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Male and female Ethiopian and Kenyan runners are the fastest and the youngest in both half and full marathon

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Abstract

In major marathon races such as the 'World Marathon Majors', female and male East African runners particularly from Ethiopia and Kenya are the fastest. However, whether this trend appears for female and male Ethiopians and Kenyans at recreational level runners (i.e. races at national level) and in shorter road races (e.g. in half-marathon races) has not been studied yet. Thus, the aim of the present study was to examine differences in the performance and the age of female and male runners from East Africa (i.e. Ethiopians and Kenyans) between half- and full marathons. Data from 508,108 athletes (125,894 female and 328,430 male half-marathoners and 10,205 female and 43,489 male marathoners) originating from 126 countries and competing between 1999 and 2014 in all road-based half-marathons and marathons held in one country (Switzerland) were analysed using Chi square (χ^2) tests, mixed-effects regression analyses and one-way analyses of variance. In half-marathons, 48 women (0.038 %) and 63 men (0.019 %) were from Ethiopia and 80 women (0.063 %) and 134 men (0.040 %) from Kenya. In marathons, three women (0.029 %) and 15 men (0.034 %) were from Ethiopia and two women (0.019 %) and 33 men (0.075 %) from Kenya. There was no statistically significant association between the nationality of East Africans and the format of a race. In both women and men, the fastest race times in half-marathons and marathons were achieved by East African runners ($p < 0.001$). Ethiopian and Kenyan runners were the youngest in both sexes and formats of race ($p < 0.001$). In summary, women and men from Ethiopia and Kenya, despite they accounted for <0.1 % in half-marathons and marathons, achieved the fastest race times and were the youngest in both half-marathons and marathons. These findings confirmed in the case of half-marathon the trend previously observed in marathon races for a better performance and a younger age in East African runners from Ethiopia and Kenya.

Keywords: Age, Athletes, Endurance, Sex, Long-distance, Nationality, Running

Background

Marathon and half-marathon races are very popular running events held all over the world with an increasing number of both races and participants during the last decades. For instance, in the USA, there were more than 1200 marathons held in 2014 compared to about 300 marathons held in 2000 (www.runningusa.org/2015-national-runner-survey). The number of successful

marathon finishers increased from 25,000 in 1976 to the all-time high of 550,637 in 2014. Compared to marathons, however, most of the runners competed in the USA in half-marathons. The number of successful half-marathoners increased from 303,000 in 1990 to the all-time high of 2,046,600 in 2014 (www.runningusa.org/half-marathon-report-2015). In fact, 3.7 times more half-marathoners than marathoners competed in the USA in 2014. In smaller countries such as Switzerland in Europe, a total of 226,754 half-marathoners and 86,419 marathoners competed between 2000 and 2010 (Anthony et al. 2014). In other terms, 2.6 times more half-marathoners competed than marathoners. In 2010, 8690 women and

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21,583 men finished a half-marathon in comparison to 2904 female and 9333 male finishers in 2000, respectively, corresponding to an increase of 299 % for women and of 231 % for men over 10 years. In contrast, the number of male and female full marathoners increased until 2005 only and decreased thereafter (Anthony et al. 2014).

The dominance of East-African women and men in marathon running is well known (Hamilton 2000; Onywera et al. 2006; Tucker et al. 2015; Wilber and Pitsiladis 2012). Athletes from both Ethiopia and Kenya dominate marathon running for a long time (www.iaaf.org). In the top list of the International Association of Athletics Federations (IAAF) for male marathoners, the first best 37 marathon race times were achieved by athletes from Ethiopia and Kenya (www.iaaf.org/records/toplists/road-running/marathon/outdoor/men/senior). In women, however, the three fastest marathon race times were achieved by an athlete from Great Britain followed by two female marathoners from Kenya (www.iaaf.org/records/toplists/road-running/marathon/outdoor/women/senior). In the 'World Marathon Majors' with the largest city marathons worldwide, female and male champions are exclusively from East African particularly from Ethiopia and Kenya (www.worldmarathonmajors.com/champions/current-champions).

The reasons for the dominance of East-African runners in long and middle distance running events such as marathons included environmental conditions such as a specific geographic background (Onywera et al. 2006; Scott et al. 2003; Tucker et al. 2015). The dominance of East-African distance runners is primarily a Kenyan phenomenon, with majority of the Kenyan runners originating from the Kalenjin tribe in general and the Nandi sub-tribe in particular (Onywera et al. 2006; Tucker et al. 2015). Similar to Kenyan runners, elite Ethiopian runners are also of a distinct environmental background where marathoners mainly originate from the altitudinous regions of Arsi and Shewa (Scott et al. 2003).

However, there is paucity of information with regards to basic characteristics such as age and trends in performance of East-African half-marathoners (Aschmann et al. 2013; Cribari et al. 2013). These studies investigated all African half- and full marathoners competing in one country (Switzerland) together without a separation of East-African runners in their nationalities (Aschmann et al. 2013) or investigated a limited sample of the best athletes (Cribari et al. 2013). Indeed, East African runners particularly those from Ethiopia and Kenya account for the largest percentage of African runners in half-marathon and marathon (Aschmann et al. 2013). A recent study showed different barriers across both sex and distance (Wegner et al. 2015); hence, these trends might vary between half-marathon and marathon. The

knowledge of East African's basic characteristics such as age, participation and performance trends might help coaches, fitness trainers and sports scientists to improve their understanding of half-marathon's demands.

Therefore, the aim of this study was to investigate performance and age of Ethiopian and Kenyan half- and full marathoners who competed between 1999 and 2014 in races held within one country (Switzerland) in a sample of more than 500,000 successful finishers. We hypothesized that female and male runners from Ethiopia and Kenya would also be the fastest in half-marathon races.

Methods

Ethics

The study was approved by the Institutional Review Board of St. Gallen, Switzerland, with waiver of the requirement for informed consent given that the study involved the analysis of publicly available data.

Data collection and data analysis

All half-marathons and marathons held in Switzerland from 1999 to 2014 were identified by using 'Laufkalender Schweiz' (www.laufkalender.ch). Since 1999, all running races in Switzerland started with an electronic chip system and full race results (i.e. name, age, sex, nationality and race time of the finishers) were available since then on the website of the specific races. Of all races, only those half-marathons and marathons were considered which were held on a road, not on a trail. No mountain marathons were included; start and finish of the race had to be on the same altitude. Athletes with missing age and/or missing nationality were excluded from data analysis. In order to avoid a selection bias due to a limitation to top runners, we considered all finishers from all countries. To investigate a trend in participation and performance, athletes from countries where at least one woman and/or one man competed in at least 8 years (i.e. half of the investigated period of time) were considered.

Statistical analysis

Each set of data was tested for normal distribution (D'Agostino and Pearson omnibus normality test) and for homogeneity of variances (Levine's test) prior to statistical analyses. Trends in participation across calendar years were analysed using regression analysis with linear growth equation models. Differences in the participation of East African runners by nationality and sex to half-marathons and marathon were examined by using Chi square (χ^2) test. To investigate changes in performance across calendar years, we used a mixed-effects regression model with running speed as the dependent variable. We analysed women and men separately for each country for both half-marathon and marathon and included calendar

year, sex, centered age, and squared centered age as fixed variables. To investigate changes in age across calendar years, we used a mixed-effects regression model with age as the dependent variable. For the change in age over time, we combined women and men for each country and included sex and calendar year as fixed variables. Differences in age and performance between athletes from multiple countries were compared using one-way analysis of variance (ANOVA) with subsequent Tukey's multiple comparison tests with a single pooled variance. Statistical analyses were performed using IBM SPSS Statistics (Version 22, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (Version 6.01, GraphPad Software, La Jolla, CA, USA). Significance was accepted at $p < 0.05$ (two-sided for t tests). Data in the text and tables are given as mean \pm standard deviation (SD).

Results

Participation

Data from a total of 508,108 (125,894 female and 328,430 male half-marathoners and 10,205 female and 43,489 male marathoners) athletes was considered. These runners originated from a total of 126 countries spread around the globe. Table 1 summarizes the athletes from the considered countries for data analysis across calendar years in half-marathons (35 countries) and marathons (15 countries).

In half-marathons, 48 women (0.038 %) and 63 men (0.019 %) originated from Ethiopia and 80 women (0.063 %) and 134 men (0.040 %) from Kenya. In marathons, three women (0.029 %) and 15 men (0.034 %) were from Ethiopia and two women (0.019 %) and 33 men (0.075 %) from Kenya. There was no statistically significant association between the nationality of East Africans and the format of the race [$\chi^2(1) = 0.001$, $p = 0.978$]; that was, both Ethiopians and Kenyans equally participated to half-marathons versus marathons. Also, there was no association between male East Africans and the format of the race [$\chi^2(1) = 0.001$, $p = 0.922$]; i.e. both male Ethiopians and Kenyans accounted equally to the two formats.

Most of the successful finishers originated from Switzerland, Germany and France in both half-marathons and marathons. In half-marathons, the number of women ($r^2 = 0.98$, $p < 0.0001$) and men ($r^2 = 0.98$, $p < 0.0001$) increased significantly. Similarly, the number of women ($r^2 = 0.46$, $p = 0.0041$) and men ($r^2 = 0.51$, $p = 0.0019$) increased significantly in marathons. Regarding the considered countries, the number of female half-marathoners from Canada ($r^2 = 0.81$, $p = 0.002$), Germany ($r^2 = 0.97$, $p = 0.005$), Switzerland ($r^2 = 0.97$, $p = 0.005$) and Belgium ($r^2 = 0.72$, $p < 0.0001$) increased significantly. For male half-marathoners, the number of participants from France ($r^2 = 0.97$, $p = 0.018$),

Great Britain ($r^2 = 0.88$, $p = 0.036$), Principality of Liechtenstein ($r^2 = 0.87$, $p < 0.0001$), Poland ($r^2 = 0.65$, $p < 0.0001$), South Africa ($r^2 = 0.63$, $p = 0.006$) and Argentina ($r^2 = 0.70$, $p < 0.0001$) increased significantly. In marathoners, there was no significant increase in the number of men regarding the country. In women, however, participants from France ($r^2 = 0.46$, $p = 0.0275$) and Japan ($r^2 = 0.47$, $p = 0.0039$) increased significantly their numbers.

Trends in performance and age across calendar years

Table 2 shows the running speed of the female and male half-marathoners. Running speed decreased significantly in women from France, Switzerland, and Australia, but increased in women from Norway and Portugal (Table 3). In men, running speed decreased in athletes from Germany (Table 4). Table 5 presents running speed of female and male marathoners. Running speed remained unchanged in female marathoners (Table 6) but increased in British men (Table 7). Table 8 presents the age of the female and male half-marathoners. Age increased significantly across calendar years in women from Austria and Norway and in men from Japan and Norway (Table 9). In marathoners (Table 10), age decreased significantly in men from Italy and Principality of Liechtenstein, but increased significantly in men from Poland (Table 11).

Performance of the fastest and age of the youngest

Table 12 presents running speed and age of female and male half-marathoners and marathoners sorted from the fastest to the slowest and from the youngest to the oldest. In absolute values, women from Kenya and Ethiopia were running the fastest. Kenyan women were not faster than Ethiopian women ($p > 0.05$) but they were significantly faster than all other women ($p < 0.001$ to $p < 0.0001$). Ethiopian women were not faster than women from Kenya, Portugal, Principality of Liechtenstein and Hungary ($p > 0.05$), but significantly faster than all other women ($p < 0.001$ to $p < 0.0001$). For men, Kenyans and Ethiopians were running the fastest regarding in absolute terms. Kenyan men were not faster than Ethiopian men ($p > 0.05$), but significantly faster than all other men ($p < 0.001$ to $p < 0.0001$). Ethiopian men were not faster than men from Portugal, Principality of Liechtenstein, Italy, Switzerland and Hungary ($p > 0.05$), but significantly faster than all other men ($p < 0.001$ to $p < 0.0001$).

Considering age, women from Ethiopia and Kenya were the youngest in absolute terms. However, Ethiopian women were not younger than women from Russia, Czech Republic, Argentina, India, Slovenia, Ireland, USA, Great Britain, Poland, Canada, Greece, Denmark and Spain ($p > 0.05$). Considering athletes from the other countries, women from Ethiopia were

Table 1 Number of women and men considered by nationality for half-marathons and marathons, sorted by the overall participation

| Country | Number of years | Number of women | Number of men | Overall |
|--------------------------|-----------------|-----------------|---------------|---------|
| Half-marathon | | | | |
| Ethiopia | 14 | 24 | 48 | 72 |
| Kenya | 14 | 80 | 134 | 214 |
| Switzerland | 15 | 108,509 | 283,353 | 391,862 |
| Germany | 15 | 5782 | 16,332 | 22,114 |
| France | 15 | 5889 | 14,511 | 20,400 |
| Italy | 15 | 984 | 2820 | 3804 |
| Austria | 15 | 897 | 2141 | 3038 |
| Great Britain | 15 | 872 | 2124 | 2996 |
| USA | 15 | 331 | 909 | 1240 |
| Liechtenstein | 15 | 304 | 675 | 979 |
| Belgium | 14 | 180 | 567 | 747 |
| Spain | 15 | 227 | 483 | 710 |
| Canada | 15 | 208 | 411 | 619 |
| Netherlands | 15 | 163 | 438 | 601 |
| Japan | 15 | 167 | 398 | 565 |
| Sweden | 14 | 111 | 246 | 357 |
| Finland | 13 | 85 | 223 | 308 |
| Poland | 14 | 100 | 199 | 299 |
| Portugal | 15 | 56 | 190 | 246 |
| Denmark | 15 | 60 | 186 | 246 |
| Luxembourg | 15 | 85 | 146 | 231 |
| Hungary | 14 | 51 | 175 | 226 |
| Czech Republic | 15 | 62 | 162 | 224 |
| Australia | 14 | 48 | 139 | 187 |
| Russia | 14 | 62 | 109 | 171 |
| Norway | 15 | 55 | 110 | 165 |
| Brazil | 10 | 40 | 86 | 126 |
| Mexico | 10 | 28 | 71 | 99 |
| Greece | 12 | 20 | 74 | 94 |
| Republic of South Africa | 11 | 32 | 44 | 76 |
| Israel | 8 | 12 | 57 | 69 |
| India | 8 | 23 | 45 | 68 |
| Ireland | 14 | 11 | 24 | 35 |
| Argentina | 8 | 13 | 22 | 35 |
| Slovenia | 8 | 7 | 20 | 27 |
| Marathon | | | | |
| Ethiopia | 8 | 3 | 15 | 18 |
| Kenya | 13 | 2 | 33 | 35 |
| Switzerland | 15 | 8376 | 35,084 | 43,460 |
| Germany | 15 | 683 | 3319 | 4002 |
| France | 15 | 539 | 2428 | 2967 |
| Austria | 15 | 119 | 375 | 494 |
| Great Britain | 15 | 97 | 389 | 486 |
| Italy | 15 | 67 | 357 | 424 |
| USA | 11 | 40 | 268 | 308 |
| Japan | 15 | 48 | 119 | 167 |
| Belgium | 8 | 14 | 123 | 137 |

Table 1 continued

| Country | Number of years | Number of women | Number of men | Overall |
|---------------|-----------------|-----------------|---------------|---------|
| Canada | 12 | 30 | 103 | 133 |
| Liechtenstein | 11 | 25 | 78 | 103 |
| Spain | 8 | 18 | 57 | 75 |
| Poland | 8 | 14 | 52 | 66 |

significantly younger ($p < 0.001$ to $p < 0.0001$). For men, runners from Kenya and Ethiopia were the youngest in absolute values. However, they were not younger than athletes from Russia, Czech Republic, Poland, South Africa, Canada, Australia, Argentina, India, Portugal, USA and Greece ($p > 0.05$) but significantly younger than men from all other countries ($p < 0.001$ to $p < 0.0001$).

In marathon, women from Ethiopia and Kenya were faster than women from all other countries ($p < 0.001$ to $p < 0.0001$). However, Ethiopian women were not faster than Kenyan women ($p > 0.05$). For men, the fastest running speeds were achieved by athletes from Kenya, Ethiopia and Principality of Liechtenstein. Kenyan men were faster than men from all other countries ($p < 0.001$ to $p < 0.0001$) with the exception of Ethiopian men ($p > 0.05$). Ethiopian men were, however, not faster than men from Liechtenstein, Switzerland, Belgium, Spain, Italy, France, Great Britain, Germany and USA ($p > 0.05$).

Women from Ethiopia and Kenya were the youngest in absolute terms. However, only women from Japan were significantly older than women from Ethiopia ($p = 0.001$) but not all other women ($p > 0.05$). Considering Kenyan women, no statistical significant differences were found between the countries ($p > 0.05$). For men, Ethiopians and Kenyans were the youngest in absolute terms. Ethiopian men were not younger than Kenyan men ($p > 0.05$), but significantly younger than men from all other countries ($p < 0.001$ to $p < 0.0001$). Men from Kenya were not younger than men from Liechtenstein, Great Britain, Poland and the USA, but significantly younger than men from all other countries ($p < 0.001$ to $p < 0.0001$).

Discussion

This study intended to investigate performance and age of female and male Ethiopian and Kenyan half-marathoners and marathoners competing in races held in one country. The most important findings for female and male half-marathoners and marathoners from Ethiopia and Kenya were that, (1) they accounted for less than 0.1 %, (2) they were running the fastest and, (3) they were the youngest.

Low participation of East African runners

A first important finding was that runners from Kenya and Ethiopia accounted for less than 0.1 % in both half-marathons and marathons. The small percentage of participants from these countries should be attributed partially to the distance between these countries and the place of race. Considering the nationality of participants, one might observe a very large number of local participants followed by participants from the neighbouring countries.

Although athletes from neighbouring countries such as Germany, France, Italy and Austria were very numerous, also athletes from very remote countries such as the United States, Japan and Australia competed more numerous than athletes from Ethiopia and Kenya. A very likely explanation could be the income of persons living in these countries since they need to spend money for the travel to and the stay in Switzerland. Costs of living are very high in Switzerland compared to other countries (www.numbeo.com/cost-of-living/country_result.jsp?country=Switzerland). When we compare the gross domestic product (GDP) per capita for persons living in East African countries such as Ethiopia (www.indexmundi.com/ethiopia/gdp_per_capita_%28ppp%29.html) and in Kenya (http://www.indexmundi.com/kenya/gdp_per_capita_%28ppp%29.html) with \$1300 and \$1800, respectively, persons from the other countries such as the United States of America (www.indexmundi.com/united_states/gdp_per_capita_%28ppp%29.html), Japan (www.indexmundi.com/japan/gdp_per_capita_%28ppp%29.html) and Australia (www.indexmundi.com/australia/gdp_per_capita_%28ppp%29.html) have a GDP of \$52,800, \$ 37,100, and \$43,000, respectively. With these higher GDP, persons from the United States of America, Japan and Australia might easier travel to Switzerland for competing in a marathon than persons from Ethiopia and Kenya.

The finding that mainly local athletes compete in races followed by athletes from surrounding countries confirms recent findings for other races. For example, in long-distance triathletes competing in the 'Ironman Hawaii', women and men from the United States of America dominated both participation and performance (Dähler et al. 2014). In solo swimmers crossing the 'English Channel'

Table 2 Running speed (km/h) with mean \pm SD for the annual fastest female and male East-African and Non-African half-marathoners

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|----------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Women | | | | | | | | |
| Ethiopia | 8.60 | 14.66 \pm 7.42 | 8.10 | | 19.57 | 19.59 | 19.63 | 14.14 \pm 5.27 |
| Kenya | | 14.79 \pm 7.29 | | 9.43 \pm 0.35 | 14.99 \pm 8.04 | 14.18 \pm 4.69 | 16.52 \pm 3.36 | 18.84 \pm 1.89 |
| Austria | 7.49 \pm 3.04 | 8.02 \pm 3.64 | 7.84 \pm 3.30 | 8.02 \pm 3.06 | 7.98 \pm 2.98 | 8.78 \pm 3.59 | 8.44 \pm 3.43 | 8.99 \pm 3.54 |
| Canada | | 5.07 \pm 1.30 | 7.78 \pm 4.39 | 7.16 \pm 3.70 | 5.86 \pm 2.10 | 9.13 \pm 4.75 | 7.76 \pm 2.72 | 7.01 \pm 2.56 |
| Czech Republic | 5.09 \pm 1.34 | 4.51 | 8.13 \pm 4.82 | 5.63 \pm 0.79 | 8.85 \pm 3.83 | 10.83 \pm 2.99 | 8.11 \pm 3.16 | 10.13 |
| Denmark | | 10.81 \pm 0.83 | 7.23 \pm 4.15 | 8.84 \pm 4.10 | 10.42 \pm 1.16 | 9.58 \pm 3.40 | 7.49 \pm 2.77 | 6.87 \pm 2.85 |
| Spain | 9.87 \pm 3.23 | 10.25 \pm 2.32 | 10.53 \pm 4.01 | 10.02 \pm 3.15 | 11.01 \pm 1.86 | 9.78 \pm 2.81 | 10.07 \pm 3.05 | 10.69 \pm 2.29 |
| France | 10.21 \pm 3.23 | 9.99 \pm 3.02 | 9.47 \pm 3.25 | 9.94 \pm 3.28 | 9.72 \pm 3.17 | 9.68 \pm 3.40 | 9.70 \pm 3.48 | 9.27 \pm 3.42 |
| Great Britain | 9.81 \pm 1.99 | 9.83 \pm 2.84 | 9.18 \pm 3.29 | 8.33 \pm 3.13 | 10.38 \pm 3.03 | 9.63 \pm 3.20 | 10.26 \pm 2.93 | 9.38 \pm 3.08 |
| Germany | 8.49 \pm 2.97 | 8.35 \pm 3.47 | 8.46 \pm 3.15 | 8.39 \pm 3.22 | 8.61 \pm 3.35 | 8.31 \pm 3.27 | 8.48 \pm 3.40 | 8.31 \pm 3.17 |
| Italy | 9.76 \pm 3.07 | 10.02 \pm 3.26 | 10.4 \pm 3.10 | 11.7 \pm 2.62 | 10.01 \pm 3.31 | 11.35 \pm 2.92 | 10.68 \pm 3.10 | 10.98 \pm 3.11 |
| Japan | 6.21 \pm 2.80 | 6.15 \pm 2.47 | 7.35 \pm 2.53 | 7.94 \pm 2.95 | 6.57 \pm 3.37 | 6.20 \pm 2.48 | 6.52 \pm 1.96 | 8.09 \pm 2.77 |
| Liechtenstein | 10.21 \pm 2.09 | 10.17 \pm 2.32 | 11.49 \pm 2.51 | 11.51 \pm 2.25 | 10.96 \pm 2.63 | 10.85 \pm 3.55 | 11.26 \pm 1.50 | 9.94 \pm 2.66 |
| Luxembourg | 5.87 \pm 1.58 | 7.80 \pm 3.15 | 8.15 \pm 4.64 | 8.19 \pm 3.56 | 8.25 \pm 3.33 | 6.86 \pm 2.39 | 7.45 \pm 1.22 | 8.61 \pm 3.06 |
| Netherlands | 10.90 \pm 1.25 | 11.56 \pm 2.30 | 10.79 \pm 1.16 | 11.47 \pm 2.19 | 9.51 \pm 2.63 | 10.12 \pm 2.68 | 10.45 \pm 4.47 | 8.97 \pm 3.29 |
| Norway | | 6.83 \pm 3.05 | 7.12 \pm 4.66 | 9.7 \pm 1.93 | 4.56 | 9.59 \pm 3.81 | 10.27 \pm 3.84 | 8.45 \pm 4.13 |
| Portugal | | 10.97 | 13.53 | 8.41 \pm 3.32 | 11.08 \pm 2.74 | 10.12 \pm 3.31 | 10.15 \pm 3.98 | 11.52 \pm 3.36 |
| Switzerland | 10.59 \pm 2.97 | 10.75 \pm 2.87 | 10.63 \pm 2.91 | 10.63 \pm 2.92 | 10.58 \pm 2.90 | 10.57 \pm 2.90 | 10.45 \pm 2.93 | 10.51 \pm 2.90 |
| USA | 12.05 \pm 0.61 | 9.50 \pm 2.92 | 9.39 \pm 3.02 | 8.67 \pm 3.46 | 7.90 \pm 3.10 | 8.58 \pm 3.60 | 8.34 \pm 3.27 | 8.88 \pm 2.62 |
| Australia | | 10.96 | 9.08 \pm 4.03 | 9.89 \pm 3.60 | 9.85 \pm 4.61 | | 8.09 \pm 3.28 | 8.12 \pm 3.14 |
| Belgium | 8.22 \pm 3.49 | | 9.62 \pm 5.59 | 7.70 \pm 2.50 | 9.50 \pm 1.87 | 7.88 \pm 2.19 | 8.99 \pm 3.28 | 7.83 \pm 3.10 |
| Hungary | 8.44 | 9.09 | | 8.46 | 11.79 | 10.96 | 11.62 | 10.07 \pm 3.41 |
| Ireland | 9.44 \pm 4.42 | 11.13 | 10.45 \pm 0.33 | 8.60 \pm 3.12 | 11.12 \pm 3.02 | 10.49 \pm 2.69 | | 11.99 \pm 1.66 |
| Poland | 8.19 \pm 5.46 | | 5.17 \pm 1.00 | 4.39 | 9.58 \pm 3.89 | 7.41 \pm 2.78 | 7.49 \pm 2.98 | 7.80 \pm 3.18 |
| Russia | 11.19 | 9.73 \pm 0.24 | 9.60 | 8.00 | | 9.05 \pm 3.13 | 7.31 \pm 2.71 | 8.42 \pm 2.99 |
| Sweden | 5.04 | | 7.05 \pm 3.13 | 11.66 \pm 1.29 | 9.58 \pm 3.82 | 10.02 \pm 2.09 | 9.35 \pm 3.67 | 7.47 \pm 2.66 |
| Finland | 10.80 \pm 0.50 | 5.07 | | 8.42 \pm 4.75 | | 6.76 \pm 3.14 | 6.14 \pm 2.01 | 7.43 \pm 0.33 |
| Greece | | | | | 5.82 | 6.39 | 10.65 | 12.02 |
| South Africa | | | | 6.76 \pm 2.45 | 11.59 | 12.73 | 5.32 | 5.06 \pm 0.12 |
| Brazil | 9.95 \pm 0.67 | 12.10 \pm 2.16 | | 5.49 | 10.28 | 11.06 | 8.72 \pm 4.37 | |
| Mexico | | | | | | 9.76 | | 10.07 \pm 1.18 |
| Argentina | | | | 9.74 | | | | 10.44 |
| India | | 9.74 | | | | 10.48 | 9.63 \pm 1.48 | 10.62 \pm 1.09 |
| Israel | | | | | | 4.37 | 4.50 | |
| Slovenia | | | | | | | 5.06 | |
| Men | | | | | | | | |
| Ethiopia | 9.71 \pm 2.04 | 19.11 | 13.41 \pm 6.70 | 8.13 \pm 0.79 | 12.93 \pm 7.40 | 10.84 \pm 5.18 | 8.39 \pm 0.39 | 12.24 \pm 5.34 |
| Kenya | 12.76 \pm 4.68 | 14.62 \pm 5.32 | 12.24 \pm 5.38 | 14.7 \pm 5.13 | 12.31 \pm 6.99 | 10.78 \pm 4.83 | 15.35 \pm 5.68 | 11.47 \pm 4.39 |
| Austria | | 9.36 \pm 3.57 | 11.77 \pm 2.60 | 9.87 \pm 3.42 | 8.97 \pm 2.26 | 11.03 \pm 1.91 | 8.98 \pm 3.12 | 7.38 \pm 2.43 |
| Canada | 7.81 \pm 3.15 | 6.99 \pm 2.69 | 8.32 \pm 3.28 | 7.78 \pm 3.05 | 8.95 \pm 3.65 | 7.29 \pm 2.87 | 6.35 \pm 2.61 | 5.91 \pm 2.34 |
| Czech Republic | 8.06 \pm 2.00 | 10.45 \pm 3.87 | 10.3 \pm 2.72 | 11.15 \pm 3.54 | 8.85 \pm 4.47 | 10.01 \pm 2.75 | 9.63 \pm 3.10 | 8.94 \pm 2.96 |
| Denmark | | 6.68 \pm 1.70 | 7.04 \pm 2.49 | 8.65 \pm 2.96 | 6.91 \pm 2.03 | 8.25 \pm 2.94 | 8.65 \pm 2.90 | 9.15 \pm 3.74 |
| Spain | 10.63 \pm 3.75 | 11.23 \pm 1.76 | 9.84 \pm 3.25 | 8.32 \pm 3.01 | 9.24 \pm 2.84 | 8.88 \pm 3.00 | 8.41 \pm 3.41 | 9.07 \pm 2.89 |
| France | 9.82 \pm 3.37 | 9.43 \pm 3.35 | 9.47 \pm 3.33 | 9.72 \pm 3.37 | 9.49 \pm 3.29 | 9.39 \pm 3.32 | 9.56 \pm 3.35 | 9.83 \pm 3.33 |
| Great Britain | 9.49 \pm 2.92 | 9.32 \pm 3.16 | 9.31 \pm 3.16 | 9.34 \pm 3.09 | 9.89 \pm 2.84 | 9.06 \pm 3.04 | 9.19 \pm 3.16 | 9.37 \pm 3.11 |
| Germany | 8.58 \pm 3.26 | 8.56 \pm 3.25 | 8.42 \pm 3.16 | 8.58 \pm 3.28 | 8.35 \pm 3.23 | 8.44 \pm 3.21 | 8.28 \pm 3.23 | 8.60 \pm 3.18 |
| Italy | 10.55 \pm 3.16 | 10.55 \pm 3.01 | 10.73 \pm 3.05 | 10.54 \pm 2.86 | 10.59 \pm 3.17 | 10.64 \pm 3.23 | 10.82 \pm 3.00 | 10.68 \pm 3.18 |

