Original Article

Participation and performance trends in 161km ultra-marathons in terms of nationality – a retrospective data analysis of worldwide participation from 1998-2011

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ABSTRACT

Gerosa, D., Rüst, C.A., Rosemann, T. & Knechtle, B. (2014). Participation and performance trends in 161km ultra-marathons in terms of nationality – a retrospective data analysis of worldwide participation from 1998-2011. *J. Hum. Sport Exerc., 9*(2), pp.592-615. This study investigated the nationalities of finishers, the annual number of finishers participating in a specific region and the performance of athletes regarding their nationality of all 161km ultra-marathons held worldwide from 1998 to 2011. The associations between nationality and performance and changes in performance across years in 36,425 finishers were analysed using correlation and linear regression analyses. Participation increased significantly for athletes originating from North America, Europe and Australia (P<0.01). Most runners originated from the USA (84%). The share of US-American athletes decreased significantly from 89.6% (1998) to 75.9% (2011) (P<0.01), while the share of European finishers increased significantly from 1.6% (1998) to 14.5% (2011) (P<0.01). The share of finishers competing in races held in the USA decreased significantly from 92.1% (1998) to 80.7% (2011) (P<0.01), while the share of finishers competing in European races increased significantly from 0% (1998) to 12.8% (2011) (P<0.01). The share of US-American athletes in the annual top ten decreased significantly from 76% (1998) to 52% (2011) (P<0.01), while the share of European athletes in the annual top ten increased significantly from 1% (1998) to 18% (2011) (P<0.01). Top ten US-American athletes achieved the fastest race times ever in women and men. Top ten European runners improved their performance to a higher extent than US-American athletes. These findings indicate that (i) ultra-marathoners originating from the USA dominated 161km ultra-marathons in participation and performance, (ii) 161km ultra-marathons were becoming more popular in Europe, and (iii) European athletes increasingly tended to compete in European races rather than to compete in the USA and improved their performance across years. **Key words**: RUNNING, ULTRA-ENDURANCE, GENDER.

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INTRODUCTION

A 161km (100miles) ultra-marathon is an ultra-endurance running discipline, where athletes run on roads, tracks or off-road trails (Hoffman et al., 2010). During the last three decades, ultra-marathon running has gained in popularity with an increasing number of participants (Ehrensperger et al., 2013; Knechtle et al., 2011, 2012; Sehovic et al., 2013; Shoak et al., 2013a). For 161km ultra-marathons held in the USA, both the annual number of races and the number of participants increased exponentially since 1977, the year when the first official 161km ultra-marathon, the 'Western States Endurance Run', was held in Northern California, USA (Hoffman and Wegelin, 2009).

There were several studies investigating aspects of demographic and social characteristics of 161km ultra-marathoners in terms of age and gender (Hoffman et al., 2010b; Hoffman & Fogard, 2012; Hoffman & Wegelin, 2009; Rüst et al., 2013b). One of the reasons for the increase in participation in 161km ultra-marathons was an increase in participation among runners >40 years of age (Hoffman et al., 2010b). More than two thirds of all 161km ultra-marathoners were older than 40 years and 161km ultra-marathoners were on average five years older than marathoners (Hoffman et al., 2010b). Hoffman & Fogard (2012) showed that the mean age of 161km ultra-marathoners was 42.8±7.9 years for women and 44.8±10.1 years for men, within a range of 20 to 72 years. This was younger than the mean age of 100km ultra-marathoners with 46.5±10.8 years for women and 46.8±10.9 years for men (Knechtle et al., 2012).

Age might have a considerable influence on ultra-running performance (Hoffman & Fogard, 2012; Hoffman & Wegelin, 2009; Knechtle et al., 2012; Zingg et al., 2013). Rüst et al. (2013b) examined the age of peak running performance of the best 161km ultra-marathoners worldwide. The mean ages of the annual ten fastest runners were 39.2±6.2 years for women and 37.2±6.1 years for men. In contrast, for 24-hour ultra-marathoners, the mean ages of the annual ten fastest runners were 43.2±2.6 years for women and 40.9±2.5 years for men (Peter et al., 2014). The ten fastest runners in 161km ultra-marathons were therefore ~3 years younger than the fastest 24-hour ultra-marathoners. Compared to the mean age of the fastest marathoners with 29.8±4.2 for women and 28.9±3.8 for men (Hunter et al., 2011), 161km ultra-marathoners were around ten years older.

Beside age, gender may also have a substantial influence on performance in 161km ultra-marathoners since the fastest women were running ~20% slower than the fastest men (Hoffman, 2010). For 161km ultra-marathons held in the USA, participation among women increased from virtually none in the late 1970s to ~20% since 2004 (Hoffman et al., 2010b; Hoffman & Wegelin, 2009). Compared to 100km ultra-marathons with a share of ~13% in women (Knechtle et al., 2012), women were more represented in 161km ultra-marathons than in 100km ultra-marathons.

In recent years, a considerable improvement in worldwide 161km ultra-marathon performance has been reported (Rüst et al., 2013). From 1998 to 2011, the annual top ten performances improved by 13.7% for women and by 14.5% for men (Rüst et al., 2013). Beside gender and age, also other variables might have a significant influence on performance such as training (Hoffman & Fogard, 2011), anthropometric characteristics such as body mass index (Hoffman, 2008a; Hoffman & Fogard, 2011) and percent body fat (Hoffman et al., 2010a) and also external factors such as environmental factors (Parise and Hoffman, 2011; Wegelin and Hoffman, 2011) or the use of drugs (Hoffman & Fogard, 2011). Training might be the key for a successful finish of an ultra-marathon (Knechtle et al., 2010). It has been shown that a higher training volume led to faster race times in 161km ultra-marathoners and to a lower risk of dropping out due to injuries (Hoffman & Fogard, 2011). Running experience might also lead to profound improvements in

performance in ultra-marathoners (Hoffman & Fogard, 2011; Hoffman & Fogard, 2012; Knechtle et al., 2010). Although one third of all ultra-marathoners had limited running experience at the first ultra-marathon (Hoffman and Krishnan, 2013), ultra-marathoners had a mean running experience of ~16.2 years at running shorter distances (Hoffman and Krishnan, 2013) and 161km ultra-marathoners had a mean running experience of 7.6±6.3 years in ultra-running (Hoffman & Fogard, 2012).

The body composition of an athlete might determine the success in particular ultra-endurance events. Ultra-marathoners had a higher body mass index compared to middle to marathon distance runners due to greater fat stores and a higher skeletal muscle mass (Hoffman, 2008a). A significant correlation was found dependent on body mass index and percent body fat with running speed in ultra-marathoners (Hoffman, 2008a; Hoffman et al., 2010a; Hoffman & Fogard, 2011). Environmental factors such as hot temperatures also proved to have a negative effect on running performance, although to a higher extent on faster athletes (Parise & Hoffman, 2011; Wegelin & Hoffman, 2011). Hoffman & Fogard (2011) revealed a high overall use of non-steroidal anti-inflammatory drugs (NSAIDs). It is obvious that analgesics might lead to a higher probability of success.

Apart from these variables, it is most likely that also other variables such as ethnicity and cultural background might be influencing the performance in ultra-marathoners. Recent findings assumed that the length of an ultra-marathon may influence the nationality of the fastest runners and nationality might have a substantial role in running performance. For example, East African runners dominated in distance running up to the marathon distance (Hamilton, 2000; Larsen, 2003; Onywera et al., 2006). However, in ultra-marathons such as the 'Swiss Alpine Marathon', East African runners seemed to be in an inferior position (Harm et al., 2013).

Previous studies reported an increase in popularity of ultra-endurance events such as swimming (Eichenberger et al., 2014), cycling (Shoak et al., 2013b), running (Cejka et al., 2013; Ehrensperger et al., 2013; Sehovic et al., 2013; Shoak et al., 2013a) and triathlon (Jeffery et al., 2012; Knechtle et al., 2011; Lepers et al., 2012; Rüst et al., 2014) in Europe. Regarding ultra-marathoners, a recent study demonstrated that European athletes, especially from France, were dominating 100km ultra-marathons in terms of participation, although the best performances belonged to Japanese athletes (Cejka et al., 2013). Shoak et al. (2013a) showed that 81.9% of all athletes participating in multi-stage ultra-marathons originated from Europe, most of them were from France. Furthermore, European athletes were dominating in terms of performance (Rüst et al., 2014) as well as participation and performance in other ultra-endurance sports disciplines such as ultra-triathlons (Jeffery et al., 2012; Lepers et al., 2012), 12-hour ultra-marathons (Sehovic et al., 2013), and 6-hour ultra-marathons (Ehrensperger et al., 2013). However, in contrast to these findings, Japanese runners were again dominating in ultra-marathons of 200km and more in length (Knechtle et al., 2013).

These findings highlight the importance of nationality in ultra-marathon performance. To date, no study examined the nationalities of participants competing in 161km ultra-marathons, where 161km ultra-marathons were held and the performance of the competitors referring to their nationality. Therefore, the aims of this study were to analyse (i) participation trends in 161km ultra-marathons, (ii) the origin of 161km ultra-marathoners, (iii) in which countries athletes competed in 161km ultra-marathons and, (iv) the performance trend of 161km ultra-marathoners of the different nationalities competing in races held all over the world in the time period from 1998 to 2011. Based upon recent findings, we hypothesised (i) an increase in the annual number of participants in 161km ultra-marathons, (ii) US-American athletes would dominate 161km ultra-marathons in both participation and performance, (iii) 161km ultra-marathons would

become more popular in Europe and that (iv) the performance of European athletes would improve to a higher extent than the performance of US-American athletes.

MATERIAL AND METHODS

Ethics

All procedures used in the study met the ethical standards of the Swiss Academy of Medical Sciences and were approved by the Institutional Review Board of Kanton St. Gallen, Switzerland with a waiver of the requirement for informed consent of the participants given the fact that the study involved the analysis of publicly available data.

