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ORIGINAL RESEARCH

Age of peak performance in 50-km ultramarathoners – is it older than in marathoners?

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Purpose: Despite the increasing popularity of 50-km ultramarathons during the last few years, only limited information is available regarding the trends in its performance and participation. The aim of the present study was to examine the age of peak running performance in female and male 50-km ultramarathoners using second-order nonlinear regression analyses.
Methods: Data from 494,414 runners (124,045 women and 370,369 men) who finished a 50-km ultramarathon between 1975 to 2016 were analyzed.
Results: When the top ten finishers in 1-year age-groups were analyzed, the age of peak running speed was 41 years in both women and men. When the fastest finishers in 1-year age-group intervals were analyzed, the age of peak running speed was 40 years in women and 39 years in men.
Conclusion: In summary, the age of peak running speed in 50-km ultramarathoners is older than what has been reported by previous studies for marathons. Women seem to achieve the best race time in a 50-km ultramarathon later in life compared with men. These findings are of great practical value for coaches and fitness trainers when setting performance goals for 50-km ultramarathon runners.
Keywords: master athlete, running, sex difference, ultra-endurance, aerobic capacity, aging, cardiorespiratory fitness

Introduction

In competitive sports, each sports discipline seems to have its specific age of peak performance depending on the duration of the event.[1] For example, in long-distance running, the age of peak ultramarathon performance seems to increase with increasing race duration.[2]

In long-distance running, such as marathon and ultramarathon running, the age of peak performance has been well investigated. Recent studies demonstrated that the relationship between age and running time was U-shaped. In marathon running, the age of the fastest race time ranges between 25 and 35 years, depending on the analysis (age-group intervals) and the nationality and performance level of the runners.[3–5] Whereas, in ultramarathon running, the age of the fastest athletes seems to be higher than in marathon running and has been investigated for 100-km running,[6] for 100-mile (161-km) running,[7] and running races held in hours and days.[2] It appears that the running performance in these ultramarathon events peaks above the age of 35 years.[2,6–8]

To the best of our knowledge, there is no information for the age of peak performance for the shortest ultramarathon race, such as the 50-km race distance, in men and women. Since many hundreds of thousands of runners participate in 50-km ultramarathons (http://statistik.d-u-v.org/index.php), such knowledge would be of great

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practical value for runners competing in this distance and for their coaches. Being aware of the age of peak performance can help coaches for planning and optimizing the preparation of their runners.

Therefore, the aim of the present study was to investigate the age of peak performance in female and male 50-km ultramarathoners. Since the distance of 50 km is very close to the marathon distance of 42.195 km, we hypothesized that the age of peak performance in a 50-km ultramarathon would be ~25–35 years and therefore younger than in a 100-km[6] and a 100-mile[7] ultramarathon due to the fact that the age of peak ultramarathon performance increases with increasing race duration.[2] Furthermore, a secondary aim was to examine the variation in the trends of performance and participation across calendar years in 50-km ultramarathons.

Materials and methods

Ethical approval

The Institutional Review Board of Kanton St. Gallen, Switzerland, approved all procedures used in this study with a waiver of the requirement for informed consent from the participants, given the fact that the study involved the analysis of publicly available data. This study was conducted in accordance with recognized ethical standards according to the Declaration of Helsinki adopted in 1964 and revised in 2013.

Methodology

All runners who finished a 50-km ultramarathon held worldwide were considered. All data were obtained from the website of Deutsche Ultramarathon Vereinigung, where all ultramarathons are recorded under http://statistik.d-u-v.org/.

We identified 494,414 runners (ie, 124,045 women and 370,369 men) who finished a 50-km ultramarathon between 1975 and 2016 after we excluded duplicate cases (ie, where runners were recorded both in the open race and in the championship race such as a European or a World Championship) and athletes with extreme scores (ie, average running speed <2.5 km/h or >30 km/h).