Table 2 continued

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Japan | 4.14 ± 0.31 | 6.47 ± 3.61 | 6.51 ± 3.43 | 5.55 ± 2.22 | 7.03 ± 2.61 | 7.03 ± 3.97 | 7.03 ± 3.03 | 5.93 ± 2.90 |
| Liechtenstein | 10.92 ± 2.10 | 10.09 ± 2.76 | 10.61 ± 2.48 | 10.57 ± 2.78 | 11.17 ± 1.84 | 10.76 ± 2.48 | 10.57 ± 3.07 | 10.84 ± 2.37 |
| Luxembourg | 9.41 ± 3.96 | 7.14 ± 3.04 | 6.82 ± 2.23 | 6.88 ± 2.58 | 6.85 ± 2.40 | 8.23 ± 2.93 | 8.04 ± 3.00 | 7.48 ± 3.02 |
| Netherlands | 10.39 ± 4.64 | 9.52 ± 2.15 | 10.99 ± 3.41 | 9.02 ± 3.67 | 8.85 ± 3.23 | 9.75 ± 3.09 | 9.02 ± 3.05 | 10.63 ± 4.05 |
| Norway | 12.91 | 7.29 ± 0.30 | 10.91 ± 2.32 | 9.11 ± 2.42 | 8.20 ± 3.73 | 9.20 ± 2.66 | 9.96 ± 1.05 | 9.71 ± 3.80 |
| Portugal | 12.04 ± 1.87 | 12.87 ± 0.62 | 12.37 ± 2.79 | 11.63 ± 3.25 | 9.60 ± 2.92 | 11.82 ± 1.97 | 9.39 ± 3.48 | 11.76 ± 2.08 |
| Switzerland | 10.31 ± 3.05 | 10.52 ± 2.96 | 10.50 ± 2.94 | 10.38 ± 2.96 | 10.43 ± 2.98 | 10.43 ± 2.95 | 10.41 ± 2.98 | 10.44 ± 2.99 |
| USA | 7.44 ± 3.01 | 7.83 ± 3.35 | 7.44 ± 3.07 | 7.79 ± 3.31 | 8.02 ± 2.75 | 8.25 ± 2.69 | 8.97 ± 2.72 | 8.41 ± 3.20 |
| Australia | | 9.36 ± 3.57 | 11.77 ± 2.60 | 9.87 ± 3.42 | 8.97 ± 2.26 | 11.03 ± 2.91 | 8.98 ± 3.12 | 7.38 ± 2.43 |
| Belgium | 9.57 ± 3.14 | 9.7 ± 2.92 | 9.93 ± 3.16 | 8.68 ± 3.45 | 9.00 ± 3.16 | 9.54 ± 3.40 | 9.93 ± 2.43 | 9.17 ± 3.37 |
| Hungary | | 12.34 | 11.70 ± 1.26 | 8.79 ± 3.02 | 10.93 ± 3.01 | 9.21 ± 2.83 | 11.46 ± 2.42 | 11.23 ± 2.74 |
| Ireland | 9.17 ± 5.65 | 9.84 ± 2.78 | 7.95 ± 2.65 | 7.14 ± 3.44 | 8.15 ± 3.25 | 7.55 ± 3.84 | 8.57 ± 3.16 | 8.48 ± 3.58 |
| Poland | 6.20 ± 1.79 | 5.52 ± 0.84 | 8.77 ± 2.71 | 8.69 ± 5.06 | 11.68 ± 3.38 | 9.43 ± 5.84 | 9.28 ± 2.95 | 8.93 ± 2.87 |
| Russia | | 8.17 ± 4.61 | 8.53 ± 3.25 | 9.29 ± 2.78 | 7.45 ± 2.53 | 8.18 ± 2.56 | 8.61 ± 2.09 | 9.26 ± 2.81 |
| Sweden | 8.29 ± 4.64 | 7.26 ± 4.06 | 9.08 ± 2.67 | 7.36 ± 3.64 | 7.98 ± 3.01 | 8.33 ± 3.71 | 7.95 ± 3.48 | 8.04 ± 3.23 |
| Finland | 7.66 ± 4.62 | 7.36 ± 2.81 | 7.37 ± 2.67 | 6.95 ± 2.59 | 5.22 ± 1.75 | 7.56 ± 2.68 | 8.10 ± 2.65 | 8.24 ± 3.08 |
| Greece | 5.65 | 5.60 | 6.52 ± 0.82 | 6.52 ± 3.20 | 11.17 ± 1.66 | 9.93 ± 4.58 | 8.53 ± 3.53 | 8.40 ± 4.46 |
| South Africa | 4.24 | | | 4.80 | | 7.93 ± 3.70 | 10.72 | 7.91 ± 4.32 |
| Brazil | 5.21 ± 0.56 | 7.45 ± 3.02 | 8.91 ± 3.46 | | 6.97 ± 3.01 | | | 6.70 ± 1.90 |
| Mexico | 10.67 | 10.56 | 6.32 | 7.00 ± 2.84 | 8.26 ± 3.64 | 6.28 ± 2.79 | 5.68 | 11.90 ± 0.42 |
| Argentina | | | | | 9.24 | 6.13 | 4.24 | 5.96 |
| India | | 9.57 ± 2.06 | 9.86 ± 0.45 | 7.89 | 9.92 ± 0.88 | | 9.93 ± 0.78 | 9.58 ± 0.88 |
| Israel | | 10.44 ± 3.74 | | 6.05 ± 0.69 | 13.25 ± 0.04 | 7.88 ± 4.88 | 5.88 | 6.13 ± 1.58 |
| Slovenia | | 5.75 | 6.89 | 5.58 ± 1.53 | 11.48 | 11.62 | 8.49 ± 5.25 | 8.89 ± 3.77 |
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Women | | | | | | | | |
| Ethiopia | 9.90 ± 3.96 | 15.01 ± 4.45 | 12.86 ± 5.72 | 13.86 ± 5.98 | 11.05 ± 4.50 | 15.73 ± 5.65 | 10.44 ± 5.79 | 12.03 ± 4.74 |
| Kenya | 13.44 ± 4.18 | 16.39 ± 4.74 | 16.66 ± 5.50 | 13.39 ± 7.36 | 11.63 ± 4.81 | 14.07 ± 5.28 | 15.96 ± 5.42 | 12.08 ± 5.73 |
| Austria | 7.71 ± 2.64 | 7.63 ± 2.90 | 7.56 ± 2.55 | 8.10 ± 3.15 | 7.79 ± 3.13 | 8.27 ± 3.31 | 7.82 ± 3.26 | 7.84 ± 3.14 |
| Canada | 6.09 ± 3.02 | 7.10 ± 3.19 | 7.88 ± 3.84 | 7.86 ± 4.29 | 7.45 ± 3.47 | 7.14 ± 3.04 | 7.13 ± 2.98 | 7.59 ± 3.34 |
| Czech Republic | 7.09 ± 2.73 | 12.49 ± 1.72 | 9.53 ± 4.79 | 9.46 ± 7.30 | 9.44 ± 3.61 | 8.54 ± 3.36 | 14.24 ± 5.94 | 10.53 ± 2.73 |
| Denmark | 7.86 ± 3.89 | 5.19 | 6.82 ± 2.96 | 9.61 ± 2.48 | 7.86 ± 2.83 | 9.65 ± 3.71 | 8.04 ± 3.40 | 10.24 ± 3.50 |
| Spain | 9.87 ± 3.40 | 9.55 ± 3.32 | 9.55 ± 2.86 | 11.20 ± 2.95 | 9.26 ± 3.37 | 10.49 ± 2.88 | 9.54 ± 3.55 | 9.56 ± 3.45 |
| France | 9.35 ± 3.40 | 9.82 ± 3.32 | 9.58 ± 3.37 | 9.45 ± 3.31 | 9.44 ± 3.32 | 9.54 ± 3.17 | 9.40 ± 3.26 | 9.28 ± 3.31 |
| Great Britain | 8.35 ± 3.58 | 9.53 ± 2.97 | 9.48 ± 3.21 | 9.63 ± 3.01 | 9.03 ± 3.13 | 8.79 ± 3.13 | 8.73 ± 3.00 | 9.14 ± 3.28 |
| Germany | 8.58 ± 3.24 | 8.43 ± 3.09 | 8.61 ± 3.23 | 8.39 ± 3.08 | 8.31 ± 3.13 | 8.50 ± 3.19 | 8.16 ± 3.27 | 8.42 ± 3.21 |
| Italy | 10.91 ± 3.34 | 11.17 ± 2.97 | 11.30 ± 3.06 | 10.91 ± 3.55 | 10.82 ± 3.13 | 10.00 ± 3.40 | 10.74 ± 3.07 | 10.47 ± 2.92 |
| Japan | 5.93 ± 2.94 | 6.03 ± 2.53 | 5.64 ± 1.97 | 6.55 ± 2.41 | 5.72 ± 2.53 | 5.41 ± 1.78 | 5.55 ± 2.90 | 6.95 ± 3.00 |
| Liechtenstein | 11.17 ± 1.82 | 10.81 ± 1.91 | 11.11 ± 2.31 | 10.36 ± 2.96 | 11.28 ± 2.94 | 11.16 ± 2.53 | 10.63 ± 2.92 | 11.33 ± 2.54 |
| Luxembourg | 8.11 ± 2.34 | 8.14 ± 3.27 | 9.20 ± 2.78 | 8.36 ± 2.96 | 10.69 ± 2.62 | 8.00 ± 3.03 | 7.80 ± 3.28 | 7.23 ± 2.42 |
| Netherlands | 9.01 ± 3.60 | 9.18 ± 3.27 | 8.96 ± 3.39 | 8.96 ± 3.48 | 9.19 ± 3.50 | 9.45 ± 3.83 | 9.54 ± 3.35 | 9.85 ± 3.10 |
| Norway | 9.03 ± 3.29 | 7.62 ± 3.02 | 8.66 ± 0.69 | 11.22 ± 5.16 | 10.88 ± 1.43 | 12.37 ± 0.60 | 11.79 ± 1.32 | 11.12 ± 2.75 |
| Portugal | 10.08 ± 3.62 | 13.55 ± 5.79 | 13.38 ± 1.35 | 12.12 ± 0.72 | 12.47 | 15.11 ± 3.09 | 10.49 ± 4.48 | 12.28 ± 2.50 |
| Switzerland | 10.35 ± 2.97 | 10.48 ± 2.92 | 10.55 ± 2.90 | 10.50 ± 2.92 | 10.53 ± 2.94 | 10.46 ± 2.94 | 10.43 ± 2.95 | 10.41 ± 2.95 |
| USA | 8.80 ± 3.00 | 8.81 ± 3.73 | 9.07 ± 3.17 | 8.69 ± 3.81 | 8.54 ± 2.97 | 9.19 ± 3.06 | 8.78 ± 2.88 | 8.20 ± 3.29 |
| Australia | 8.24 ± 3.18 | 8.71 | 10.99 ± 0.60 | 7.37 ± 3.14 | 10.75 ± 2.72 | 6.52 ± 1.65 | 6.99 ± 3.22 | 7.60 ± 2.60 |
| Belgium | 7.98 ± 3.11 | 7.27 ± 2.86 | 8.29 ± 3.30 | 8.01 ± 3.48 | 8.66 ± 3.23 | 9.60 ± 3.07 | 8.23 ± 3.12 | 9.32 ± 3.10 |
| Hungary | 9.16 ± 1.44 | 11.03 | 10.16 ± 2.24 | 11.68 | 9.79 ± 3.84 | 12.71 ± 2.62 | 11.64 ± 1.45 | 10.94 ± 2.68 |
| Ireland | 10.68 | 10.91 | 9.53 ± 2.66 | 9.55 ± 4.34 | 8.61 ± 3.35 | 9.73 ± 2.70 | 10.25 ± 3.59 | 8.47 ± 3.34 |

Table 2 continued

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Poland | 7.86 ± 3.43 | 10.36 ± 3.87 | 8.64 ± 2.75 | 8.07 ± 4.13 | 11.18 ± 3.66 | 7.73 ± 5.63 | 10.67 ± 3.45 | 8.29 ± 2.65 |
| Russia | 6.06 | 8.62 ± 1.93 | 11.04 ± 4.56 | 11.40 ± 2.66 | 10.26 ± 2.10 | 8.33 ± 2.18 | 9.97 ± 3.41 | 10.18 ± 0.66 |
| Sweden | 7.31 ± 3.34 | 7.16 ± 2.98 | 9.39 ± 3.78 | 9.73 ± 3.90 | 7.98 ± 2.84 | 7.57 ± 2.82 | 7.36 ± 3.03 | 8.42 ± 3.20 |
| Finland | 8.74 ± 6.63 | 5.40 ± 1.36 | 6.50 ± 3.09 | 5.54 ± 1.03 | 5.97 ± 2.95 | 6.18 ± 1.90 | 5.90 ± 1.85 | 8.03 ± 3.53 |
| Greece | 10.02 ± 1.19 | 7.17 | 5.08 | 9.06 | 6.80 | 7.71 ± 3.94 | 11.79 ± 1.20 | 9.14 ± 2.16 |
| South Africa | 11.31 ± 1.03 | 8.83 ± 2.10 | 8.22 ± 2.89 | | 9.44 ± 1.14 | 9.04 ± 3.87 | 7.47 ± 3.19 | 7.43 |
| Brazil | 9.84 ± 2.47 | 9.45 ± 2.48 | 9.95 ± 1.26 | 6.80 ± 3.46 | 7.80 ± 3.30 | 10.23 ± 1.14 | 9.27 ± 1.28 | 8.98 ± 2.97 |
| Mexico | 10.97 ± 0.92 | 9.24 ± 0.15 | 11.97 ± 2.03 | 7.75 ± 2.36 | 6.81 ± 2.78 | 7.82 ± 3.91 | 7.45 | 9.25 ± 1.79 |
| Argentina | 12.68 | | 11.85 | 4.50 ± 0.25 | 4.98 | 10.69 ± 1.09 | 12.53 ± 2.37 | 10.44 ± 1.89 |
| India | 9.85 ± 0.91 | | 9.09 | | 10.01 ± 0.93 | | 10.92 ± 1.75 | 10.8 ± 1.75 |
| Israel | | | 13.38 | 9.64 | 5.41 ± 0.18 | 8.74 | 8.56 ± 3.24 | 13.18 ± 1.01 |
| Slovenia | 5.61 | | 9.28 ± 4.70 | | 7.82 ± 3.48 | | | 5.54 |
| Men | | | | | | | | |
| Ethiopia | 10.80 ± 4.09 | 15.38 ± 5.10 | 9.87 ± 4.18 | 8.75 ± 0.70 | 11.34 ± 4.62 | 7.94 ± 0.52 | 13.60 ± 4.71 | 10.78 ± 4.94 |
| Kenya | 14.85 ± 5.54 | 12.67 ± 5.10 | 13.56 ± 4.77 | 11.77 ± 4.17 | 11.58 ± 4.70 | 10.86 ± 4.81 | 10.42 ± 3.17 | 13.14 ± 4.80 |
| Austria | 9.36 ± 3.01 | 10.55 ± 2.78 | 11.75 ± 2.30 | 9.81 ± 2.90 | 8.21 ± 2.92 | 9.43 ± 3.00 | 8.31 ± 3.18 | 9.25 ± 2.82 |
| Canada | 6.79 ± 3.43 | 6.33 ± 3.14 | 7.63 ± 3.17 | 7.77 ± 3.07 | 7.24 ± 2.77 | 7.5 ± 3.20 | 7.62 ± 3.15 | 8.29 ± 3.34 |
| Czech Republic | 8.35 ± 3.03 | 8.47 ± 3.99 | 8.23 ± 4.09 | 9.64 ± 3.40 | 6.25 ± 1.60 | 7.84 ± 2.92 | 7.51 ± 2.93 | 9.10 ± 3.82 |
| Denmark | 9.08 ± 2.97 | 9.36 ± 2.55 | 8.59 ± 3.08 | 7.92 ± 2.65 | 5.99 ± 2.49 | 7.08 ± 2.70 | 8.41 ± 3.14 | 8.02 ± 2.96 |
| Spain | 9.76 ± 2.91 | 10.74 ± 2.85 | 10.30 ± 2.59 | 8.74 ± 2.87 | 8.61 ± 3.40 | 10.22 ± 2.92 | 9.76 ± 3.37 | 8.79 ± 3.03 |
| France | 9.56 ± 3.34 | 9.48 ± 3.26 | 9.46 ± 3.33 | 9.52 ± 3.33 | 9.43 ± 3.35 | 9.38 ± 3.30 | 9.50 ± 3.34 | 9.54 ± 3.30 |
| Great Britain | 9.29 ± 2.94 | 8.88 ± 3.06 | 8.51 ± 3.06 | 8.88 ± 3.16 | 9.00 ± 3.12 | 8.95 ± 3.29 | 8.63 ± 3.24 | 8.66 ± 3.16 |
| Germany | 8.75 ± 3.26 | 8.57 ± 3.25 | 8.79 ± 3.32 | 8.34 ± 3.13 | 8.35 ± 3.17 | 8.34 ± 3.24 | 8.39 ± 3.15 | 8.29 ± 3.17 |
| Italy | 10.56 ± 3.32 | 10.90 ± 3.04 | 10.54 ± 3.27 | 10.41 ± 3.14 | 10.24 ± 3.32 | 10.10 ± 3.27 | 10.09 ± 3.28 | 10.18 ± 3.37 |
| Japan | 6.95 ± 3.17 | 5.64 ± 2.41 | 6.15 ± 2.52 | 6.94 ± 3.02 | 7.00 ± 3.13 | 7.32 ± 3.23 | 6.37 ± 2.84 | 6.20 ± 2.44 |
| Liechtenstein | 10.65 ± 3.20 | 10.17 ± 2.68 | 10.84 ± 2.43 | 10.83 ± 2.81 | 10.86 ± 2.80 | 10.41 ± 2.80 | 10.23 ± 2.89 | 10.18 ± 2.81 |
| Luxembourg | 9.47 ± 3.24 | 8.76 ± 3.63 | 7.81 ± 2.80 | 8.34 ± 2.30 | 8.43 ± 2.69 | 7.60 ± 2.54 | 6.68 ± 2.23 | 8.15 ± 3.89 |
| Netherlands | 9.21 ± 3.14 | 9.34 ± 3.31 | 9.71 ± 3.49 | 9.27 ± 3.03 | 10.31 ± 3.35 | 8.90 ± 3.29 | 9.65 ± 3.06 | 8.94 ± 3.51 |
| Norway | 8.12 ± 2.09 | 8.86 ± 0.28 | 10.53 ± 2.96 | 7.19 ± 3.29 | 7.84 ± 2.91 | 9.80 ± 3.54 | 8.92 ± 3.32 | 10.12 ± 3.20 |
| Portugal | 11.48 ± 2.40 | 10.45 ± 2.55 | 11.52 ± 2.59 | 10.86 ± 3.65 | 11.52 ± 4.09 | 11.34 ± 1.68 | 9.84 ± 3.66 | 10.65 ± 2.92 |
| Switzerland | 10.43 ± 2.99 | 10.46 ± 2.96 | 10.45 ± 2.95 | 10.41 ± 2.98 | 10.43 ± 2.96 | 10.38 ± 2.99 | 10.39 ± 3.02 | 10.44 ± 2.99 |
| USA | 8.41 ± 2.91 | 8.05 ± 2.93 | 7.87 ± 2.89 | 8.65 ± 2.76 | 8.38 ± 3.18 | 8.01 ± 3.03 | 7.74 ± 3.15 | 8.08 ± 3.16 |
| Australia | 9.36 ± 3.01 | 10.55 ± 2.78 | 11.75 ± 2.30 | 9.81 ± 2.90 | 8.21 ± 2.92 | 9.43 ± 3.00 | 8.31 ± 3.18 | 9.25 ± 2.82 |
| Belgium | 9.49 ± 2.92 | 8.46 ± 3.22 | 9.20 ± 2.78 | 8.41 ± 3.00 | 8.43 ± 3.07 | 7.31 ± 2.52 | 8.33 ± 2.85 | 8.86 ± 2.86 |
| Hungary | 8.52 ± 3.40 | 9.11 ± 4.00 | 9.54 ± 2.78 | 9.24 ± 2.79 | 9.74 ± 2.76 | 9.55 ± 3.17 | 11.73 ± 1.69 | 10.21 ± 2.69 |
| Ireland | 8.90 ± 2.50 | 9.31 ± 2.85 | 8.80 ± 3.29 | 10.25 ± 3.17 | 9.36 ± 3.08 | 8.56 ± 2.93 | 7.67 ± 2.97 | 8.59 ± 3.40 |
| Poland | 7.48 ± 3.00 | 9.23 ± 3.36 | 9.01 ± 4.29 | 8.18 ± 3.84 | 7.52 ± 2.96 | 8.20 ± 3.84 | 8.28 ± 3.32 | 9.37 ± 3.35 |
| Russia | 11.05 ± 2.22 | 8.55 ± 3.57 | 7.65 ± 3.03 | 8.00 ± 2.78 | 7.89 ± 2.98 | 8.16 ± 2.96 | 7.98 ± 2.77 | 8.61 ± 2.32 |
| Sweden | 7.43 ± 2.89 | 9.01 ± 3.11 | 6.64 ± 2.25 | 8.04 ± 2.67 | 7.86 ± 3.25 | 8.58 ± 3.32 | 9.12 ± 3.17 | 8.45 ± 3.39 |
| Finland | 8.05 ± 3.47 | 7.84 ± 2.48 | 7.84 ± 3.20 | 7.78 ± 3.31 | 6.35 ± 1.99 | 6.58 ± 2.74 | 6.30 ± 1.72 | 6.01 ± 2.14 |
| Greece | 8.29 ± 3.10 | 7.10 ± 2.30 | 9.98 ± 3.77 | 7.81 ± 2.91 | 8.60 ± 6.27 | 7.78 ± 2.60 | 10.31 ± 2.36 | 8.35 ± 2.92 |
| South Africa | 8.63 ± 1.61 | 10.38 ± 1.53 | 9.37 ± 3.48 | 7.06 ± 3.19 | 6.71 ± 3.78 | 10.31 ± 4.19 | 8.00 ± 4.50 | 6.10 ± 2.32 |
| Brazil | 7.31 ± 2.50 | 8.41 ± 3.06 | 7.60 ± 2.82 | 10.22 ± 3.11 | 7.94 ± 3.19 | 7.34 ± 3.03 | 9.36 ± 2.94 | 7.78 ± 2.68 |
| Mexico | 9.04 ± 3.93 | 10.32 ± 2.81 | 9.71 ± 6.11 | 9.19 ± 3.75 | 9.57 ± 3.57 | 8.97 ± 3.36 | 8.01 ± 3.50 | 6.99 ± 3.16 |
| Argentina | 10.55 | 5.85 | 9.55 ± 3.14 | 7.25 ± 3.00 | 4.63 ± 0.21 | 11.09 ± 3.30 | 11.16 ± 0.53 | 8.67 ± 3.14 |
| India | 5.40 | 10.78 ± 3.92 | 6.87 ± 2.68 | 6.38 ± 2.90 | 9.44 ± 1.51 | 9.65 ± 0.17 | 8.22 ± 3.74 | 8.58 ± 2.95 |
| Israel | 8.7 ± 2.60 | 8.93 ± 4.48 | 8.78 ± 3.51 | 10.09 ± 3.80 | 7.13 ± 2.68 | 8.91 ± 2.18 | 9.42 ± 3.68 | 10.21 ± 4.32 |
| Slovenia | | | 9.50 ± 3.82 | 4.58 | 10.82 | 7.16 ± 3.24 | 8.06 ± 4.48 | |

