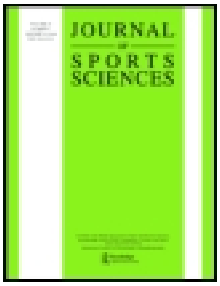

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Participation and performance trends in 100-km ultra-marathons worldwide

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Abstract

The aims of the present study were to (1) investigate the participation trends for the origin of athletes competing in 100-km ultra-marathons and (2) determine the nationalities of athletes achieving the fastest 100-km race times worldwide. Race times and nationality from 112,283 athletes (15,204 women and 97,079 men) from 102 countries who completed a 100-km ultra-marathon worldwide between 1998 and 2011 were investigated using single- and multi-level regression analyses. The number of finishers increased exponentially, both for women and men. Most of the finishers (73.5%) were from Europe, in particular, France (30.4%). The number of finishers from Japan, Germany, Italy, Poland and the United States of America increased exponentially during the studied period. For women, runners from Canada became slower while those from Italy became faster over time. For men, runners from Belgium, Canada and Japan became slower. Between 1998 and 2011, the ten best race times were achieved by Japanese runners for both women with 457.1 (s = 28.8) min and men with 393.4 (s = 9.6) min. To summarise, most of the finishers in 100-km ultra-marathons originated from Europe, but the best performances belong to Japanese runners. Although East African runners dominate running up to a marathon, Japanese were the best in 100 km.

Keywords: *ultra-running, nationality, performance*

Introduction

In the last 20 years, the popularity of ultra-marathon running races worldwide has increased (Eichenberger, Knechtle, Rüst, Rosemann, & Lepers, 2012; Knechtle, Rüst, Rosemann, & Lepers, 2012; Knoth, Knechtle, Rüst, Rosemann, & Lepers, 2012). In recent years, there has been an increased interest in investigating participation and performance trends in ultra-endurance events, mainly in ultra-running (Abou Shoak, Knechtle, Rüst, Lepers, & Rosemann, 2013; Knechtle et al., 2012; Knoth et al., 2012). For example, participation and performance trends have previously been analysed for 161-km ultra-marathons in North America (Hoffman, 2010; Hoffman, Ong, & Wang, 2010; Hoffman & Wegelin, 2009) where Hoffman et al. (2010) reported an exponential increase in the annual number of finishers in 161-km ultra-marathons during the last three decades.

Even though the participation in 161-km ultra-marathons increased, the number of athletes competing in running endurance-races in this distance remained low (Hoffman et al., 2010) compared with running races of shorter distances such as a marathon (Lepers & Cattagni, 2012). This growth in the number of finishers was mainly ascribed to an increase in the participation of runners over 40 years of age and increased participation by women (Hoffman et al., 2010). In 161-km ultra-marathons, the participation rate of women steadily increased from virtually none in the late 1970s to nearly 20%, where it has remained since 2004 (Hoffman et al., 2010). Similarly, Eichenberger et al. (2012) reported that the percentage of female finishers in the 78-km mountain ultra-marathon the "Swiss Alpine Marathon" increased to 16% in 2011. Previous studies demonstrated that 70–80% of the overall finishers in 100-km and 161-km ultra-marathons were middle-aged and older ("masters") athletes

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(Hoffman & Wegelin, 2009; Hoffman et al., 2010; Knechtle et al., 2012). For 100-km ultra-marathons, the percentage of finishers increased for the age groups 40–49 and 50–59 years, for both women and men (Knechtle et al., 2012).

Correlations between physiological characteristics (Landman, Landman, & Fatehi, 2012; Larsen, 2003; Saltin et al., 1995; Saunders, Pyne, Telford, & Hawley, 2004), psychological aspects (Baker & Horton, 2003; Iso-Ahola, 1995), anthropometric characteristics (Knechtle, Duff, Welzel, & Kohler, 2009; Knechtle, Knechtle, Barandun, & Rosemann, 2011; Knechtle, Knechtle, & Rosemann, 2010; Knechtle, Knechtle, Rosemann, & Lepers, 2010; Knechtle, Knechtle, Schulze, & Kohler, 2008), training variables (Billat, Demarle, Slawinski, Paiva, & Koralsztein, 2001; Knechtle et al., 2010; Knechtle, Wirth, Knechtle, & Rosemann, 2010) and the success in running distances up to marathons and ultra-marathons have been investigated. Other factors such as ethnicity and nationality could also influence endurance performance such as marathon running (Hamilton, 2000; Larsen, 2003; Onywera, 2009; Onywera, Scott, Boit, & Pitsiladis, 2006; Scott & Pitsiladis, 2007; Scott et al., 2003; Wilber & Pitsiladis, 2012). Since the 1968 Mexico City Olympics, Kenyan and Ethiopian runners have dominated the international middle- and long-distance running (Wilber & Pitsiladis, 2012). Furthermore, Kenyan athletes have been pre-eminent in the International Association of Athletics Federation's (IAAF) World Cross-Country Championships, road-racing circuit and marathons (Larsen, 2003; Onywera et al., 2006; Wilber & Pitsiladis, 2012).

Data on the nationality of ultra-marathoners are scarce (Abou Shoak et al., 2013; Knoth et al., 2012). No study has investigated participation trends for 100-km ultra-marathons worldwide. Analyses of the historical development of participation according to the sex of runners, geography and nationality trends in ultra-triathlons have occurred (Jeffery et al., 2012; Lepers, Knechtle, Knechtle, & Rosemann, 2011; Rüst, Knechtle, Knechtle, Rosemann, & Lepers, 2012). For ultra-triathlons held worldwide, Lenherr, Knechtle, Rüst, Rosemann and Lepers (2012) investigated countries in which ultra-triathlons were held, and nationalities that had the most triathletes competing in these races. They demonstrated that most of the ultra-triathlons (56.7%) had been held in Europe and participation was dominated by European athletes. For Double Iron ultra-triathlon, the number of races in Europe increased since 1989 in contrast to the USA, where the first Double Iron ultra-triathlon in 1985 was launched, but only one such race has been held (Rüst, Knechtle, Knechtle, Lepers, et al., 2012; Sigg et al., 2012). African and Australian athletes were in the minority of ultra-triathletes, indicating that participation of these athletes is irregular (Lenherr et al., 2012).

