and Thomas Rosemann helped in drafting the manuscript.

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Competing interests
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Consent for publication
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Additional information

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