Statistical analysis

The acceptable type I error was set at $p<0.05$. Data were presented as mean ± SD. The linear and nonlinear regression analyses were performed by using GraphPad Prism Version 7.0 (GraphPad Software, Inc., La Jolla, CA, USA); all other statistical analyses were carried out by using IBM SPSS Version 23.0 (IBM Corporation, Armonk, NY, USA). The men-to-women ratio was calculated for the whole sample and each age-group. We examined the association of sex and age-group, ie, whether the men-to-women ratio varied by age-groups, using χ^2 and Cramer's φ (φ_C) to evaluate the magnitude of association. In addition, the association of sex and calendar year was examined. We used two approaches to classify the participants into age-groups: 1) 5-year groups from <20 to >84 years and 2) 1-year groups from 15 to 80 years. Furthermore, in each approach, we examined all runners, the top ten, and the single top finisher. A two-way analysis of variance (ANOVA) examined the main effects of sex, age-group, calendar year, and the sex × age-group and sex × calendar year interactions on race speed, followed by a Bonferroni post hoc analysis. The magnitude of differences in the ANOVA was evaluated by using partial η^2 as trivial ($\eta^2<0.01$), small ($0.01\le\eta^2<0.06$), moderate ($0.06\le\eta^2<0.14$), and large ($\eta^2\ge0.14$).[12] The abovementioned ANOVA was run twice, one considering all finishers and one considering only the top ten runners. The age with the fastest race time considering age-groups in 1-year and 5-year age intervals was calculated using a nonlinear regression model with a second-order (quadratic) polynomial function ($y=ax^2+bx+c$) that fitted the data. The vertex of the quadratic function was calculated as $p(x|y) = (-\frac{b}{2a} \mid C - \frac{b^2}{4a})$. We determined the age with the fastest speed both for the fastest women and men and for all women and men in 1-year and 5-year age intervals.

Results

Participation trends

For both women (Table 1) and men (Table 2), participation increased in all age-groups across calendar years.

Sex difference in running speed

For all finishers, we found a small main effect of sex on running speed ($p<0.001$, $\eta^2=0.011$), where men were faster by +7.5% than women (8.35±2.26 km/h vs 7.77±1.91 km/h, respectively). For the top ten finishers, we found a medium main effect of sex on running speed ($p<0.001$, $\eta^2=0.116$), where men were faster by +16.6% than women (14.29±2.82 km/h vs 12.25±2.89 km/h, respectively). That is, the magnitude of the sex difference was larger when the top ten finishers were considered rather than all finishers.

Performance trends across years

Considering the trend in running speed across calendar years, we found in 50 km a small main effect of calendar year on running speed ($p<0.001$, $\eta^2=0.053$), with the slowest running speed in 2016 and the fastest in 1975 (Figure 1). Running

Table 1 Finishers by age-group and calendar year in women

Year	Age (years)															Total
	<20	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	>84	
1977	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2
1978	0	1	0	0	3	2	0	0	0	0	0	0	0	0	0	6
1979	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	3
1980	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0	6
1981	0	0	1	5	1	1	2	0	0	0	0	0	0	0	0	10
1982	1	1	0	3	0	3	3	0	0	0	0	0	0	0	0	11
1983	1	1	0	3	3	0	4	0	0	0	0	0	0	0	0	12
1984	0	0	3	3	2	1	3	0	0	0	0	0	0	0	0	12
1985	0	0	2	1	2	2	4	0	0	0	0	0	0	0	0	11
1986	0	0	0	0	2	1	2	2	1	0	0	0	0	0	0	8
1987	0	0	0	1	2	2	1	2	0	0	0	0	0	0	0	8
1988	0	2	2	3	9	4	2	3	1	0	0	0	0	0	0	26
1989	0	2	3	8	15	11	11	2	4	2	0	0	0	0	0	58
1990	0	0	5	6	20	18	10	8	2	2	2	0	0	0	0	73
1991	0	0	2	4	2	5	3	2	1	0	2	0	0	0	0	21
1992	0	1	4	6	19	11	13	10	2	3	2	1	0	0	0	72
1993	0	0	4	8	8	12	11	9	2	1	1	0	0	0	0	56
1994	0	1	4	5	11	16	12	10	4	1	1	0	0	0	0	65
1995	1	4	6	15	22	37	18	26	20	3	1	1	0	0	0	154
1996	0	4	21	34	45	72	48	29	40	8	4	1	0	0	0	306
1997	2	0	7	32	34	46	27	37	28	3	3	3	1	0	0	223
1998	4	3	14	29	44	40	36	30	18	6	2	1	2	0	0	229
1999	1	6	18	38	54	59	67	39	23	12	6	1	0	0	0	324
2000	0	4	21	47	56	70	68	43	17	13	3	0	2	0	0	344
2001	1	31	89	216	274	280	226	91	37	21	8	0	2	0	0	1,276
2002	2	18	96	226	295	327	234	111	45	29	4	1	1	1	0	1,390
2003	0	21	92	177	239	257	182	119	44	30	5	3	1	1	0	1,171
2004	2	31	106	216	333	345	249	125	60	34	6	4	1	0	0	1,512
2005	2	24	74	149	290	288	270	130	71	25	7	5	0	1	0	1,336
2006	2	23	77	166	295	350	311	170	83	34	20	2	1	0	0	1,534
2007	4	40	86	204	319	399	407	230	116	55	23	7	0	1	0	1,891
2008	8	27	116	201	299	384	370	252	110	54	22	2	0	1	0	1,846
2009	7	44	175	333	442	504	483	345	160	69	29	5	2	0	0	2,598
2010	5	80	422	682	854	1,060	925	540	231	92	37	7	5	0	0	4,940
2011	9	129	613	1,010	1,404	1,493	1,244	822	363	117	52	13	6	0	0	7,275
2012	14	153	572	1,015	1,342	1,536	1,253	927	403	148	71	14	5	1	0	7,454
2013	32	332	1,254	2,278	2,689	2,988	2,432	1,671	823	341	110	28	7	0	0	14,985
2014	49	434	1,489	2,664	3,314	3,519	3,008	1,978	926	355	120	28	5	3	0	17,892
2015	45	321	1,132	2,267	2,839	3,200	2,612	1,809	790	335	110	36	12	2	0	15,510
2016	72	614	2,129	3,736	4,628	4,814	4,144	2,790	1,234	554	191	53	15	1	2	24,977
Total	264	2,352	8,639	15,795	20,214	22,160	18,695	12,362	5,659	2,347	842	216	68	12	2	109,627