These findings emphasise the importance of factors such as origin and geography in other endurance sports disciplines such as long-distance running. For runners, the majority of the most successful Kenyan runners originated from Rift Valley province and belonged to the Kalenjin ethnic group. Kenyan runners, particularly the international athletes, originate from a distinctive environmental background in terms of geographical distribution and ethnicity (Onywera et al., 2006). Living and training in the highlands of the Great Rift Valley partly contributes to the excellent performance in distance running because of chronic exposure to hypoxic conditions (Schmidt et al., 2002; Wilber & Pitsiladis, 2012). Additionally, athletes had to travel far to school when they were children, commonly by running. Kenyan success in distance running is also based on their specific body composition, because their long and slender legs might lead to advantages in biomechanical and metabolic effectiveness (Larsen, Christensen, Nolan, & Sndergaard, 2004; Wilber & Pitsiladis, 2012). Furthermore, international Kenyan runners stated economic reasons to become a competitive athlete, as success in distance running enables them to advance to the top ranks in their society (Onywera et al., 2006).

Considering ultra-marathon distances, of note is the Japanese dominance in ultra-marathon running. For the world best list in 100-km events, Japanese runners hold the current world record of 6 h 13 min 33 s for men (http://www.iaaf.org/records/toplists/road-running/100-kilometres/outdoor/men/senior) and 6 h 33 min 11 s for women (http://www.iaaf.org/records/toplists/road-running/100-kilometres/outdoor/women/senior). In men, three of the top ten race times were achieved by Japanese runners. In women, five of the top ten race times were obtained by athletes originating from Japan. Japanese runners seemed also to dominate running distances longer than 100-km ultra-marathons. In the 246-km ultra-marathon "Spartathlon", the greatest number of finishers between 2000 and 2012 were from Japan for both women and men. In the "Spartathlon", Japanese women achieved the fastest race times while Japanese men were second behind athletes from Greece (Knechtle, Rüst, & Rosemann, 2013).

These findings highlight the importance of environmental, geographical and national aspects in endurance and ultra-endurance running. Thus, it would be informative to analyse the worldwide participation and performance trends in 100-km ultra-marathons. In the present study, we focus on the development of participation in 100-km ultra-marathon races held worldwide across the time period of 1998 through 2011, with special emphasis on the nationality of the finishers. The aim of the study was to investigate worldwide changes in runner demographics of both women and men in 100-km races. We hypothesised first an increase in participation in 100-km ultra-marathons across years, and second, that Japanese athletes would dominate 100-km running races even though Kenyans dominate Olympic long-distance track events and marathons.

Materials and methods

The present study was approved by the Institutional Review Board of St. Gallen, Switzerland.

Data sampling and data analysis

The data for this study were obtained from the race websites "Deutsche Ultramarathon-Vereinigung" (http://www.ultra-marathon.org), "United Nations Statistic Division" (http://unstats.un.org) and "The World Bank" (http://data.worldbank.org).

All athletes who participated in a 100-km ultra-marathon worldwide between 1998 and 2011 were analysed for the association between demography and performance. 1998 was the year when electronic registration of race results started and paper results were not available from all races held before this date. Data before 1998 were incomplete because for the earlier years, rankings from 100-km ultra-marathon races were not gapless and for some races, were not available. We therefore decided to analyse only athletes who participated from 1998.

Among the distribution of the number of participants, we investigated changes in the number of finishers coming from specific regions. Because of the large number of countries from which athletes originated, we decided to restrict to the ten countries with the total highest number of finishers. Changes in the number of finishers and of the annual ten best running times in women and men originating from different countries were investigated for the ten countries with the total highest number of finishers. These were France, Japan, Italy, Germany, Switzerland, United States of America, Poland, Canada, Korea and Spain. Finally, we analysed for these ten countries the coherence of development in population, income per head and the number of finishers.

Statistical analysis

Data in the text and figures are presented as mean ± standard deviation (s). To increase the reliability of data analyses, each set of data was tested for normal distribution (D'Agostino and Pearson omnibus normality test) and for homogeneity of variances (Levene's test) before statistical analyses. Trends in participation were analysed using regression with linear and exponential growth equation models. For each set of data (*e.g.* each age group), both models were compared using Akaike's Information Criteria (AICc) to determine the model that had the highest probability of correctness. Single- and multi-level regression analyses investigated changes in performance of the finishers. A hierarchical regression model avoided the impact of a cluster-effect on results where a particular athlete from a specific country finished more than once for the analysis of the annual top athlete per country. Regression analyses of performance were corrected for age of athletes to prevent a misinterpretation of the "age-effect" as a "time-effect" since age is an important predictor variable for 100-km race times (Knechtle et al., 2010). To find differences between inclusion and exclusion of athletes with multiple finishes in the ten countries with the highest number of finishes, the two conditions (with and without multiple finishes) were compared using a two-way analysis of variance (ANOVA) with subsequent Sidak's multiple comparison test for the complete set of athletes from ten countries, divided by sex, where men and women were analysed separately. Statistical analyses were performed using IBMSPSS Statistics (Versions 21, IBMSPSS, Chicago, IL, USA) and GraphPad Prism (Versions 6.01, GraphPad Software, La Jolla, CA, USA). Significance was accepted at $P < 0.05$ (two-sided for t-tests). Effect size was calculated using Cohen's f^2 for hierarchical multiple regression and was defined as small for $f^2 = 0.02$, medium for $f^2 = 0.15$ and large for $f^2 = 0.35$.

Results

Participation trends

From 1998 to 2011, a total of 112,283 athletes (15,204 women and 97,079 men) finished a 100-km ultra-marathon worldwide. The annual number of finishers increased exponentially across years for both women and men (Figure 1). The percentage of women remained unchanged across years at 15.3% ($s = 1.3$) of the total field per year.

Most of the finishers originated from Europe (Figure 2), followed by athletes from Asia and North America. European finishers accounted for 73.5% of the overall field (Table I). When the athletes were sorted by the country of origin, most of the finishers originated from France, followed by athletes from Japan and Italy (Figure 3). French runners accounted for 30.4% of the overall field (Table II).

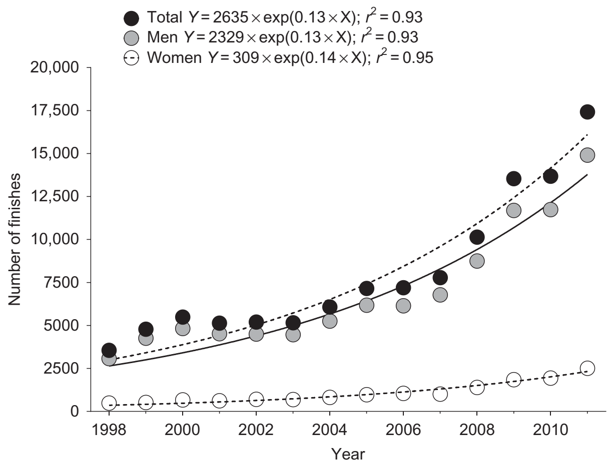

Figure 1. Annual number of female, male and overall finishers.