Data for Non-African runners are sorted in order of the number of finishers of each country

Table 3 Results of the mixed-effects regression analyses for change in running speed in female half-marathoners across years

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------|-------------|------------|----------|--------|---------|-------------|-------------|
| | | | | | | Upper | Lower |
| Ethiopia | | | | | | | |
| Constant term | 293.167388 | 371.574985 | 43.863 | 0.789 | 0.434 | -455.758951 | 1042.093726 |
| Year | -0.140332 | 0.184932 | 43.873 | -0.759 | 0.452 | -0.513068 | 0.232405 |
| Cage | -0.173148 | 0.135294 | 36.958 | -1.280 | 0.209 | -0.447291 | 0.100995 |
| Cage ² | -0.004387 | 0.006022 | 27.717 | -0.728 | 0.472 | -0.016727 | 0.007954 |
| Kenya | | | | | | | |
| Constant term | -21.426837 | 150.844832 | 36.330 | -0.142 | 0.888 | -327.257984 | 284.404310 |
| Year | 0.017207 | 0.075087 | 36.326 | 0.229 | 0.820 | -0.135029 | 0.169443 |
| Cage | -0.144332 | 0.060829 | 27.148 | -2.373 | 0.025 | -0.269111 | -0.019552 |
| Cage ² | -0.003215 | 0.003653 | 30.133 | -0.880 | 0.386 | -0.010674 | 0.004243 |
| Austria | | | | | | | |
| Constant term | 31.578045 | 29.443671 | 597.888 | 1.072 | 0.284 | -26.247547 | 89.403637 |
| Year | -0.011598 | 0.014658 | 597.871 | -0.791 | 0.429 | -0.040386 | 0.017190 |
| Cage | -0.028602 | 0.006916 | 600.177 | -4.136 | 0.000 | -0.042184 | -0.015021 |
| Cage ² | 0.000663 | 0.000536 | 608.882 | 1.237 | 0.217 | -0.000390 | 0.001716 |
| Canada | | | | | | | |
| Constant term | -125.514888 | 73.115253 | 155.945 | -1.717 | 0.088 | -269.938931 | 18.909154 |
| Year | 0.066249 | 0.036396 | 155.933 | 1.820 | 0.071 | -0.005644 | 0.138143 |
| Cage | -0.020679 | 0.014519 | 170.268 | -1.424 | 0.156 | -0.049340 | 0.007982 |
| Cage ² | 7.822872E-5 | 0.001161 | 162.137 | 0.067 | 0.946 | -0.002214 | 0.002370 |
| Czech Republic | | | | | | | |
| Constant term | -220.270108 | 155.839548 | 40.611 | -1.413 | 0.165 | -535.086061 | 94.545845 |
| Year | 0.113694 | 0.077609 | 40.610 | 1.465 | 0.151 | -0.043086 | 0.270474 |
| Cage | -0.080535 | 0.051903 | 45.473 | -1.552 | 0.128 | -0.185044 | 0.023974 |
| Cage ² | 0.003476 | 0.004529 | 46.743 | 0.768 | 0.447 | -0.005637 | 0.012589 |
| Denmark | | | | | | | |
| Constant term | -144.099673 | 142.620810 | 55.173 | -1.010 | 0.317 | -429.897999 | 141.698652 |
| Year | 0.076052 | 0.070989 | 55.174 | 1.071 | 0.289 | -0.066203 | 0.218308 |
| Cage | -0.012618 | 0.030636 | 58.407 | -0.412 | 0.682 | -0.073934 | 0.048697 |
| Cage ² | -0.000446 | 0.002495 | 59.214 | -0.179 | 0.859 | -0.005439 | 0.004546 |
| Spain | | | | | | | |
| Constant term | -5.366288 | 67.028907 | 141.702 | -0.080 | 0.936 | -137.872163 | 127.139587 |
| Year | 0.007615 | 0.033366 | 141.702 | 0.228 | 0.820 | -0.058344 | 0.073574 |
| Cage | 0.001968 | 0.014710 | 129.823 | 0.134 | 0.894 | -0.027134 | 0.031069 |
| Cage ² | -0.000865 | 0.001169 | 144.790 | -0.740 | 0.461 | -0.003175 | 0.001445 |
| France | | | | | | | |
| Constant term | 51.171466 | 15.295732 | 4653.214 | 3.345 | 0.001 | 21.184581 | 81.158350 |
| Year | -0.020670 | 0.007613 | 4653.140 | -2.715 | 0.007 | -0.035595 | -0.005744 |
| Cage | -0.023120 | 0.003408 | 4755.183 | -6.783 | 0.000 | -0.029801 | -0.016438 |
| Cage ² | -0.000602 | 0.000252 | 4810.855 | -2.392 | 0.017 | -0.001095 | -0.000109 |
| Great Britain | | | | | | | |
| Constant term | 28.901729 | 42.017402 | 749.113 | 0.688 | 0.492 | -53.584137 | 111.387595 |
| Year | -0.009779 | 0.020917 | 749.099 | -0.468 | 0.640 | -0.050842 | 0.031283 |
| Cage | 0.009513 | 0.009652 | 844.541 | 0.986 | 0.325 | -0.009432 | 0.028457 |
| Cage ² | -0.001723 | 0.000775 | 871.578 | -2.222 | 0.027 | -0.003245 | -0.000201 |
| Germany | | | | | | | |
| Constant term | 15.158368 | 14.956731 | 4456.047 | 1.013 | 0.311 | -14.164251 | 44.480986 |

Table 3 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------------------|-------------|-------------|------------|---------|---------|-------------|-------------|
| | | | | | | Upper | Lower |
| Year | -0.003244 | 0.007446 | 4455.945 | -0.436 | 0.663 | -0.017841 | 0.011353 |
| Cage | -0.023479 | 0.002955 | 3893.061 | -7.946 | 0.000 | -0.029272 | -0.017686 |
| Cage ² | -0.000163 | 0.000198 | 3910.190 | -0.822 | 0.411 | -0.000551 | 0.000225 |
| Italy | | | | | | | |
| Constant term | 55.277603 | 39.067728 | 844.859 | 1.415 | 0.157 | -21.403589 | 131.958795 |
| Year | -0.022114 | 0.019449 | 844.831 | -1.137 | 0.256 | -0.060287 | 0.016060 |
| Cage | -0.049367 | 0.010292 | 954.174 | -4.797 | 0.000 | -0.069565 | -0.029169 |
| Cage ² | -0.001914 | 0.000776 | 961.174 | -2.467 | 0.014 | -0.003436 | -0.000391 |
| Japan | | | | | | | |
| Constant term | 70.707877 | 63.986213 | 101.377 | 1.105 | 0.272 | -56.217842 | 197.633596 |
| Year | -0.031946 | 0.031855 | 101.405 | -1.003 | 0.318 | -0.095133 | 0.031242 |
| Cage | -0.047542 | 0.017703 | 159.965 | -2.685 | 0.008 | -0.082504 | -0.012579 |
| Cage ² | 0.001527 | 0.000930 | 166.855 | 1.641 | 0.103 | -0.000310 | 0.003363 |
| Principality of Liechtenstein | | | | | | | |
| Constant term | 10.483455 | 64.869741 | 255.178 | 0.162 | 0.872 | -117.264786 | 138.231696 |
| Year | 0.000233 | 0.032291 | 255.155 | 0.007 | 0.994 | -0.063358 | 0.063823 |
| Cage | -0.012747 | 0.013132 | 275.553 | -0.971 | 0.333 | -0.038598 | 0.013105 |
| Cage ² | -0.001544 | 0.001094 | 290.811 | -1.411 | 0.159 | -0.003697 | 0.000610 |
| Luxembourg | | | | | | | |
| Constant term | -47.666634 | 97.322485 | 48.909 | -0.490 | 0.626 | -243.252737 | 147.919469 |
| Year | 0.027753 | 0.048451 | 48.906 | 0.573 | 0.569 | -0.069617 | 0.125123 |
| Cage | -0.023725 | 0.013396 | 31.814 | -1.771 | 0.086 | -0.051017 | 0.003567 |
| Cage ² | 0.001603 | 0.001046 | 30.499 | 1.533 | 0.136 | -0.000532 | 0.003737 |
| Netherlands | | | | | | | |
| Constant term | 133.938661 | 125.455169 | 149.777 | 1.068 | 0.287 | -113.951882 | 381.829205 |
| Year | -0.062003 | 0.062457 | 149.769 | -0.993 | 0.322 | -0.185413 | 0.061407 |
| Cage | -0.011427 | 0.021283 | 105.363 | -0.537 | 0.592 | -0.053626 | 0.030771 |
| Cage ² | 0.000320 | 0.001177 | 84.597 | 0.272 | 0.786 | -0.002020 | 0.002660 |
| Norway | | | | | | | |
| Constant term | -487.272616 | 173.193914 | 54.820 | -2.813 | 0.007 | -834.386566 | -140.158666 |
| Year | 0.247478 | 0.086290 | 54.821 | 2.868 | 0.006 | 0.074537 | 0.420419 |
| Cage | -0.115170 | 0.020554 | 36.162 | -5.603 | 0.000 | -0.156850 | -0.073491 |
| Cage ² | 0.002664 | 0.001240 | 33.459 | 2.150 | 0.039 | 0.000144 | 0.005185 |
| Portugal | | | | | | | |
| Constant term | -474.101901 | 231.004145 | 55.403 | -2.052 | 0.045 | -936.968950 | -11.234851 |
| Year | 0.241610 | 0.114974 | 55.397 | 2.101 | 0.040 | 0.011234 | 0.471987 |
| Cage | -0.006509 | 0.059010 | 54.339 | -0.110 | 0.913 | -0.124800 | 0.111783 |
| Cage ² | 0.004436 | 0.005816 | 53.398 | 0.763 | 0.449 | -0.007227 | 0.016100 |
| Switzerland | | | | | | | |
| Constant term | 17.415465 | 3.082751 | 85,158.813 | 5.649 | 0.000 | 11.373300 | 23.457631 |
| Year | -0.003429 | 0.001535 | 85,155.422 | -2.235 | 0.025 | -0.006437 | -0.000422 |
| Cage | -0.010236 | 0.000499 | 71,948.591 | -20.518 | 0.000 | -0.011214 | -0.009259 |
| Cage ² | -0.000417 | 3.413093E-5 | 70,505.318 | -12.217 | 0.000 | -0.000484 | -0.000350 |
| United States of America | | | | | | | |
| Constant term | -102.180938 | 71.308524 | 295.142 | -1.433 | 0.153 | -242.518553 | 38.156677 |
| Year | 0.055053 | 0.035488 | 295.135 | 1.551 | 0.122 | -0.014789 | 0.124895 |
| Cage | -0.011404 | 0.012867 | 301.169 | -0.886 | 0.376 | -0.036725 | 0.013917 |
| Cage ² | 0.001037 | 0.000928 | 305.711 | 1.118 | 0.265 | -0.000789 | 0.002863 |

Table 3 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|--------------------------|-------------|------------|---------|--------|---------|-------------|------------|
| | | | | | | Upper | Lower |
| Australia | | | | | | | |
| Constant term | 535.990276 | 98.301322 | 13.686 | 5.453 | 0.000 | 324.700562 | 747.279990 |
| Year | -0.262740 | 0.048925 | 13.688 | -5.370 | 0.000 | -0.367899 | -0.157580 |
| Cage | 0.063641 | 0.055873 | 47.462 | 1.139 | 0.260 | -0.048733 | 0.176014 |
| Cage ² | -0.002360 | 0.002842 | 46.702 | -0.830 | 0.411 | -0.008078 | 0.003358 |
| Belgium | | | | | | | |
| Constant term | 7.038611 | 107.628613 | 165.205 | 0.065 | 0.948 | -205.466290 | 219.543511 |
| Year | 0.000697 | 0.053552 | 165.225 | 0.013 | 0.990 | -0.105038 | 0.106433 |
| Cage | 0.000626 | 0.015637 | 117.693 | 0.040 | 0.968 | -0.030341 | 0.031593 |
| Cage ² | 0.000700 | 0.001032 | 108.364 | 0.678 | 0.499 | -0.001345 | 0.002745 |
| Hungary | | | | | | | |
| Constant term | -275.257629 | 154.694094 | 51.000 | -1.779 | 0.081 | -585.818982 | 35.303724 |
| Year | 0.142544 | 0.076947 | 51.000 | 1.853 | 0.070 | -0.011933 | 0.297021 |
| Cage | -0.083478 | 0.047940 | 51.000 | -1.741 | 0.088 | -0.179721 | 0.012765 |
| Cage ² | 0.000717 | 0.002086 | 51.000 | 0.344 | 0.732 | -0.003470 | 0.004904 |
| Ireland | | | | | | | |
| Constant term | -33.859940 | 165.743508 | 57.989 | -0.204 | 0.839 | -365.633001 | 297.913121 |
| Year | 0.021718 | 0.082524 | 57.993 | 0.263 | 0.793 | -0.143473 | 0.186909 |
| Cage | -0.036636 | 0.037101 | 37.244 | -0.987 | 0.330 | -0.111793 | 0.038521 |
| Cage ² | -0.000562 | 0.003459 | 32.491 | -0.162 | 0.872 | -0.007603 | 0.006480 |
| Poland | | | | | | | |
| Constant term | -72.726997 | 104.051935 | 60.961 | -0.699 | 0.487 | -280.794379 | 135.340384 |
| Year | 0.040347 | 0.051798 | 60.974 | 0.779 | 0.439 | -0.063230 | 0.143924 |
| Cage | -0.053476 | 0.023476 | 65.801 | -2.278 | 0.026 | -0.100351 | -0.006601 |
| Cage ² | -0.001860 | 0.001865 | 69.955 | -0.997 | 0.322 | -0.005579 | 0.001859 |
| Russia | | | | | | | |
| Constant term | -106.441127 | 155.565229 | 42.567 | -0.684 | 0.498 | -420.260572 | 207.378318 |
| Year | 0.057206 | 0.077443 | 42.538 | 0.739 | 0.464 | -0.099022 | 0.213434 |
| Cage | -0.072584 | 0.042398 | 55.257 | -1.712 | 0.093 | -0.157542 | 0.012374 |
| Cage ² | 0.004846 | 0.003169 | 47.538 | 1.529 | 0.133 | -0.001528 | 0.011219 |
| Sweden | | | | | | | |
| Constant term | 75.820147 | 143.966277 | 104.839 | 0.527 | 0.600 | -209.643494 | 361.283787 |
| Year | -0.033856 | 0.071641 | 104.838 | -0.473 | 0.637 | -0.175909 | 0.108197 |
| Cage | -0.016537 | 0.020415 | 67.482 | -0.810 | 0.421 | -0.057279 | 0.024206 |
| Cage ² | 0.001067 | 0.001713 | 108.162 | 0.623 | 0.535 | -0.002328 | 0.004462 |
| Finland | | | | | | | |
| Constant term | -46.926724 | 100.378904 | 55.066 | -0.467 | 0.642 | -248.085146 | 154.231697 |
| Year | 0.027006 | 0.049943 | 55.068 | 0.541 | 0.591 | -0.073079 | 0.127091 |
| Cage | -0.053711 | 0.015750 | 46.121 | -3.410 | 0.001 | -0.085411 | -0.022011 |
| Cage ² | 0.001208 | 0.001076 | 44.445 | 1.123 | 0.268 | -0.000960 | 0.003376 |
| Greece | | | | | | | |
| Constant term | -105.607974 | 339.956176 | 18.425 | -0.311 | 0.760 | -818.651669 | 607.435721 |
| Year | 0.056703 | 0.169175 | 18.428 | 0.335 | 0.741 | -0.298130 | 0.411535 |
| Cage | 0.011301 | 0.080214 | 18.335 | 0.141 | 0.889 | -0.157002 | 0.179604 |
| Cage ² | 0.005226 | 0.004315 | 20.000 | 1.211 | 0.240 | -0.003776 | 0.014227 |
| Republic of South Africa | | | | | | | |
| Constant term | 195.281269 | 261.100120 | 30.776 | 0.748 | 0.460 | -337.393318 | 727.955856 |
| Year | -0.093079 | 0.130031 | 30.771 | -0.716 | 0.479 | -0.358359 | 0.172201 |

Table 3 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------|-------------|------------|--------|--------|---------|-------------|-------------|
| | | | | | | Upper | Lower |
| Cage | -0.033597 | 0.065427 | 31.996 | -0.514 | 0.611 | -0.166869 | 0.099674 |
| Cage ² | 0.000214 | 0.003268 | 27.237 | 0.066 | 0.948 | -0.006488 | 0.006916 |
| Brazil | | | | | | | |
| Constant term | 178.944876 | 212.772674 | 32.077 | 0.841 | 0.407 | -254.418110 | 612.307863 |
| Year | -0.084760 | 0.105910 | 32.083 | -0.800 | 0.429 | -0.300469 | 0.130949 |
| Cage | -0.054561 | 0.036085 | 32.952 | -1.512 | 0.140 | -0.127981 | 0.018860 |
| Cage ² | 0.003708 | 0.002066 | 37.833 | 1.795 | 0.081 | -0.000475 | 0.007891 |
| Mexico | | | | | | | |
| Constant term | -208.359308 | 343.548300 | 13.049 | -0.606 | 0.555 | -950.268215 | 533.549600 |
| Year | 0.108288 | 0.170848 | 13.048 | 0.634 | 0.537 | -0.260670 | 0.477246 |
| Cage | 0.017053 | 0.033477 | 1.149 | 0.509 | 0.691 | -0.297964 | 0.332070 |
| Cage ² | -0.004284 | 0.002132 | 1.006 | -2.009 | 0.293 | -0.031003 | 0.022435 |
| Argentina | | | | | | | |
| Constant term | 171.161142 | 449.529264 | 12.527 | 0.381 | 0.710 | -803.726404 | 1146.048688 |
| Year | -0.080710 | 0.223646 | 12.527 | -0.361 | 0.724 | -0.565727 | 0.404306 |
| Cage | -0.121342 | 0.107487 | 7.809 | -1.129 | 0.292 | -0.370266 | 0.127582 |
| Cage ² | 0.004002 | 0.011220 | 5.403 | 0.357 | 0.735 | -0.024206 | 0.032210 |
| India | | | | | | | |
| Constant term | -180.991329 | 118.481416 | 23.000 | -1.528 | 0.140 | -426.088812 | 64.106153 |
| Year | 0.095159 | 0.058967 | 23.000 | 1.614 | 0.120 | -0.026822 | 0.217141 |
| Cage | 0.034212 | 0.026224 | 23.000 | 1.305 | 0.205 | -0.020037 | 0.088460 |
| Cage ² | 0.002970 | 0.002305 | 23.000 | 1.288 | 0.210 | -0.001798 | 0.007737 |
| Israel | | | | | | | |
| Constant term | 1791.341424 | 749.677965 | 4.526 | 2.389 | 0.068 | -198.063460 | 3780.746308 |
| Year | -0.884457 | 0.372205 | 4.522 | -2.376 | 0.069 | -1.872464 | 0.103550 |
| Cage | -0.130351 | 0.107475 | 8.468 | -1.213 | 0.258 | -0.375823 | 0.115121 |
| Cage ² | -0.026869 | 0.011891 | 11.589 | -2.260 | 0.044 | -0.052880 | -0.000858 |
| Slovenia | | | | | | | |
| Constant term | -31.714993 | 134.226844 | 13.547 | -0.236 | 0.817 | -320.508524 | 257.078539 |
| Year | 0.020363 | 0.066884 | 13.547 | 0.304 | 0.765 | -0.123540 | 0.164266 |
| Cage | -0.084123 | 0.046744 | 8.409 | -1.800 | 0.108 | -0.191009 | 0.022763 |
| Cage ² | -0.001050 | 0.002818 | 9.076 | -0.373 | 0.718 | -0.007416 | 0.005317 |

Data for Non-African runners are sorted in order of the number of finishers of each country

Cage centered age, Cage² centered age squared

between 1875 and 2013, the most representative nations in the 'English Channel Swim' were Great Britain, the United States of America, Australia and Ireland. The fastest swim times were, however, not achieved by local athletes but by athletes from the United States of America, Australia and Great Britain (Knechtle et al. 2014).