Data sampling and data analysis

The data set for this study was obtained from the race website 'Deutsche Ultramarathon-Vereinigung' (DUV) (www.ultra-marathon.org). Data from all athletes who ever participated in a 161km ultra-marathon between 1975 and 2011 were collected and analysed regarding the association between nationality and performance.

Between 1975 and 2011, a total number of 39,381 athletes were registered in the rankings of the database from DUV. Since for the earlier years before 1998 the records were not gapless and for some races not available, we decided to analyse only athletes who participated between 1998 and 2011. These athletes were investigated regarding participation, nationality, and performance. Nine male Americans were excluded from analysis because they were underage.

Amongst the distribution of the number of participants, we also investigated the change in the annual number of participants originating from and participating in specific regions. Due to the enormous number of countries where the athletes originated from we decided to show the distribution only for the ten countries per continent with the total (i.e. women and men) highest number of participants. The change in the annual number of participants originating from different countries was investigated for the ten countries with the total highest number of women and men, which were the United States of America (USA), Canada (CAN), South Africa (RSA), Germany (GER), Australia (AUS), Great Britain (GBR), Sweden (SWE), Belgium (BEL), Japan (JPN) and France (FRA). Correlation analyses were performed to investigate potential associations between a change in the annual number of participants and the change in the general population and Gross national Income per capita of the above mentioned countries. Demographic data were obtained from 'The World Bank' (http://data.worldbank.org) and 'Eurostat – European Commission' (http://epp.eurostat.ec.europa.eu). To analyse the running performance of the fastest runners, the race times of the annual top ten (i.e., the annual ten fastest race times) women and men were examined. Only races with at least ten finishers were considered.

Statistical Analysis

In order to increase the reliability of the data analyses, each set of data was tested for normal distribution and for homogeneity of variances prior to statistical analyses. Normal distribution was tested using a D'Agostino and Pearson omnibus normality test and homogeneity of variances was tested using a Levene's test in case of two groups and with a Bartlett's test in case of more than two groups. To investigate a potential change in a variable across years, linear regression was used. A potential association between a change in the annual number of participants and the change in the general population and Gross national Income per capita was analysed using correlation analyses. Statistical analyses were performed using IBM

SPSS Statistics (Version 19, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (Version 5, GraphPad Software, La Jolla, CA, USA). Significance was accepted at P<0.01 (two-sided for t-tests).

RESULTS

Number of participants

From 1998 to 2011, a total of 36,425 athletes, including 29,496 men (81%) and 6,929 women (19%) finished a 161km ultra-marathon successfully. The number of overall participants increased in an exponential manner (r^2=0.93, P<0.01) (Figure 1). At first from 1998 to 2002, the annual number of finishers remained relatively stable within a range of 1,504 to 1,687 athletes. After 2002, there was an increase in the annual number of finishers by 25.1% followed by an increasing annual growth. Then in 2007, there was another leap in the annual number of participants by 16.8% and in 2009, there was a third leap of 27.9%. From 1998 to 2004, the annual number of female finishers increased at a higher rate than those of men and therefore expanded their share from 16.5% to 20.5%. After 2004, the share of women remained on the same level at ~20% up until 2011.

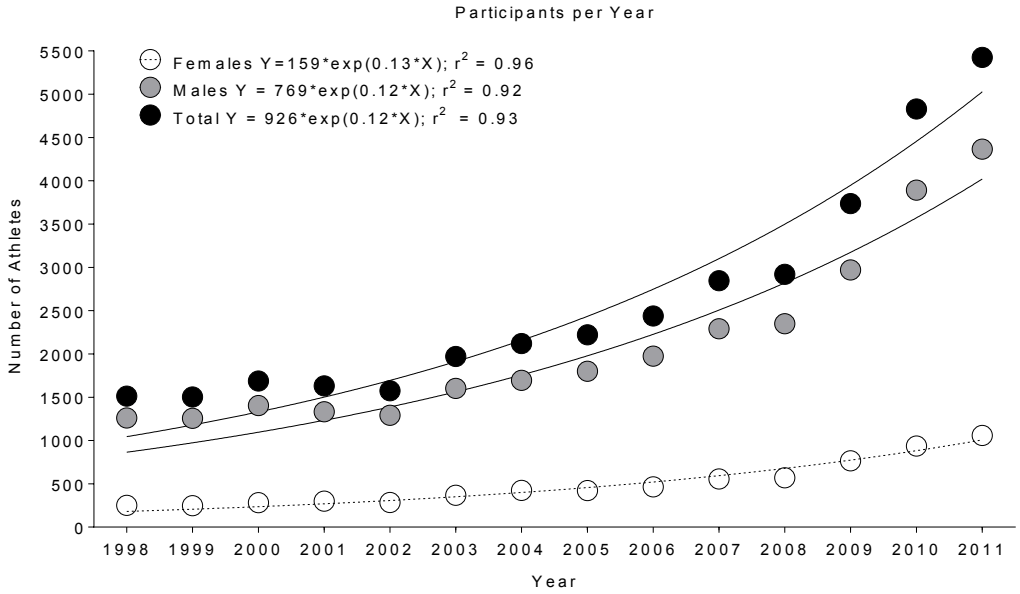


Figure 1. *Number of annual female and male participants*

Participants originating from specific regions

Finishers originated from 61 different countries. Of all considered participants, 32,199 (88.4%) originated from North America, 2,367 (6.5%) from Europe, 1,045 (2.9%) from Africa, 430 (1.2%) from Australia, including New Zealand, 263 (0.7%) from Asia and 121 (0.3%) from South America (Figure 2). Most of the participants originated from the following countries: 30,564 (84%) from the USA, 1,635 (4.5%) from Canada, 1,035 (2.8%) from South Africa, 877 (2.4%) from Germany, 678 (1.9%) from Great Britain and 370 (1%) from Australia (Figure 3). The annual number of both US-American (r^2=0.84, P<0.01) and European athletes (r^2=0.58, P<0.01) increased significantly over the studied period. In 2011, 4,120 athletes originating from the USA and 784 athletes originating from Europe accomplished a 161km ultra-marathon successfully. The annual number of athletes originating from Canada also increased significantly (r^2=0.85, P<0.01) to 1,635 finishers in 2011. The annual number of finishers originating from Australia fluctuated between 1 and 30 in the time span from 1998 to 2007. Since 2007, their number linearly increased

(r^2=0.96, P<0.01) from 19 (1998) to 94 (2011) finishers. The annual number of African runners was not following a certain pattern and was swinging between 44 and 120 finishers. Among all 1,045 African athletes, only 10 athletes were from other countries than South Africa. From those were 8 runners from Tanzania. Finishers from Asia were never more than 20 runners per year until 2011, where their number increased to 107, with 55 runners from Japan. The annual number of runners from South America slightly increased in a volatile manner up to 21 finishers in 2011.

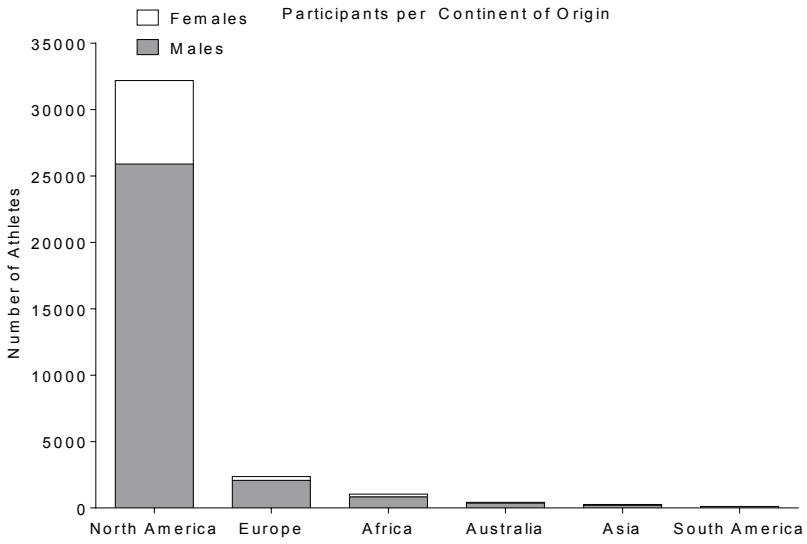


Figure 2. *Number of male and female participants originating from a specific continent*

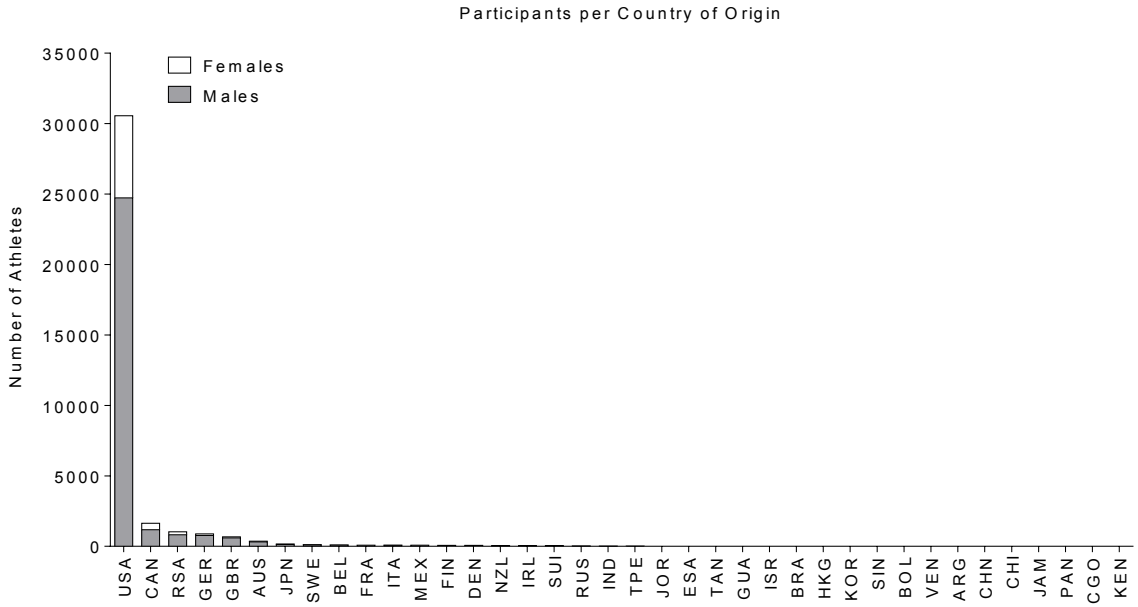


Figure 3. *Number of male and female participants that came from a specific continent. The figure shows maximal 10 countries per continent. The countries are ordered by the total number of female and male athletes in decreasing order from left*