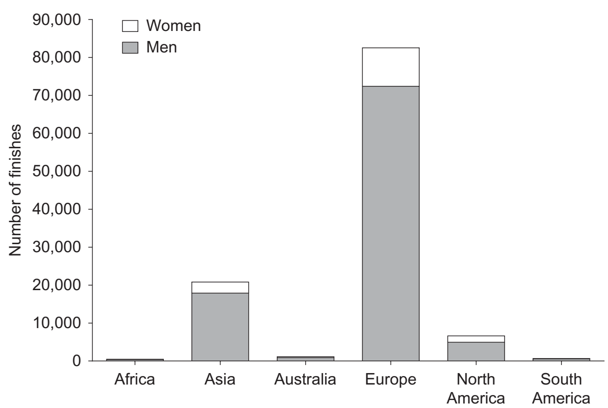

Figure 2. Number of female and male finishers considering the continent where the race was held. The continents are sorted by alphabetical order from left to right.

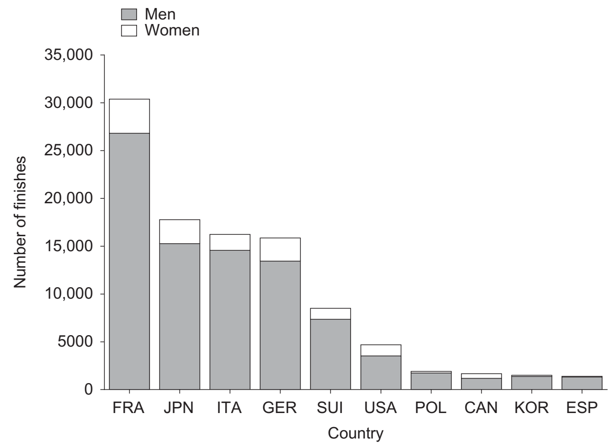

Figure 3. Number of female and male finishers considering the country where the race was held. The ten countries with the highest number of finishers were considered and sorted from left to right.

Note: FRA = France, JPN = Japan, ITA = Italy, GER = Germany, SUI = Switzerland, USA = United States of America, POL = Poland, CAN = Canada, KOR = Korea, ESP = Spain.

Figure 4 presents the change in the number of finishers across years, considering the continent of origin. The number of finishers increased exponentially for women (Panel A) and men (Panel B), with the exception of South African women and North American men where the increase was linear. For African runners, the number of finishers did not increase.

Figure 5 presents changes in the number of finishers for the country of origin. The number of female finishers from Japan, Germany, Italy, Poland and the United States of America increased exponentially. For the other countries, the number of finishers increased linearly, with the exception of Swiss women, where the number remained unchanged across years (Panel A). For men (Panel B), the number of finishers increased exponentially in athletes originating from Japan, Germany, Italy, Poland and the United States of America. For the other countries, the number of finishers increased linearly with the exception of Swiss men with an exponential decrease in finishers.

Performance trends

Figure 6 shows the changes in race time for women (Panel A) and men (Panel B) originating from the ten countries with the highest numbers of finishers. For women, runners from Canada became slower (Cohen's f^2 = 0.25) and runners from Italy became faster (Cohen's f^2 = 0.15) when controlled for multiple participation and age of the athletes (Table III). For athletes of other countries, race times remained unchanged. For men, athletes from Belgium (Cohen's f^2 = 0.26), Canada (Cohen's f^2 = 0.18) and Japan (Cohen's f^2 = 0.35) slowed also when

Table I. Number of finishers by continent of origin of the athlete.

Continent	Women	Men	Overall	Percent of all runners%
Europe	10,129	72,426	82,555	73.5
Asia	2912	17,903	20,815	18.5
North America	1687	4936	6623	5.9
Australia	268	871	1139	1.0
South America	91	569	660	0.6
Africa	117	357	474	0.4

Table II. Number of finishers by country of origin of the athlete.

Country	Women	Men	Overall	Percent of all runners%
France	3573	26,817	30,390	30.4
Japan	2502	15,276	17,778	17.8
Italy	1674	14,565	16,239	16.3
Germany	2414	13,446	15,860	15.9
Switzerland	1139	7360	8499	8.5
United States of America	1164	3523	4687	4.7
Poland	167	1737	1904	1.9
Canada	483	1175	1658	1.6
Korea	120	1376	1496	1.5
Spain	67	1320	1387	1.4

