Research Article

Do Skiers with Similar Race Time but Different Age Pace Similarly in a Cross-Country Ski Marathon?

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Abstract

Pacing strategies have mainly been investigated for runners, but little is known for cross-country skiers. We investigated the pacing strategies in 105,565 female and male age group athletes competing between 1998 and 2016 in the 'Engadin Ski Marathon'. This race is the largest cross-country skiing marathon held in Europe covering the exact distance of a marathon. Split times are taken at the time stations 10 km (A), 20 km (B) and 35 km (C). We hypothesized to find a difference in pacing between younger and older athletes with similar race times. We calculated three percentage changes of speed, Change A (100 × (split2 - split1)/split1), Change B (100 × (split3 - split2)/split2) and Change C (100 × (split4 - split3)/split3). The men-to-women ratio was lower in the slower performance groups. In both women and men, the faster groups were more prevalent in the younger age groups and the slower groups in the older age groups; only the < 2 hours group increased speed in Change A. A non-linear variation of change in speed was observed across performance groups in Change B and C. The differences in variation of pacing by performance groups among age groups were trivial. In summary, the findings did not confirm our hypothesis that skiers of different age with similar race time would pace differently. Therefore, sex and performance, not age, should be the main criteria for coaches and skiers in order to optimize the pacing strategy in a cross-country skiing marathon.

Keywords: Sports, Athletes, Sex Difference

1. Background

The pacing strategy during an endurance event can have a significant impact on performance. Six different pacing strategies, such as negative, all-out, positive, even, parabolic-shaped and variable pacing, have been described (1). Generally, during endurance events, well trained athletes tend to adopt a positive pacing strategy, where the athlete progressively slows after peak speed is reached (1).

For four decades, pacing has been well studied in the other major endurance modes of exercise, such as running (2), cycling (3) and swimming (4). Aspects of pacing have preferably been investigated in running events of different distances in track-running from 800 m to 10,000 m (5-7) and in road running races of different distances such as 5 km (8), 10 km (9), half-marathon (10), marathon (11-15), 100-km ultra-marathon (16-19), 161-km ultra-marathon (20-22), running events of different durations such as 6-hour run (23), 24-hour run (24), and cross-country running (25, 26).

However, in contrast to running, very little is known about pacing in cross-country skiing (27).

Different variables such as age, sex, performance level and experience seem to influence the pacing strategy of athletes in cross-country skiing (27, 28). In 10 km and 15 km cross-country skiing races held in World Cup, World Championships, and Olympic events, women and men demonstrated a positive pacing pattern with a decline in speed from the first to the last lap (28). In longer cross-country skiing races such as the 'Vasaloppet' covering a total distance of 90 km, women showed a more even pacing profile than men with the same finish time, start group, age, and race experience. Men were faster in the first half whereas women were faster in the second half of the race (27). Also, performance level has an influence on pacing in cross-country ski races. During 10 km and 15 km cross-country skiing races held in World Cup, World Championships, and Olympic Games, slower male skiers were characterized by a quick start relative to their average velocity, with a greater

decrease in race speed during the race compared to the faster skiers (28).

Performance in cross-country skiing has been shown to be influenced by a series of physiological, psychological, technical and tactical characteristics, including pacing. In addition, pacing of performance groups has usually been examined by considering quartiles of performance (19, 29). Although the use of quartiles allowed the assignment of an equal number of participants in each performance group, it might be of limited practical value for coaches and athletes, because the cut-off points of groups did make sense from a statistical point of view but not from a sport perspective. Coaches and athletes might be more interested to know the pacing of a specific 'race time' group, i.e. what was the pacing strategy of athletes achieving a specific race time.

However, we have no knowledge whether differences between younger and older cross-country skiers in pacing exist. For 100-km ultra-marathoners, it has been shown that younger athletes (i.e. younger than 24 years) were slower than older athletes (i.e. older than 24 years) and older athletes did not slow down more than younger athletes (18). Therefore, the aim of this study was to investigate whether differences in pacing strategies do exist between younger and older cross-country skiers competing in a cross-country skiing race covering the distance of a marathon. We expected to find differences in pacing among skiers with similar performance and different ages due to the effect of aging on performance.

2. Methods

2.1. Ethical Approval

All procedures used in the study were approved by the institutional review board of Kanton St. Gallen, Switzerland, with a waiver of the requirement for informed consent of the participants since the study involved the analysis of publicly available data.