speed decreased from 8.51±1.07 km/h (1977) to 7.29±1.77 km/h (2016) in women and from 14.64±1.56 km/h (1975) to 7.98±2.17 km/h (2016) in men. There was a trivial sex × calendar year interaction on running speed (p<0.001, η^2=0.003), where sex difference decreased across calendar years.

Finishers by age-group

Most finishers were recorded for both women and men in the age-group of 40–44 years (Figure 2). The total men-to-women ratio was 4.13. A sex × age-group association was found (χ^2=3010.482, p<0.001, φ=0.083) with the smallest men-to-women ratio in the 25–29 age-group (2.45) and the largest in the >84 age-group (11.00; Figure 2). A sex × calendar year association was observed (χ^2=1947.963, p<0.001, φ=0.067) with the men-to-women ratio being >30 before 1981 and being the lowest in 2016 (2.58).

Running speed by age-groups

When all finishers were considered in 5-year age-groups, a small main effect of age-group on running speed was observed (p<0.001, η^2=0.014) with older runners being slower than their younger counterparts (Figure 3). In addition,

Table 2 Finishers by age-group and calendar year in men

Year	Age (years)															Total
	<20	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	>84	
1975	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	3
1977	2	4	13	15	26	14	3	1	0	0	0	0	0	0	0	78
1978	3	22	29	30	52	45	13	1	2	1	0	0	0	0	0	198
1979	4	24	34	25	54	53	14	4	1	1	0	0	0	0	0	214
1980	10	21	29	21	39	40	20	4	1	1	0	0	0	0	0	186
1981	4	3	16	25	20	25	15	6	1	2	0	0	0	0	0	117
1982	8	10	26	25	17	23	19	6	3	0	0	0	0	0	0	137
1983	8	5	20	31	17	29	25	11	2	1	0	0	0	0	0	149
1984	0	4	13	26	27	32	31	7	2	1	0	0	0	0	0	143
1985	0	4	6	34	27	36	26	12	2	0	1	0	0	0	0	148
1986	0	5	8	21	17	19	21	7	2	0	0	0	0	0	0	100
1987	1	4	14	11	25	20	22	9	3	1	0	0	0	0	0	110
1988	1	3	9	8	27	34	23	14	7	1	2	0	0	0	0	129
1989	2	8	19	43	69	63	70	54	22	2	2	1	0	0	0	355
1990	0	6	20	37	58	59	55	36	28	5	6	2	0	0	0	312
1991	0	1	2	3	10	14	11	9	6	6	5	1	0	0	0	68
1992	0	4	19	24	33	28	28	38	14	4	6	1	0	0	0	199
1993	1	2	11	14	25	28	21	34	6	9	4	2	0	0	0	157
1994	1	3	20	31	38	50	44	37	30	8	5	1	1	0	0	269
1995	5	9	38	58	108	132	143	85	92	33	9	3	1	0	0	716
1996	1	16	73	153	184	234	224	180	147	68	14	8	0	0	0	1,302
1997	4	15	22	84	119	168	153	132	97	44	14	11	2	0	0	865
1998	6	8	41	106	120	158	161	124	92	50	18	6	3	0	0	893
1999	4	29	75	148	220	229	260	213	133	80	22	12	7	0	0	1,432
2000	2	19	53	157	222	291	273	250	137	85	34	10	4	0	0	1,537
2001	9	125	493	888	1,227	1,198	924	595	294	175	45	9	4	1	0	5,987