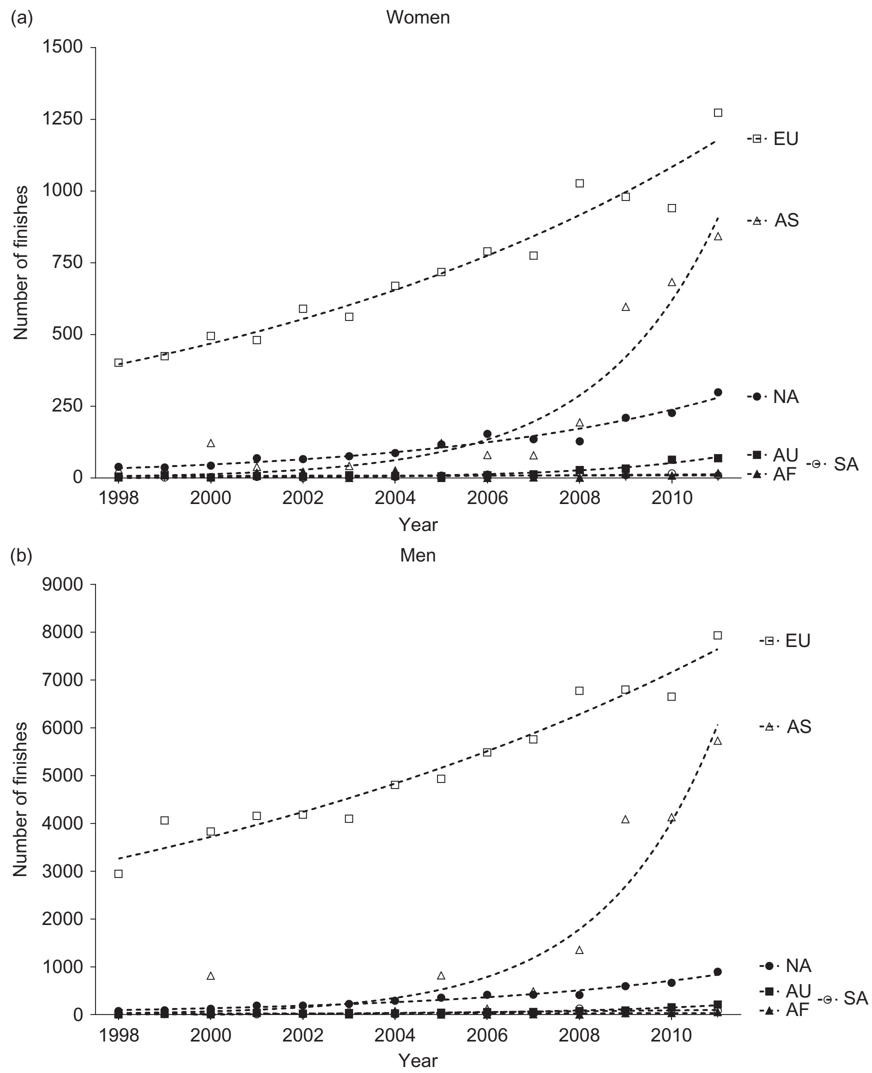

Figure 4. Change in the number of female (Panel A) and male (Panel B) runners across years considering the continent where the race was held.

Note: AF = Africa, AS = Asia, AU = Australia, EU = Europe, NA = North America, SA = South America.

controlled for multiple participation and age of the athletes (Table IV). For athletes of other countries, race times remained unchanged.

Figure 7 presents the race times of the ten fastest women (Panel A) and men (Panel B) sorted by country in alphabetical order. We distinguished

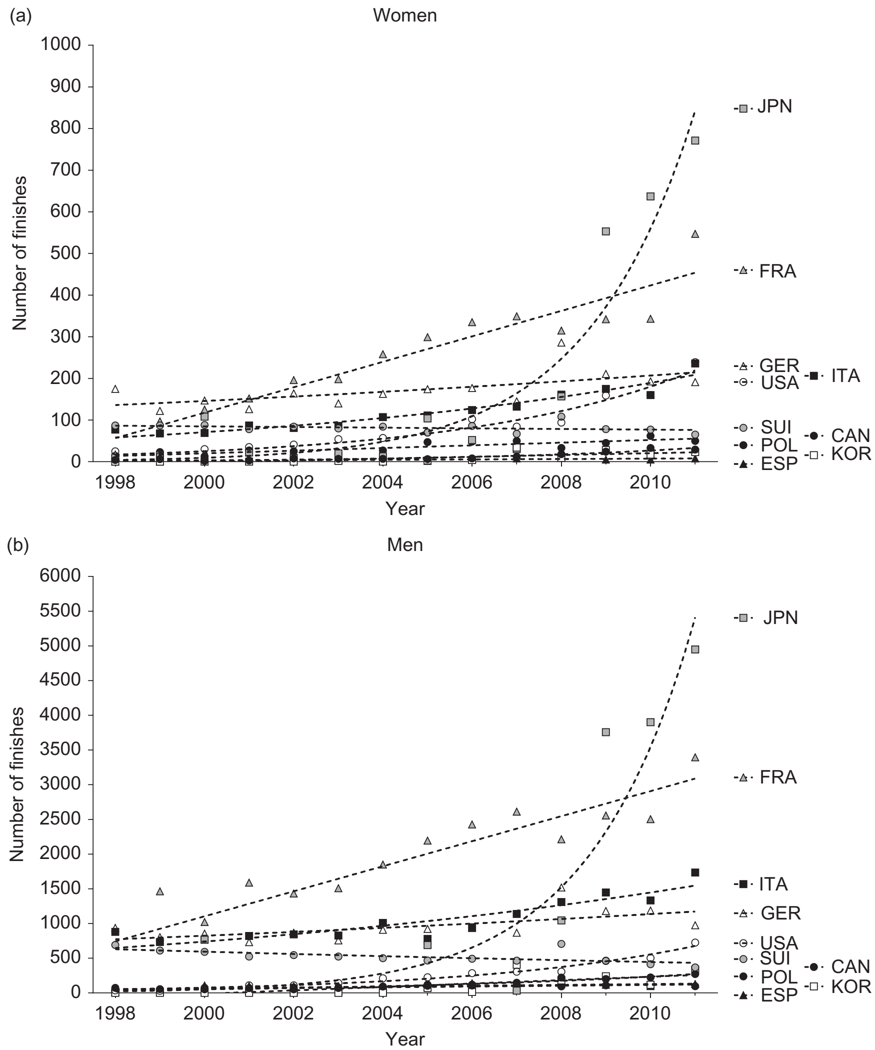

Figure 5. Change in the number of female (Panel A) and male (Panel B) runners across years considering the country where the race was held. The ten countries with the highest number of finishers were considered.

Note: CAN = Canada, ESP = Spain, FRA = France, GER = Germany, ITA = Italy, JPN = Japan, KOR = Korea, POL = Poland, SUI = Switzerland, USA = United States of America.

between the ten fastest race times with and without multiple finishes. Japanese women and men achieved the fastest race times when athletes with multiple finishes among the first ten were considered (Table V), with the exclusion of multiple finishes of one athlete within the first ten (Table VI).

Discussion

This study is the first study to describe the development of participation for the nationality of finishers in 100-km ultra-marathon races held worldwide across the time period of 1998 through 2011. In accordance with our hypotheses, we found an increase in finishers over time and the fastest race times for Japanese athletes in 100-km running performance.

A rising number of 100-km finishers worldwide

An important finding was the exponential increase of the total number of finishers across the years. Moreover, this growth was mainly ascribed to athletes originating from Japan, Germany, Italy, Poland and the United States of America. It seems likely that ultra-marathons have become the extreme challenge for an increasing number of athletes, whereas marathon symbolises a trial for many participants (Hoffman et al., 2010). A 100-km ultra-marathon can be considered another milestone in gaining experience for athletes aiming to compete in ultra-marathon over longer distances of several hundreds of kilometres (Knechtle et al., 2010).