2.2. The Race

The 'Engadin Ski Marathon' is an annually held cross-country ski race in Switzerland, Europe that takes place on the second Sunday of March in the upper Engadin valley between Maloja and S-chanf. The race started in 1969, has been a part of the Worldloppet, and is one of the major cross-country skiing events in the Alps in Europe. Between 11,000 and 13,000 skiers participate annually in 'Engadin Ski Marathon'. Since 1998, the total distance covered is 42 km. In that year, the race was extended by 2 km to match the distance of a full marathon. The 'Engadin Ski Marathon' is a freestyle race, but there are separate tracks for skiers

practicing classic style for all but the narrowest parts of the race. Participation is open to anyone from the age of 16 years. In Silvaplana (10 km, 1,790 m above sea level), Pontresina (20 km, 1,805 m above sea level) and La Punt-Chamues-ch (35 km, 1,687 m above sea level), split times are taken at the time stations.

The race course of the 'Engadin Ski Marathon' is hilly in the first part (Figure 1). The race starts in Maloja at 1,820 m above sea level. The track leads over the frozen lakes in Lake Sils (1,796 m above sea level) and Lake Silvaplana (1,790 m above sea level). After passing St. Moritz (1,822 m above sea level) there is a forested climb in the Stazerwald. The proceeding descent to Pontresina (1,805 m above sea level) then leads to the runway of Samedan Airport (1,707 m above sea level) and afterwards on the right side of the Engadin valley, passing several small communities such as La Punt-Chamues-ch (1,687 m above sea level) and Zuoz (1,716 m above sea level) before reaching the finish in S-chanf at 1,670 m above sea level.

2.3. Data Sampling

All athletes who finished the 'Engadin Ski Marathon' between 1998 and 2016 were considered. Data with name, age and sex of the athletes were obtained from the publicly available race website of the 'Engadin Skin Marathon' at www.engadin-skimarathon.ch. Before 1998, data were not recorded electronically. The initial sample was 105,587 participants, classified in 5-year age groups. Twenty-two participants with missing split times were excluded from further analysis, resulting in a final sample of 105,565 participants.

2.4. Statistical Analysis

The statistical package IBM SPSS v.20.0 (SPSS, Chicago, USA) was used to perform all statistical analyses and the software GraphPad Prism v. 7.0 (GraphPad Software, San Diego, USA) to create figures. Descriptive statistics (mean $\pm$ standard deviation) were used for all variables. We created six performance groups according to race time (< 2 hours, 2 - 2.5 hours, 2.5 - 3, 3 - 3.5, 3.5 - 4.0, and > 4 hours) to allow an 'absolute' comparison among age groups, e.g. the athletes in age group 50 - 55 years with a race time 3 - 3.5 hours were compared with athletes in age group 20 - 25 years with the same race time. A two-way ANOVA examined the main effects of sex, age group, performance group and split, and the performance group $\times$ split and performance group $\times$ age group interaction on race speed, followed by a Bonferroni post-hoc analysis. The magnitude of differences in the ANOVA was evaluated using eta squared (η^2) as trivial ($\eta^2 < 0.01$), small ($0.01 \leq \eta^2 < 0.06$), moderate ($0.06 \leq \eta^2 < 0.14$) and large ($\eta^2 \geq 0.14$). We calculated
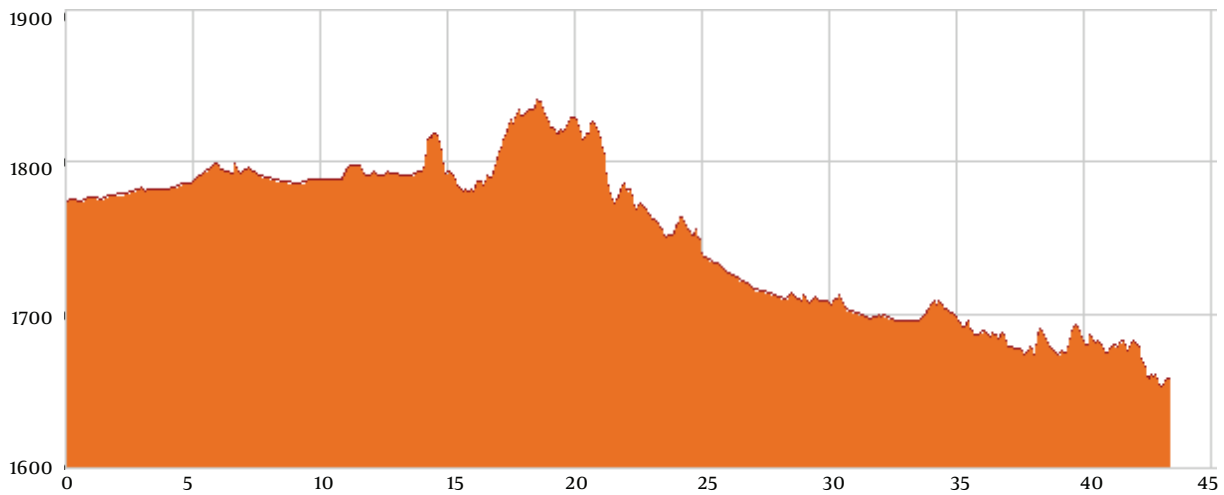
Figure 1. Course profile (30)