However, the most likely explanation for the very low participation of East African runners in half-marathons and marathons held in Switzerland are economic reasons. For Kenyan runners, marathon running is a means of making money to help their families, parents and siblings (Onywera et al. 2006; Onywera 2009). Onywera (2009) described economic reasons for Kenyan athletes as one of

the most important factors to compete in marathon running, which might be undercharged so far (Hamilton and Weston 2000). Prize money in Swiss half-marathons and marathons is very low compared to prize money offered in the 'World Marathon Majors' (www.worldmarathonmajors.com). For the winner in the 'Zurich Marathon' in Switzerland, the prize money is 10,000 Swiss Francs (www.zurichmarathon.ch) which is very low in contrast to the prize money offered in large city marathons. Indeed, overall prize money in races of the 'World Marathon Majors' is considerably higher (www.worldmarathonmajors.com). In the 'BMW Berlin Marathon', the 'Tokyo Marathon', and the 'Virgin London Marathon' the prize money is \$1,000,000,

Table 4 Results of the mixed-effects regression analyses for change in running speed in male half-marathoners across years

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------|------------|------------|------------|---------|---------|-------------|-------------|
| | | | | | | Upper | Lower |
| Ethiopia | | | | | | | |
| Constant term | 98.099117 | 174.871376 | 30.494 | 0.561 | 0.579 | -258.793601 | 454.991835 |
| Year | -0.043552 | 0.087058 | 30.500 | -0.500 | 0.620 | -0.221226 | 0.134123 |
| Cage | -0.250494 | 0.185335 | 45.246 | -1.352 | 0.183 | -0.623723 | 0.122734 |
| Cage ² | -0.012719 | 0.007260 | 42.721 | -1.752 | 0.087 | -0.027363 | 0.001925 |
| Kenya | | | | | | | |
| Constant term | 88.307393 | 103.114750 | 61.076 | 0.856 | 0.395 | -117.878135 | 294.492921 |
| Year | -0.037470 | 0.051349 | 61.091 | -0.730 | 0.468 | -0.140145 | 0.065205 |
| Cage | -0.066120 | 0.029956 | 133.511 | -2.207 | 0.029 | -0.125371 | -0.006870 |
| Cage ² | -0.002035 | 0.001386 | 133.757 | -1.469 | 0.144 | -0.004776 | 0.000706 |
| Austria | | | | | | | |
| Constant term | 8.193904 | 15.718906 | 1374.455 | 0.521 | 0.602 | -22.641739 | 39.029547 |
| Year | 0.000216 | 0.007826 | 1374.306 | 0.028 | 0.978 | -0.015136 | 0.015568 |
| Cage | -0.016008 | 0.004315 | 1443.906 | -3.710 | 0.000 | -0.024471 | -0.007544 |
| Cage ² | -0.000501 | 0.000294 | 1458.820 | -1.702 | 0.089 | -0.001078 | 7.633939E-5 |
| Canada | | | | | | | |
| Constant term | -21.298964 | 52.088221 | 337.247 | -0.409 | 0.683 | -123.757696 | 81.159769 |
| Year | 0.014351 | 0.025943 | 337.200 | 0.553 | 0.580 | -0.036679 | 0.065382 |
| Cage | -0.024635 | 0.011096 | 359.294 | -2.220 | 0.027 | -0.046457 | -0.002814 |
| Cage ² | 0.000544 | 0.000695 | 362.647 | 0.783 | 0.434 | -0.000822 | 0.001910 |
| Czech Republic | | | | | | | |
| Constant term | 154.008680 | 81.928758 | 100.744 | 1.880 | 0.063 | -8.520953 | 316.538313 |
| Year | -0.072109 | 0.040820 | 100.777 | -1.767 | 0.080 | -0.153086 | 0.008869 |
| Cage | -0.003265 | 0.013101 | 75.567 | -0.249 | 0.804 | -0.029361 | 0.022830 |
| Cage ² | -0.002162 | 0.000996 | 78.010 | -2.171 | 0.033 | -0.004144 | -0.000179 |
| Denmark | | | | | | | |
| Constant term | 73.075047 | 85.575129 | 152.801 | 0.854 | 0.394 | -95.988101 | 242.138195 |
| Year | -0.032295 | 0.042595 | 152.782 | -0.758 | 0.450 | -0.116447 | 0.051857 |
| Cage | 0.004069 | 0.013983 | 120.832 | 0.291 | 0.772 | -0.023615 | 0.031752 |
| Cage ² | -0.002067 | 0.000851 | 124.782 | -2.429 | 0.017 | -0.003752 | -0.000383 |
| Spain | | | | | | | |
| Constant term | 73.070026 | 58.997907 | 419.804 | 1.239 | 0.216 | -42.898085 | 189.038138 |
| Year | -0.031824 | 0.029368 | 419.811 | -1.084 | 0.279 | -0.089550 | 0.025902 |
| Cage | -0.015581 | 0.013136 | 435.510 | -1.186 | 0.236 | -0.041399 | 0.010238 |
| Cage ² | 0.001634 | 0.000911 | 471.708 | 1.793 | 0.074 | -0.000156 | 0.003425 |
| France | | | | | | | |
| Constant term | 2.152551 | 8.424878 | 11,440.730 | 0.255 | 0.798 | -14.361653 | 18.666754 |
| Year | 0.003734 | 0.004195 | 11,440.223 | 0.890 | 0.373 | -0.004488 | 0.011956 |
| Cage | -0.024520 | 0.002065 | 11,842.861 | -11.874 | 0.000 | -0.028568 | -0.020472 |
| Cage ² | -0.000555 | 0.000144 | 11,634.921 | -3.864 | 0.000 | -0.000837 | -0.000274 |
| Great Britain | | | | | | | |
| Constant term | 37.386616 | 22.952563 | 1729.593 | 1.629 | 0.104 | -7.631084 | 82.404316 |
| Year | -0.014237 | 0.011430 | 1729.576 | -1.246 | 0.213 | -0.036654 | 0.008181 |
| Cage | -0.007171 | 0.005013 | 1775.835 | -1.430 | 0.153 | -0.017003 | 0.002662 |
| Cage ² | -0.000507 | 0.000363 | 1811.205 | -1.399 | 0.162 | -0.001218 | 0.000204 |
| Germany | | | | | | | |
| Constant term | 26.340398 | 7.339500 | 12,201.868 | 3.589 | 0.000 | 11.953816 | 40.726980 |

Table 4 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|--------------------------|-------------|-------------|-------------|---------|---------|-------------|--------------|
| | | | | | | Upper | Lower |
| Year | -0.008802 | 0.003654 | 12,201.252 | -2.409 | 0.016 | -0.015965 | -0.001639 |
| Cage | -0.015672 | 0.001614 | 11,817.685 | -9.708 | 0.000 | -0.018836 | -0.012508 |
| Cage ² | -0.000337 | 0.000106 | 11,885.807 | -3.164 | 0.002 | -0.000545 | -0.000128 |
| Italy | | | | | | | |
| Constant term | 32.563297 | 20.328196 | 2372.545 | 1.602 | 0.109 | -7.299571 | 72.426164 |
| Year | -0.010999 | 0.010122 | 2372.366 | -1.087 | 0.277 | -0.030847 | 0.008850 |
| Cage | -0.045951 | 0.005681 | 2514.295 | -8.089 | 0.000 | -0.057090 | -0.034812 |
| Cage ² | -0.000765 | 0.000380 | 2470.087 | -2.015 | 0.044 | -0.001510 | -2.039314E-5 |
| Japan | | | | | | | |
| Constant term | 14.867692 | 48.121533 | 316.697 | 0.309 | 0.758 | -79.810599 | 109.545984 |
| Year | -.003770 | 0.023954 | 316.650 | -.157 | 0.875 | -.050900 | 0.043360 |
| Cage | -.058721 | 0.010081 | 397.745 | -5.825 | 0.000 | -.078540 | -.038902 |
| Cage ² | 4.080624E-5 | 0.000449 | 341.270 | 0.091 | 0.928 | -.000843 | 0.000924 |
| Fürstentum Liechtenstein | | | | | | | |
| Constant term | 36.488409 | 42.462409 | 604.502 | 0.859 | 0.391 | -46.903349 | 119.880168 |
| Year | -0.012766 | 0.021142 | 604.548 | -0.604 | 0.546 | -0.054287 | 0.028756 |
| Cage | -0.001820 | 0.009507 | 565.166 | -0.191 | 0.848 | -0.020492 | 0.016853 |
| Cage ² | -0.001896 | 0.000777 | 592.741 | -2.438 | 0.015 | -0.003422 | -0.000369 |
| Luxembourg | | | | | | | |
| Constant term | -15.253456 | 80.615224 | 92.293 | -0.189 | 0.850 | -175.355473 | 144.848561 |
| Year | 0.011431 | 0.040137 | 92.287 | 0.285 | 0.776 | -0.068280 | 0.091143 |
| Cage | -0.065466 | 0.021046 | 112.887 | -3.111 | 0.002 | -0.107162 | -0.023770 |
| Cage ² | 0.002067 | 0.001460 | 76.329 | 1.415 | 0.161 | -0.000842 | 0.004975 |
| Netherlands | | | | | | | |
| Constant term | 43.412228 | 54.590318 | 317.931 | 0.795 | 0.427 | -63.991689 | 150.816144 |
| Year | -0.016855 | 0.027175 | 317.960 | -0.620 | 0.536 | -0.070321 | 0.036612 |
| Cage | -0.029740 | 0.011819 | 303.713 | -2.516 | 0.012 | -0.052998 | -0.006482 |
| Cage ² | -0.001104 | 0.000799 | 294.009 | -1.382 | 0.168 | -0.002675 | 0.000468 |
| Norway | | | | | | | |
| Constant term | -108.473099 | 87.956547 | 66.260 | -1.233 | 0.222 | -284.071127 | 67.124929 |
| Year | 0.058583 | 0.043794 | 66.285 | 1.338 | 0.186 | -0.028848 | 0.146014 |
| Cage | 0.003335 | 0.021397 | 98.282 | 0.156 | 0.876 | -0.039125 | 0.045796 |
| Cage ² | -0.001692 | 0.001159 | 78.629 | -1.460 | 0.148 | -0.004000 | 0.000615 |
| Portugal | | | | | | | |
| Constant term | 67.632099 | 92.672293 | 171.225 | 0.730 | 0.467 | -115.295174 | 250.559373 |
| Year | -0.028137 | 0.046162 | 171.263 | -0.610 | 0.543 | -0.119256 | 0.062982 |
| Cage | 0.009515 | 0.023055 | 186.876 | 0.413 | 0.680 | -0.035968 | 0.054997 |
| Cage ² | -0.001022 | 0.001966 | 185.843 | -0.520 | 0.604 | -0.004900 | 0.002855 |
| Switzerland | | | | | | | |
| Constant term | 8.817285 | 1.667403 | 223,427.050 | 5.288 | 0.000 | 5.549219 | 12.085351 |
| Year | 0.000791 | 0.000830 | 223,414.735 | 0.953 | 0.340 | -0.000836 | 0.002418 |
| Cage | -0.010964 | 0.000294 | 204,230.290 | -37.270 | 0.000 | -0.011540 | -0.010387 |
| Cage ² | -0.000368 | 2.032780E-5 | 202,092.789 | -18.089 | 0.000 | -0.000408 | -0.000328 |
| United States of America | | | | | | | |
| Constant term | 54.392263 | 32.424867 | 708.442 | 1.677 | 0.094 | -9.268067 | 118.052594 |
| Year | -0.023017 | 0.016143 | 708.387 | -1.426 | 0.154 | -0.054711 | 0.008677 |
| Cage | -0.009382 | 0.006245 | 705.174 | -1.502 | 0.133 | -0.021643 | 0.002878 |
| Cage ² | -0.000283 | 0.000441 | 689.741 | -0.641 | 0.521 | -0.001149 | 0.000583 |

Table 4 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|--------------------------|--------------|------------|---------|--------|---------|-------------|------------|
| | | | | | | Upper | Lower |
| Australia | | | | | | | |
| Constant term | 52.302602 | 107.606779 | 108.032 | 0.486 | 0.628 | -160.991990 | 265.597194 |
| Year | -0.021678 | 0.053582 | 108.089 | -0.405 | 0.687 | -0.127885 | 0.084529 |
| Cage | -0.013969 | 0.030696 | 133.451 | -0.455 | 0.650 | -0.074683 | 0.046745 |
| Cage ² | -0.000317 | 0.002070 | 136.856 | -0.153 | 0.878 | -0.004411 | 0.003776 |
| Belgium | | | | | | | |
| Constant term | 107.524420 | 49.224327 | 501.956 | 2.184 | 0.029 | 10.813323 | 204.235517 |
| Year | -0.049210 | 0.024501 | 501.911 | -2.008 | 0.045 | -0.097348 | -0.001073 |
| Cage | -0.033350 | 0.009176 | 447.125 | -3.635 | 0.000 | -0.051383 | -0.015317 |
| Cage ² | -7.340408E-5 | 0.000666 | 417.563 | -0.110 | 0.912 | -0.001382 | 0.001235 |
| Hungary | | | | | | | |
| Constant term | 5.737883 | 94.942100 | 159.346 | 0.060 | 0.952 | -181.769287 | 193.245052 |
| Year | 0.002193 | 0.047257 | 159.320 | 0.046 | 0.963 | -0.091137 | 0.095523 |
| Cage | -0.021118 | 0.020068 | 158.936 | -1.052 | 0.294 | -0.060752 | 0.018515 |
| Cage ² | 0.001436 | 0.001087 | 174.946 | 1.320 | 0.188 | -0.000710 | 0.003582 |
| Ireland | | | | | | | |
| Constant term | 138.624168 | 77.025730 | 130.753 | 1.800 | 0.074 | -13.753783 | 291.002120 |
| Year | -0.064935 | 0.038349 | 130.724 | -1.693 | 0.093 | -0.140799 | 0.010930 |
| Cage | 0.012905 | 0.020461 | 147.172 | 0.631 | 0.529 | -0.027530 | 0.053340 |
| Cage ² | 0.001772 | 0.001597 | 146.087 | 1.110 | 0.269 | -0.001384 | 0.004928 |
| Poland | | | | | | | |
| Constant term | 86.086931 | 104.182157 | 192.160 | 0.826 | 0.410 | -119.400506 | 291.574369 |
| Year | -0.038832 | 0.051868 | 192.148 | -0.749 | 0.455 | -0.141137 | 0.063472 |
| Cage | -0.092905 | 0.018121 | 167.220 | -5.127 | 0.000 | -0.128680 | -0.057130 |
| Cage ² | 0.001517 | 0.001224 | 171.169 | 1.239 | 0.217 | -0.000899 | 0.003933 |
| Russia | | | | | | | |
| Constant term | 211.097501 | 112.913539 | 96.255 | 1.870 | 0.065 | -13.026515 | 435.221517 |
| Year | -0.100778 | 0.056233 | 96.273 | -1.792 | 0.076 | -0.212397 | 0.010840 |
| Cage | -0.066677 | 0.024282 | 81.019 | -2.746 | 0.007 | -0.114991 | -0.018364 |
| Cage ² | -0.004585 | 0.001957 | 62.648 | -2.343 | 0.022 | -0.008497 | -0.000674 |
| Sweden | | | | | | | |
| Constant term | 23.098100 | 70.780786 | 194.032 | 0.326 | 0.745 | -116.500399 | 162.696600 |
| Year | -0.007622 | 0.035234 | 193.992 | -0.216 | 0.829 | -0.077113 | 0.061870 |
| Cage | -0.041879 | 0.012513 | 177.901 | -3.347 | 0.001 | -0.066573 | -0.017186 |
| Cage ² | -0.000214 | 0.000893 | 193.338 | -0.239 | 0.811 | -0.001976 | 0.001548 |
| Finland | | | | | | | |
| Constant term | 8.266275 | 52.736089 | 163.256 | 0.157 | 0.876 | -95.866485 | 112.399036 |
| Year | -0.000566 | 0.026249 | 163.232 | -0.022 | 0.983 | -0.052397 | 0.051266 |
| Cage | -0.041553 | 0.011615 | 170.064 | -3.578 | 0.000 | -0.064481 | -0.018625 |
| Cage ² | 0.000222 | 0.000718 | 147.558 | 0.309 | 0.758 | -0.001197 | 0.001640 |
| Greece | | | | | | | |
| Constant term | -61.629272 | 138.778354 | 63.917 | -0.444 | 0.658 | -338.877861 | 215.619317 |
| Year | 0.034774 | 0.069126 | 63.920 | 0.503 | 0.617 | -0.103324 | 0.172871 |
| Cage | -0.045672 | 0.029991 | 67.495 | -1.523 | 0.132 | -0.105525 | 0.014181 |
| Cage ² | 0.001362 | 0.002210 | 66.813 | 0.616 | 0.540 | -0.003050 | 0.005774 |
| Republic of South Africa | | | | | | | |
| Constant term | 97.835143 | 206.579371 | 37.822 | 0.474 | 0.639 | -320.427710 | 516.097997 |
| Year | -0.045155 | 0.102815 | 37.832 | -0.439 | 0.663 | -0.253323 | 0.163012 |

Table 4 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------|-------------|------------|--------|--------|---------|-------------|-------------|
| | | | | | | Upper | Lower |
| Cage | -0.114764 | 0.045331 | 42.716 | -2.532 | 0.015 | -0.206201 | -0.023327 |
| Cage ² | 0.002014 | 0.003936 | 43.893 | 0.512 | 0.611 | -0.005919 | 0.009947 |
| Brazil | | | | | | | |
| Constant term | 69.573202 | 122.101031 | 76.685 | 0.570 | 0.570 | -173.576935 | 312.723340 |
| Year | -0.030992 | 0.060774 | 76.687 | -0.510 | 0.612 | -0.152015 | 0.090032 |
| Cage | -0.005665 | 0.035651 | 84.804 | -0.159 | 0.874 | -0.076551 | 0.065221 |
| Cage ² | 0.000800 | 0.002584 | 85.927 | 0.310 | 0.758 | -0.004337 | 0.005937 |
| Mexico | | | | | | | |
| Constant term | 41.878671 | 159.784287 | 57.808 | 0.262 | 0.794 | -277.986904 | 361.744245 |
| Year | -0.016374 | 0.079565 | 57.848 | -0.206 | 0.838 | -0.175650 | 0.142902 |
| Cage | 0.004652 | 0.037631 | 61.634 | 0.124 | 0.902 | -0.070580 | 0.079884 |
| Cage ² | 0.000324 | 0.002948 | 56.403 | 0.110 | 0.913 | -0.005580 | 0.006229 |
| Argentina | | | | | | | |
| Constant term | -280.869673 | 275.764919 | 14.061 | -1.019 | 0.326 | -872.087719 | 310.348372 |
| Year | 0.143819 | 0.137206 | 14.060 | 1.048 | 0.312 | -0.150341 | 0.437979 |
| Cage | -0.105665 | 0.095288 | 20.398 | -1.109 | 0.280 | -0.304184 | 0.092855 |
| Cage ² | -0.008941 | 0.013370 | 20.476 | -0.669 | 0.511 | -0.036788 | 0.018907 |
| India | | | | | | | |
| Constant term | 184.538334 | 187.481998 | 40.972 | 0.984 | 0.331 | -194.097033 | 563.173702 |
| Year | -0.087437 | 0.093418 | 40.964 | -0.936 | 0.355 | -0.276104 | 0.101229 |
| Cage | -0.043125 | 0.036785 | 44.595 | -1.172 | 0.247 | -0.117232 | 0.030982 |
| Cage ² | -0.000763 | 0.003355 | 41.543 | -0.228 | 0.821 | -0.007536 | 0.006009 |
| Israel | | | | | | | |
| Constant term | 23.126668 | 168.388173 | 45.039 | 0.137 | 0.891 | -316.016346 | 362.269682 |
| Year | -0.006935 | 0.083826 | 45.030 | -0.083 | 0.934 | -0.175766 | 0.161896 |
| Cage | -0.016089 | 0.022043 | 28.717 | -0.730 | 0.471 | -0.061192 | 0.029014 |
| Cage ² | -0.000399 | 0.001451 | 29.170 | -0.275 | 0.785 | -0.003365 | 0.002567 |
| Slovenia | | | | | | | |
| Constant term | 449.153792 | 328.346727 | 19.574 | 1.368 | 0.187 | -236.722979 | 1135.030562 |
| Year | -0.219405 | 0.163419 | 19.579 | -1.343 | 0.195 | -0.560762 | 0.121952 |
| Cage | -0.078618 | 0.063055 | 11.412 | -1.247 | 0.237 | -0.216792 | 0.059557 |
| Cage ² | 0.003187 | 0.005660 | 11.316 | 0.563 | 0.584 | -0.009229 | 0.015603 |

Data for Non-African runners are sorted in order of the number of finishers of each country

Cage centered age, Cage² centered age squared

in the 'Boston Marathon' \$846,000, in the 'TCS NYC Marathon' \$805,000 and in the 'Bank of America Chicago Marathon' \$560,000 (www.bestroadraces.com/brr100.php/prizes). The differences in prize money seem very similar in half-marathon compared to marathon. In a large half-marathon held in Switzerland such as the 'Hallwilerseelauf', the prize money for both women and men for the top five is, however, only CHF 600, 400, 300, 200, and 100, respectively (www.hallwilerseelauf.ch). In an elite half-marathon such as the 'IAAF/AL-Bank World Half Marathon Championships', a total prize purse of US\$245,000 will be paid by the IAAF for the men's and women's races (www.iaaf.org/news/news/prize-money).

East African runners were the fastest in half-marathons and marathons

A second finding was that female and male runners from Kenya and Ethiopia were the fastest in both half-marathons and marathons. The dominance of East African runners was evident for both marathon and half-marathon but differed from longer distances. For instance, it has been shown that male Japanese runners were the best in 100-km ultra-marathons (Cejka et al. 2014). The trend in performance across years should be explained by a model showing that human speed after having progressed fast in the past has now reached a plateau and further progression should be attributed to an enlarged

Table 5 Running speed (km/h) with mean \pm SD for female and male East-African and Non-African marathoners