Even though there has been a noticeable increase in the participation in 100-km ultra-marathons, these races keep attracting a small number of athletes

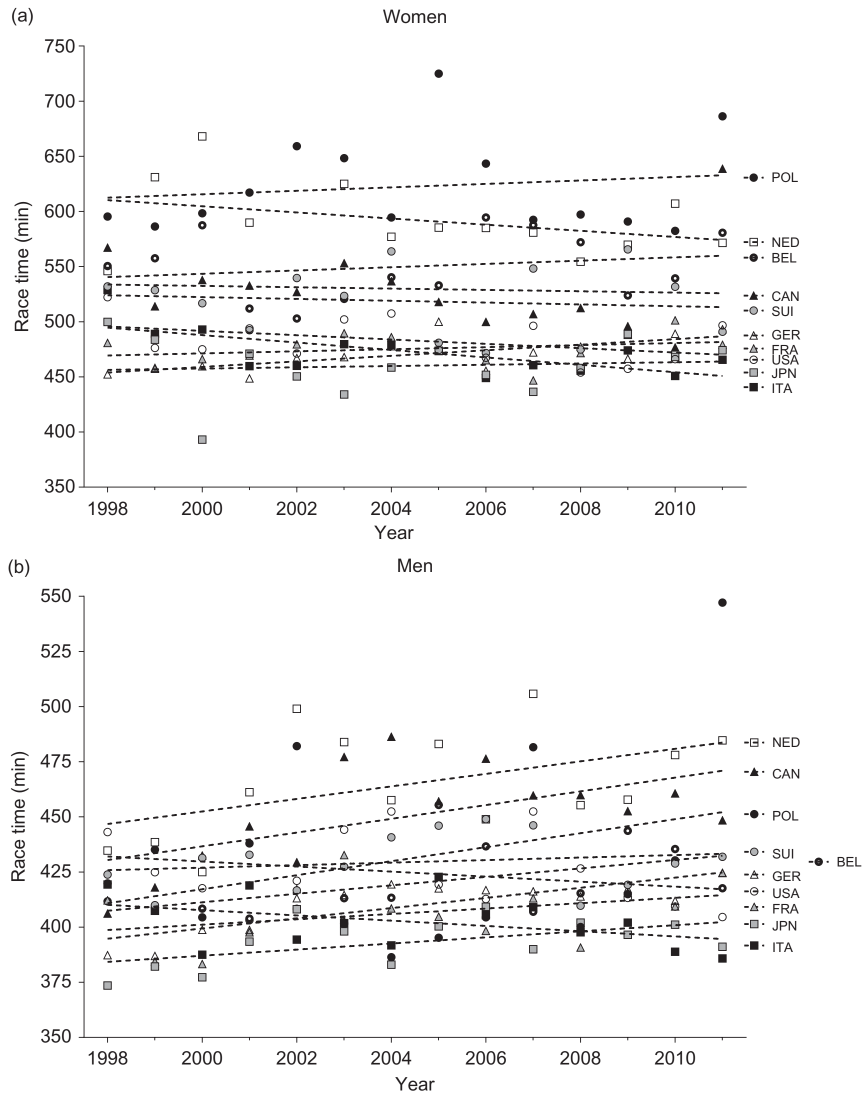

Figure 6. Change in race time of the annual ten fastest women (Panel A) and men (Panel B) considering the nationality of the athlete.
Note: BEL = Belgium, CAN = Canada, ESP = Spain, FRA = France, GER = Germany, ITA = Italy, JPN = Japan, POL = Poland, SUI = Switzerland, USA = United States of America.

compared with shorter distances such as marathons (Lepers & Cattagni, 2012). Previous work demonstrated that master athletes (>40 years old) accounted for an increased participation in ultra-marathons (Hoffman, 2010; Hoffman & Wegelin, 2009; Hoffman et al., 2010; Knechtle et al., 2012). A possible explanation for the increase in 100-km finishers of older age groups is the general rise in age both in developed and developing countries (Northridge, 2012).

Europe presents the highest number of finishers in 100-km ultra-marathons

A further important finding was that Europe had the greatest number of finishers. In particular, France had the largest number of runners during the 14-year period. The greater participation of these athletes is probably attributable to the popularity of ultra-marathons in Europe compared with other continents. However, the number of finishers from Asia also increased exponentially; Asian athletes were second behind European athletes in terms of participation.

Correlation analyses were performed to investigate associations between the increase of finishers and the change in the general population of the specific country. Table VII presents the association of the total number of finishers with the general population of the ten countries with the overall highest number of finishers and the mean income per person. The increase in the number of athletes originating from France, Italy, United States of America, Switzerland, Belgium, Netherlands and Canada was significantly

Table III. Multi-level regression analyses for change in performance across years for women (model 1) with correction for multiple participations (model 2) and age of athletes with multiple participations (model 3). Countries are presented in alphabetical order.

Model	β	SE (β)	Stand. β	T	*P*
			Belgium		
1	1.489	2.052	0.205	0.726	0.482
2	1.489	2.052	0.205	0.726	0.482
3	3.475	2.646	0.479	1.314	0.216
			Canada		
1	2.524	0.796	0.675	3.169	0.008
2	2.524	0.796	0.675	3.169	0.008
3	3.036	0.721	0.812	4.213	0.001
			France		
1	0.943	0.936	0.279	1.007	0.334
2	0.943	0.936	0.279	1.007	0.334
3	1.999	1.538	0.592	1.300	0.220
			Germany		
1	−0.609	2.701	−0.065	−0.225	0.825
2	−0.609	2.701	−0.065	−0.225	0.825
3	−0.022	2.665	−0.002	−0.008	0.994
			Italy		
1	−3.372	1.078	−0.670	−3.129	0.009
2	−3.372	1.078	−0.670	−3.129	0.009
3	−4.183	0.980	−0.831	−4.270	0.001
			Japan		
1	0.577	1.849	0.090	0.312	0.761
2	0.577	1.849	0.090	0.312	0.761
3	0.876	2.149	0.138	0.408	0.692
			Netherland		
1	−2.786	2.206	−0.356	−1.263	0.233
2	−2.786	2.206	−0.356	−1.263	0.233
3	−2.768	2.306	−0.354	−1.200	0.258
			Poland		
1	1.564	2.968	0.150	0.527	0.608
2	1.564	2.968	0.150	0.527	0.608
3	7.199	2.912	0.692	2.472	0.031
			Switzerland		
1	−0.830	2.173	−0.110	−0.382	0.709
2	−0.830	2.173	−0.110	−0.382	0.709
3	−0.941	1.834	−0.124	−0.513	0.618
			United States of America		
1	−1.968	1.279	−0.406	−1.539	0.150
2	−1.968	1.279	−0.406	−1.539	0.150
3	−0.554	1.365	−0.114	−0.406	0.693

Table IV. Multi-level regression analyses for change in performance across years for men (model 1) with correction for multiple participations (model 2) and age of athletes with multiple participations (model 3). Countries are presented in alphabetical order.