2002	12	119	460	853	1,203	1,272	1,008	670	378	211	73	26	6	1	0	6,292
2003	9	85	370	692	913	1,007	799	579	335	179	75	25	9	0	0	5,077
2004	7	83	389	800	1,113	1,211	983	662	381	164	73	24	5	2	0	5,897
2005	15	61	273	610	816	931	881	604	410	191	103	41	8	2	0	4,946
2006	11	99	292	689	931	1,138	1,052	780	506	232	120	38	12	3	1	5,904
2007	11	118	281	650	901	1,182	1,161	895	607	326	156	51	12	6	0	6,357
2008	19	114	342	691	966	1,179	1,141	940	534	337	172	54	12	6	1	6,508
2009	29	180	548	963	1,379	1,557	1,557	1,107	724	444	181	101	12	1	0	8,783
2010	31	253	959	1,817	2,527	2,849	2,680	1,979	1,167	663	231	94	23	7	0	15,280
2011	48	409	1,580	2,862	3,925	4,011	3,791	2,662	1,494	808	355	109	39	1	1	22,095
2012	55	364	1,367	2,731	3,775	4,256	3,961	2,991	1,685	934	416	144	32	5	1	22,717
2013	133	792	2,850	5,663	7,093	8,077	6,994	5,629	3,226	1,739	775	245	57	7	5	43,285
2014	139	979	3,298	6,229	8,425	9,588	8,020	6,061	3,588	1,899	850	269	71	6	6	49,428
2015	108	664	2,689	5,422	7,277	8,507	7,259	5,599	3,432	1,672	764	231	66	12	2	43,704
2016	255	1,209	4,338	8,235	10,981	12,205	10,481	7,938	4,765	2,460	1,083	377	86	14	5	64,432
Total	958	5,883	21,140	40,926	55,006	61,993	54,367	40,965	24,356	12,837	5,614	1,896	472	74	22	326,509

a trivial sex × age-group interaction on running speed was shown (p<0.001, η^2<0.001) with the sex difference being smaller in the older age-groups than in the younger age-groups. When the top ten finishers by 5-year age-groups were considered, a large main effect of age-group on running speed was found (p<0.001, η^2=0.949; Figure 4). Moreover, a large sex × age-group interaction on running speed was observed (p<0.001, η^2=0.324). That is, the main effect of age-group and the sex × age-group interaction on running speed had larger magnitude when the top ten finishers were considered compared with all finishers. When all finishers were considered in 1-year age-group intervals, a small main effect of age-group on running speed was observed (p<0.001, η^2=0.014; Figure 5). In addition, a trivial sex × age-group interaction on running speed was shown (p<0.001, η^2=0.001). When the top ten finishers by 1-year age-group intervals were considered, a large main effect of age-group on running speed was found (p<0.001, η^2=0.926; Figure 6). Furthermore, a large sex × age-group interaction on running speed was observed (p<0.001, η^2=0.194). The main effect of

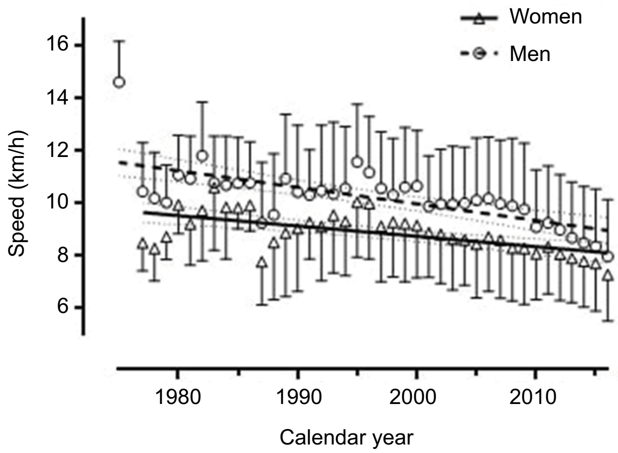

Figure 1 Running speed across calendar years considering all finishers.
Note: Error bars represent SD.