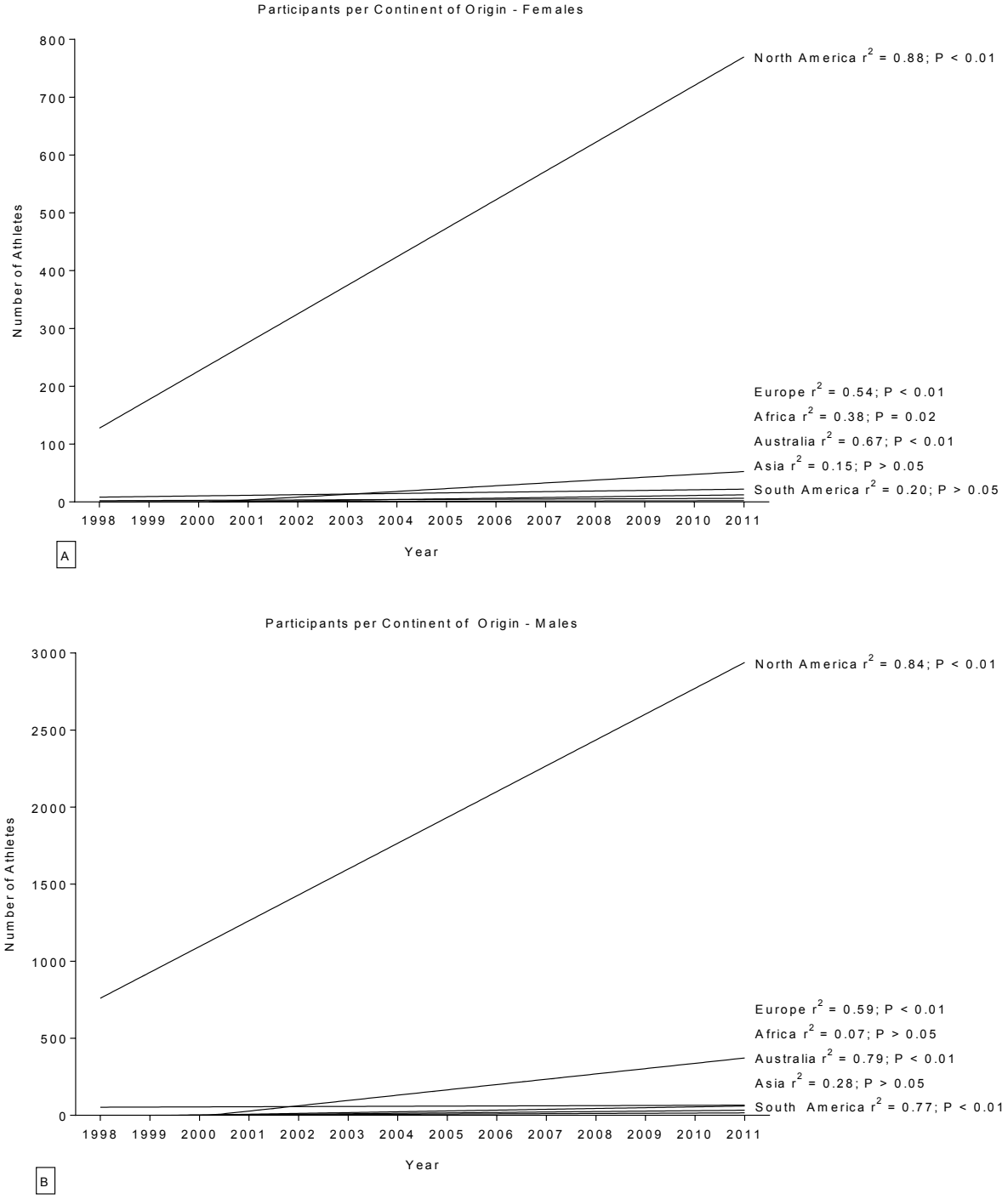


Figure 4. *Change in the annual number of athletes originating from different continents for women (Panel A) and men (Panel B)*

The share of US-American athletes of the overall field decreased significantly from 89.6% (1998) to 75.9% (2011) (r^2=0.57, P<0.01), while the share of European finishers increased significantly from 1.6% (1998) to 14.5% (2011) (r^2=0.63, P<0.01). The share of Canadian finishers slightly increased from 3.6% (1998) to 4.2% (2011) (r^2=0.30, P<0.05), the share of Australian finishers increased significantly from 0.1% (1998) to 1.6% (2011) (r^2=0.74, P<0.01) and the share of South African finishers decreased significantly from 4.2% (1998) to 1.3% (2011) (r^2=0.61, P<0.01). Therefore, the trend lines of North American and European athletes were increasing for both women and men; whereas those of other continents remained relatively flat (Figure 4). Table 1 shows the annual number of finishers originating from the ten countries with the total highest number of participants. Countries with the largest increase in participants were the USA, Canada, Germany, Great Britain, and Australia. The annual number of athletes originating from Germany and Great Britain considerably increased after 2009.

Table 1. *Annual number of finishers originating from the ten countries with the total highest number of participants*[2]

	RSA	JPN	AUS	BEL	FRA	GBR	GER	SWE	CAN	USA
					Women					
1998	10	3				1	2		6	228
1999	16	3					1		10	217
2000	13	4					10	1	26	224
2001	15	3			1		1	1	32	244
2002	7	1					2		14	256
2003	9	1	3	1		2	1		17	328
2004	5	2	2				7		21	380
2005	9	3	3		1		10		24	368
2006	13	4	1			5	2		26	406
2007	24	1	1	2	2	1	5		43	470
2008	21	1	9			4	5		34	490
2009	26	2	11			12	6	9	52	635
2010	28	2	12			21	16	8	81	744
2011	17	6	13			32	36	7	69	840
	RSA	JPN	AUS	BEL	FRA	GBR	GER	SWE	CAN	USA
					Men					
1998	53	3	2	2	3	1	6		48	1126
1999	64	10		3	4	6	11	1	43	1109
2000	79	9	3	3	4	5	44		45	1193
2001	61	6	2	2	3	8	8		49	1180
2002	46	4	2	2	1	2	29		47	1143
2003	37	6	21	6	7	11	28		46	1416
2004	47	8	20	2	6	7	32		76	1487
2005	34	3	20	2	3	15	41	2	71	1578
2006	48	1	11	5	7	26	33	3	83	1725
2007	67	6	16	25	8	23	44	6	116	1934
2008	68	3	38	5	7	43	40	5	95	2002
2009	75	6	49	4	7	80	53	17	143	2454
2010	89	12	59	8	6	171	141	26	158	3100
2011	54	49	72	16	16	202	263	27	160	3278

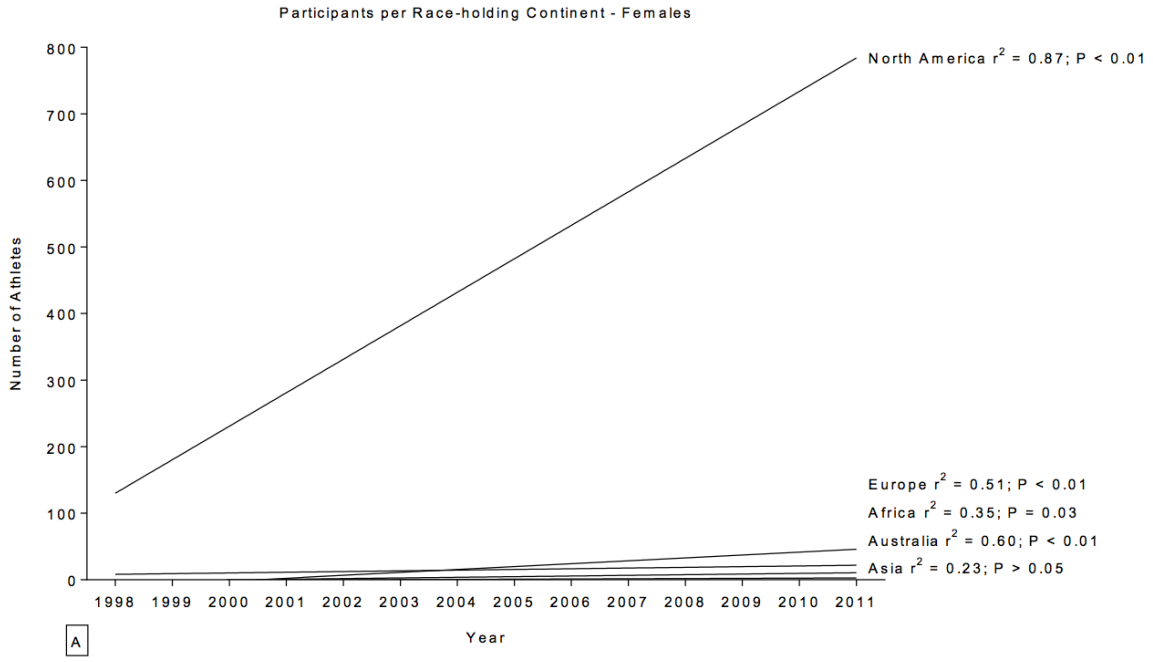
Abbreviations: South Africa (RSA), Japan (JPN), Australia (AUS), Belgium (BEL), France (FRA), Great Britain (GBR), Germany (GER), Sweden (SWE), Canada (CAN), United States of America (USA).