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Women | | | | | | | | |
| Ethiopia | | | | | | | 18.64 | |
| Kenya | | | | | | 18.26 | | |
| Austria | 16.42 \pm 1.62 | 18.32 \pm 1.81 | 12.34 | 13.83 \pm 5.78 | 12.36 \pm 2.18 | 9.80 \pm 0.21 | 12.65 \pm 3.26 | 12.39 \pm 2.43 |
| France | 13.70 \pm 4.13 | 13.77 \pm 4.01 | 13.83 \pm 4.05 | 13.72 \pm 3.88 | 12.42 \pm 3.98 | 13.38 \pm 3.97 | 13.82 \pm 4.43 | 13.27 \pm 4.05 |
| Great Britain | | 10.50 \pm 1.45 | 12.73 \pm 4.45 | 13.14 \pm 5.02 | 12.96 \pm 3.95 | 13.46 \pm 4.35 | 14.47 \pm 4.58 | 12.72 \pm 2.65 |
| Germany | 11.68 \pm 2.24 | 11.17 \pm 2.63 | 13.90 \pm 3.79 | 12.20 \pm 3.77 | 12.63 \pm 3.78 | 12.11 \pm 3.34 | 13.04 \pm 3.68 | 13.00 \pm 3.60 |
| Italy | 17.10 | 19.19 \pm 0.52 | 19.64 \pm 1.30 | 12.67 \pm 5.70 | 11.93 \pm 3.77 | 15.39 \pm 4.39 | 12.06 \pm 4.28 | 18.78 \pm 1.77 |
| Japan | 14.13 | 10.96 | 11.72 \pm 5.02 | 7.88 \pm 1.11 | 18.28 | 13.34 \pm 4.69 | 14.27 \pm 5.01 | 18.70 |
| Switzerland | 14.46 \pm 4.34 | 15.30 \pm 4.19 | 14.74 \pm 4.13 | 15.03 \pm 4.06 | 15.60 \pm 4.01 | 15.44 \pm 4.09 | 15.08 \pm 4.14 | 15.20 \pm 4.12 |
| Canada | | | | 9.31 | 10.29 \pm 5.82 | 8.00 \pm 1.63 | 12.51 | 12.85 \pm 7.29 |
| Liechtenstein | | 11.65 | 9.92 \pm 2.39 | | 16.05 \pm 5.43 | | 18.13 \pm 1.01 | 19.75 \pm 0.15 |
| USA | | 17.95 | | | | 17.17 \pm 4.07 | 13.92 \pm 4.10 | 9.85 \pm 1.43 |
| Belgium | 10.77 | | | | 19.87 \pm 0.49 | 10.95 \pm 0.37 | 11.65 \pm 1.62 | 10.90 \pm 0.79 |
| Spain | | | | | | | 12.48 | |
| Poland | | | | 11.24 \pm 0.64 | 8.85 | | | |
| Men | | | | | | | | |
| Ethiopia | | | 17.47 \pm 2.28 | | | | | |
| Kenya | | 18.81 | 17.95 \pm 1.44 | | 17.61 \pm 1.97 | 17.43 \pm 1.62 | 17.28 | |
| Austria | | | 12.66 \pm 0.09 | 9.10 | 19.37 | 16.18 | 14.40 \pm 7.02 | 15.59 \pm 5.27 |
| France | 14.08 \pm 4.06 | 13.47 \pm 3.67 | 13.17 \pm 3.75 | 13.17 \pm 3.30 | 13.28 \pm 3.79 | 13.41 \pm 3.84 | 13.50 \pm 3.89 | 12.87 \pm 3.48 |
| Great Britain | 9.27 \pm 0.96 | 12.54 \pm 3.61 | 12.01 \pm 3.57 | 15.21 \pm 2.94 | 15.02 \pm 4.05 | 14.08 \pm 3.79 | 14.15 \pm 4.51 | 13.26 \pm 3.82 |
| Germany | 12.51 \pm 3.32 | 13.02 \pm 3.78 | 12.67 \pm 3.28 | 12.60 \pm 3.48 | 12.89 \pm 3.70 | 13.00 \pm 3.66 | 12.49 \pm 3.55 | 12.89 \pm 3.65 |
| Italy | 16.23 \pm 4.37 | 12.51 \pm 3.77 | 12.85 \pm 2.99 | 12.49 \pm 4.01 | 12.50 \pm 3.24 | 14.23 \pm 4.04 | 13.66 \pm 3.90 | 15.14 \pm 3.86 |
| Japan | 15.09 | 14.42 | 12.84 \pm 5.70 | 11.47 | 11.45 \pm 3.85 | 11.09 \pm 4.17 | 12.92 \pm 4.63 | 11.53 \pm 3.41 |
| Switzerland | 14.41 \pm 3.99 | 14.84 \pm 4.09 | 14.73 \pm 4.07 | 14.77 \pm 4.09 | 14.93 \pm 4.11 | 14.71 \pm 4.08 | 14.76 \pm 4.04 | 14.83 \pm 4.06 |
| Canada | 14.00 \pm 0.72 | 18.98 | 12.22 \pm 4.96 | 12.37 \pm 4.83 | 10.50 \pm 3.91 | 10.90 \pm 3.36 | 11.12 \pm 4.09 | 13.14 \pm 4.06 |
| Liechtenstein | | | 18.70 | 17.56 \pm 1.45 | 19.11 \pm 1.21 | 15.41 \pm 4.16 | 17.42 \pm 3.08 | 17.80 \pm 1.43 |
| USA | 12.39 \pm 3.85 | 10.79 \pm 1.55 | 11.25 \pm 3.38 | 13.62 \pm 3.72 | 12.12 \pm 3.55 | 12.65 \pm 4.21 | 12.14 \pm 3.48 | 12.86 \pm 4.29 |
| Belgium | | 12.23 | | 14.97 \pm 5.32 | 14.80 \pm 4.67 | 13.65 \pm 4.98 | 12.71 \pm 4.02 | 12.70 \pm 3.91 |
| Spain | | 13.08 | 19.33 | 18.87 \pm 1.06 | 13.90 \pm 5.05 | 12.63 \pm 2.21 | 13.37 \pm 4.71 | 14.10 \pm 2.28 |
| Poland | | 10.07 | | 11.65 \pm 1.73 | 9.05 | 10.36 \pm 2.31 | 9.73 | 17.70 \pm 2.29 |
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Women | | | | | | | | |
| Ethiopia | | | | | 18.78 | 19.24 | | |
| Kenya | | | | | 18.49 | | | |
| Austria | 11.84 \pm 2.64 | 12.88 \pm 3.92 | 12.48 \pm 1.87 | 14.49 \pm 4.76 | 11.09 \pm 1.30 | 13.21 \pm 3.31 | 11.29 \pm 2.23 | 11.40 \pm 2.61 |
| France | 13.09 \pm 3.75 | 14.14 \pm 4.36 | 13.60 \pm 4.05 | 13.04 \pm 3.72 | 13.37 \pm 3.81 | 13.48 \pm 3.89 | 14.01 \pm 3.65 | 13.47 \pm 4.22 |
| Great Britain | 14.06 \pm 4.43 | 12.85 \pm 4.03 | 13.15 \pm 0.79 | 13.31 \pm 4.35 | 14.81 \pm 4.85 | 11.46 \pm 5.80 | 14.10 \pm 3.80 | 12.67 \pm 3.57 |
| Germany | 13.71 \pm 3.85 | 12.97 \pm 3.48 | 12.89 \pm 3.93 | 13.47 \pm 4.39 | 12.81 \pm 3.56 | 13.24 \pm 3.62 | 13.45 \pm 4.25 | 12.94 \pm 3.87 |
| Italy | 16.34 \pm 3.92 | 17.44 \pm 3.70 | 12.78 \pm 3.09 | 18.82 \pm 1.04 | 17.47 \pm 1.84 | 16.90 \pm 4.52 | 18.56 \pm 0.80 | 16.05 \pm 4.56 |
| Japan | 13.33 \pm 4.01 | 14.24 \pm 4.74 | 19.90 | 13.66 \pm 1.15 | 11.80 \pm 4.36 | 18.00 \pm 0.39 | 18.49 \pm 0.20 | 19.47 \pm 1.09 |
| Switzerland | 15.20 \pm 4.07 | 14.90 \pm 4.16 | 15.21 \pm 4.08 | 14.98 \pm 4.27 | 15.03 \pm 4.09 | 14.72 \pm 4.14 | 15.24 \pm 4.14 | 14.76 \pm 4.02 |
| Canada | 17.99 | 18.53 \pm 0.86 | 14.73 \pm 6.33 | 9.44 \pm 1.67 | 12.47 \pm 3.63 | 8.06 \pm 2.00 | 12.10 \pm 3.62 | 11.97 \pm 6.90 |
| Liechtenstein | 18.78 \pm 0.79 | 18.31 \pm 2.04 | 16.96 \pm 4.11 | 12.09 | 16.55 | 16.95 \pm 3.38 | | 18.56 \pm 0.24 |
| USA | 12.12 \pm 4.17 | 13.84 \pm 3.76 | 10.03 \pm 0.19 | 9.39 \pm 0.59 | 10.36 \pm 1.59 | 15.87 | | 12.08 \pm 5.31 |
| Belgium | 11.66 | 9.07 | | 13.07 | 9.30 | | | |
| Spain | 17.96 \pm 1.64 | 10.75 | 12.95 \pm 1.50 | | 11.79 \pm 1.48 | 12.19 \pm 0.21 | 19.09 | 12.79 \pm 1.39 |
| Poland | | | 12.25 | 10.67 | 11.69 \pm 0.57 | 18.01 \pm 0.67 | 15.50 \pm 3.96 | 12.10 \pm 1.93 |

Table 5 continued

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Men | | | | | | | | |
| Ethiopia | 15.67 ± 3.28 | 16.26 | 17.34 ± 1.61 | 15.87 ± 0.21 | 15.13 | | 15.91 ± 1.04 | 15.18 |
| Kenya | 16.88 ± 2.65 | 18.43 ± 0.25 | 18.50 ± 0.19 | 18.10 ± 0.58 | 17.49 ± 0.47 | 17.96 | 18.15 ± 1.28 | 17.47 ± 1.68 |
| Austria | 17.87 ± 0.91 | 15.28 ± 5.19 | | 10.60 | | | 20.29 | 12.44 ± 3.74 |
| France | 13.12 ± 3.79 | 13.69 ± 4.00 | 13.61 ± 3.96 | 13.21 ± 3.77 | 13.21 ± 3.67 | 13.21 ± 3.86 | 13.34 ± 3.66 | 13.70 ± 3.82 |
| Great Britain | 13.08 ± 4.04 | 13.28 ± 4.01 | 12.66 ± 3.74 | 13.39 ± 3.95 | 12.97 ± 3.97 | 12.64 ± 3.82 | 13.63 ± 3.90 | 12.48 ± 3.49 |
| Germany | 13.05 ± 3.77 | 12.64 ± 3.50 | 12.93 ± 3.62 | 13.07 ± 3.80 | 12.98 ± 3.69 | 13.07 ± 3.70 | 13.07 ± 3.54 | 13.27 ± 3.93 |
| Italy | 14.54 ± 4.07 | 15.13 ± 4.17 | 14.34 ± 4.05 | 12.79 ± 3.71 | 12.93 ± 4.05 | 13.30 ± 4.03 | 13.40 ± 4.10 | 12.38 ± 3.35 |
| Japan | 11.22 ± 2.74 | 12.79 ± 3.82 | 11.81 ± 4.02 | 10.66 ± 3.95 | 11.61 ± 4.59 | 11.73 ± 4.31 | 14.45 ± 5.00 | 12.46 ± 7.03 |
| Switzerland | 14.78 ± 4.07 | 14.87 ± 4.09 | 14.77 ± 4.08 | 14.83 ± 4.11 | 14.87 ± 4.12 | 14.75 ± 4.01 | 14.89 ± 4.08 | 14.69 ± 4.07 |
| Canada | 10.77 ± 3.77 | 11.27 ± 4.86 | 11.81 ± 5.97 | 10.40 ± 3.80 | 15.25 ± 4.45 | | 15.17 ± 3.47 | 11.91 ± 3.81 |
| Liechtenstein | 17.17 ± 4.41 | 14.70 ± 4.35 | 17.54 ± 3.04 | 14.28 ± 3.91 | 15.47 ± 3.96 | 17.08 ± 3.03 | 13.58 ± 2.56 | 12.86 ± 6.57 |
| USA | 12.66 ± 4.14 | 13.53 ± 4.23 | 14.33 ± 4.11 | 13.08 ± 3.48 | 11.93 ± 3.60 | 12.98 ± 4.14 | 12.05 ± 4.83 | 13.13 ± 3.79 |
| Belgium | 14.31 ± 3.42 | 15.03 ± 4.37 | 15.70 ± 3.87 | 14.64 ± 4.89 | 15.56 ± 4.04 | 15.47 ± 4.08 | 14.05 ± 4.00 | 13.10 ± 3.38 |
| Spain | 15.98 ± 3.85 | 12.45 ± 4.53 | 15.46 ± 3.52 | 13.76 ± 4.25 | 15.59 ± 6.41 | 12.84 ± 3.40 | 15.76 ± 5.81 | 13.19 ± 3.71 |
| Poland | 13.60 ± 5.11 | 12.51 ± 2.25 | 10.35 ± 1.28 | 10.29 ± 0.05 | 13.84 ± 3.37 | 13.04 ± 4.68 | 10.45 ± 0.69 | 11.93 |

Data for Non-African runners are sorted in order of the number of finishers of each country

population of runners and improved training practices (Desgorces et al. 2012).

East African runners were the youngest in half-marathons and marathons

A third important finding was that women and men from Kenya and Ethiopia were the youngest in both half-marathons and marathons. Their mean age is considerably lower as has been reported for elite and recreational marathoners. The age of elite marathoners is at around 29–30 years when the nationality was not considered (Hunter et al. 2011). In female and male marathoners competing between 1979 and 2014 in the ‘Stockholm Marathon’, the age of the fastest marathon performance was even higher with 34.3 ± 2.6 years (Lehto 2015). In a study investigating runners competing in Swiss half-marathons and marathons from 2000 to 2010 and considering the top five African and Non-African runners, the mean age of the male runners was significantly higher for Non-African runners than for African runners in both half-marathons (Non-African runners 31.1 ± 6.4 years, African runners 26.2 ± 4.9 years) and marathons (Non-African runners 33.0 ± 4.8 years, African runners 28.6 ± 3.8 years). In marathons, the top five female Non-African runners (31.6 ± 4.8 years) were ~4 years older than the top five female African runners (27.8 ± 5.3 years) (Aschmann et al. 2013). The difference in age between East Africans and Europeans found in the present study was not in agreement with a previous comparison between African and non-African runners of marathons and half-marathons (Cribari et al. 2013)

indicating that the younger age was a specific characteristic of East Africans and should not be generalized to all African runners.

Physiological interpretation

For the dominance of East African runners such as Kenyan runners, physiological aspects need to be considered (Larsen 2003; Larsen and Sheel 2015). It has been supported that running speed sustained over a prolonged time depends on the maximal sustainable VO_2 (oxygen uptake) and running economy (Millet et al. 2012). A comparison between European and Eritrean long-distance runners showed that Eritreans, despite having a lower $\text{VO}_{2\text{max}}$ (maximum oxygen uptake), had a better running economy at 19 km h^{-1} (Santos-Concejero et al. 2015). A better running economy might explain the supremacy of East Africans in the marathon, and the delayed glycogen depletion and reduced thermal stress have been suggested to be associated with a better running economy (Millet et al. 2012). An exceptional biomechanical and metabolic economy, chronic exposition to altitude, sociocultural background and a strong psychological motivation were highlighted as other factors of this supremacy (Onywera 2009; Wilber and Pitsiladis 2012). Moreover, the impact of stereotypes has also been noticed because, independently from the possible existence of physiological advantages in East Africans, the belief that such differences exist can impact performance by creating a psychological atmosphere (Baker and Norton 2003). With regards to their nutritional habits, a research on the dietary intake of Ethiopian long distance

Table 6 Results of the mixed-effects regression analyses for change in running speed across years in female marathoners

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------|-------------|------------|----------|--------|---------|--------------|-------------|
| | | | | | | Upper | Lower |
| Ethiopia | | | | | | | |
| Constant term | 147.793813 | 321.794557 | 36.803 | 0.459 | 0.649 | -504.341821 | 799.929446 |
| Year | -0.067200 | 0.160260 | 36.789 | -0.419 | 0.677 | -0.391981 | 0.257581 |
| Cage | -0.041199 | 0.045279 | 39.863 | -0.910 | 0.368 | -0.132721 | 0.050323 |
| Cage ² | -0.000791 | 0.001556 | 27.290 | -0.508 | 0.615 | -0.003983 | 0.002401 |
| Kenya | | | | | | | |
| Constant term | 12.643951 | 134.413655 | 31.473 | 0.094 | 0.926 | -261.327748 | 286.615651 |
| Year | 0.001310 | 0.067007 | 31.470 | 0.020 | 0.985 | -0.135269 | 0.137890 |
| Cage | 0.004584 | 0.031623 | 33.197 | 0.145 | 0.886 | -0.059740 | 0.068908 |
| Cage ² | 0.000926 | 0.001504 | 28.885 | 0.616 | 0.543 | -0.002150 | 0.004002 |
| Austria | | | | | | | |
| Constant term | 319.000059 | 151.126310 | 115.787 | 2.111 | 0.037 | 19.669554 | 618.330564 |
| Year | -0.152749 | 0.075258 | 115.782 | -2.030 | 0.045 | -0.301810 | -0.003688 |
| Cage | -0.059867 | 0.033352 | 105.113 | -1.795 | 0.076 | -0.125998 | 0.006264 |
| Cage ² | 0.003428 | 0.002369 | 91.358 | 1.447 | 0.151 | -0.001277 | 0.008132 |
| France | | | | | | | |
| Constant term | -69.668517 | 73.011026 | 423.181 | -0.954 | 0.341 | -213.177937 | 73.840903 |
| Year | 0.041647 | 0.036362 | 423.171 | 1.145 | 0.253 | -0.029825 | 0.113119 |
| Cage | -0.007736 | 0.019534 | 524.950 | -0.396 | 0.692 | -0.046111 | 0.030640 |
| Cage ² | -0.000529 | 0.001375 | 513.572 | -0.385 | 0.701 | -0.003230 | 0.002172 |
| Great Britain | | | | | | | |
| Constant term | -32.852390 | 202.043235 | 96.505 | -1.163 | 0.871 | -433.878261 | 368.173481 |
| Year | 0.023039 | 0.100666 | 96.499 | 0.229 | 0.819 | -0.176769 | 0.222846 |
| Cage | 0.057327 | 0.032752 | 62.676 | 1.750 | 0.085 | -0.008129 | 0.122782 |
| Cage ² | 0.001266 | 0.003499 | 87.271 | 0.362 | 0.718 | -0.005689 | 0.008220 |
| Germany | | | | | | | |
| Constant term | -57.013601 | 61.704926 | 558.626 | -0.924 | 0.356 | -178.215628 | 64.188427 |
| Year | 0.035049 | 0.030733 | 558.613 | 1.140 | 0.255 | -0.025317 | 0.095415 |
| Cage | -0.018041 | 0.010289 | 360.049 | -1.754 | 0.080 | -0.038274 | 0.002192 |
| Cage ² | -0.000917 | 0.000669 | 425.048 | -1.370 | 0.172 | -0.002232 | 0.000399 |
| Italy | | | | | | | |
| Constant term | 12.643951 | 134.413655 | 31.473 | 0.094 | 0.926 | -261.327748 | 286.615651 |
| Year | 0.001310 | 0.067007 | 31.470 | 0.020 | 0.985 | -0.135269 | 0.137890 |
| Cage | 0.004584 | 0.031623 | 33.197 | 0.145 | 0.886 | -0.059740 | 0.068908 |
| Cage ² | 0.000926 | 0.001504 | 28.885 | 0.616 | 0.543 | -0.002150 | 0.004002 |
| Japan | | | | | | | |
| Constant term | -556.744907 | 324.548340 | 44.540 | -1.715 | 0.093 | -1210.605221 | 97.115408 |
| Year | 0.284663 | 0.161722 | 44.521 | 1.760 | 0.085 | -0.041159 | 0.610486 |
| Cage | 0.002091 | 0.056456 | 36.733 | 0.037 | 0.971 | -0.112328 | 0.116511 |
| Cage ² | -0.001140 | 0.002306 | 47.736 | -0.494 | 0.623 | -0.005776 | 0.003496 |
| Switzerland | | | | | | | |
| Constant term | 19.166945 | 16.359822 | 5730.128 | 1.172 | 0.241 | -12.904491 | 51.238380 |
| Year | -0.001923 | 0.008148 | 5729.834 | -0.236 | 0.813 | -0.017896 | 0.014051 |
| Cage | 0.000169 | 0.002164 | 3789.103 | 0.078 | 0.938 | -0.004074 | 0.004412 |
| Cage ² | -0.000271 | 0.000151 | 3903.532 | -1.798 | 0.072 | -0.000566 | 2.449756E-5 |
| Canada | | | | | | | |
| Constant term | -84.838438 | 294.677013 | 21.509 | -0.288 | 0.776 | -696.771246 | 527.094370 |
| Year | 0.049412 | 0.146619 | 21.493 | 0.337 | 0.739 | -0.255073 | 0.353897 |

Table 6 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------------------|--------------|------------|--------|--------|---------|--------------|-------------|
| | | | | | | Upper | Lower |
| Cage | -0.016467 | 0.105620 | 20.899 | -0.156 | 0.878 | -0.236180 | 0.203247 |
| Cage ² | -0.005069 | 0.008542 | 26.178 | -0.593 | 0.558 | -0.022621 | 0.012484 |
| Principality of Liechtenstein | | | | | | | |
| Constant term | 134.396574 | 114.930718 | 8.628 | 1.169 | 0.274 | -127.312878 | 396.106027 |
| Year | -0.058934 | 0.057365 | 8.641 | -1.027 | 0.332 | -0.189530 | 0.071661 |
| Cage | 0.000824 | 0.052738 | 11.742 | 0.016 | 0.988 | -0.114363 | 0.116012 |
| Cage ² | -0.000182 | 0.005460 | 13.149 | -0.033 | 0.974 | -0.011963 | 0.011599 |
| United States of America | | | | | | | |
| Constant term | 147.793813 | 321.794557 | 36.803 | 0.459 | 0.649 | -504.341821 | 799.929446 |
| Year | -0.067200 | 0.160260 | 36.789 | -0.419 | 0.677 | -0.391981 | 0.257581 |
| Cage | -0.041199 | 0.045279 | 39.863 | -0.910 | 0.368 | -0.132721 | 0.050323 |
| Cage ² | -0.000791 | 0.001556 | 27.290 | -0.508 | 0.615 | -0.003983 | 0.002401 |
| Belgium | | | | | | | |
| Constant term | 832.877872 | 481.304102 | 14.000 | 1.730 | 0.106 | -199.416758 | 1865.172502 |
| Year | -0.409025 | 0.239884 | 14.000 | -1.705 | 0.110 | -0.923525 | 0.105475 |
| Cage | 0.113307 | 0.073728 | 14.000 | 1.537 | 0.147 | -0.044823 | 0.271437 |
| Cage ² | -0.008065 | 0.005950 | 14.000 | -1.356 | 0.197 | -0.020826 | 0.004695 |
| Spain | | | | | | | |
| Constant term | 578.599477 | 459.378710 | 18.000 | 1.260 | 0.224 | -386.519821 | 1543.718775 |
| Year | -0.280844 | 0.228570 | 18.000 | -1.229 | 0.235 | -0.761053 | 0.199365 |
| Cage | 0.085302 | 0.054009 | 9.306 | 1.579 | 0.148 | -0.036264 | 0.206868 |
| Cage ² | -0.006105 | 0.004734 | 8.582 | -1.290 | 0.231 | -0.016894 | 0.004684 |
| Poland | | | | | | | |
| Constant term | -1007.316625 | 429.834844 | 14.000 | -2.343 | 0.034 | -1929.220678 | -85.412573 |
| Year | 0.507475 | 0.213730 | 14.000 | 2.374 | 0.032 | 0.049069 | 0.965881 |
| Cage | -0.022253 | 0.077353 | 14.000 | -0.288 | 0.778 | -0.188158 | 0.143652 |
| Cage ² | 0.001802 | 0.005561 | 14.000 | 0.324 | 0.751 | -0.010126 | 0.013730 |

Data for Non-African runners are sorted in order of the number of finishers of each country

Cage centered age, Cage² centered age squared

runners has shown that they met most recommendations for endurance athletes (Beis et al. 2011). A study on the diet of Kenyan endurance runners revealed that it composed mostly by carbohydrates (~67 %) and less by protein (~15 %) or fat (~17 %) (Fudge et al. 2006).

In addition to the abovementioned physiological factors, Eastern African runners might differ from runners of other origin with regards to other specific anthropometric characteristics (Kohn et al. 2007; Lucia et al. 2006; Prommer et al. 2010; Vernillo et al. 2013). For instance, compared to elite German 10-km runners, elite Kenyan runners had a similar VO_2max ($\text{ml min}^{-1} \text{kg}^{-1}$) but were lighter by more than 9 kg (Prommer et al. 2010). Xhosa 10-km runners had also similar VO_2max ($\text{ml min}^{-1} \text{kg}^{-1}$) as their Caucasian counterparts, but they were lighter and shorter (Kohn et al. 2007). Eritrean distance runners had a lower body mass index and a better running

economy at 21 km h^{-1} than Spanish runners, whereas their VO_2max was similar (Lucia et al. 2006). In top class Kenyan marathoners, ectomorphy is dominant, but endomorphy and mesomorphy is more than one-half unit lower (Vernillo et al. 2013).