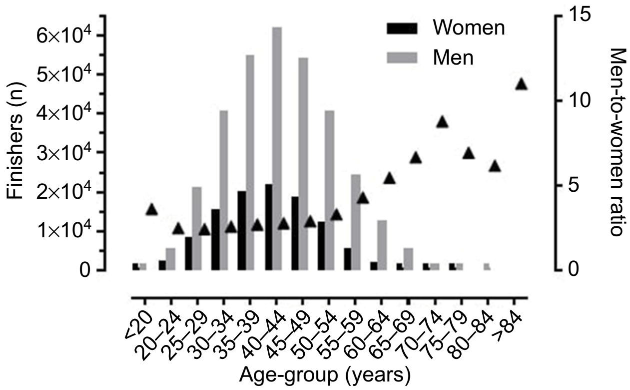

Figure 2 Finishers by sex and 5-year age-group.

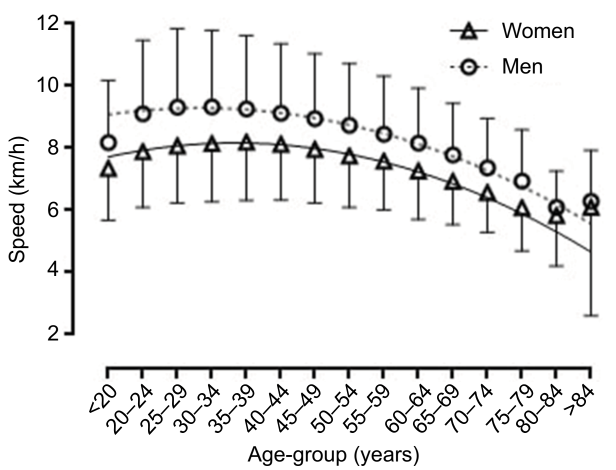

Figure 3 Speed by sex and age-group considering all finishers in 5-year age-groups.
Note: Error bars represent SD.

age-group and the sex × age-group interaction on running speed had larger magnitude when the top ten finishers were considered compared with all finishers, as it has been found in the analysis using 5-year age-groups.

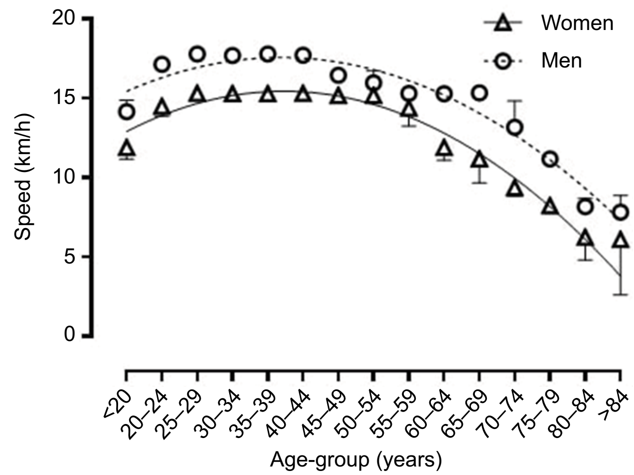

Figure 4 Speed by sex and age-group considering top ten finishers in 5-year age-groups.
Note: Error bars represent SD.

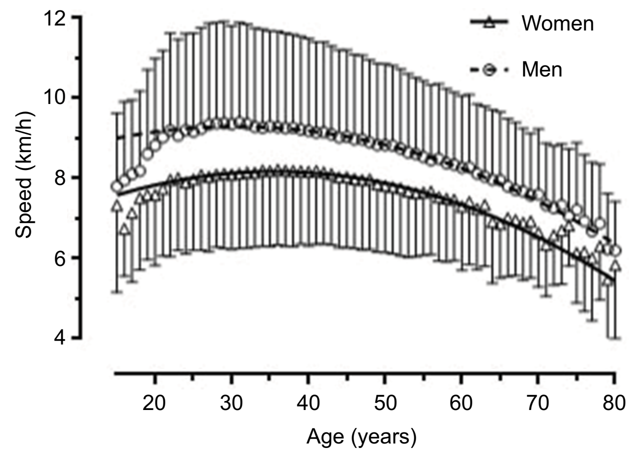

Figure 5 Speed by sex and age-group considering all finishers in 1-year age-groups.
Note: Error bars represent SD.

Age by sex and calendar year

Men (43.2±10.2 years) were older than women (41.4±9.4 years; $p<0.001$; Figure 7). The age of finishers of both sexes increased through time (Figure 8). The age increased from 38.00±4.24 years in women (1977) and 33.33±7.51 years in men (1975) to 41.15±9.49 years in women and 42.95±10.26 years in men (2016). The regression equations were $y=0.117 \times x - 192.5$ ($R^2=0.27$, $p<0.001$) in women and $y=0.220 \times x - 397.4$ ($R^2=0.53$, $p<0.001$) in men.