[2] Data were retrieved from 'Deutsche Ultramarathon Vereinigung'.

Participation in specific regions

161km races took place on all continents and in 21 different countries with an increasing number of races and participants. A total of 33,205 finishers (91.16%) participated in races held in North America and only 3,220 (8.8%) in other continents, namely in Europe with 1,760 (4.8%), in Africa with 1,039 (2.9%), in Australia with 342 (0.9%), in Asia with 70 (0.2%) and in South America with 9 (0.02%) finishers. Most runners participated in races held in the USA with 88.18% of the overall field. The annual number of finishers participating in 161km ultra-marathons held in the USA increased significantly (r^2=0.85, P<0.01) from 1,392 (1998) to 4,382 (2011). The annual number of finishers participating in 161km ultra-marathons held in Europe (r^2=0.54, P<0.01) and Australia (r^2=0.67, P<0.01) also increased significantly from 0 (1998) to 697 (2011) athletes in Europe and from 7 (1998) to 89 (2011) athletes in Australia, respectively. The years before 2008 were erratic with annual numbers between 0 and 88 (Europe), respectively 7 and 22 (Australia).

The share of finishers competing in races held in the USA decreased significantly from 92.1% (1998) of the total field to 80.7% (2011) (r^2=0.61, P<0.01). Also here in contrast, the share of finishers competing in European races increased significantly from 0% (1998) to 12.8% (2011) (r^2=0.64, P<0.01) with most finishers competing in Germany and in Great Britain. In Africa, the number of finishers between 1998 and 2011 was swinging between 38 and 121 runners per year, whereas in Asia literally no race was held until the year 2011, during which 68 athletes finished successfully a race. Among them were 20 athletes competing in a race held in Japan. In South America, the number of finishers was too small to draw any conclusion from. The share of all European finishers who participated in races held in the USA decreased significantly from 100% (1998) to 10% (2011) (P<0.01). Figure 5 shows the trend of the annual number of finishers competing in races held on different continents. The trend lines of athletes participating in races held in North America and Europe were increasing for both women and men, whereas those of other continents remained relatively flat. Figure 6 shows the distribution of finishers from a specific continent, who participated in races held on a specific continent. There, it is obvious that all finishers from a specific continent predominantly competed in their home continent. Only 126 out of 1,760 participants competing in races held in Europe were North American athletes. On the other hand, only 664 out of 33,205 participants competing in races held in North America were European athletes.



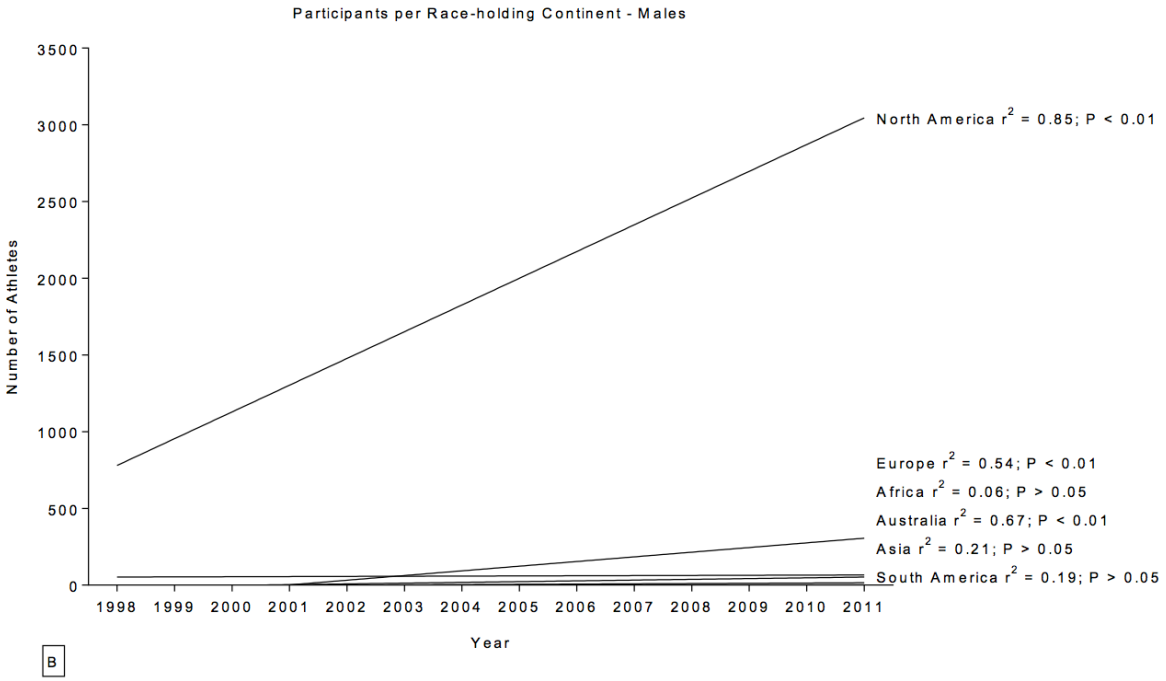
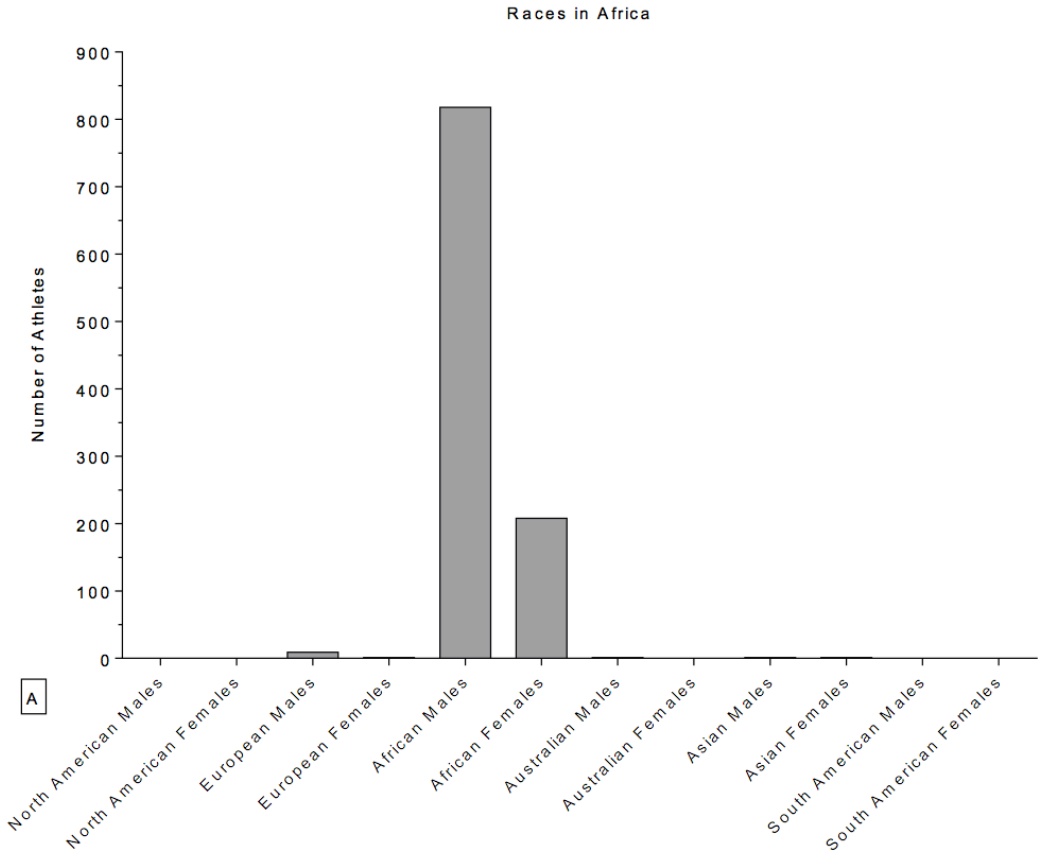
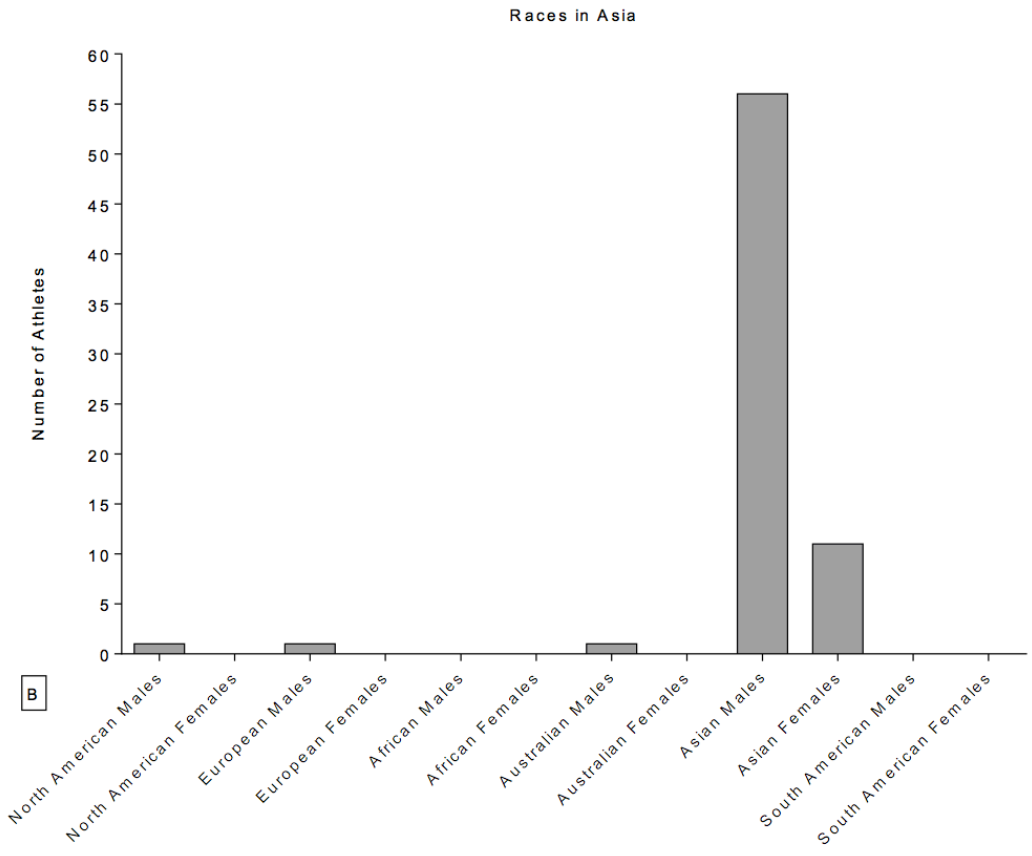
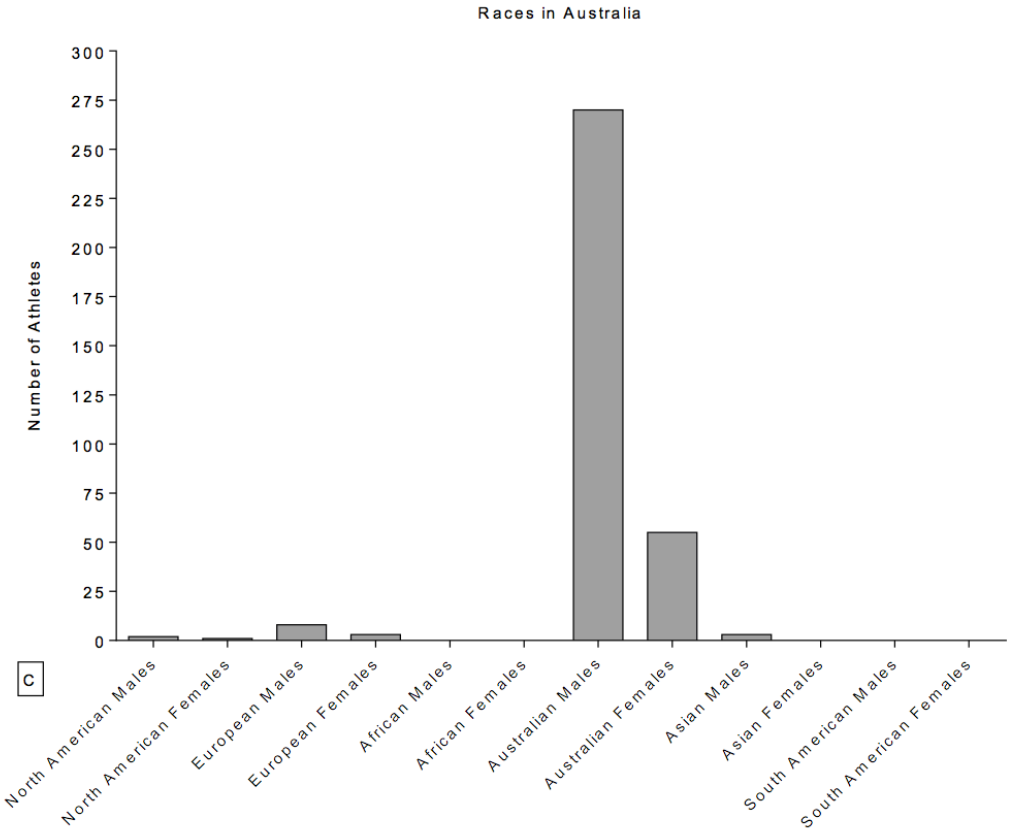
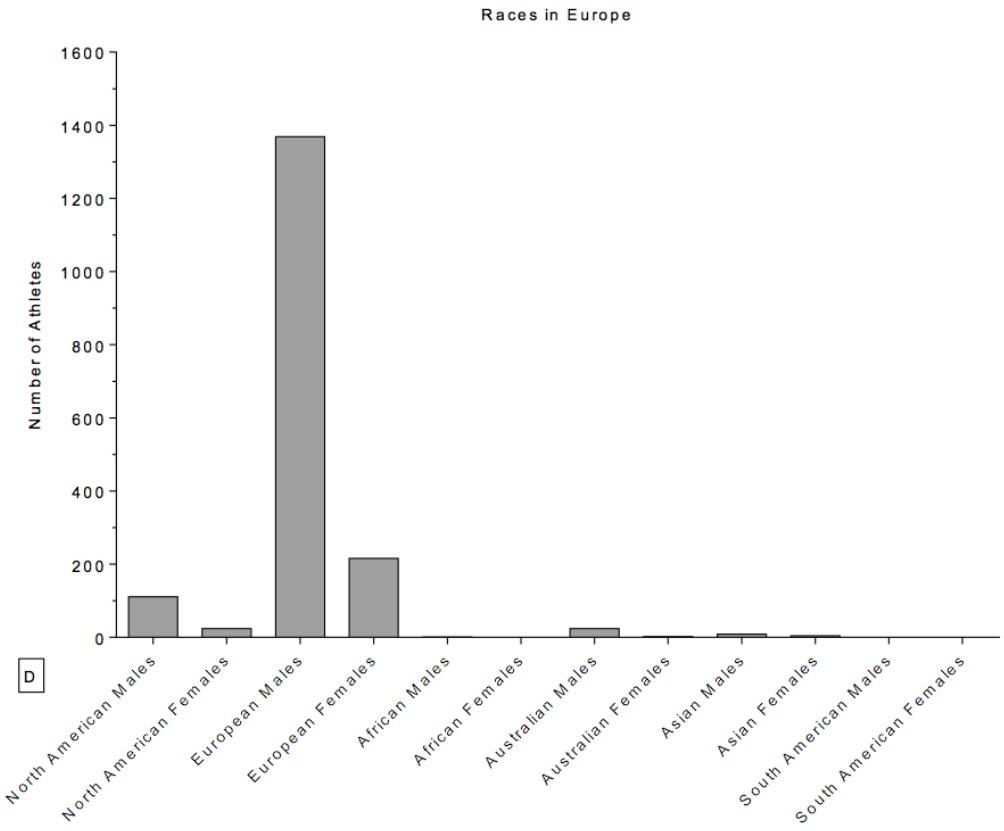