three percentage changes of speed, change A (100 × (split2 - split1)/split1), change B (100 × (split3 - split2)/split2) and change C (100 × (split4 - split3)/split3). These changes refer to the time stations (i.e. Silvaplana = Change A, Pontresina = Change B and La Punt = Change C) during the race.

In addition, to study differences in speed and change of speed by sex, age group, performance group and split, we used a mixed-effects regression model with participants as random variables, whereas sex, performance group and age group were assigned as fixed variables. In addition, we examined interaction effects between these fixed variables. Akaike information criterion (AIC) was used to select the final model. Alpha level was set at 0.05.

3. Results

A sex × performance group association was observed (χ^2 = 4147.22, P < 0.001, Cramer's φ = 0.198) with the men-to-women ratio decreasing with increasing race time (Figure 2). For instance, the men-to-women ratio was 14.1 in the < 2 hours group and 2.5 in the > 4 hours group. An age group × performance group association was shown in women (χ^2 = 1302.15, P < 0.001, Cramer's φ = 0.259) and in men (χ^2 = 8306.92, P < 0.001, Cramer's φ = 0.310) with the faster performance groups being more prevalent in young age groups and the slower performance groups in older age groups (Figure 3). For instance, the < 2 hours group had 296 (out of 1,513, i.e. 19.6%) men in age group -20 years, but only 21 (out of 4,107, i.e. 0.5%) in the age group 65 - 70 years.

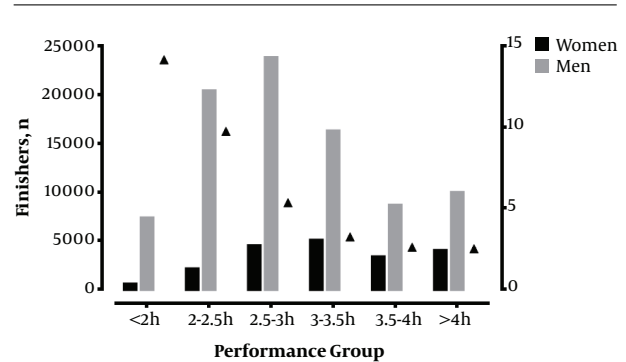A moderate main effect of performance group on change A was observed (P < 0.001, η^2 = 0.074) (Figure 4 and

Figure 2. Distribution of performance groups by sex and men-to-women ratio ($\triangle$)