Age of peak running speed

Considering all finishers in 5-year age-groups, the age of peak running speed was 35–39 years in women and 30–34 years in men (Figure 3; Table 3). Considering the top 10 finishers in

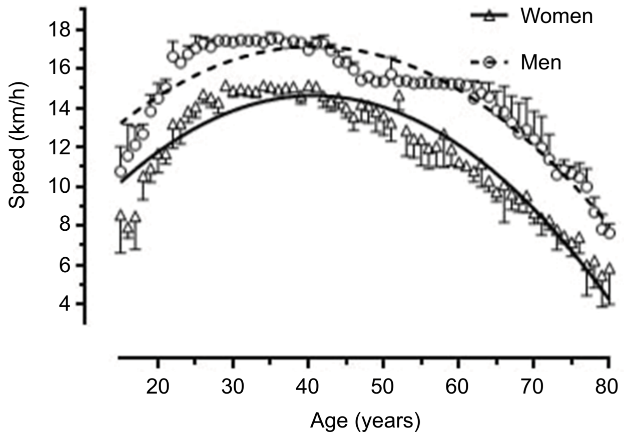

Figure 6 Speed by sex and age-group considering top ten finishers in 1-year age-groups.
Note: Error bars represent SD.

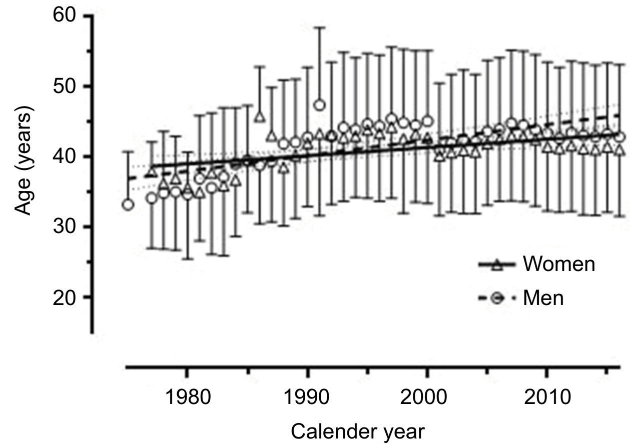

Figure 8 Age by calendar years and sex.
Note: Error bars represent SD.

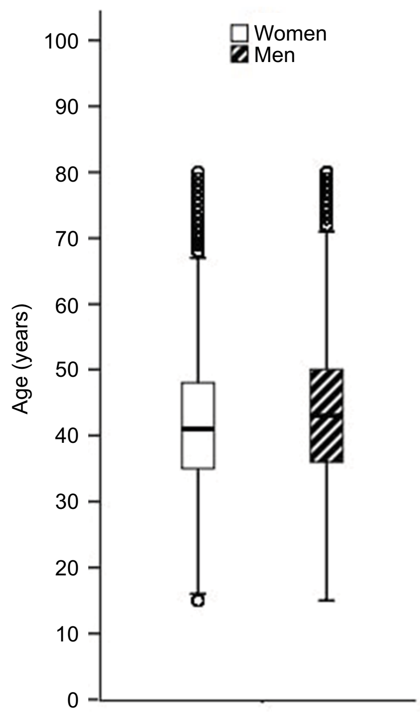

Figure 7 Box plots presenting age by sex and race.
Note: Error bars represent SD.

5-year age-groups, the age of peak running speed was 35–39 years in women and 35–39 years in men (Figure 4; Table 3). Considering all finishers in 1-year age-groups, the age of peak running speed was 36 years in women and 31 years in men (Figure 5; Table 4). Considering the top ten finishers in 1-year age-groups, the age of peak running speed was 41 years in both women and men (Figure 6; Table 4). When the single top finishers were examined in 1-year age-groups, the age of peak running speed was 40 years in women and 39 years in men (Figure 9; Table 4).