Model	β	SE (β)	Stand. β	T	*P*
			Belgium		
1	1.919	0.957	0.501	2.005	0.068
2	1.919	0.957	0.501	2.005	0.068
3	2.894	0.891	0.755	3.247	0.008
			Canada		
1	3.119	1.297	0.570	2.405	0.033
2	3.119	1.297	0.570	2.405	0.033
3	3.120	1.354	0.570	2.303	0.042
			France		
1	1.216	0.935	0.352	1.301	0.218
2	1.216	0.935	0.352	1.301	0.218
3	1.102	0.799	0.319	1.379	0.195
			Germany		
1	2.310	0.480	0.812	4.815	<0.0001
2	2.310	0.480	0.812	4.815	<0.0001
3	0.983	0.458	0.345	2.147	0.055
			Italy		
1	−1.194	0.768	−0.409	−1.554	0.146
2	−1.194	0.768	−0.409	−1.554	0.146
3	−0.972	0.934	−0.333	−1.041	0.320
			Japan		
1	1.386	0.650	0.524	2.134	0.054
2	1.386	0.650	0.524	2.134	0.054
3	1.222	0.444	0.462	2.755	0.019
			Netherland		
1	2.842	1.472	0.487	1.930	0.078
2	2.842	1.472	0.487	1.930	0.078
3	2.810	1.525	0.481	1.842	0.093
			Poland		
1	3.177	2.921	0.300	1.087	0.298
2	3.177	2.921	0.300	1.087	0.298
3	2.992	3.330	0.282	0.898	0.388
			Switzerland		
1	0.572	0.874	0.186	0.654	0.525
2	0.572	0.874	0.186	0.654	0.525
3	0.761	0.937	0.247	0.813	0.434
			United States of America		
1	−1.138	1.122	−0.281	−1.014	0.330
2	−1.138	1.122	−0.281	−1.014	0.330
3	−1.391	1.381	−0.343	−1.007	0.335

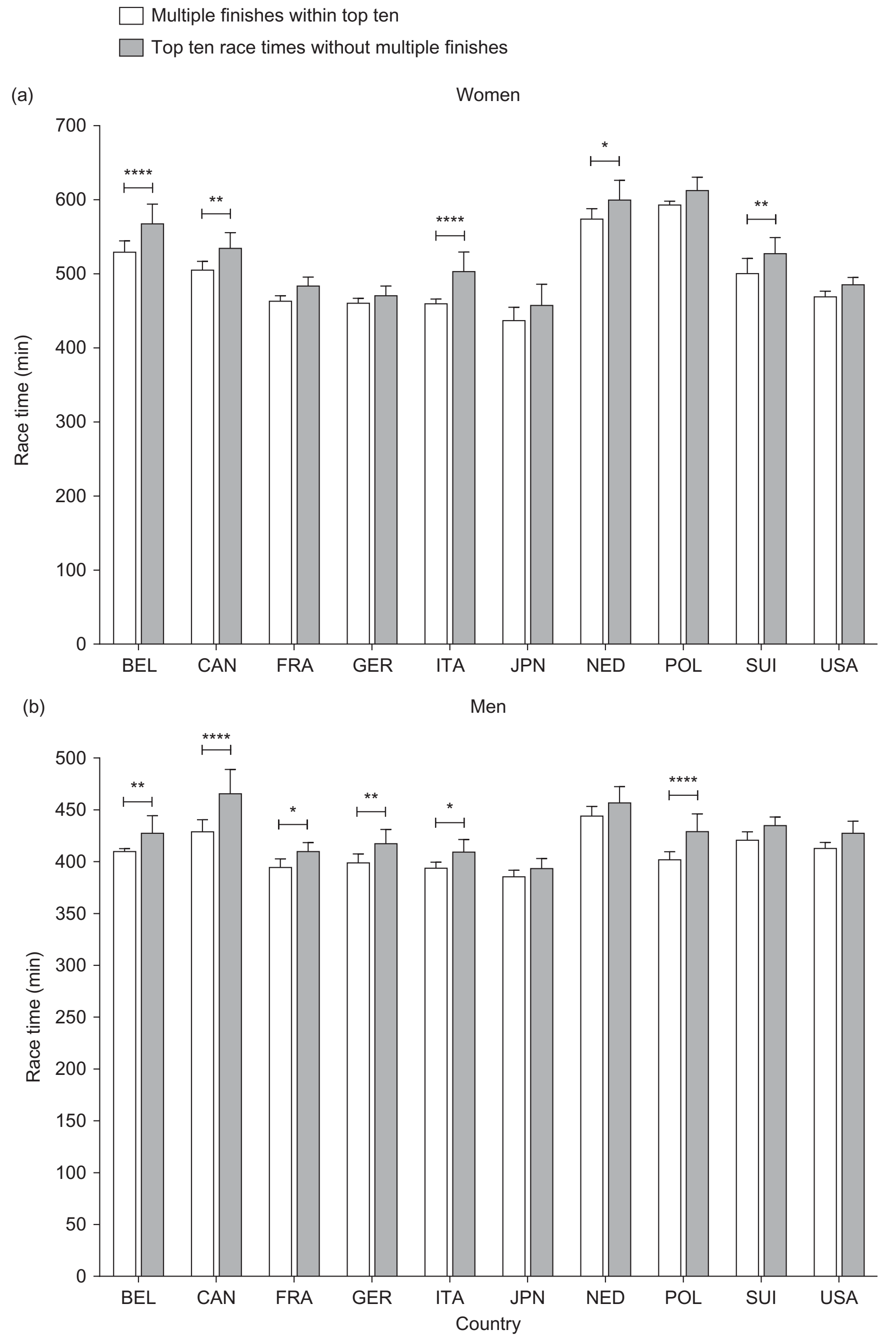

Figure 7. Race time of the ten fastest women (Panel A) and men (Panel B) considering the nationality of the athlete.
Note: * = $P < 0.05$, ** = $P < 0.01$, **** = $P < 0.0001$. BEL = Belgium, CAN = Canada, FRA = France, GER = Germany, ITA = Italy, JPN = Japan, NED = Netherlands, POL = Poland, SUI = Switzerland, USA = United States of America.

related to the change in the general population in their countries.