A review of genetic and lifestyle factors of the performance of the East Africans distance runners concluded that the findings on candidate genes linked to performance of Caucasian populations were not confirmed in East Africans showing research methods' limitations and the polygenic nature of performance (Tucker et al. 2013). This was in agreement with another review showing that distance running success of East Africans was not based on a unique genetic profile (Wilber and Pitsiladis 2012). Another parameter that has not been studied previously as much as the abovementioned parameters might be the physical activity and inactivity levels when athletes did

Table 7 Results of the mixed-effects regression analyses for change in running speed across years in male marathoners

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------------------|-------------|-------------|------------|--------|---------|-------------|------------|
| | | | | | | Upper | Lower |
| Austria | | | | | | | |
| Constant term | 119.014606 | 78.665485 | 352.571 | 1.513 | 0.131 | -35.698004 | 273.727215 |
| Year | -0.053124 | 0.039182 | 352.518 | -1.356 | 0.176 | -0.130183 | 0.023936 |
| Cage | -0.053906 | 0.018537 | 374.501 | -2.908 | 0.004 | -0.090356 | -0.017456 |
| Cage ² | 0.002858 | 0.001180 | 374.482 | 2.423 | 0.016 | 0.000538 | 0.005179 |
| France | | | | | | | |
| Constant term | 12.224516 | 32.400764 | 1943.299 | 0.377 | 0.706 | -51.319391 | 75.768423 |
| Year | 0.000774 | 0.016138 | 1943.341 | 0.048 | 0.962 | -0.030876 | 0.032424 |
| Cage | -0.042530 | 0.007858 | 2185.277 | -5.412 | 0.000 | -0.057940 | -0.027119 |
| Cage ² | 0.001220 | 0.000546 | 2369.390 | 2.235 | 0.025 | 0.000150 | 0.002290 |
| Great Britain | | | | | | | |
| Constant term | 168.008185 | 77.417245 | 265.471 | 2.170 | 0.031 | 15.578253 | 320.438116 |
| Year | -0.076916 | 0.038558 | 265.527 | -1.995 | 0.047 | -0.152834 | -0.000997 |
| Cage | -0.003050 | 0.013447 | 228.557 | -0.227 | 0.821 | -0.029546 | 0.023446 |
| Cage ² | 0.000290 | 0.001143 | 251.114 | 0.254 | 0.800 | -0.001961 | 0.002541 |
| Germany | | | | | | | |
| Constant term | -26.616836 | 25.282326 | 2510.280 | -1.053 | 0.293 | -76.193187 | 22.959515 |
| Year | 0.019883 | 0.012593 | 2510.229 | 1.579 | 0.114 | -0.004811 | 0.044578 |
| Cage | -0.007977 | 0.005083 | 2186.239 | -1.570 | 0.117 | -0.017944 | 0.001990 |
| Cage ² | 0.000147 | 0.000344 | 2231.865 | 0.427 | 0.669 | -0.000528 | 0.000822 |
| Italy | | | | | | | |
| Constant term | 82.322203 | 91.156734 | 288.896 | 0.903 | 0.367 | -97.093338 | 261.737745 |
| Year | -0.033932 | 0.045393 | 288.917 | -0.748 | 0.455 | -0.123275 | 0.055411 |
| Cage | -0.058144 | 0.019311 | 261.042 | -3.011 | 0.003 | -0.096169 | -0.020119 |
| Cage ² | 0.000191 | 0.001214 | 322.202 | 0.157 | 0.875 | -0.002199 | 0.002580 |
| Japan | | | | | | | |
| Constant term | 49.803604 | 170.811818 | 103.019 | 0.292 | 0.771 | -288.960603 | 388.567811 |
| Year | -0.018372 | 0.085088 | 103.003 | -0.216 | 0.829 | -0.187123 | 0.150380 |
| Cage | -0.086555 | 0.031059 | 107.375 | -2.787 | 0.006 | -0.148123 | -0.024987 |
| Cage ² | 0.001926 | 0.001684 | 107.206 | 1.144 | 0.255 | -0.001412 | 0.005264 |
| Switzerland | | | | | | | |
| Constant term | 25.878076 | 7.195438 | 22,373.993 | 3.596 | 0.000 | 11.774513 | 39.981639 |
| Year | -0.005404 | 0.003584 | 22,373.571 | -1.508 | 0.132 | -0.012428 | 0.001620 |
| Cage | -0.002664 | 0.001012 | 17,294.094 | -2.633 | 0.008 | -0.004647 | -0.000681 |
| Cage ² | -0.000235 | 6.583543E-5 | 17,295.657 | -3.565 | 0.000 | -0.000364 | -0.000106 |
| Canada | | | | | | | |
| Constant term | -106.659105 | 171.420255 | 81.342 | -0.622 | 0.536 | -447.709874 | 234.391663 |
| Year | 0.059022 | 0.085420 | 81.336 | 0.691 | 0.492 | -0.110927 | 0.228971 |
| Cage | -0.050496 | 0.030360 | 68.401 | -1.663 | 0.101 | -0.111073 | 0.010080 |
| Cage ² | 0.006306 | 0.001988 | 62.037 | 3.172 | 0.002 | 0.002332 | 0.010280 |
| Principality of Liechtenstein | | | | | | | |
| Constant term | 236.267620 | 241.570336 | 77.992 | 0.978 | 0.331 | -244.662729 | 717.197969 |
| Year | -0.109511 | 0.120377 | 77.993 | -0.910 | 0.366 | -0.349164 | 0.130142 |
| Cage | 0.034908 | 0.042003 | 73.075 | 0.831 | 0.409 | -0.048802 | 0.118618 |
| Cage ² | 0.001951 | 0.003222 | 72.523 | 0.606 | 0.547 | -0.004471 | 0.008373 |
| United States of America | | | | | | | |
| Constant term | 179.260596 | 91.774367 | 188.890 | 1.953 | 0.052 | -1.773750 | 360.294941 |
| Year | -0.082585 | 0.045712 | 188.881 | -1.807 | 0.072 | -0.172757 | 0.007587 |

Table 7 continued

| Parameter | Estimate | SE | DF | T | p value | 95 % CI | |
|-------------------|-------------|------------|---------|--------|---------|-------------|------------|
| | | | | | | Upper | Lower |
| Cage | 0.003829 | 0.014234 | 167.444 | 0.269 | 0.788 | -0.024273 | 0.031931 |
| Cage ² | 0.000319 | 0.000945 | 149.574 | 0.338 | 0.736 | -0.001548 | 0.002186 |
| Belgium | | | | | | | |
| Constant term | 220.791210 | 167.798520 | 108.714 | 1.316 | 0.191 | -111.789810 | 553.372230 |
| Year | -0.102767 | 0.083486 | 108.675 | -1.231 | 0.221 | -0.268238 | 0.062704 |
| Cage | -0.029095 | 0.030424 | 119.603 | -0.956 | 0.341 | -0.089335 | 0.031145 |
| Cage ² | 0.000194 | 0.002163 | 96.384 | 0.090 | 0.929 | -0.004099 | 0.004486 |
| Spain | | | | | | | |
| Constant term | -130.890461 | 169.416654 | 5.528 | -0.773 | 0.471 | -554.170969 | 292.390047 |
| Year | 0.072247 | 0.084311 | 5.528 | 0.857 | 0.427 | -0.138405 | 0.282899 |
| Cage | -0.050933 | 0.030883 | 5.028 | -1.649 | 0.160 | -0.130185 | 0.028319 |
| Cage ² | 0.001306 | 0.004902 | 56.210 | 0.266 | 0.791 | -0.008513 | 0.011125 |
| Poland | | | | | | | |
| Constant term | -173.031933 | 285.748419 | 50.731 | -0.606 | 0.548 | -746.769620 | 400.705753 |
| Year | 0.092292 | 0.142290 | 50.736 | 0.649 | 0.520 | -0.193403 | 0.377986 |
| Cage | -0.019397 | 0.026881 | 30.284 | -0.722 | 0.476 | -0.074273 | 0.035480 |
| Cage ² | -0.000780 | 0.001881 | 35.444 | -0.414 | 0.681 | -0.004597 | 0.003038 |
| Kenya | | | | | | | |
| Constant term | 31.727578 | 85.570347 | 33.000 | 0.371 | 0.713 | -142.366603 | 205.821759 |
| Year | -0.007558 | 0.042603 | 33.000 | -0.177 | 0.860 | -0.094234 | 0.079119 |
| Cage | -0.192695 | 0.042007 | 33.000 | -4.587 | 0.000 | -0.278159 | -0.107230 |
| Cage ² | -0.005855 | 0.002387 | 33.000 | -2.453 | 0.020 | -0.010712 | -0.000999 |
| Ethiopia | | | | | | | |
| Constant term | 185.271970 | 155.298262 | 15.000 | 1.193 | 0.251 | -145.738439 | 516.282379 |
| Year | -0.085404 | 0.077000 | 15.000 | -1.109 | 0.285 | -0.249526 | 0.078718 |
| Cage | -0.708418 | 0.358618 | 15.000 | -1.975 | 0.067 | -1.472793 | 0.055957 |
| Cage ² | -0.034788 | 0.014889 | 15.000 | -2.337 | 0.034 | -0.066522 | -0.003053 |

Data for Non-African runners are sorted in order of the number of finishers of each country

Cage centered age, Cage² centered age squared

not practise their sport. Surprisingly, a study in marathon and half-marathon runners showed that these athletes trained for 6.5 h weekly, but they also spent much more time sitting (Whitfield et al. 2014). The aforementioned study found no relationship between sitting time and performance. However, potential differences in non-sport physical activities and inactivity levels between East Africans and Europeans should be examined in future studies.

Limitations

A limitation of this analysis is the fact that an athlete may have changed his/her nationality, where, for example, an athlete from an African country might have been naturalized in another country. As an example, the Swiss marathoner Tadesse Abraham was born in Eritrea but is now a Swiss citizen. He won three marathons and one half-marathon in Switzerland (www.tadesse-abraham.ch).

On the other hand, the focus of the present study was on half-marathon runners' characteristics (i.e. age, participation and performance) with regards to marathon. Since there was no evidence that the above-mentioned concern about the nationality appeared differently to the two events (half-marathon vs. marathon), it might be supported that it did not affect the overall findings.

Conclusions

In summary, women and men from Kenya and Ethiopia, despite they accounted for less than 0.1 % in half-marathons and marathons, achieved the fastest race times and were the youngest in both half-marathons and marathon. These findings confirmed in the case of half-marathon the trend previously observed in marathon races for a better performance and a younger age in East African runners compared to Non-African runners.

Table 8 Age (years) with mean \pm SD of female and male East-African and Non-African half-marathoners

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|----------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Women | | | | | | | | |
| Ethiopia | 20 | 26 \pm 1 | 30 | | 36 | 37 | 35 | 26 \pm 10 |
| Kenya | | 29 \pm 9 | | 35 \pm 6 | 37 \pm 1 | 29 \pm 6 | 28 \pm 7 | 28 \pm 5 |
| Austria | | 40 | 50 \pm 8 | 44 \pm 3 | 37 \pm 8 | | 38 \pm 7 | 44 \pm 1 |
| Canada | | 49 \pm 4 | 44 \pm 10 | 40 \pm 9 | 44 \pm 9 | 53 \pm 7 | 41 \pm 13 | 35 \pm 6 |
| Czech Republic | 37 \pm 14 | 49 | 31 \pm 5 | 33 \pm 18 | 34 \pm 7 | 34 \pm 5 | 35 \pm 5 | 27 |
| Denmark | | 36 \pm 0 | 34 \pm 4 | 36 \pm 5 | 33 \pm 9 | 42 \pm 12 | 48 \pm 9 | 46 \pm 7 |
| Spain | 43 \pm 22 | 40 \pm 16 | 36 \pm 5 | 37 \pm 7 | 38 \pm 8 | 37 \pm 9 | 43 \pm 9 | 37 \pm 9 |
| France | 42 \pm 10 | 43 \pm 10 | 41 \pm 9 | 41 \pm 9 | 42 \pm 9 | 42 \pm 10 | 42 \pm 10 | 42 \pm 10 |
| Great Britain | 37 \pm 7 | 39 \pm 10 | 41 \pm 12 | 39 \pm 9 | 39 \pm 8 | 36 \pm 8 | 38 \pm 9 | 39 \pm 10 |
| Germany | 43 \pm 10 | 43 \pm 9 | 45 \pm 10 | 43 \pm 9 | 44 \pm 9 | 44 \pm 9 | 43 \pm 9 | 43 \pm 10 |
| Italy | 41 \pm 9 | 48 \pm 9 | 46 \pm 11 | 41 \pm 9 | 42 \pm 11 | 42 \pm 9 | 42 \pm 10 | 39 \pm 9 |
| Japan | 36 \pm 13 | 57 \pm 22 | 61 \pm 7 | 50 \pm 15 | 50 \pm 12 | 54 \pm 12 | 49 \pm 15 | 48 \pm 18 |
| Liechtenstein | 44 \pm 4 | 46 \pm 10 | 41 \pm 6 | 45 \pm 8 | 40 \pm 8 | 39 \pm 9 | 40 \pm 8 | 44 \pm 10 |
| Luxembourg | 47 \pm 21 | 42 \pm 11 | 35 \pm 7 | 40 \pm 7 | 44 \pm 12 | 42 \pm 14 | 37 \pm 8 | 45 \pm 7 |
| Netherlands | 44 \pm 6 | 47 \pm 1 | 43 \pm 13 | 40 \pm 7 | 43 \pm 11 | 45 \pm 11 | 40 \pm 11 | 43 \pm 10 |
| Norway | | 60 \pm 1 | 55 \pm 16 | 39 \pm 16 | 56 | 41 \pm 13 | 45 \pm 15 | 50 \pm 13 |
| Portugal | | 54 | 41 | 44 \pm 14 | 46 \pm 9 | 36 \pm 9 | 38 \pm 10 | 36 \pm 8 |
| Switzerland | 41 \pm 10 | 41 \pm 10 | 41 \pm 10 | 41 \pm 10 | 41 \pm 10 | 41 \pm 10 | 41 \pm 10 | 41 \pm 10 |
| USA | 26 \pm 3 | 35 \pm 9 | 36 \pm 10 | 44 \pm 19 | 34 \pm 12 | 36 \pm 10 | 42 \pm 12 | 41 \pm 13 |
| Australia | | 40 | 50 \pm 8 | 44 \pm 3 | 37 \pm 8 | | 38 \pm 7 | 44 \pm 1 |
| Belgium | 53 \pm 21 | | 47 \pm 21 | 38 \pm 16 | 44 \pm 10 | 37 \pm 10 | 38 \pm 11 | 44 \pm 7 |
| Hungary | 68 | 65 | | 72 | 43 | 41 | 33 | 46 \pm 7 |
| Ireland | 37 \pm 7 | 44 | 38 \pm 1 | 43 \pm 2 | 42 \pm 11 | 36 \pm 6 | | 41 \pm 5 |
| Poland | 44 \pm 12 | | 43 \pm 7 | 30 | 36 \pm 11 | 39 \pm 10 | 45 \pm 11 | 34 \pm 5 |
| Russia | 52 | 29 \pm 5 | 28 | 30 | | 42 \pm 11 | 38 \pm 12 | 32 \pm 5 |
| Sweden | 27 | | 42 \pm 12 | 48 \pm 11 | 34 \pm 7 | 38 \pm 6 | 43 \pm 16 | 44 \pm 13 |
| Finland | 33 \pm 1 | 44 | | 44 \pm 18 | | 40 \pm 10 | 44 \pm 12 | 40 \pm 4 |
| Greece | | | | | 39 | 48 | 32 | 33 |
| South Africa | | | | 47 \pm 11 | 35 | 52 | 36 | 44 \pm 1 |
| Brazil | 45 \pm 16 | 50 \pm 4 | | 40 | 41 | 46 | 50 \pm 4 | |
| Mexico | | | | | | 37 | | 38 \pm 6 |
| Argentina | | | | 38 | | | | 32 |
| India | | 29 | | | | 47 | 36 \pm 7 | 43 \pm 11 |
| Israel | | | | | | 64 | 59 | |
| Slovenia | | | | | | | 47 | |
| Men | | | | | | | | |
| Ethiopia | 30 \pm 6 | 27 | 30 \pm 3 | 27 \pm 4 | 23 \pm 1 | 24 \pm 2 | 25 \pm 6 | 28 \pm 3 |
| Kenya | 26 \pm 1 | 26 \pm 5 | 30 \pm 3 | 29 \pm 5 | 32 \pm 2 | 37 \pm 20 | 32 \pm 18 | 27 \pm 5 |
| Austria | | 43 \pm 5 | 38 \pm 5 | 38 \pm 13 | 40 \pm 11 | 42 \pm 12 | 35 \pm 7 | 41 \pm 6 |
| Canada | 40 \pm 10 | 39 \pm 12 | 40 \pm 16 | 36 \pm 11 | 39 \pm 12 | 40 \pm 10 | 42 \pm 14 | 37 \pm 10 |
| Czech Republic | 37 \pm 6 | 37 \pm 13 | 31 \pm 10 | 33 \pm 6 | 40 \pm 13 | 38 \pm 8 | 35 \pm 9 | 37 \pm 11 |
| Denmark | | 47 \pm 8 | 47 \pm 14 | 41 \pm 12 | 33 \pm 9 | 47 \pm 14 | 40 \pm 9 | 43 \pm 14 |
| Spain | 35 \pm 11 | 42 \pm 8 | 34 \pm 7 | 42 \pm 10 | 42 \pm 11 | 43 \pm 10 | 43 \pm 11 | 42 \pm 10 |
| France | 41 \pm 10 | 42 \pm 10 | 41 \pm 9 | 42 \pm 10 | 42 \pm 10 | 41 \pm 10 | 42 \pm 10 | 41 \pm 9 |
| Great Britain | 40 \pm 10 | 40 \pm 10 | 41 \pm 11 | 39 \pm 10 | 41 \pm 11 | 39 \pm 10 | 41 \pm 10 | 43 \pm 11 |
| Germany | 44 \pm 10 | 44 \pm 10 | 43 \pm 10 | 43 \pm 10 | 43 \pm 10 | 43 \pm 10 | 43 \pm 10 | 43 \pm 10 |
| Italy | 44 \pm 11 | 42 \pm 8 | 43 \pm 10 | 42 \pm 10 | 43 \pm 9 | 41 \pm 9 | 42 \pm 8 | 41 \pm 9 |
| Japan | 66 \pm 5 | 51 \pm 16 | 48 \pm 13 | 54 \pm 11 | 47 \pm 19 | 46 \pm 15 | 55 \pm 14 | 44 \pm 17 |

Table 8 continued

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|----------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Liechtenstein | 38 ± 7 | 40 ± 8 | 44 ± 9 | 41 ± 11 | 40 ± 9 | 41 ± 9 | 41 ± 11 | 41 ± 10 |
| Luxembourg | 43 ± 14 | 37 ± 3 | 37 ± 6 | 43 ± 11 | 43 ± 10 | 43 ± 9 | 42 ± 9 | 42 ± 11 |
| Netherlands | 50 ± 10 | 41 ± 16 | 35 ± 9 | 39 ± 11 | 36 ± 8 | 38 ± 12 | 38 ± 7 | 39 ± 10 |
| Norway | 33 | 28 ± 6 | 43 ± 14 | 40 ± 13 | 39 ± 8 | 32 ± 9 | 34 ± 7 | 44 ± 19 |
| Portugal | 45 ± 8 | 46 ± 8 | 41 ± 9 | 38 ± 9 | 39 ± 11 | 37 ± 8 | 38 ± 6 | 39 ± 10 |
| Switzerland | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 |
| USA | 41 ± 12 | 43 ± 12 | 39 ± 11 | 41 ± 11 | 41 ± 13 | 41 ± 10 | 40 ± 9 | 40 ± 12 |
| Australia | | 43 ± 5 | 38 ± 5 | 38 ± 13 | 40 ± 11 | 42 ± 12 | 35 ± 7 | 41 ± 6 |
| Belgium | 43 ± 16 | 44 ± 11 | 43 ± 9 | 42 ± 10 | 40 ± 11 | 36 ± 10 | 42 ± 13 | 42 ± 11 |
| Hungary | | 41 | 46 ± 16 | 39 ± 10 | 48 ± 15 | 47 ± 14 | 42 ± 16 | 43 ± 13 |
| Ireland | 34 ± 10 | 38 ± 6 | 42 ± 9 | 42 ± 7 | 40 ± 11 | 37 ± 5 | 35 ± 4 | 37 ± 6 |
| Poland | 40 ± 12 | 38 ± 8 | 40 ± 7 | 37 ± 9 | 32 ± 16 | 37 ± 17 | 38 ± 13 | 39 ± 11 |
| Russia | | 38 ± 9 | 34 ± 11 | 33 ± 8 | 40 ± 15 | 41 ± 7 | 40 ± 12 | 34 ± 6 |
| Sweden | 47 ± 13 | 45 ± 19 | 40 ± 8 | 43 ± 10 | 46 ± 14 | 40 ± 13 | 42 ± 11 | 43 ± 12 |
| Finland | 61 ± 8 | 41 ± 10 | 47 ± 13 | 40 ± 10 | 44 ± 16 | 43 ± 13 | 43 ± 11 | 42 ± 13 |
| Greece | 37 | 31 | 43 ± 4 | 31 ± 9 | 34 ± 7 | 37 ± 6 | 44 ± 13 | 33 ± 4 |
| South Africa | 40 | | | 52 | | 39 ± 6 | 38 | 41 ± 17 |
| Brazil | 46 ± 18 | 53 ± 13 | 44 ± 14 | | 42 ± 11 | | | 47 ± 6 |
| Mexico | 46 | 40 | 52 | 38 ± 13 | 40 ± 8 | 47 ± 13 | 46 | 30 ± 10 |
| Argentina | | | | | 39 | 30 | 51 | 39 |
| India | | 40 ± 9 | 48 ± 2 | 34 | 42 ± 7 | | 38 ± 9 | 36 ± 8 |
| Israel | | 46 ± 6 | | 50 ± 4 | 36 ± 2 | 31 ± 4 | 39 | 43 ± 26 |
| Slovenia | | 62 | 35 | 48 ± 6 | 39 | 44 | 39 ± 3 | 37 ± 2 |
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Women | | | | | | | | |
| Ethiopia | 29 ± 5 | 41 ± 14 | 34 ± 8 | 28 ± 6 | 29 ± 7 | 27 ± 7 | 33 ± 8 | 27 ± 5 |
| Kenya | 27 ± 6 | 29 ± 5 | 29 ± 8 | 29 ± 0 | 34 ± 9 | 30 ± 4 | 30 ± 6 | 29 ± 4 |
| Austria | 53 ± 12 | 35 | 41 ± 2 | 40 ± 11 | 55 ± 19 | 48 ± 14 | 43 ± 5 | 40 ± 5 |
| Canada | 37 ± 7 | 37 ± 8 | 35 ± 7 | 37 ± 10 | 43 ± 11 | 41 ± 11 | 38 ± 11 | 41 ± 13 |
| Czech Republic | 40 ± 9 | 42 ± 8 | 40 ± 8 | 32 ± 4 | 34 ± 8 | 38 ± 9 | 34 ± 11 | 33 ± 6 |
| Denmark | 37 ± 6 | 45 | 46 ± 7 | 41 ± 12 | 36 ± 12 | 40 ± 9 | 35 ± 4 | 43 ± 9 |
| Spain | 42 ± 10 | 43 ± 8 | 41 ± 9 | 43 ± 5 | 44 ± 7 | 38 ± 9 | 43 ± 10 | 43 ± 10 |
| France | 43 ± 10 | 41 ± 9 | 42 ± 9 | 42 ± 9 | 41 ± 9 | 40 ± 10 | 41 ± 10 | 41 ± 9 |
| Great Britain | 38 ± 11 | 38 ± 9 | 38 ± 9 | 41 ± 11 | 39 ± 10 | 41 ± 10 | 39 ± 9 | 38 ± 10 |
| Germany | 43 ± 10 | 43 ± 10 | 44 ± 10 | 43 ± 10 | 43 ± 10 | 44 ± 10 | 43 ± 10 | 43 ± 10 |
| Italy | 42 ± 11 | 43 ± 10 | 41 ± 9 | 44 ± 10 | 42 ± 10 | 43 ± 10 | 42 ± 9 | 42 ± 9 |
| Japan | 50 ± 17 | 45 ± 16 | 42 ± 14 | 42 ± 13 | 52 ± 14 | 53 ± 13 | 50 ± 9 | 47 ± 16 |
| Liechtenstein | 42 ± 12 | 38 ± 10 | 40 ± 10 | 41 ± 10 | 39 ± 10 | 46 ± 10 | 43 ± 9 | 38 ± 9 |
| Luxembourg | 41 ± 9 | 46 ± 12 | 38 ± 7 | 37 ± 9 | 37 ± 7 | 43 ± 9 | 41 ± 10 | 44 ± 12 |
| Netherlands | 43 ± 9 | 46 ± 9 | 48 ± 10 | 43 ± 8 | 42 ± 9 | 50 ± 13 | 41 ± 8 | 46 ± 11 |
| Norway | 47 ± 13 | 52 ± 13 | 56 ± 15 | 36 ± 14 | 41 ± 13 | 33 ± 6 | 49 ± 19 | 63 ± 2 |
| Portugal | 42 ± 10 | 45 ± 11 | 48 ± 6 | 46 ± 5 | 36 | 41 ± 13 | 40 ± 4 | 46 ± 4 |
| Switzerland | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 |
| USA | 38 ± 11 | 38 ± 10 | 38 ± 8 | 38 ± 11 | 42 ± 13 | 37 ± 9 | 38 ± 10 | 39 ± 10 |
| Australia | 53 ± 12 | 35 | 41 ± 2 | 40 ± 11 | 55 ± 19 | 48 ± 14 | 43 ± 5 | 40 ± 5 |
| Belgium | 43 ± 14 | 47 ± 12 | 39 ± 11 | 42 ± 10 | 43 ± 11 | 42 ± 6 | 44 ± 8 | 37 ± 8 |
| Hungary | 48 ± 10 | 41 | 47 ± 9 | 47 | 47 ± 18 | 42 ± 8 | 51 ± 14 | 50 ± 12 |
| Ireland | 32 | 49 | 33 ± 5 | 36 ± 10 | 32 ± 5 | 43 ± 4 | 40 ± 7 | 38 ± 11 |
| Poland | 38 ± 6 | 33 ± 5 | 32 ± 7 | 45 ± 13 | 43 ± 10 | 44 ± 13 | 37 ± 9 | 43 ± 10 |