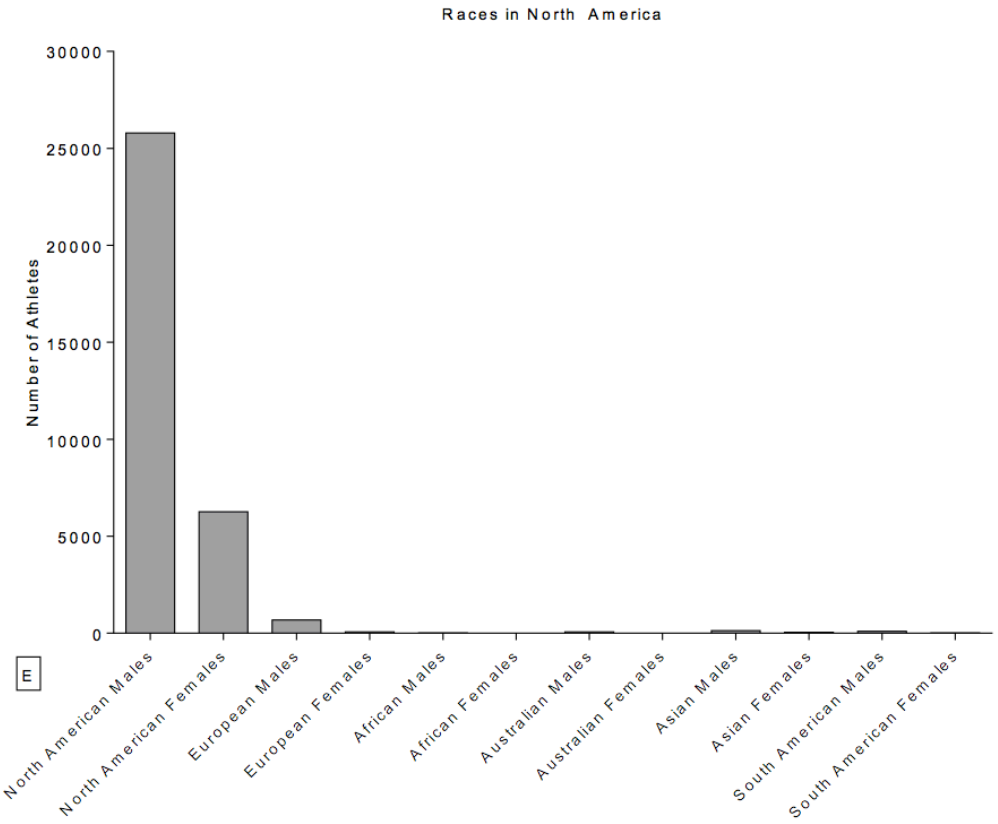
Figure 5. *Change in the annual number of athletes competing in races held on different continents for women (Panel A) and men (Panel B)*




Races in Asia
Number of Athletes
60
55
50
45
40
35
30
25
20
15
10
5
0
B
North American Males
North American Females
European Males
European Females
African Males
African Females
Australian Males
Australian Females
Asian Males
Asian Females
South American Males
South American Females


Races in Australia
Number of Athletes
300
275
250
225
200
175
150
125
100
75
50
25
0
C
North American Males
North American Females
European Males
European Females
African Males
African Females
Australian Males
Australian Females
Asian Males
Asian Females
South American Males
South American Females