Table 3 Parameters in the second-order polynomial regression race speed (km/h)=a+bx+cx^2 using the race speed of all and top ten runners in 5-year age-groups

Parameter	Women	Men
All finishers		
a (km/h)	7.449	8.901
b (km/h/year)	0.309	0.215
c (km/h/year^2)	–0.039	–0.029
Age (years)	35–39	30–34
Running speed (km/h)	8.17	9.30
R^2	0.02	0.03
Top ten finishers		
a (km/h)	11.630	14.350
b (km/h/year)	1.395	1.193
c (km/h/year^2)	–0.128	–0.111
Age (years)	35–39	35–39
Running speed (km/h)	15.44	17.56
R^2	0.91	0.91

Discussion

The purpose of this study was to investigate the age of peak ultramarathon performance in the 50-km race distance. The main finding of the present study was that the fastest 50-km ultramarathon race time is expected to be achieved at an older age compared with the marathon, and women seem to be older when achieving their best race time. The age of peak running performance varied depending upon whether all finishers, the top ten finishers, or the fastest finishers (in 1-year or 5-year age-group intervals) were considered: 1) when the top ten were considered in 5-year age-groups, the fastest runners were at the age of ~35–39 years; 2) when all finishers were considered, the age of peak running speed was 30–39 years; 3) when all finishers were considered in 1-year age-group intervals, the age of peak running speed was 36 years in women and 31 years in men; 4) when the

Table 4 Parameters in the second-order polynomial regression race speed (km/h)=a+bx+cx² using the race speed of all and top ten runners in 1-year age-groups

Parameter	Women	Men
All finishers		
a (km/h)	6.428	8.188
b (km/h/year)	0.098	0.073
c (km/h/year²)	–0.001	–0.001
Age (years)	36	31
Running speed (km/h)	8.18	9.30
R^2	0.02	0.03
Top ten finishers		
a (km/h)	3.547	7.329
b (km/h/year)	0.546	0.482
c (km/h/year²)	–0.007	–0.006
Age (years)	41	41
Running speed (km/h)	14.64	17.15
R^2	0.83	0.84
Top finishers		
a (km/h)	6.868	10.640
b (km/h/year)	0.438	0.352
c (km/h/year²)	–0.005	–0.004
Age (years)	40	39
Running speed (km/h)	15.65	17.58
R^2	0.86	0.80

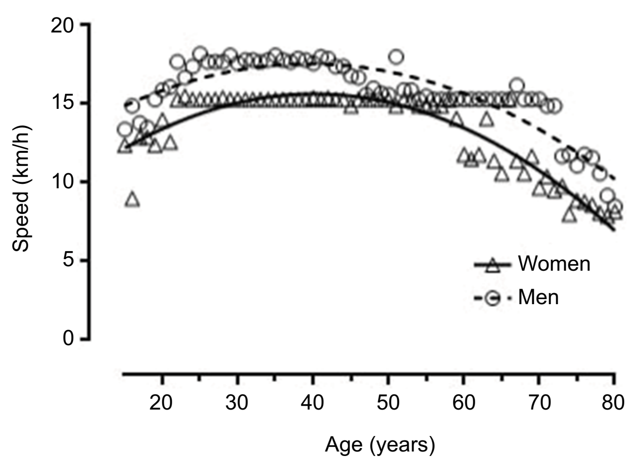

Figure 9 Speed by sex and age-group considering the single top finisher in 1-year age-groups.

top ten finishers in 1-year age-groups were analyzed, the age of peak running speed was 41 years in both women and men; and 5) when the fastest in 1-year age-group intervals were analyzed, the age of peak running speed was 40 years in women and 39 years in men.

Lara et al[9] showed for elite marathoners that the fastest race time was obtained at 27 years in men and at 29 years in women. When the relationship between elite marathon race times and age in 1-year intervals by using the world single age records in marathon running from 5 to 93 years was analyzed, elite marathon race times improved from 5 to ~20 years, remained linear between ~20 and ~35 years, and started to increase at the age of ~35 years in a curvilinear manner with increasing age in both women and men.[10] In addition, Lehto[11] showed recently that a second-order (nonlinear) polynomial with $y=a+bx+cx^2$ best described the age-related changes in performance in recreational male marathoners competing in the Stockholm Marathon. Lehto[11] found that the age of peak marathon performance was ~34 years when both all runners and the fastest runners in 1-year age intervals were analyzed. Unfortunately, only male runners were investigated.

Potential explanations for the older age of peak running speed in 50-km ultramarathoners than expected could be the trend across calendar years, where an increased age of finishers has been observed. The increase in age in peak ultramarathon performance appears typical for this sports discipline. When the age of runners competing in time-limited ultramarathons held from 6 hours to 10 days during 1975–2013 was analyzed, the age of peak performance increased across calendar years.[2] The increase in the age of peak performance has also been reported for elite Ironman triathletes competing in the "Ironman Hawaii." When the changes in the age and performances of the annual top ten women and men competing at the Ironman World Championship, the "Ironman Hawaii", from 1983 to 2012 were analyzed, the age of annual top ten female and male triathletes increased over the last three decades while their performances improved.[13] In the present ultramarathoners, the fact that performance did not improve should be attributed to the concurrent increase in participation rates. In addition, the older age of peak performance in ultramarathoners compared with marathoners might reflect the corresponding older age of finishers in ultramarathons. For instance, Rust et al[14] showed that ultramarathoners were older by 3 years than marathoners. An approach of ultramarathoners in selecting a distance to run is to aim at longer distances than that already covered in the past; thus, ultramarathoners are more experienced than marathoners. For instance, a comparative study reported 34 and 12 completed marathons for ultramarathon and marathoners, respectively.[14]