Table 8 continued

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|----------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Russia | 38 | 33 ± 5 | 36 ± 8 | 34 ± 14 | 34 ± 6 | 34 ± 11 | 37 ± 16 | 36 ± 7 |
| Sweden | 58 ± 11 | 44 ± 13 | 40 ± 14 | 37 ± 10 | 44 ± 12 | 41 ± 9 | 42 ± 13 | 41 ± 10 |
| Finland | 48 ± 5 | 57 ± 2 | 48 ± 15 | 41 ± 9 | 54 ± 7 | 43 ± 10 | 47 ± 11 | 44 ± 8 |
| Greece | 33 ± 1 | 45 | 47 | 40 | 33 | 34 ± 6 | 53 ± 14 | 40 ± 4 |
| South Africa | 37 ± 7 | 48 ± 15 | 40 ± 5 | | 52 ± 13 | 47 ± 14 | 39 ± 9 | 47 |
| Brazil | 52 ± 26 | 45 ± 16 | 40 ± 15 | 41 ± 6 | 45 ± 7 | 43 ± 19 | 43 ± 9 | 39 ± 5 |
| Mexico | 36 ± 2 | 43 ± 21 | 43 ± 5 | 41 ± 11 | 50 ± 5 | 39 ± 9 | 43 | 38 ± 5 |
| Argentina | 36 | | 28 | 43 ± 4 | 34 | 46 ± 11 | 40 ± 10 | 36 ± 2 |
| India | 41 ± 15 | | 25 | | 35 ± 6 | | 33 ± 5 | 42 ± 1 |
| Israel | | | 28 | 31 | 52 ± 0 | 29 | 36 ± 11 | 44 ± 2 |
| Slovenia | 41 | | 47 ± 9 | | 30 ± 4 | | | 42 |
| Men | | | | | | | | |
| Ethiopia | 31 ± 5 | 30 ± 6 | 25 ± 6 | 27 ± 4 | 32 ± 7 | 33 ± 7 | 26 ± 5 | 27 ± 5 |
| Kenya | 29 ± 4 | 27 ± 4 | 32 ± 13 | 30 ± 5 | 29 ± 7 | 29 ± 5 | 28 ± 4 | 31 ± 5 |
| Austria | 40 ± 13 | 35 ± 6 | 35 ± 9 | 43 ± 11 | 36 ± 8 | 44 ± 15 | 41 ± 11 | 39 ± 8 |
| Canada | 37 ± 13 | 36 ± 14 | 36 ± 10 | 41 ± 11 | 37 ± 14 | 42 ± 12 | 40 ± 10 | 39 ± 12 |
| Czech Republic | 39 ± 12 | 41 ± 13 | 40 ± 12 | 37 ± 11 | 38 ± 13 | 36 ± 8 | 35 ± 10 | 41 ± 10 |
| Denmark | 40 ± 11 | 40 ± 10 | 42 ± 7 | 45 ± 12 | 40 ± 10 | 44 ± 9 | 39 ± 10 | 43 ± 10 |
| Spain | 42 ± 9 | 41 ± 11 | 40 ± 8 | 40 ± 10 | 41 ± 10 | 41 ± 9 | 40 ± 10 | 36 ± 8 |
| France | 42 ± 10 | 42 ± 10 | 41 ± 10 | 42 ± 10 | 42 ± 10 | 42 ± 9 | 42 ± 9 | 42 ± 10 |
| Great Britain | 41 ± 11 | 40 ± 11 | 41 ± 11 | 40 ± 10 | 41 ± 10 | 40 ± 10 | 40 ± 10 | 40 ± 11 |
| Germany | 43 ± 10 | 43 ± 10 | 43 ± 10 | 43 ± 10 | 43 ± 10 | 44 ± 10 | 43 ± 10 | 43 ± 10 |
| Italy | 42 ± 10 | 43 ± 9 | 43 ± 10 | 43 ± 10 | 43 ± 10 | 43 ± 9 | 43 ± 10 | 44 ± 10 |
| Japan | 47 ± 17 | 49 ± 18 | 49 ± 16 | 46 ± 17 | 52 ± 16 | 50 ± 15 | 54 ± 15 | 48 ± 14 |
| Liechtenstein | 42 ± 10 | 42 ± 9 | 42 ± 9 | 41 ± 8 | 43 ± 9 | 41 ± 9 | 41 ± 9 | 41 ± 9 |
| Luxembourg | 41 ± 10 | 38 ± 8 | 38 ± 12 | 37 ± 10 | 39 ± 11 | 39 ± 6 | 46 ± 7 | 46 ± 9 |
| Netherlands | 44 ± 12 | 45 ± 10 | 43 ± 11 | 42 ± 11 | 44 ± 10 | 42 ± 11 | 42 ± 11 | 43 ± 9 |
| Norway | 45 ± 11 | 37 ± 11 | 44 ± 11 | 51 ± 14 | 41 ± 15 | 45 ± 10 | 51 ± 11 | 43 ± 12 |
| Portugal | 38 ± 9 | 39 ± 10 | 42 ± 8 | 36 ± 9 | 39 ± 11 | 38 ± 8 | 42 ± 12 | 44 ± 8 |
| Switzerland | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 | 41 ± 10 |
| USA | 38 ± 11 | 42 ± 11 | 39 ± 10 | 40 ± 9 | 38 ± 11 | 40 ± 12 | 39 ± 10 | 41 ± 10 |
| Australia | 40 ± 13 | 35 ± 6 | 35 ± 9 | 43 ± 11 | 36 ± 8 | 44 ± 15 | 41 ± 11 | 39 ± 8 |
| Belgium | 40 ± 11 | 39 ± 8 | 39 ± 10 | 42 ± 12 | 42 ± 10 | 44 ± 11 | 43 ± 10 | 44 ± 11 |
| Hungary | 43 ± 14 | 43 ± 9 | 52 ± 16 | 45 ± 12 | 42 ± 15 | 46 ± 16 | 38 ± 15 | 47 ± 9 |
| Ireland | 39 ± 9 | 45 ± 12 | 37 ± 8 | 39 ± 11 | 42 ± 9 | 41 ± 11 | 44 ± 11 | 43 ± 9 |
| Poland | 40 ± 9 | 40 ± 13 | 38 ± 14 | 39 ± 13 | 39 ± 11 | 38 ± 11 | 38 ± 10 | 37 ± 11 |
| Russia | 33 ± 6 | 42 ± 7 | 37 ± 10 | 35 ± 10 | 35 ± 7 | 37 ± 10 | 40 ± 12 | 36 ± 6 |
| Sweden | 45 ± 9 | 41 ± 11 | 44 ± 12 | 42 ± 14 | 46 ± 12 | 45 ± 12 | 43 ± 13 | 43 ± 12 |
| Finland | 41 ± 13 | 41 ± 8 | 46 ± 14 | 41 ± 9 | 43 ± 13 | 43 ± 12 | 40 ± 12 | 41 ± 11 |
| Greece | 37 ± 8 | 43 ± 11 | 44 ± 14 | 43 ± 14 | 33 ± 7 | 52 ± 10 | 39 ± 11 | 44 ± 14 |
| South Africa | 41 ± 9 | 30 ± 5 | 30 ± 5 | 44 ± 7 | 34 ± 4 | 37 ± 16 | 39 ± 9 | 38 ± 8 |
| Brazil | 47 ± 10 | 43 ± 7 | 41 ± 7 | 45 ± 13 | 44 ± 11 | 44 ± 11 | 44 ± 8 | 47 ± 11 |
| Mexico | 45 ± 12 | 36 ± 9 | 47 ± 3 | 41 ± 4 | 41 ± 8 | 40 ± 14 | 40 ± 7 | 41 ± 7 |
| Argentina | 44 | 46 | 35 ± 4 | 38 ± 4 | 40 ± 5 | 42 ± 9 | 36 ± 5 | 41 ± 7 |
| India | 38 | 33 ± 9 | 46 ± 11 | 42 ± 14 | 39 ± 6 | 32 ± 6 | 34 ± 7 | 37 ± 5 |
| Israel | 39 ± 12 | 39 ± 12 | 42 ± 10 | 47 ± 17 | 43 ± 12 | 47 ± 15 | 41 ± 9 | 41 ± 10 |
| Slovenia | | | 42 ± 21 | 41 | 39 | 43 ± 16 | 39 ± 11 | |

Data for Non-African runners are sorted in order of the number of finishers of each country

Table 9 Results of the mixed-effects regression analyses for change in age across years in half-marathoners

| Parameter | Estimate | SE | DF | T | p value |
|----------------|-------------|------------|------------|--------|---------|
| Ethiopia | | | | | |
| Constant term | -182.511370 | 314.486675 | 91.467 | -0.580 | 0.563 |
| Female sex | 1.680182 | 1.432541 | 72.982 | 1.173 | 0.245 |
| Calendar year | 0.104919 | 0.156633 | 91.480 | 0.670 | 0.505 |
| Kenya | | | | | |
| Constant term | 8.235275 | 288.742638 | 208.395 | 0.029 | 0.977 |
| Female sex | -0.121674 | 1.317439 | 68.640 | -0.092 | 0.927 |
| Calendar year | 0.010794 | 0.143794 | 208.376 | 0.075 | 0.940 |
| Austria | | | | | |
| Constant term | 194.074686 | 73.655324 | 2996.146 | 2.635 | 0.008 |
| Female sex | -1.709831 | 0.481769 | 1362.215 | -3.549 | <0.0001 |
| Calendar year | -0.075364 | 0.036673 | 2996.074 | -2.055 | 0.040 |
| Canada | | | | | |
| Constant term | 160.945071 | 202.099830 | 612.252 | 0.796 | 0.426 |
| Female sex | -1.870259 | 1.338345 | 281.258 | -1.397 | 0.163 |
| Calendar year | -0.059563 | 0.100658 | 612.236 | -0.592 | 0.554 |
| Czech Republic | | | | | |
| Constant term | -103.672165 | 314.871371 | 203.897 | -0.329 | 0.742 |
| Female sex | -1.866522 | 1.674310 | 123.397 | -1.115 | 0.267 |
| Calendar year | 0.070316 | 0.156835 | 203.856 | 0.448 | 0.654 |
| Denmark | | | | | |
| Constant term | 635.928991 | 345.802767 | 242.013 | 1.839 | 0.067 |
| Female sex | -1.207578 | 1.995708 | 124.433 | -0.605 | 0.546 |
| Calendar year | -0.295499 | 0.172164 | 242.020 | -1.716 | 0.087 |
| Spain | | | | | |
| Constant term | 4.345138 | 173.122867 | 707.441 | 0.025 | 0.980 |
| Female sex | -0.414857 | 0.961543 | 416.419 | -0.431 | 0.666 |
| Calendar year | 0.018514 | 0.086181 | 707.444 | 0.215 | 0.830 |
| France | | | | | |
| Constant term | 40.876029 | 30.739542 | 20,221.009 | 1.330 | 0.184 |
| Female sex | -0.363674 | 0.201893 | 9121.960 | -1.801 | 0.072 |
| Calendar year | 0.000558 | 0.015305 | 20,220.731 | 0.036 | 0.971 |
| Great Britain | | | | | |
| Constant term | 62.808682 | 86.098036 | 2964.716 | 0.730 | 0.466 |
| Female sex | -1.582820 | 0.555386 | 1329.593 | -2.850 | 0.004 |
| Calendar year | -0.010529 | 0.042874 | 2964.669 | -0.246 | 0.806 |
| Germany | | | | | |
| Constant term | 47.516840 | 32.418394 | 21,887.424 | 1.466 | 0.143 |
| Female sex | 0.269587 | 0.192793 | 9869.455 | 1.398 | 0.162 |
| Calendar year | -0.002199 | 0.016141 | 21,888.087 | -0.136 | 0.892 |
| Italy | | | | | |
| Constant term | 99.335607 | 63.935535 | 3599.246 | 1.554 | 0.120 |
| Female sex | -0.964511 | 0.478133 | 1789.232 | -2.017 | 0.044 |
| Calendar year | -0.027856 | 0.031834 | 3599.102 | -0.875 | 0.382 |
| Japan | | | | | |
| Constant term | 774.526324 | 242.816752 | 456.029 | 3.190 | 0.002 |
| Female sex | -0.297851 | 1.873820 | 298.110 | -0.159 | 0.874 |
| Calendar year | -0.361601 | 0.120894 | 456.006 | -2.991 | 0.003 |

Table 9 continued

| Parameter | Estimate | SE | DF | T | p value |
|--------------------------|-------------|------------|-------------|--------|---------|
| Liechtenstein | | | | | |
| Constant term | 86.887276 | 148.175736 | 975.830 | 0.586 | 0.558 |
| Female sex | -0.191866 | 0.758997 | 586.133 | -0.253 | 0.801 |
| Calendar year | -0.022614 | 0.073778 | 975.840 | -0.307 | 0.759 |
| Luxembourg | | | | | |
| Constant term | -164.038413 | 297.385871 | 212.919 | -0.552 | 0.582 |
| Female sex | -0.327141 | 1.355426 | 151.704 | -0.241 | 0.810 |
| Calendar year | 0.102236 | 0.148098 | 212.984 | 0.690 | 0.491 |
| Netherlands | | | | | |
| Constant term | -523.086955 | 207.948527 | 597.809 | -2.515 | 0.012 |
| Female sex | 0.885014 | 1.109896 | 324.076 | 0.797 | 0.426 |
| Calendar year | 0.281968 | 0.103524 | 597.796 | 2.724 | 0.007 |
| Norway | | | | | |
| Constant term | -912.882656 | 459.239160 | 164.453 | -1.988 | 0.048 |
| Female sex | 6.870747 | 2.584284 | 91.195 | 2.659 | 0.009 |
| Calendar year | 0.475098 | 0.228639 | 164.454 | 2.078 | 0.039 |
| Portugal | | | | | |
| Constant term | -51.331697 | 261.757709 | 235.116 | -0.196 | 0.845 |
| Female sex | 1.523814 | 1.797020 | 119.389 | 0.848 | 0.398 |
| Calendar year | 0.046577 | 0.130365 | 235.105 | 0.357 | 0.721 |
| Switzerland | | | | | |
| Constant term | 41.194097 | 0.025301 | 124,980.522 | 1.174 | 0.101 |
| Female sex | 0.130365 | 0.045674 | 144,203.009 | 2.854 | 0.401 |
| Calendar year | -0.003405 | 0.004187 | | -0.813 | 0.759 |
| United States of America | | | | | |
| Constant term | 59.833065 | 149.760218 | 1239.031 | 0.400 | 0.690 |
| Female sex | -0.210582 | 0.907549 | 602.658 | -0.232 | 0.817 |
| Calendar year | -0.009517 | 0.074571 | 1239.035 | -0.128 | 0.898 |
| Australia | | | | | |
| Constant term | 352.823540 | 240.345850 | 102.968 | 1.468 | 0.145 |
| Female sex | 0.724548 | 1.955842 | 120.491 | 0.370 | 0.712 |
| Calendar year | -0.155166 | 0.119654 | 102.965 | -1.297 | 0.198 |
| Belgium | | | | | |
| Constant term | 32.115986 | 200.805249 | 711.224 | 0.160 | 0.873 |
| Female sex | 0.194925 | 1.089004 | 423.817 | 0.179 | 0.858 |
| Calendar year | 0.005088 | 0.099966 | 711.329 | 0.051 | 0.959 |
| Hungary | | | | | |
| Constant term | 306.588165 | 391.814434 | 209.053 | 0.782 | 0.435 |
| Female sex | 1.793288 | 2.174815 | 181.126 | 0.825 | 0.411 |
| Calendar year | -0.129388 | 0.195061 | 209.050 | -0.663 | 0.508 |
| Ireland | | | | | |
| Constant term | -234.096789 | 266.979012 | 233.252 | -0.877 | 0.381 |
| Female sex | -1.746638 | 1.660739 | 110.543 | -1.052 | 0.295 |
| Calendar year | 0.136751 | 0.132924 | 233.250 | 1.029 | 0.305 |
| Poland | | | | | |
| Constant term | 80.619356 | 304.876109 | 293.818 | 0.264 | 0.792 |
| Female sex | 1.372858 | 1.636758 | 169.363 | 0.839 | 0.403 |
| Calendar year | -0.020831 | 0.151805 | 293.811 | -0.137 | 0.891 |

Table 9 continued

| Parameter | Estimate | SE | DF | T | p value |
|--------------------------|-------------|------------|---------|--------|---------|
| Russia | | | | | |
| Constant term | 172.423406 | 334.325523 | 166.780 | 0.516 | 0.607 |
| Female sex | -1.652883 | 1.736428 | 115.009 | -0.952 | 0.343 |
| Calendar year | -0.067115 | 0.166487 | 166.786 | -0.403 | 0.687 |
| Sweden | | | | | |
| Constant term | 289.316852 | 335.082052 | 353.960 | 0.863 | 0.388 |
| Female sex | -0.592306 | 1.563797 | 209.865 | -0.379 | 0.705 |
| Calendar year | -0.122190 | 0.166817 | 353.950 | -0.732 | 0.464 |
| Finland | | | | | |
| Constant term | -59.142933 | 311.996766 | 307.703 | -0.190 | 0.850 |
| Female sex | 3.608451 | 1.778953 | 155.630 | 2.028 | 0.044 |
| Calendar year | 0.049886 | 0.155324 | 307.703 | 0.321 | 0.748 |
| Greece | | | | | |
| Constant term | -892.527239 | 519.331793 | 93.956 | -1.719 | 0.089 |
| Female sex | -0.405076 | 2.897113 | 68.342 | -0.140 | 0.889 |
| Calendar year | 0.464430 | 0.258636 | 93.954 | 1.796 | 0.076 |
| Republic of South Africa | | | | | |
| Constant term | 636.290049 | 640.320419 | 75.353 | 0.994 | 0.324 |
| Female sex | 2.142126 | 2.784791 | 44.423 | 0.769 | 0.446 |
| Calendar year | -0.296861 | 0.318625 | 75.353 | -0.932 | 0.354 |
| Brazil | | | | | |
| Constant term | 390.737458 | 494.198576 | 122.510 | 0.791 | 0.431 |
| Female sex | -1.389051 | 2.469821 | 73.141 | -0.562 | 0.576 |
| Calendar year | -0.171769 | 0.245978 | 122.514 | -0.698 | 0.486 |
| Mexico | | | | | |
| Constant term | 342.919947 | 496.145544 | 92.343 | 0.691 | 0.491 |
| Female sex | -0.070202 | 2.152566 | 68.580 | -0.033 | 0.974 |
| Calendar year | -0.150281 | 0.246976 | 92.326 | -0.608 | 0.544 |
| Argentina | | | | | |
| Constant term | -133.127127 | 591.831333 | 31.764 | -0.225 | 0.823 |
| Female sex | -2.442123 | 2.570733 | 24.433 | -0.950 | 0.351 |
| Calendar year | 0.086027 | 0.294531 | 31.768 | 0.292 | 0.772 |
| India | | | | | |
| Constant term | 647.670352 | 567.767634 | 57.387 | 1.141 | 0.259 |
| Female sex | -0.840896 | 2.566219 | 39.798 | -0.328 | 0.745 |
| Calendar year | -0.302860 | 0.282792 | 57.372 | -1.071 | 0.289 |
| Israel | | | | | |
| Constant term | 369.720687 | 818.353267 | 61.363 | 0.452 | 0.653 |
| Female sex | 2.219258 | 4.361460 | 43.335 | 0.509 | 0.613 |
| Calendar year | -0.162596 | 0.407397 | 61.348 | -0.399 | 0.691 |
| Slovenia | | | | | |
| Constant term | -780.162274 | 551.609835 | 27.991 | -1.414 | 0.168 |
| Female sex | -7.106008 | 2.764787 | 23.422 | -2.570 | 0.017 |
| Calendar year | 0.409617 | 0.274536 | 27.999 | 1.492 | 0.147 |

Data for Non-African runners are sorted in order of the number of finishers of each country

Table 10 Age (years) with mean \pm SD of female and male East-African and Non-African marathoners

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Women | | | | | | | | |
| Ethiopia | | | | | | | 32 | |
| Kenya | | | | | | 32 | | |
| Austria | 47 \pm 4 | 45 \pm 15 | 32 | 26 \pm 8 | 37 \pm 4 | 45 \pm 7 | 40 \pm 11 | 41 \pm 11 |
| France | 40 \pm 9 | 47 \pm 7 | 45 \pm 11 | 43 \pm 9 | 47 \pm 10 | 46 \pm 9 | 45 \pm 8 | 44 \pm 8 |
| Great Britain | | 34 \pm 4 | 42 \pm 18 | 29 \pm 12 | 43 \pm 11 | 40 \pm 9 | 40 \pm 9 | 40 \pm 12 |
| Germany | 45 \pm 9 | 46 \pm 11 | 48 \pm 12 | 48 \pm 11 | 44 \pm 10 | 45 \pm 13 | 44 \pm 10 | 44 \pm 9 |
| Italy | 43 | 61 \pm 16 | 36 \pm 16 | 52 \pm 2 | 50 \pm 4 | 48 \pm 8 | 40 \pm 6 | 33 \pm 4 |
| Japan | 63 | 66 | 42 \pm 17 | 43 \pm 30 | 57 | 47 \pm 18 | 53 \pm 17 | 52 |
| Switzerland | 41 \pm 11 | 42 \pm 10 | 42 \pm 11 | 41 \pm 10 | 42 \pm 10 | 42 \pm 11 | 43 \pm 11 | 41 \pm 11 |
| Canada | | | | 38 | 49 \pm 10 | 55 \pm 1 | 54 | 48 \pm 7 |
| Liechtenstein | | 44 | 52 \pm 8 | | 42 \pm 11 | | 48 \pm 21 | 40 \pm 4 |
| USA | | 51 | | | | 29 \pm 2 | 39 \pm 14 | 40 \pm 17 |
| Belgium | 28 | | | | 41 | 43 \pm 18 | 41 \pm 13 | 46 \pm 13 |
| Spain | | | | | | | 40 | |
| Poland | | | | 25 | 30 \pm 1 | | | |
| Men | | | | | | | | |
| Ethiopia | | | 28 \pm 3 | | | | | |
| Kenya | | 33 | 24 \pm 4 | | 29 \pm 6 | 29 \pm 8 | 29 | |
| Austria | 52 \pm 4 | 43 \pm 14 | 45 \pm 10 | 45 \pm 9 | 42 \pm 7 | 45 \pm 7 | 44 \pm 8 | 44 \pm 9 |
| France | 43 \pm 8 | 41 \pm 10 | 44 \pm 11 | 44 \pm 10 | 44 \pm 10 | 44 \pm 9 | 44 \pm 9 | 43 \pm 9 |
| Great Britain | 34 \pm 8 | 38 \pm 16 | 39 \pm 11 | 46 \pm 13 | 43 \pm 12 | 39 \pm 10 | 41 \pm 11 | 43 \pm 10 |
| Germany | 40 \pm 9 | 44 \pm 9 | 44 \pm 9 | 45 \pm 9 | 44 \pm 9 | 44 \pm 9 | 43 \pm 9 | 43 \pm 9 |
| Italy | 52 \pm 10 | 45 \pm 8 | 50 \pm 8 | 42 \pm 9 | 44 \pm 9 | 43 \pm 12 | 44 \pm 13 | 41 \pm 9 |
| Japan | 41 | 64 | 36 \pm 7 | 64 | 57 \pm 8 | 51 \pm 13 | 46 \pm 17 | 45 \pm 14 |
| Switzerland | 42 \pm 11 | 43 \pm 11 | 42 \pm 11 | 42 \pm 11 | 42 \pm 11 | 42 \pm 10 | 42 \pm 11 | 42 \pm 11 |
| Canada | 44 \pm 6 | 45 | 33 \pm 6 | 44 \pm 5 | 41 \pm 12 | 38 \pm 12 | 43 \pm 14 | 42 \pm 16 |
| Liechtenstein | | | 29 | 53 \pm 15 | 44 \pm 10 | 40 \pm 8 | 41 \pm 8 | 43 \pm 7 |
| USA | 45 \pm 9 | 55 \pm 8 | 41 \pm 8 | 36 \pm 14 | 37 \pm 10 | 40 \pm 11 | 44 \pm 10 | 42 \pm 13 |
| Belgium | | 38 | | 44 \pm 10 | 41 \pm 12 | 37 \pm 15 | 43 \pm 18 | 43 \pm 11 |
| Spain | | 54 | 45 | 28 \pm 3 | 57 \pm 9 | 44 \pm 4 | 42 \pm 10 | 41 \pm 11 |
| Poland | | 31 | | 27 \pm 4 | 58 | 40 \pm 12 | 49 | 30 \pm 1 |
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Women | | | | | | | | |
| Ethiopia | | | | | 21 | 26 | | |
| Kenya | | | | | 35 | | | |
| Austria | 44 \pm 7 | 39 \pm 10 | 43 \pm 7 | 43 \pm 6 | 44 \pm 4 | 45 \pm 7 | 40 \pm 3 | 41 \pm 10 |
| France | 41 \pm 9 | 44 \pm 9 | 42 \pm 10 | 43 \pm 10 | 45 \pm 9 | 43 \pm 8 | 43 \pm 10 | 45 \pm 9 |
| Great Britain | 40 \pm 10 | 37 \pm 9 | 39 \pm 10 | 38 \pm 18 | 38 \pm 7 | 45 \pm 9 | 36 \pm 8 | 40 \pm 12 |
| Germany | 43 \pm 8 | 44 \pm 10 | 43 \pm 10 | 41 \pm 11 | 44 \pm 11 | 44 \pm 10 | 41 \pm 11 | 45 \pm 10 |
| Italy | 44 \pm 13 | 44 \pm 14 | 55 \pm 16 | 45 \pm 10 | 41 \pm 19 | 55 \pm 11 | 41 \pm 23 | 44 \pm 18 |
| Japan | 54 \pm 18 | 50 \pm 18 | 61 | 50 \pm 19 | 56 \pm 13 | 49 \pm 11 | 56 \pm 8 | 57 \pm 2 |
| Switzerland | 42 \pm 10 | 43 \pm 11 | 42 \pm 11 | 41 \pm 11 | 42 \pm 11 | 42 \pm 10 | 42 \pm 11 | 42 \pm 11 |
| Canada | 25 | 41 \pm 17 | 41 \pm 4 | 38 \pm 10 | 41 \pm 15 | 32 \pm 0 | 35 \pm 3 | 33 \pm 7 |
| Liechtenstein | 33 \pm 10 | 33 \pm 8 | 39 \pm 9 | 42 | 53 | 39 \pm 8 | | 46 \pm 21 |
| USA | 44 \pm 17 | 44 \pm 22 | 37 \pm 11 | 62 \pm 8 | 50 \pm 25 | 31 | | 41 \pm 20 |
| Belgium | 52 \pm 13 | 29 | | 46 | 54 | | | |
| Spain | 46 \pm 8 | 34 | 43 \pm 7 | | 41 \pm 2 | 43 \pm 10 | 44 | 40 \pm 13 |
| Poland | | | 18 | 38 | 52 \pm 1 | 49 \pm 13 | 40 \pm 11 | 39 \pm 2 |