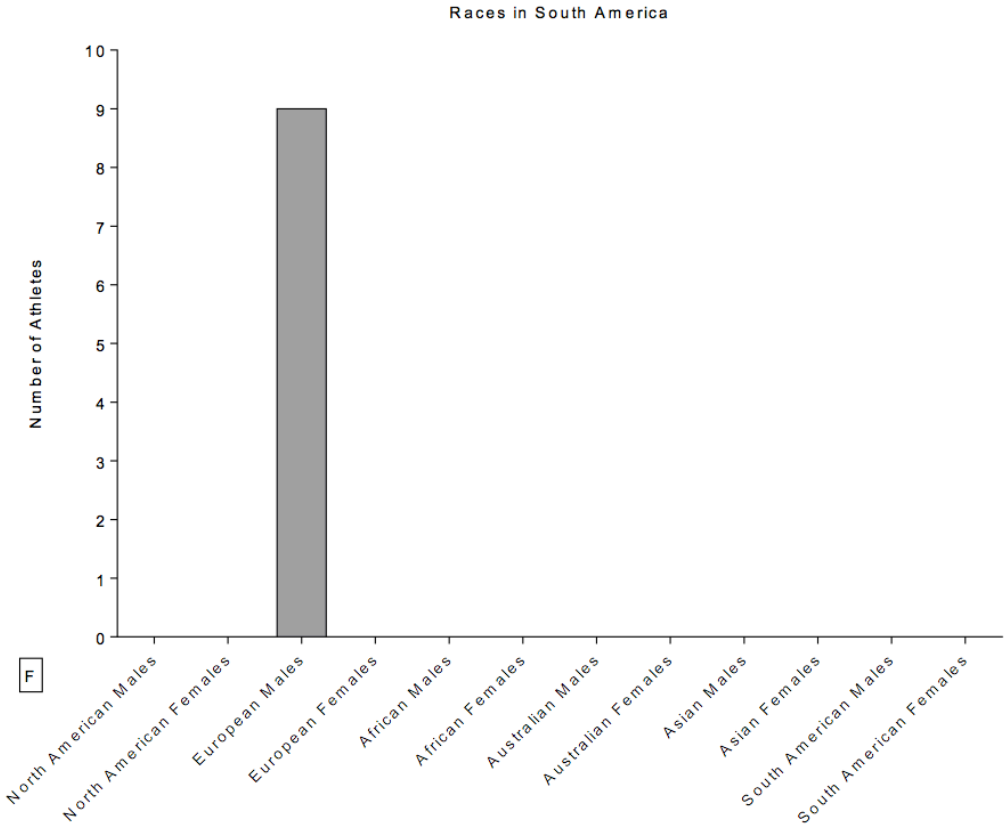


Figure 6. *Home continent of athletes participating in a specific continent*

Correlation between income, population and participation

Correlation analyses were performed to investigate potential associations between a change in the annual number of participants and a change in the general population and income per capita of the ten countries with the total highest number of participants. The annual number of participants increased significantly for all countries except for South Africa, Japan and Belgium (Table 2). The general population increased significantly for all countries except for Japanese and German men. Income per person increased significantly for all countries. The correlation between participants and population was significant for the USA, Canada, Great Britain, Australia and Sweden and the correlation between participants and income per person was significant for the USA, Canada and Australia for both women and men (Table 3).

Table 2. *Change of finishers, population and income of the ten countries with the total highest number of finishers*[3]

	Finishers Men				Population (in 1000) Men				Finishers Women				Population (in 1000) Women				Income per Person (in US$) Men & Women			
		2011	r^2	*P*	1998	2011	r^2	*P*	1998	2011	r^2	*P*	1998	2011	r^2	*P*	1998	2011	r^2	*P*
RSA	53	54	0.06	0.3993	20580	24533	0.98	< 0.0001	10	17	0.38	0.0195	21320	26054	0.99	< 0.0001	3290	6950	0.83	< 0.0001
JPN	3	49	0.19	0.1212	61890	62238	0.19	0.1201	3	6	0.00	0.8974	64520	65580	0.77	< 0.0001	33510	45130	0.76	< 0.0001
AUS	2	72	0.80	< 0.0001	9292	11112	0.99	< 0.0001	0	13	0.73	0.0001	9419	11211	0.99	< 0.0001	21810	50150	0.89	< 0.0001
BEL	2	16	0.28	0.0530	4989	5418	0.95	< 0.0001	0	0	0.01	0.7052	5214	5630	0.95	< 0.0001	26030	45680	0.88	< 0.0001
FRA	3	16	0.51	0.0043	29150	31622	1.00	< 0.0001	0	0	0.00	0.8381	31035	33749	0.99	< 0.0001	25110	42690	0.87	< 0.0001
GBR	1	202	0.61	0.0009	28458	30883	0.98	< 0.0001	1	32	0.55	0.0023	30029	31870	0.97	< 0.0001	23900	38450	0.74	< 0.0001
GER	6	263	0.49	0.0054	39983	40100	0.02	0.5923	2	36	0.37	0.0201	42064	41698	0.57	0.0019	27060	44560	0.86	< 0.0001
SWE	0	27	0.65	0.0005	4374	4707	0.94	< 0.0001	0	7	0.44	0.0094	4477	4742	0.93	< 0.0001	29520	53160	0.88	< 0.0001
CAN	48	160	0.85	< 0.0001	14972	17107	1.00	< 0.0001	6	69	0.72	0.0001	15276	17377	1.00	< 0.0001	20310	46730	0.94	< 0.0001
USA	1126	3278	0.84	< 0.0001	135230	153240	1.00	< 0.0001	228	840	0.88	< 0.0001	140624	158348	1.00	< 0.0001	32150	50650	0.93	< 0.0001

Abbreviations: South Africa (RSA), Japan (JPN), Australia (AUS), Belgium (BEL), France (FRA), Great Britain (GBR), Germany (GER), Sweden (SWE), Canada (CAN), United States of America (USA).

Table 3. *Correlation between income per person, population and participation for the ten countries with the total highest number of participants*[4]

	Finishers / Population Men		Finishers / Population Women		Finishers / Income Men		Finishers / Income Women	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
RSA	0.195	0.50	0.568	<0.05	0.309	0.28	0.676	<0.01
JPN	-0.014	0.96	-0.118	0.69	0.657	<0.05	0.434	0.12
AUS	0.919	<0.01	0.885	<0.01	0.906	<0.01	0.893	<0.01
BEL	0.544	<0.05	0.043	0.89	0.518	0.06	0.09	0.76
FRA	0.704	<0.01	0.09	0.76	0.668	<0.01	0.088	0.77
GBR	0.844	<0.01	0.829	<0.01	0.417	0.14	0.363	0.20
GER	-0.229	0.43	-0.683	<0.01	0.63	<0.05	0.573	<0.05
SWE	0.912	<0.01	0.784	<0.01	0.731	<0.01	0.546	<0.05
CAN	0.942	<0.01	0.87	<0.01	0.922	<0.01	0.814	<0.01
USA	0.91	<0.01	0.935	<0.01	0.806	<0.01	0.836	<0.01

Abbreviations: South Africa (RSA), Japan (JPN), Australia (AUS), Belgium (BEL), France (FRA), Great Britain (GBR), Germany (GER), Sweden (SWE), Canada (CAN), United States of America (USA).

[3] Data were retrieved from 'The Worldbank'.

[4] Data were retrieved from 'The Worldbank'.

Table 4. *Annual numbers of the ten fastest athletes of 161km ultra-marathons with at least ten finishers, sorted by nationality*[5]

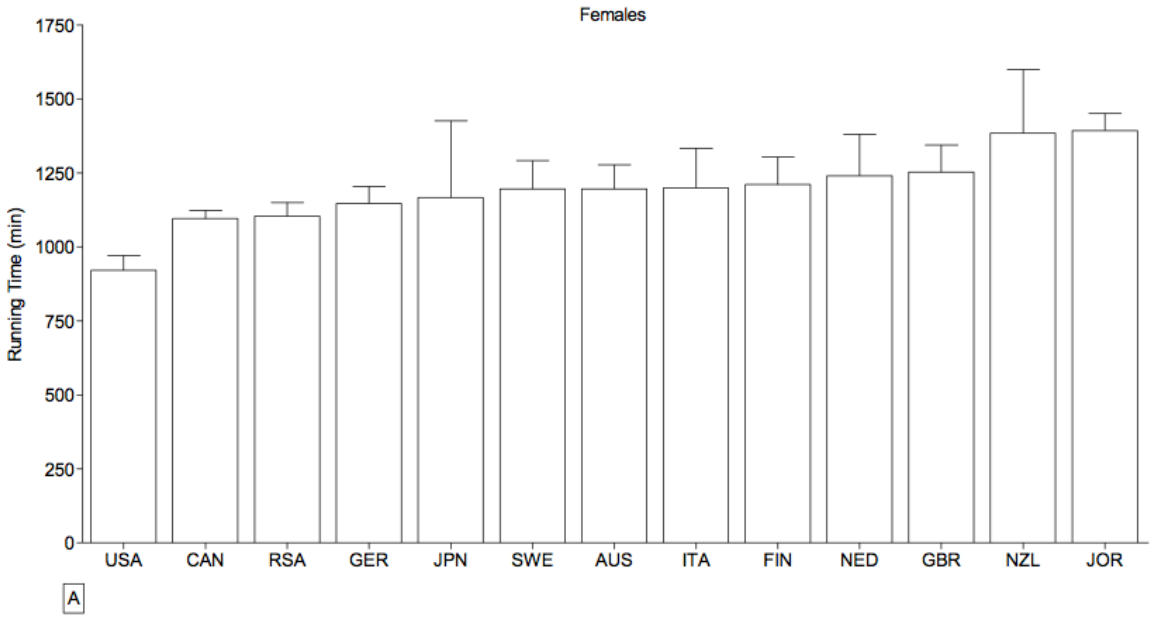
	NA		EU																													AU		AF	AS												SA				
Year	USA	CAN	GER	GBR	FRA	BEL	POL	SUI	CZE	ITA	SVK	FIN	POR	AUT	SWE	DEN	HUN	IRL	NOR	ESP	NED	ROU	GRE	EST								AUS	NZL	RSA	JPN	RUS	JOR	KOR	IND	SRI	CHN	TPE					MEX	BOL	BRA	ARG	JAM
1998	142	12	3			2																										1		20																	
1999	163	9	2	1		1	1	1																										20	2																
2000	168	14	12	2		2	1		4	1	1																					2		20	1	1											1				
2001	166	22	1	2	1	1				2		1	1																					19	2												2				
2002	161	26	11			1																												20													1				
2003	222	20	3	5		2		1		11				1																				10		20	1												4				
2004	237	38	13	3	2					1																								11		20	1		1										3				
2005	256	33	8	3	1										1																			2		20	1	1											4				
2006	283	30	2	5												1		1		1														9		20		1	1	2									3				
2007	286	41	17	12	1	7		1		1					4		3			1															1	29	2												3	1			
2008	358	33	15	20	3	3		4		2									1		1	7												21		29												2		1		
2009	414	58	25	32	2	1		1		2				2	9	6	4	4	2		1	1												20		39	1		1		2	1					2				
2010	556	69	58	55	1	4		1		1	1	4			8	10	2		4	1	7		1											23	8	29	3											2			1	1
2011	590	41	80	57	6	9				10		6		4	5	7		6	7	1	6			1										20	1	19	19	11					2	5				2		4	1	