Apart from the association with increases in general population, we also investigated associations between changes in the number of finishers and changes in mean income in the general population. Hoffman and Fogard (2012) investigated demographic characteristics of 161-km ultra-marathoners and reported that participants in 161-km ultramarathons were mostly middle-aged (>45 years) married men who are well-educated and rarely missed work because of illness or injury and maintained appropriate body mass compared with the general population. The increase in the number of athletes from France, Italy, Japan, United States of America, Switzerland, Belgium, Poland, Netherlands and Canada was associated with the change in mean income per person in their countries. We found a positive correlation between the number of finishers and both the mean income and

Table V. Race times in min ± *s* of the fastest athletes sorted by country with inclusion of athletes with multiple race times within the top ten.

Women		Men	
Japan	436.8 (*s* = 18.1)	Japan	385.4 (*s* = 6.4)
Italy	459.5 (*s* = 6.6)	Italy	393.6 (*s* = 5.9)
Germany	460.3 (*s* = 6.6)	France	394.5 (*s* = 8.2)
France	463.1 (*s* = 7.3)	Germany	398.8 (*s* = 8.7)
USA	468.9 (*s* = 7.8)	Poland	401.8 (*s* = 7.8)
Switzerland	500.4 (*s* = 20.4)	Belgium	409.7 (*s* = 2.9)
Canada	505.1 (*s* = 11.8)	Switzerland	420.7 (*s* = 8.2)
Belgium	529.2 (*s* = 15.4)	USA	412.7 (*s* = 5.8)
Netherlands	574.1 (*s* = 13.9)	Canada	428.8 (*s* = 11.7)
Poland	593.0 (*s* = 5.2)	Netherlands	443.9 (*s* = 9.5)

the change in population in the specific countries. Athletes with a high income are more likely to attend ultra-marathons than athletes from an economically underdeveloped nation such as an African country.

This underlines our finding that a 100-km ultra-marathoner is characterised by an athlete who is a man from an industrialised country such as a European country. Hence, economic reasons don't appear to be a motive to compete in 100-km ultra-marathons for Europeans, but rather social motivations. For master athletes, sport is an opportunity to achieve social recognition and to have social interaction. They enjoy their participation, are committed and self-determined (Hodge, Allen, & Smellie, 2008).

Apart from demographic aspects, motivation might also act as an important contributing factor to the participation of athletes. Individual sport participants such as runners have a high interest/enjoyment motivation and they seem to focus on the challenge itself as a purpose for participation (Frederick & Ryan, 1993). However, especially the main reasons for the involvement of master athletes might be the key. In the "100 km Lauf Biel" held in Switzerland from 1998 to 2010, the age group 40–49 years registered the greatest number of finishers for

Table VI. Race times in min ± *s* of the fastest athletes sorted by country without multiple athletes with multiple race times within the top ten.

Women		Men	
Japan	457.2 (*s* = 28.8)	Japan	393.4 (*s* = 9.6)
Germany	470.5 (*s* = 12.9)	Italy	409.3 (*s* = 12.1)
France	483.4 (*s* = 12.3)	France	409.8 (*s* = 8.6)
USA	485.1 (*s* = 10.1)	Germany	417.4 (*s* = 13.6)
Italy	503.1 (*s* = 26.3)	Belgium	427.3 (*s* = 16.9)
Switzerland	527.3 (*s* = 21.7)	USA	427.4 (*s* = 11.6)
Canada	534.3 (*s* = 21.3)	Poland	429.0 (*s* = 17.1)
Belgium	567.4 (*s* = 26.8)	Switzerland	434.8 (*s* = 8.2)
Netherlands	599.6 (*s* = 26.7)	Netherlands	456.6 (*s* = 15.8)
Poland	612.4 (*s* = 18.1)	Canada	465.6 (*s* = 23.3)

Table VII. Relationship of the total number of finishers with population and the association of the total number of finishers with mean income per person of the ten countries with the highest number of finishers. The countries are sorted by the number of finishers in 2011.

	Finishers				Population (in 1000)				Income per person (in US$)				Finishers/population		Finishers/income	
	1998	2011	r^2	*P*	1998	2011	r^2	*P*	1998	2011	r^2	*P*	*r*	*P*	*r*	*P*
FRA	199	6183	0.51	<0.01	58,398	63,126	1.00	<0.01	22,860	35,860	0.97	<0.01	0.74	<0.01	0.74	<0.01
ITA	2836	4696	0.72	<0.01	56,907	60,789	0.96	<0.01	23,660	32,350	0.92	<0.01	0.87	<0.01	0.79	<0.01
JPN	22	2605	0.51	<0.01	126,400	127,817	0.59	<0.01	24,690	35,510	0.95	<0.01	0.48	>0.05	0.82	<0.01
GER	1992	1446	0.04	>0.05	82,029	82,163	0.09	>0.05	23,910	40,170	0.97	<0.01	–0.54	0.05	0.29	>0.05
USA	246	1419	0.92	<0.01	275,854	313,085	1.00	<0.01	32,060	48,890	0.95	<0.01	0.96	<0.01	0.90	<0.01
SUI	787	454	0.56	<0.01	7110	7702	0.97	<0.01	31,220	50,900	0.96	<0.01	–0.70	<0.01	–0.75	<0.01
BEL	75	339	0.40	0.02	10,203	10,951	0.96	<0.01	24,820	39,300	0.98	<0.01	0.55	0.04	0.66	0.01
POL	137	317	0.63	<0.01	38,283	38,204	0.56	<0.01	9310	20,450	0.97	<0.01	–0.42	>0.05	0.85	<0.01
NED	208	227	0.34	0.03	15,707	16,656	0.97	<0.01	25,220	43,770	0.95	<0.01	0.56	0.04	0.65	0.01
CAN	43	189	0.67	<0.01	30,155	24,483	1.00	<0.01	24,630	39,830	0.96	<0.01	0.80	<0.01	0.85	<0.01

Note: FRA = France, ITA = Italy, JPN = Japan, GER = Germany, USA = United States of America, SUI = Switzerland, BEL = Belgium, POL = Poland, NED = Netherlands, CAN = Canada.

both women and men (Knechtle et al., 2012). Factors such as pleasure, health and fitness benefits, social affiliation and competition seemed the primary motivations of master athletes (Shaw & Ostrow, 2005).