In addition, we observed a trend that women were generally older than men when achieving their fastest race times. These results confirm recent findings of Hoffman[15] in retrospective data analysis from 1977 through 2008 in 161-km ultramarathoners, which showed that the fastest race times were achieved by athletes in the age-group of 30–39 years in men and in 40–49 years in women. The sex difference in the age of peak performance might be attributed to the variation in participation rates by age-groups, where a trend of relatively less women participating in the older groups was observed; thus, it might be assumed that the older women are more "selected" compared with the men of their age and perform relatively better compared with men inducing a swift of the race speed–age curve to the right.

In our study, the mean age of all men competing in 50-km ultramarathon race was older than the mean age of all women (43.2±10.2 vs 41.4±9.4 years), which was in accordance with age-related differences in the men-to-women ratio. The men-to-women ratio started to increase at about the age of 50 years; therefore, relatively more men competed in the older age-groups compared with women. The younger mean age of women, compared with men, should be mostly due to sociological factors, such as the delayed participation of women in this sport for the first time (1977 in women vs 1975 in men). The lower rates of women participation in 50-km ultramarathon race are in agreement with studies examining sex differences in sports participation and are associated with sex differences in motivation,[16] which may have their origin in childhood,[17] adolescence,[18] and young adulthood.[19]

The age of peak performance in 50-km ultramarathon race in the present study varied depending on the applied methodological approaches; that is, whether all, the top ten, or the fastest finishers were considered or whether the finishers were classified in 1- or 5-year age-group intervals. It should be highlighted that all approaches are useful; however, they have certain advantages and disadvantages. For instance, considering the top ten finishers results in well-fitted modeling of the relationship between performance and age ($0.91 \leq R^2 \leq 0.96$, 5-year age interval, Table 1; $0.72 \leq R^2 \leq 0.84$, 1-year age interval, Table 2), whereas when all finishers are considered the modeling is weaker ($0.02 \leq R^2 \leq 0.04$, 5-year age interval, Table 1; $0.02 \leq R^2 \leq 0.04$, 1-year age interval). The discrepancy between the two methodological approaches indicates that considering the top runners by age-group is more appropriate to study the relationship between performance and age. Furthermore, the analysis of top runners instead of all runners resulted in larger sex difference in performance (16.6% vs 7.5%, respectively). These differences partially reflect the higher scores of VO_{2max} in men (eg, +9.3% in elite marathon runners[20]), which highlights that elite women runners are expected to reduce the gap to men in the future.

The ages of peak performance in the 50-km ultramarathon race may be affected by the number of participants in each age-group. Most finishers in ultramarathon races were recorded in the age-group of 40–44 years for both women and men. The reasons for greater participation in this age-group are not clear. When the demographic characteristics of 161-km ultramarathoners were investigated, the mean age of 489 runners was 44.5±9.8 years, and the runners were generally men (80.2%), were married (70.1%), and had bachelor's (43.6%) or graduate (37.2%) degrees.[21]

With regard to the limitations of the present study, it should be highlighted that the age of peak performance varies by distance in ultramarathons; thus, caution is needed when generalizing the findings in these 50-km ultramarathons to other distances. On the other hand, the strength of the study is the very large number of finishers who were analyzed, which allows drawing safe conclusions about the estimation of the age of peak performance. These findings are of both theoretical and practical values. From a theoretical point of view, we observed that the age of peak performance in 50 km is older than the age of peak aerobic capacity, which suggests that a good aerobic capacity is not "transformed" into performance. From a practical perspective, coaches and fitness trainers working with runners competing in this distance might benefit from the knowledge of the age of peak performance, as this will assist them to design long-term training strategies and to set age-tailored goals for athletes participating in ultramarathon races.

Conclusion

The age of peak running speed in 50-km ultramarathoners (41 years for top ten finishers in 1-year age-groups) is older than that reported for marathoners, independently from whether the finishers were considered in 1- or 5-year age-groups. This is possibly due to the age of participants competing in these events.

Disclosure

The authors report no conflicts of interest in this work.

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