Abbreviations: North America (NA), Europe (EU), Australia (AU), Africa (AF), Asia (AS), South America (SA), United States of America (USA), Canada (CAN), Germany (GER), Great Britain (GBR), France (FRA), Belgium (BEL), Poland (POL), Switzerland (SUI), Czech Republic (CZE), Italy (ITA), Slovakia (SVK), Finland (FIN), Portugal (POR), Austria (AUT), Sweden (SWE), Denmark (DEN), Hungary (HUN), Ireland (IRL), Norway (NOR), Spain (ESP), Netherlands (NED), Romania (ROU), Greece (GRE), Estonia (EST), Australia (AUS), New Zealand (NZL), South Africa (RSA), Japan (JPN), Russia (RUS), Jordan (JOR), South Korea (KOR), India (IND), Sri Lanka (SRI), China (CHN), Taiwan (TPE), Mexico (MEX), Bolivia (BOL), Brazil (BRA), Argentina (ARG), Jamaica (JAM).

[5] Data were retrieved from 'Deutsche Ultramarathon Vereinigung'.

Nationalities and performances

Considering the overall number of the ten fastest athletes of 161km ultra-marathons from 1998 to 2011, runners originating from North America were the most numerous with 4,448 (78%) athletes in the overall top ten (Table 4). Among them were 4,002 US-American athletes (70%). In the second place were European athletes with 679 (12%) runners of which 250 (4%) originated from Germany and 197 (3%) from Great Britain. Only 324 (6%) African runners, 129 (2%) Australian runners, 62 (1%) Asian runners and 39 (1%) South American runners were in the overall top ten so far. The number of finishers in the annual top ten increased significantly for US-American (r^2=0.85, P<0.01) and European athletes (r^2=0.63, P<0.01). The number of European athletes in the annual top ten increased from 56 (1998) to 250 (2011). However, the share of US-American athletes in the annual top ten decreased significantly from 76% (1998) to 52% (2011), while the share of European athletes increased significantly from 1% (1998) to 18% (2011). The share of German athletes in the annual top ten increased from 1% (1998) to 7% (2011) and the share of British athletes from 1% (1998) to 5% (2011). Race times of the ten fastest European athletes decreased from 1,480.8±272 min (1998) to 1,060.7±60 min (2011) for women and from 1,328.0±169 min to 903.8±53 min for men. Race times of the ten fastest US-American athletes decreased from 1,147.5±62.3 min (1998) to 1,054.8±66.9 min (2011) for women and from 961.8±39.0 min to 836.9±23.9 min for men, respectively. European athletes therefore improved their performance by 28.4% for women and by 31.9% for men as opposed to US-American athletes, who improved their performance by 8.1% for women and by 13.0% for men. Figure 7 gives an overview of race times of the overall top ten female and male athletes per country, sorted by time. US-American and Canadian athletes in the overall top ten were among the fastest runners for both women and men. Hence, runners from North America in the overall top ten were faster compared to runners from Europe and Australia.



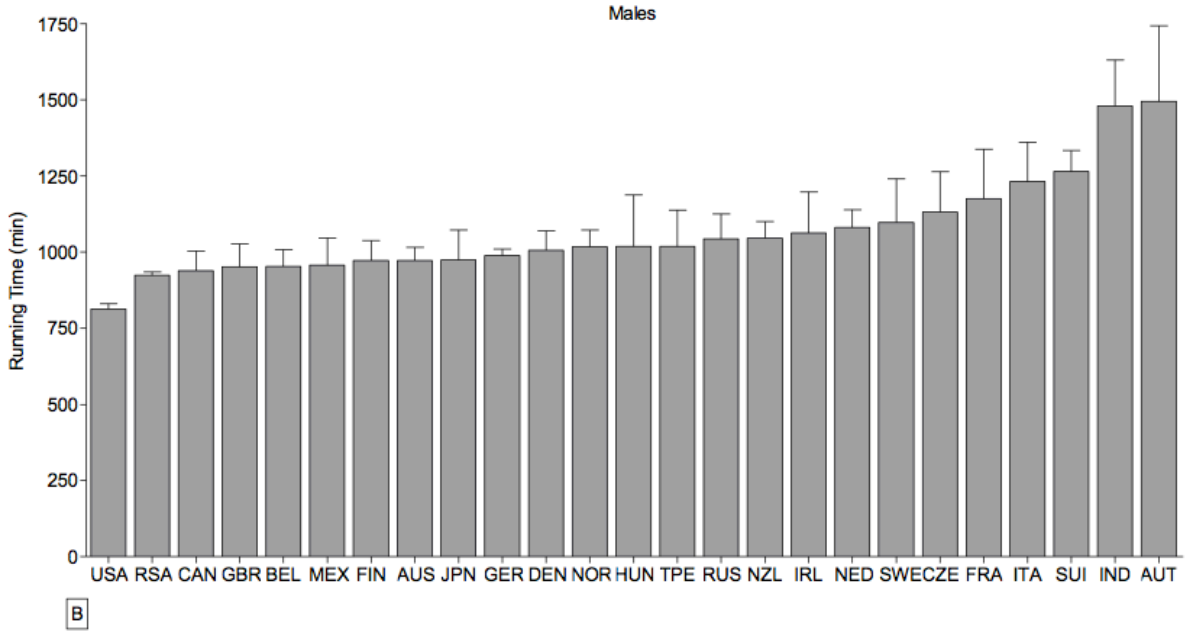


Figure 7. *Running times of the overall top ten women (Panel A) and men (Panel B) per country, sorted by time*

DISCUSSION

This study intended to analyse participation and performance trends in terms of nationality and therefore to identify from which regions 161km ultra-marathoners originated and in which regions they were competing. Furthermore, we analysed the performance of 161km ultra-marathoners of the different nationalities. The main findings were that (i) the annual number of participants in 161km ultra-marathons increased exponentially, (ii) US-American athletes dominated in terms of annual number and performance but (iii) European athletes more and more outstripped American competitors in annual number of participants and performance. Furthermore, (iv) athletes from Europe increasingly participated in races held in Europe, whereas in the past they predominantly participated in races held in the USA.

Increasing number of participants

A first main finding was that the annual number of finishers increased exponentially. This was not surprising since several studies showed an exponential increase in the annual number of participants in 161km ultra-marathons held in the USA (Hoffman, 2010; Hoffman et al., 2010b; Hoffman and Wegelin, 2009). Also other ultra-marathons such as 100km ultra-marathons (Cejka et al., 2013), multistage ultra-marathons (Shoak et al., 2013a), and 12-hour ultra-marathons (Sehovic et al., 2013) showed a significant increase in the annual number of participants as well as other ultra-endurance disciplines such as Ironman (Lepers, 2008) or ultra-triathlon (Knechtle et al., 2011).

According to our data, the growth in the annual number of finishers in 161km ultra-marathons was mainly ascribed to competitors originating from North America with 88.4% and to Europe with 6.5% of the overall total field. Beside US-American athletes, most of the participants originated from Canada, South Africa, Germany and Great Britain. Assessing the increase in the annual number of participants originating from

the ten countries with the total highest number of finishers, we showed that the annual number of participants from the USA, Germany, Great Britain, Canada, Australia, and Sweden increased significantly for both women and men. The annual numbers in women showed a significant increase for South Africa, whereas the annual numbers in men showed a significant increase for France. Japan and Belgium showed no relevant change in the annual number of participants over the years until 2011, where the number of Japanese participants increased from 14 (2010) to 55 (2011) and the number of Belgian participants increased from 8 (2010) to 16 (2011). This indicated that the participation trend of 161km ultra-marathons was mainly set by athletes originating from North America and Europe, more precisely by athletes from the USA, Canada, Germany and Great Britain.

In order to assess potential associations between the changes in the annual number of finishers of the ten countries with the highest number of finishers, we performed correlation analysis between the annual number of finishers, the general population and income per capita. For Germany, Great Britain and South Africa, income was not correlated to the annual number of finishers as opposed to the USA, Canada and Australia, except for South African women and French men. Nonetheless, Germany and Great Britain are countries which were considered to have high incomes relative to the rest of the world (http://data.worldbank.org). Since participants in 161km ultra-marathons were middle-aged, married and well educated men (Hoffman and Fogard, 2012), the higher income could provide access to a certain lifestyle, which implies more attention to personal needs e.g. avocations (Sehovic et al., 2013). Furthermore, the USA and Europe are likely to be more able to meet the expenses needed for these races than those living in other countries (Shoak et al., 2013a).