Low attendance of 100-km ultra-marathons in Africa

Surprisingly, there was no increase in the number of finishers for Africa, contrary to the finishers of the other continents. Africa counted the lowest number of finishers with 0.4% of all finishers. A reason for these findings might be that 100-km races don't appeal to Kenyan runners. Financial and other benefits afforded to marathon runners could encourage Kenyan runners to participate in marathons (Onywera et al., 2006) rather in ultra-marathons. Concerning the motivation of Kenyan national (39%) and international (34%) athletes to become a competitive athlete, both groups declared economic empowerment as their primary driver. The estimated unemployment rate in Kenya is 40%. Kenyan athletes see athletics as a means to help their families, parents and friends from the financial rewards that accrue (Onywera et al., 2006). Thus, Kenyan runners might not see ultra-marathons as attractive because of the lack of career options these vents present. For example, the winner's prize money for IAAF World Championships 2011 for marathon was US$ 60,000 (http://daegu2011.iaaf.org) whereas the winner of the IAU World Championships 2011 for 100-km ultra-marathon received only a finisher's medal (http://www.runwinschoten.nl) and generally a podium rank prize amounts to US$ 300 (http://www.ultra-marathon.org). These findings point out that it is impossible for an athlete to make money when competing in a 100-km ultra-marathons and is not a sustainable career option. It becomes obvious that athletes from an economically underdeveloped nation are not tempted to participate in ultra-marathons with the intention to earn money.

Japanese finishers in 100-km ultra-marathons

A further important finding was that Japanese runners were 17.8% of overall finishers, the second highest percentage of total finishers, even though they achieved the fastest running times in both women and men. A potential explanation for the finding that Japanese runners were not representing the highest number of athletes could be that Japanese citizens have little leisure time. The national statistics showed that more than six million people in Japan worked for 60 h or more per week during 2000 and 2004 (Iwasaki, Takahashi, & Nakata, 2006). Despite a reduction in the number of work hours for Japanese employees since the late 1980s, work hours remain higher than those in most European countries (Iwasaki et al., 2006).

We also need to consider that most races were held in Europe where 100-km ultra-marathon running seemed to be more popular than in Asia. Therefore, athletes from Japan would need to travel to Europe to attend the larger events and bear the costs of several thousand US Dollars to cover travel, accommodation (www.priceline.com) and ~80–150 US$ entry fee costs (www.ultra-marathon.org). Because of these costs and the low prize money, Japanese might be less attracted and interested to participate in 100-km ultra-marathons outside Japan. Remarkably, 100-km ultra-marathon running seemed to be on the rise in Asia and has become increasingly popular. The annual number of Asian and especially Japanese finishers increased exponentially across the investigated time period. This growth reflected an increased interest in 100-km ultra-marathons by the participating athletes.

The fastest 100-km runners worldwide

Our last important finding was that Japanese runners achieved the fastest running times for both women and men in 100-km ultra-marathons held between 1998 and 2011, even though running times of Japanese men increased during the last 14 years. Surprisingly, Japanese women and men were faster than East African runners, who are known as the best distance runners, and faster than the European athletes, representing the majority of finishers in 100-km ultra-marathons.

It is difficult to explain why Japanese women and men were the fastest 100-km ultra-marathoners worldwide, although the number of Japanese finishers was second behind French finishers. One explanation could be that Japanese ultra-marathoners were more competitive runners whereas European ultra-marathoners were more recreational runners. It is also possible that Japanese might have an advantageous genetic endowment that would be associated with an endurance effect. Previous studies demonstrated a considerable genetic influence on elite athletic performance for Japanese (Yang et al., 2003). Further, Japanese runners might be influenced by favourable factors that contribute to their success in ultra-marathons such as environmental conditions (Saltin, 1996; Scott et al., 2003), along with cultural (Scott et al., 2003) and motivational (Onywera et al., 2006; Scott et al., 2003) aspects and unique dietary intake as has been shown for East African runners (Onywera, Kiplamai, Boit, & Pitsiladis, 2004).

One might assume that Japanese runners achieved their best performances in races held in Japan. Although the world records for both women and men were achieved at the 100-km race in Lake Saroma, the second fastest time of a Japanese athlete (6 h 17 min 17 s) was achieved in Belves, France (http://www.iaaf.org/records/toplists/road-running/100-kilometres/outdoor/men/senior). For Japanese women, the second fastest time of 7 h 0 min 27 s was achieved in Winschoten, Netherlands (http://www.iaaf.org/records/toplists/road-running/100-kilometres/outdoor/women/senior). Therefore, Japanese 100-km ultra-marathoners ran fast 100-km races outside Japan.

Limitations and implications for future research

A limitation in this cross-sectional study is that influences on endurance performance such as physiological (Landman et al., 2012; Saltin et al., 1995; Saunders et al., 2004) and anthropometric characteristics (Knechtle et al., 2008, 2009, 2011; Knechtleet al., 2010), training variables (Billat et al., 2001; Knechtle et al., 2010; Knechtle, Wirth, et al., 2010), fluid and food intake (Bürge et al., 2011; Cejka, Knechtle, Knechtle, Rüst, & Rosemann, 2012; Fallon, Broad, Thompson, & Reull, 1998; Onywera et al., 2004), medical problems (Scheer & Murray, 2011) and environmental conditions of the race (El Helou et al., 2012; Ely, Cheuvront, Roberts, & Montain, 2007; Marr & Ely, 2010; Vihma, 2010) were not taken into consideration. However, this study reveals valuable data, because it provides insight into the development of participation and performance in 100-km ultra-marathon worldwide.

Conclusions

The number of finishers in 100-km ultra-marathons increased exponentially worldwide over the past 14 years. This growth was mainly for athletes originating from Japan, Germany, Italy, Poland and the United States of America. The continent with the highest number of finishers was Europe, with athletes from France showing the highest number of finishers. Japanese women and men achieved the fastest race times also when controlled for multiple finishes within the top ten ever. The reasons for the Japanese dominance in 100-km ultra-marathons are not clear. The associations of different characteristic in physiological and socioeconomic factors, with the success of the Japanese ultra-marathon runners require further investigations. Additional future studies should investigate the motivation of Japanese ultra-marathon athletes to train and compete in 100-km ultra-marathons.

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