Table 10 continued

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Men | | | | | | | | |
| Ethiopia | 24 ± 4 | 26 | 32 ± 1 | 23 ± 8 | 32 | | 28 ± 8 | 26 |
| Kenya | 35 ± 13 | 28 ± 1 | 28 ± 3 | 32 ± 5 | 29 ± 6 | 24 | 27 ± 6 | 30 ± 2 |
| Austria | 41 ± 10 | 42 ± 11 | 44 ± 10 | 43 ± 6 | 42 ± 8 | 42 ± 8 | 42 ± 7 | 45 ± 9 |
| France | 43 ± 9 | 44 ± 10 | 42 ± 11 | 43 ± 10 | 44 ± 9 | 42 ± 10 | 42 ± 10 | 44 ± 10 |
| Great Britain | 41 ± 8 | 41 ± 11 | 39 ± 11 | 41 ± 9 | 41 ± 9 | 42 ± 10 | 41 ± 11 | 35 ± 8 |
| Germany | 44 ± 10 | 43 ± 9 | 44 ± 10 | 43 ± 10 | 43 ± 10 | 43 ± 10 | 44 ± 10 | 44 ± 10 |
| Italy | 41 ± 8 | 42 ± 8 | 41 ± 9 | 47 ± 9 | 45 ± 12 | 43 ± 8 | 46 ± 9 | 43 ± 12 |
| Japan | 48 ± 14 | 48 ± 14 | 48 ± 19 | 49 ± 17 | 49 ± 17 | 42 ± 16 | 46 ± 19 | 64 ± 7 |
| Switzerland | 42 ± 11 | 42 ± 11 | 42 ± 11 | 42 ± 10 | 42 ± 11 | 42 ± 10 | 42 ± 11 | 42 ± 10 |
| Canada | 35 ± 12 | 42 ± 9 | 49 ± 8 | 46 ± 14 | 41 ± 9 | | 40 ± 7 | 50 ± 9 |
| Liechtenstein | 36 ± 14 | 42 ± 10 | 43 ± 5 | 42 ± 7 | 37 ± 4 | 30 ± 4 | 31 ± 1 | 42 ± 13 |
| USA | 45 ± 10 | 39 ± 10 | 41 ± 12 | 40 ± 9 | 41 ± 9 | 36 ± 7 | 41 ± 13 | 42 ± 10 |
| Belgium | 39 ± 8 | 38 ± 10 | 43 ± 11 | 44 ± 10 | 48 ± 13 | 42 ± 12 | 44 ± 10 | 42 ± 11 |
| Spain | 42 ± 10 | 47 ± 11 | 41 ± 9 | 35 ± 12 | 40 ± 7 | 33 ± 6 | 40 ± 12 | 44 ± 6 |
| Poland | 47 ± 5 | 38 ± 8 | 42 ± 14 | 32 ± 9 | 38 ± 14 | 50 ± 16 | 35 ± 15 | 56 |

Data for Non-African runners are sorted in order of the number of finishers of each country

Table 11 Results of the mixed-effects regression analyses for change in age across years in marathoners

| Parameter | Estimate | SE | DF | T | p value |
|---------------|-------------|------------|----------|--------|---------|
| Ethiopia | | | | | |
| Constant term | 129.282320 | 508.886678 | 16.700 | 0.254 | 0.803 |
| Female sex | -0.243651 | 3.310608 | 12.319 | -0.074 | 0.943 |
| Calendar year | -0.050632 | 0.253416 | 16.702 | -0.200 | 0.844 |
| Kenya | | | | | |
| Constant term | -112.654090 | 528.060345 | 30.357 | -0.213 | 0.832 |
| Female sex | 3.707084 | 4.569460 | 13.457 | 0.811 | 0.431 |
| Calendar year | 0.070957 | 0.263161 | 30.291 | 0.270 | 0.789 |
| Austria | | | | | |
| Constant term | 203.368427 | 202.655612 | 491.365 | 1.004 | 0.316 |
| Female sex | -2.565643 | 1.122330 | 309.176 | -2.286 | 0.023 |
| Calendar year | -0.079728 | 0.100942 | 491.362 | -0.790 | 0.430 |
| France | | | | | |
| Constant term | 118.121641 | 83.994410 | 2805.626 | 1.406 | 0.160 |
| Female sex | 0.044112 | 0.552283 | 1850.356 | 0.080 | 0.936 |
| Calendar year | -0.037087 | 0.041835 | 2805.619 | -0.887 | 0.375 |
| Great Britain | | | | | |
| Constant term | 389.692562 | 249.759353 | 477.933 | 1.560 | 0.119 |
| Female sex | -1.714608 | 1.280914 | 348.174 | -1.339 | 0.182 |
| Calendar year | -0.173769 | 0.124396 | 477.931 | -1.397 | 0.163 |
| Germany | | | | | |
| Constant term | 107.789331 | 82.298718 | 3899.573 | 1.310 | 0.190 |
| Female sex | 0.535367 | 0.472119 | 2458.948 | 1.134 | 0.257 |
| Calendar year | -0.032069 | 0.040991 | 3899.516 | -0.782 | 0.434 |
| Italy | | | | | |
| Constant term | 556.010922 | 261.000704 | 423.965 | 2.130 | 0.034 |
| Female sex | 1.394311 | 1.647994 | 289.562 | 0.846 | 0.398 |
| Calendar year | -0.255065 | 0.129966 | 423.965 | -1.963 | 0.050 |

Table 11 continued

| Parameter | Estimate | SE | DF | T | p value |
|--------------------------|--------------|------------|------------|--------|---------|
| Japan | | | | | |
| Constant term | -933.316248 | 562.194049 | 154.231 | -1.660 | 0.099 |
| Female sex | 1.996612 | 3.315609 | 104.626 | 0.602 | 0.548 |
| Calendar year | 0.488912 | 0.279931 | 154.230 | 1.747 | 0.083 |
| Switzerland | | | | | |
| Constant term | 37.165305 | 28.161538 | 39,125.737 | 1.320 | 0.187 |
| Female sex | 0.130342 | 0.144640 | 24,925.454 | 0.901 | 0.368 |
| Calendar year | 0.002333 | 0.014026 | 39,122.296 | 0.166 | 0.868 |
| Canada | | | | | |
| Constant term | -113.393911 | 476.054030 | 132.791 | -0.238 | 0.812 |
| Female sex | -2.046769 | 3.297757 | 73.295 | -0.621 | 0.537 |
| Calendar year | 0.077849 | 0.237227 | 132.790 | 0.328 | 0.743 |
| Liechtenstein | | | | | |
| Constant term | 1182.645518 | 516.645857 | 102.882 | 2.289 | 0.024 |
| Female sex | 2.754826 | 2.269941 | 72.517 | 1.214 | 0.229 |
| Calendar year | -0.569271 | 0.257412 | 102.881 | -2.212 | 0.029 |
| United States of America | | | | | |
| Constant term | 237.925017 | 383.185261 | 297.972 | 0.621 | 0.535 |
| Female sex | -1.592948 | 2.308567 | 180.960 | -0.690 | 0.491 |
| Calendar year | -0.098054 | 0.190859 | 297.985 | -0.514 | 0.608 |
| Belgium | | | | | |
| Constant term | -304.145888 | 500.299320 | 132.133 | -0.608 | 0.544 |
| Female sex | 1.923155 | 3.303639 | 100.875 | 0.582 | 0.562 |
| Calendar year | 0.172307 | 0.248996 | 132.127 | 0.692 | 0.490 |
| Spain | | | | | |
| Constant term | 519.395530 | 568.357363 | 74.188 | 0.914 | 0.364 |
| Female sex | -0.202724 | 2.587542 | 60.661 | -0.078 | 0.938 |
| Calendar year | -0.237530 | 0.282985 | 74.188 | -0.839 | 0.404 |
| Poland | | | | | |
| Constant term | -2195.393095 | 875.131990 | 54.937 | -2.509 | 0.015 |
| Female sex | -3.631775 | 3.857273 | 56.539 | -0.942 | 0.350 |
| Calendar year | 1.113417 | 0.435743 | 54.943 | 2.555 | 0.013 |

Data for Non-African runners are sorted in order of the number of finishers of each country

Table 12 Running speed and age of half-marathoners and marathoners sorted by country

| Running speed | | | | Age | | | |
|----------------|------------|----------------|------------|----------------|-------------|----------------|-------------|
| Country | Women | Country | Men | Country | Women | Country | Men |
| Half-marathon | | | | | | | |
| Kenya | 14.2 ± 5.1 | Kenya | 12.7 ± 4.8 | Ethiopia | 29.8 ± 7.7 | Ethiopia | 28.0 ± 5.2 |
| Ethiopia | 12.8 ± 5.1 | Ethiopia | 11.1 ± 4.4 | Kenya | 30.2 ± 6.0 | Kenya | 29.7 ± 8.3 |
| Portugal | 11.4 ± 3.5 | Portugal | 11.1 ± 2.9 | Russia | 35.2 ± 9.3 | Russia | 37.1 ± 9.0 |
| Liechtenstein | 10.9 ± 2.5 | Liechtenstein | 10.5 ± 2.7 | Czech Republic | 35.6 ± 8.1 | Czech Republic | 37.5 ± 10.7 |
| Hungary | 10.7 ± 2.4 | Italy | 10.4 ± 3.2 | Argentina | 38.1 ± 6.9 | Poland | 38.3 ± 11.3 |
| Italy | 10.7 ± 3.1 | Switzerland | 10.4 ± 2.9 | India | 38.3 ± 8.9 | South Africa | 38.7 ± 9.3 |
| Switzerland | 10.4 ± 2.9 | Hungary | 9.9 ± 2.9 | Slovenia | 38.5 ± 2.1 | Canada | 38.9 ± 11.9 |
| India | 10.2 ± 1.2 | France | 9.5 ± 3.3 | Ireland | 38.5 ± 7.5 | Australia | 38.9 ± 9.9 |
| Spain | 10.0 ± 3.0 | Netherlands | 9.5 ± 3.3 | USA | 38.5 ± 10.9 | Argentina | 39.2 ± 6.3 |
| Ireland | 9.8 ± 3.0 | Australia | 9.5 ± 2.9 | Great Britain | 38.8 ± 9.6 | India | 39.3 ± 8.6 |
| Argentina | 9.6 ± 3.1 | Spain | 9.4 ± 3.0 | Poland | 39.1 ± 9.9 | Portugal | 39.5 ± 9.2 |
| France | 9.5 ± 3.3 | Norway | 9.1 ± 3.0 | Canada | 39.2 ± 10.0 | USA | 39.9 ± 10.8 |
| Netherlands | 9.5 ± 3.2 | Great Britain | 9.0 ± 3.2 | Greece | 39.5 ± 9.3 | Greece | 39.9 ± 11.2 |
| Russia | 9.5 ± 2.8 | Israel | 8.9 ± 3.3 | Denmark | 40.4 ± 9.8 | Ireland | 40.2 ± 9.2 |
| Norway | 9.5 ± 2.9 | Belgium | 8.8 ± 3.0 | Spain | 40.6 ± 9.2 | Spain | 40.3 ± 9.6 |
| Great Britain | 9.2 ± 3.1 | Czech Republic | 8.8 ± 3.4 | Mexico | 40.6 ± 8.5 | Great Britain | 40.4 ± 10.4 |
| Brazil | 9.2 ± 2.5 | Ireland | 8.7 ± 3.1 | Luxembourg | 41.0 ± 9.8 | Mexico | 40.8 ± 9.0 |
| Mexico | 9.2 ± 2.4 | India | 8.7 ± 2.5 | Austria | 41.1 ± 8.5 | Switzerland | 41.2 ± 10.3 |
| Czech Republic | 9.1 ± 3.6 | Mexico | 8.7 ± 3.3 | Liechtenstein | 41.1 ± 9.7 | Liechtenstein | 41.2 ± 9.2 |
| Greece | 8.8 ± 2.7 | Greece | 8.6 ± 3.1 | Switzerland | 41.3 ± 10.3 | Luxembourg | 41.3 ± 9.2 |
| USA | 8.7 ± 3.1 | Poland | 8.5 ± 3.6 | France | 41.4 ± 9.5 | Denmark | 41.6 ± 10.7 |
| Denmark | 8.6 ± 3.0 | USA | 8.1 ± 3.0 | Belgium | 42.0 ± 10.4 | France | 41.6 ± 9.6 |
| Israel | 8.6 ± 3.6 | Germany | 8.4 ± 3.2 | Portugal | 42.3 ± 8.7 | Slovenia | 41.6 ± 16.2 |
| South Africa | 8.5 ± 2.7 | Argentina | 8.4 ± 3.0 | Australia | 42.3 ± 8.7 | Netherlands | 41.7 ± 10.6 |
| Poland | 8.5 ± 3.5 | Russia | 8.3 ± 2.7 | Italy | 42.3 ± 9.6 | Belgium | 41.8 ± 10.7 |
| Belgium | 8.4 ± 3.0 | Denmark | 8.2 ± 2.9 | Israel | 42.5 ± 12.8 | Finland | 42.1 ± 11.7 |
| Germany | 8.4 ± 3.2 | Sweden | 8.1 ± 3.1 | Sweden | 42.6 ± 11.9 | Austria | 42.3 ± 9.1 |
| Australia | 8.2 ± 2.9 | Brazil | 8.0 ± 2.9 | South Africa | 43.3 ± 9.9 | Norway | 42.5 ± 12.6 |
| Sweden | 8.2 ± 3.1 | Austria | 7.9 ± 3.1 | Germany | 43.3 ± 9.7 | Israel | 42.6 ± 11.9 |
| Luxembourg | 8.1 ± 2.8 | Slovenia | 7.9 ± 3.1 | Brazil | 43.7 ± 10.9 | Italy | 42.8 ± 9.5 |
| Austria | 7.9 ± 3.1 | South Africa | 7.8 ± 3.2 | Netherlands | 44.1 ± 9.7 | Greece | 43.1 ± 9.9 |
| Canada | 7.2 ± 3.3 | Luxembourg | 7.8 ± 2.9 | Finland | 45.6 ± 10.7 | Sweden | 43.4 ± 11.8 |
| Slovenia | 7.1 ± 2.9 | Canada | 7.4 ± 3.1 | Hungary | 48.1 ± 11.5 | Hungary | 44.2 ± 13.1 |
| Finland | 6.6 ± 2.8 | Finland | 7.0 ± 2.6 | Norway | 48.3 ± 13.5 | Brazil | 44.6 ± 9.9 |
| Japan | 6.2 ± 2.6 | Japan | 6.5 ± 2.9 | Japan | 48.8 ± 14.2 | Japan | 49.5 ± 15.8 |
| Marathon | | | | | | | |
| Ethiopia | 18.8 ± 0.3 | Kenya | 17.8 ± 1.3 | Ethiopia | 26.3 ± 5.5 | Ethiopia | 27.2 ± 4.6 |
| Kenya | 18.3 ± 0.1 | Ethiopia | 16.1 ± 1.6 | Kenya | 33.5 ± 2.1 | Kenya | 29.2 ± 6.0 |
| Liechtenstein | 16.6 ± 3.5 | Liechtenstein | 16.6 ± 3.5 | Poland | 38.5 ± 11.6 | Liechtenstein | 40.3 ± 9.0 |
| Italy | 15.8 ± 4.1 | Switzerland | 14.7 ± 4.0 | Great Britain | 39.0 ± 10.4 | Great Britain | 40.4 ± 10.2 |
| Switzerland | 15.0 ± 4.1 | Belgium | 14.4 ± 3.9 | Canada | 40.2 ± 10.0 | Poland | 40.5 ± 13.1 |
| Japan | 14.1 ± 4.4 | Spain | 14.2 ± 3.9 | Liechtenstein | 41.2 ± 10.3 | USA | 41.3 ± 10.6 |
| Spain | 13.6 ± 2.8 | Italy | 13.6 ± 3.9 | Austria | 41.5 ± 8.5 | Canada | 41.4 ± 11.1 |
| France | 13.4 ± 3.9 | France | 13.3 ± 3.8 | Spain | 41.8 ± 7.8 | Switzerland | 41.8 ± 10.5 |
| Great Britain | 13.2 ± 3.9 | Great Britain | 13.3 ± 3.9 | Switzerland | 41.9 ± 10.7 | Belgium | 42.1 ± 11.0 |
| Poland | 12.9 ± 3.4 | Germany | 12.9 ± 3.6 | USA | 43.3 ± 16.5 | Spain | 42.3 ± 9.5 |
| Germany | 12.9 ± 3.8 | USA | 12.8 ± 3.9 | Belgium | 43.4 ± 11.7 | Austria | 42.9 ± 8.5 |

Table 12 continued

| Running speed | | | | Age | | | |
|---------------|------------|---------|------------|---------|-------------|---------|-------------|
| Country | Women | Country | Men | Country | Women | Country | Men |
| Austria | 12.4 ± 3.0 | Austria | 12.3 ± 2.9 | France | 43.6 ± 9.2 | France | 43.2 ± 9.7 |
| USA | 12.3 ± 3.8 | Japan | 12.1 ± 4.1 | Germany | 43.8 ± 10.2 | Germany | 43.4 ± 9.6 |
| Canada | 11.9 ± 4.4 | Poland | 11.9 ± 3.3 | Italy | 45.0 ± 12.2 | Italy | 43.5 ± 9.9 |
| Belgium | 11.6 ± 2.6 | Canada | 11.8 ± 4.3 | Japan | 51.8 ± 14.9 | Japan | 48.0 ± 15.5 |

Authors' contributions

BK and MZ collected all data, BK, PN and VO drafted the manuscript, CR and PN performed the statistical analyses, CR and TR participated in the design and coordination and helped drafting the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Received: 29 November 2015 Accepted: 17 February 2016

Published online: 29 February 2016

References

- Anthony D, Rüst CA, Cribari M, Rosemann T, Lepers R, Knechtle B (2014) Differences in participation and performance trends in age group half and full marathoners. *Chin J Physiol* 57:209–219
- Aschmann A, Knechtle B, Cribari M, Rüst CA, Onywera V, Rosemann T, Lepers R (2013) Performance and age of African and non-African runners in half- and full marathons held in Switzerland, 2000–2010. *Open Access J Sports Med* 4:183–192
- Baker J, Norton S (2003) East African running dominance revisited: a role for stereotype threat? *Br J Sports Med* 37:553–555
- Beis LY, Willkomm L, Ross R, Bekele Z, Wolde B, Fudge B, Pitsiladis YP (2011) Food and macronutrient intake of elite Ethiopian distance runners. *J Int Soc Sports Nutr* 8:7
- Cejka N, Rüst CA, Lepers R, Onywera V, Rosemann T, Knechtle B (2014) Participation and performance trends in 100-km ultra-marathons worldwide. *J Sports Sci* 32:354–366
- Cribari M, Rüst CA, Rosemann T, Onywera V, Lepers R, Knechtle B (2013) Participation and performance trends of East-African runners in Swiss half-marathons and marathons held between 2000 and 2010. *BMC Sports Sci Med Rehabil* 5:24
- Dähler P, Rüst CA, Rosemann T, Lepers R, Knechtle B (2014) Nation related participation and performance trends in 'Ironman Hawaii' from 1985 to 2012. *BMC Sports Sci Med Rehabil* 6:16
- Desgorces FD, Berthelot G, Charmantier A, Tafflet M, Schaal K, Jarne P, Toussein JF (2012) Similar slow down in running speed progression in species under human pressure. *J Evol Biol* 25:1792–1799
- Fudge BW, Westerterp KR, Kiplamai FK, Onywera VO, Boit MK, Kayser B, Pitsiladis YP (2006) Evidence of negative energy balance using doubly labelled water in elite Kenyan endurance runners prior to competition. *Br J Nutr* 95:59–66
- Hamilton B (2000) East African running dominance: what is behind it? *Br J Sports Med* 34:391–394
- Hamilton B, Weston A (2000) Perspectives on East African middle and long distance running. *J Sci Med Sport* 3:6–8
- Hunter SK, Stevens AA, Magennis K, Skelton KW, Fauth M (2011) Is there a sex difference in the age of elite marathon runners? *Med Sci Sports Exerc* 43:656–664
- Knechtle B, Rosemann T, Rüst CA (2014) Participation and performance trends by nationality in the 'English Channel Swim' from 1875 to 2013. *BMC Sports Sci Med Rehabil* 6:34
- Kohn TA, Essén-Gustavsson B, Myburgh KH (2007) Do skeletal muscle phenotypic characteristics of Xhosa and Caucasian endurance runners differ when matched for training and racing distances? *J Appl Physiol* (1985) 103:932–940
- Larsen HB (2003) Kenyan dominance in distance running. *Comp Biochem Physiol A: Mol Integr Physiol* 136:161–170
- Larsen HB, Sheel AW (2015) The Kenyan runners. *Scand J Med Sci Sports Suppl* 4:110–118
- Lehto N (2015) Effects of age on marathon finishing time among male amateur runners in Stockholm Marathon 1979–2014. *J Sport Health Sci*. doi:10.1016/j.jshs.2015.01.008
- Lucia A, Esteve-Lanao J, Oliván J, Gómez-Gallego F, San Juan AF, Santiago C, Pérez M, Chamorro-Viña C, Foster C (2006) Physiological characteristics of the best Eritrean runners—exceptional running economy. *Appl Physiol Nutr Metab* 31:530–540
- Millet GY, Hoffman MD, Morin JB (2012) Sacrificing economy to improve running performance—a reality in the ultramarathon? *J Appl Physiol* (1985) 113:507–509
- Onywera VO (2009) East African runners: their genetics, lifestyle and athletic prowess. *Med Sport Sci* 54:102–109
- Onywera VO, Scott RA, Boit MK, Pitsiladis YP (2006) Demographic characteristics of elite Kenyan endurance runners. *J Sports Sci* 24:415–422
- Prommer N, Thoma S, Quecke L, Gutekunst T, Völzke C, Wachsmuth N, Niess AM, Schmidt W (2010) Total hemoglobin mass and blood volume of elite Kenyan runners. *Med Sci Sports Exerc* 42:791–797
- Santos-Concejero J, Oliván J, Maté-Muñoz JL, Muniesa C, Montil M, Tucker R, Lucia A (2015) Gait-cycle characteristics and running economy in elite Eritrean and European runners. *Int J Sports Physiol Perform* 10:381–387
- Scott RA, Georgiades E, Wilson RH, Goodwin WH, Wolde B, Pitsiladis YP (2003) Demographic characteristics of elite Ethiopian endurance runners. *Med Sci Sports Exerc* 35:1727–1732
- Tucker R, Santos-Concejero J, Collins M (2013) The genetic basis for elite running performance. *Br J Sports Med* 47:545–549
- Tucker R, Onywera VO, Santos-Concejero J (2015) Analysis of the Kenyan distance-running phenomenon. *Int J Sports Physiol Perform* 10:285–291
- Vernillo G, Schena F, Berardelli C, Rosa G, Galvani C, Maggioni M, Agnello L, La Torre A (2013) Anthropometric characteristics of top-class Kenyan marathon runners. *J Sports Med Phys Fitness* 53:403–408
- Wegner CE, Ridinger LL, Jordan JS, Funk DC (2015) Get serious: gender and constraints to long-distance running. *J Leis Res* 47:305–321
- Whitfield G, Pettée Gabriel KK, Kohl HW 3rd (2014) Sedentary and active: self-reported sitting time among marathon and half-marathon participants. *J Phys Act Health* 11:165–172
- Wilber RL, Pitsiladis YP (2012) Kenyan and Ethiopian distance runners: what makes them so good? *Int J Sports Physiol Perform* 7:92–102