For the USA, Canada, Great Britain and Australia, the increase in population significantly correlated with the increase in the annual number of participants. The general population in Germany did not increase since 1998 as opposed to the annual number of participants originating from Germany, which considerably increased after 2008. Therefore, it is not surprising that no correlation between Germany's population and the annual number of participants originating from Germany was found. Also for Great Britain, with the second highest annual number of participants in Europe, the increase in participants mainly occurred after 2008. Hence, the increase in the annual number of participants can only be explained by the increase in the general population for participants originating from the USA, Canada and Australia.

Other characteristics such as sporting ambitions (i.e. opting for the supreme test) could be a motive to participate in an ultra-marathon (Hoffman et al., 2010b). Furthermore, participating in such a race can lead to a meditational experience, since most of the 161km ultra-marathons were trail races (Hoffman et al., 2010b). A change in social values and striving for self-fulfilment could explain this kind of intrinsic motivation. Aspects in this favour are (i) the plateaued level of competition and race time which were observed between 1977 and 2008 (Hoffman, 2010), (ii) the higher finish rate compared to road- or track-races, which may amongst other factors be explained by trails being less boring (Hoffman et al., 2010b) and (iii) the increasing number of participants whose goal is to finish rather than compete (Hoffman, 2010). Furthermore, (iv) the lack of monetary awards may also speak for a rather intrinsic motivation in participating and competing than an extrinsic one (Hoffman, 2010).

161km ultra-marathons were becoming more popular in Europe

A second main finding was that although runners from the USA outnumbered athletes of other nationalities with 84% of all finishers, runners from Europe increased their share of the total field from 1.6% (1998) to 14.5% (2011), while the share of finishers originating from the USA decreased from 89.6% (1998) to 75.9% (2011). Since the share of South African finishers decreased from 4.2% (1998) to 1.3% (2011) and

Australia, Asia and South America could only provide a minor number of finishers, runners originating from the USA, Canada, Germany and Great Britain were mainly responsible for the increase in the annual number of participants over the years.

A third main finding was that the share of all finishers participating in Europe increased from 0% (1998) to 12.8% (2011), while the share of all finishers participating in the USA decreased from 92.1% (1998) to 80.7% (2011). It is striking hereby that US-American athletes rarely participated in other countries than the USA. US-American athletes even rarely crossed the border to Canada. Given the situation that US-American athletes competed in races held in another continent than North America, they competed primarily in races held in Europe. However, between 1998 and 2011, only 126 US athletes competed in races held in Europe, which relates to 0.4% of all US-American athletes, whereas on the other hand 664 European athletes (i.e. 238 from Germany and 143 from Great Britain) competed in races held in the USA, which relates to 28.1% of all European athletes. European athletes were the largest group of foreigners in the USA but with a rather small proportion of 2.1% of all participants finishing a race there. Nonetheless, the share of all European athletes finishing a race held in the USA decreased from 100% (1998) to ~10% (2011). However, also European athletes rarely participated in races held in other countries than the USA. As for the decreased share of US-American athletes, one could not assume that the popularity in the USA peaked off since the number of US-American athletes increased exponentially. It is more plausible that 161km ultra-marathons were becoming more popular in Europe, especially in Germany and Great Britain and therefore European athletes expanded their share of the overall field at the expense of US-American athletes. In fact, the annual number of European athletes and the annual number of athletes participating in races held in Europe increased considerably after 2008. From 2008 to 2011, the number of races held in Europe more than tripled.

The increase of the share of European athletes, the increase in the annual number of athletes which participated in races held in Europe and the decrease of the share of all European athletes finishing a race held in the USA clearly demonstrated how Europe was influenced by the USA, and hence was developing its own 161km ultra-marathon running scene. This is not surprising since Europe is known for its flair for ultra-endurance events as they were leading in terms of participation in ultra-endurance disciplines such as 100km ultra-marathons (Cejka et al., 2013), multistage ultra-marathons (Shoak et al., 2013a) and in terms of participation and performance in 12-hour ultra-marathons (Sehovic et al., 2013), in 6-hour ultra-marathons (Ehrensperger et al., 2013) as well as in ultra-triathlons (Lepers et al., 2012). Furthermore, it is desirable to stay in the home country when deciding to participate in the first 161km ultra-marathon: “There is nothing worse than training for a race that is a few thousand miles from home, then showing up and laying an egg. Your 100 miler career will be over in a jiffy.” And “Look around your typical training areas. Look at the areas you think you’ll be able to train. Now choose a 100 course the most closely resembles what you have available to you. You’ll be thankful for it in the end.” (Sherpa John, http://trailandultrarunning.com/choosing-your-first-100-miler/).

Participants from other countries

As for the other countries, participants mainly dominated in terms of numbers in countries from which they origin. This is an interesting finding since Japanese athletes were dominating in terms of participation, and Japanese women in terms of participation and performance in the ‘Spartathlon’, an ultra-marathon held in Europe over a distance of 246 km (Knechtle et al., 2013). Furthermore, Japanese athletes were dominating in terms of performance in 100km ultra-marathons worldwide (Cejka et al., 2013). However, in 161km ultra-marathons, only 162 finisher originated from Japan although the annual number of finishers from Japan increased from 14 (2010) to 55 (2011). Like in other ultra-endurance events, there were almost no athletes

from other African countries than South Africa. Presumably because some African athletes "..see athletics as a means of making money to help their families, parents and siblings." (Onywera et al., 2006). Winners of one of the five largest 161km ultra-marathons such as the 'Leadville Trail 100 Mile' (http://www.leadvilleraceseries.com), the 'Western States Endurance Run' (http://www.wser.org), the 'Vermont 100 Mile Endurance Race' (http://www.vermont100.com), the 'Rocky Raccoon 100 Mile Trail Runs' (http://www.tejastrails.com/Rocky.html) or the 'Wasatch Front 100 Mile' (http://www.wasatch100.com) were awarded with an engraved trophy.

Performance trends

According to our hypothesis that US-American athletes would dominate in terms of performance but with European athletes catching up, we focused our attention on runners originating from the USA and Europe. We therefore analysed the change in the number of US-American and European athletes in the annual top ten rankings worldwide from 1998 to 2011. Furthermore, we compared the change in race times of the ten fastest athletes originating from the USA and Europe in 1998 and 2011.

The number of finishers ranking in the annual top ten increased significantly for both US-American and European athletes. From all athletes ranked in the annual top ten, the share of US-American athletes decreased from 79% (1998) to 64% (2011). In contrast, the share of European athletes increased from 3% (1998) to 22% (2011). Also here, German and British athletes were mainly those responsible for this increase. European athletes were dominating in European races by holding 90.9% of the overall top ten rankings between 1998 and 2011, whereas US-American athletes were dominating races held in the USA with 93.4%.

A paper closely related to ours showed that from 1998 to 2011, 161km ultra-marathoners improved their performance in the annual top ten worldwide by 13.7% for women and by 14.5% for men (Rüst et al., 2013). Adapted from the same data we could show that European athletes improved their performance by even 28.4% for women and by 31.9% for men. US-American women only improved their performance by 8.1% and US-American men by 13.0%. This finding has to be treated with caution since races may be substantially distinct. For example, participants in the 'Yukon Arctic Ultra 161km' have to run in extreme cold temperatures and the trail is difficult to find within the snow-covered landscape (http://www.arcticultra.de). Hence, athletes there were slower than in other 161km ultra-marathons. Furthermore, some athletes might prefer to run only in specific events. For example, the 'Western States Endurance Run' accounted for ~20% of all 161km ultra-marathon finishes in the USA from 1977 to 2008 (Hoffman, 2010). In order to see how the annual top ten rankings changed among US-American and European athletes within a particular race, the 'Western States Endurance Run' would be the most appropriate event to do so. Derived from out data, this race attracted most of the European athletes in relation to all participating runners. Secondly, it was almost constantly held since 1974 and was one of the biggest races in terms of participation. Because of its qualifying standards it is assumed to provide a competitive environment (http://www.wser.org). There, European athletes increased from almost none top ten rankings by 2009 to four top ten rankings in 2011. US-American athletes used to be with nine to ten athletes in the top ten rankings by 2009, but since then, they diminished to only five athletes in the top ten (http://statistik.d-u-v.org/geteventlist.php).

Although European athletes considerably improved their performance, US-American athletes achieved faster race times in 2011 compared to European athletes for both women and men. Furthermore, US-American athletes were still holding the majority in the number of the annual top ten rankings in 2011. Hence, US-American athletes were dominating 161km ultra-marathons in terms of performance.

Strength, weakness, limitations and implications for future studies

A strength is the large data set, but data from DUV become updated regularly and therefore may lead to other conclusions when gathered on a later date. Smaller races might not have been considered. In this study we used information concerning nationality and race time. In addition to this, the name of the runners should also be implicated to find the participation rate of each individual and the countries each individual runs in. Furthermore, future studies should investigate whether there are significant differences in age and sex between US-American and European athletes since our data suggest that the mean age of US-American athletes is 43.8 years, while those of European athletes is 46.2 years and while the share of women remained unchanged since 2004 with around 20% of the total field, the share of European women was only around 12% in 2011. Beside age (Rüst et al., 2013; Zingg et al., 2013) and gender (Capranica et al., 2013; Wegelin and Hoffman, 2011), other factors such as body composition (Hoffman, 2008a; Hoffman et al., 2010a; Hoffman and Fogard, 2011; Rüst et al., 2012), training (Hoffman and Fogard, 2011; Rüst et al., 2012) or environmental influences (Parise and Hoffman, 2011; Wegelin and Hoffman, 2011) may explain performance differences between European athletes and US-American athletes.

CONCLUSIONS

To summarise, participation in 161km ultra-marathons increased exponentially between 1998 and 2011. Most of the participants originated from the USA and participated in races held in the USA. The share of athletes originating from Europe increased, while those of US-American athletes decreased. European athletes improved their performance to a higher extent than US-American athletes, although US-American athletes still dominate in terms of performance. European athletes increasingly participated in races held in Europe, whereas in the past, they predominantly participated in races held in the USA.

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