Table 1), where athletes in the < 2 hours group increased speed and athletes in the other groups decreased speed in a smaller (2 - 2.5 hours) or larger extent. A trivial main effect of sex on change A was shown (P < 0.001, η^2 = 0.002) with women decreasing speed more than men. A trivial sex × performance group interaction on change A was found (P = 0.002, η^2 < 0.001). Similarly, a moderate main effect of performance group on change B was observed, too (P < 0.001, η^2 = 0.072), with change B presenting an inverse U shape across performance groups, i.e. 2.5 - 3 hours and 3 - 3.5 hours performance groups increased more their speed than the faster and slower performance groups. A small main effect of sex on change B was shown (P < 0.001, η^2 = 0.010) with men presenting larger increase of speed than women. A trivial sex × performance group interaction on change B was found (P < 0.001, η^2 = 0.001). In addition, a small main effect of performance group on change C was
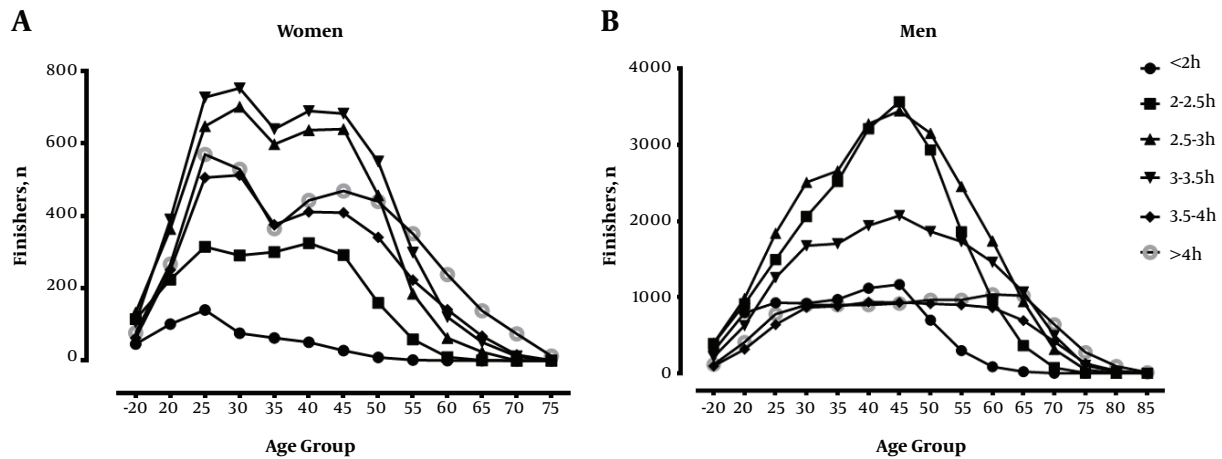
Figure 3. Distribution of performance groups by age group in women (A) and men (B)

observed (P < 0.001, η^2 = 0.034), with change C presenting a U shape across performance groups, i.e. athletes in the 2.5 - 3 hours and 3 - 3.5 hours performance groups decreased their speed more than athletes in the faster and slower performance groups. A trivial main effect of sex on change B was shown (P < 0.001, η^2 = 0.008) with women presenting a larger decrease in speed than men. A trivial sex × performance group interaction on Change C was found (P < 0.001, η^2 = 0.002).

In women, no main effect of age group on Change A (P = 0.150, η^2 = 0.001), Change B (P = 0.109, η^2 = 0.001) and Change C (P = 0.206, η^2 = 0.001) was observed. However, a trivial performance group × age group interaction on these changes was shown (P < 0.001, η^2 = 0.009; P < 0.001, η^2 = 0.004; P = 0.002, η^2 = 0.004, respectively) (Figure 5 and Table 2). In men, a trivial main effect of age group on Change A (P < 0.001, η^2 = 0.002), Change B (P < 0.001, η^2 = 0.001) and Change C (P < 0.001, η^2 = 0.001) was found (Table 3). A trivial performance group × age group interaction on Change A (P < 0.001, η^2 = 0.007), on Change B (P < 0.001, η^2 = 0.003) and Change C (P < 0.001, η^2 = 0.004) was observed.

4. Discussion

The main findings of the present study were that (i) the men-to-women ratio was lower in slower performance groups, (ii) in both women and men, the faster performance groups were more prevalent in younger age groups and the slower performance groups in older age groups, (iii) only athletes in the < 2 hours performance group increased speed in change A, (iv) a non-linear variation of change of speed was observed across performance groups

in change B and C, and (v) the age group × performance group interaction on pacing was trivial.

Younger athletes and men were relatively faster than older athletes and women.

The first main finding was that there was an imbalance in the distribution of sex among performance groups, e.g. the men-to-women ratio was close to 14 in the < 2 hours performance group and close to 2.5 in the > 4 hours performance group. This observation should be attributed to the sex difference in performance in cross-country skiing, according to which men were faster than women. In turn, the faster race time in men might reflect physiological and anthropometric differences compared to women, such as their higher maximal oxygen uptake (VO_2max) (31, 32), muscle power and body mass (33). It should be highlighted that VO_2max was a parameter that could discriminate cross-country skiers into medallists and non-medallists in Olympic games and world championships (34). Also, lean mass was related to performance of cross-country skiers (35).

In addition, we observed a performance group × age group association in both women and men, with a larger magnitude in the latter, where the faster performance groups were more prevalent in younger age groups and the slower performance groups more in the older age groups. This remark might reflect age-related differences in race time, according to which athletes in younger age groups were faster than athletes in older age groups (36). The decline in performance with aging could be attributed to the drop in performance-related parameters, such as VO_2max, which has been shown to be ~10% per decade (37).

With regards to the larger magnitude of performance group × age group association in men than in women,
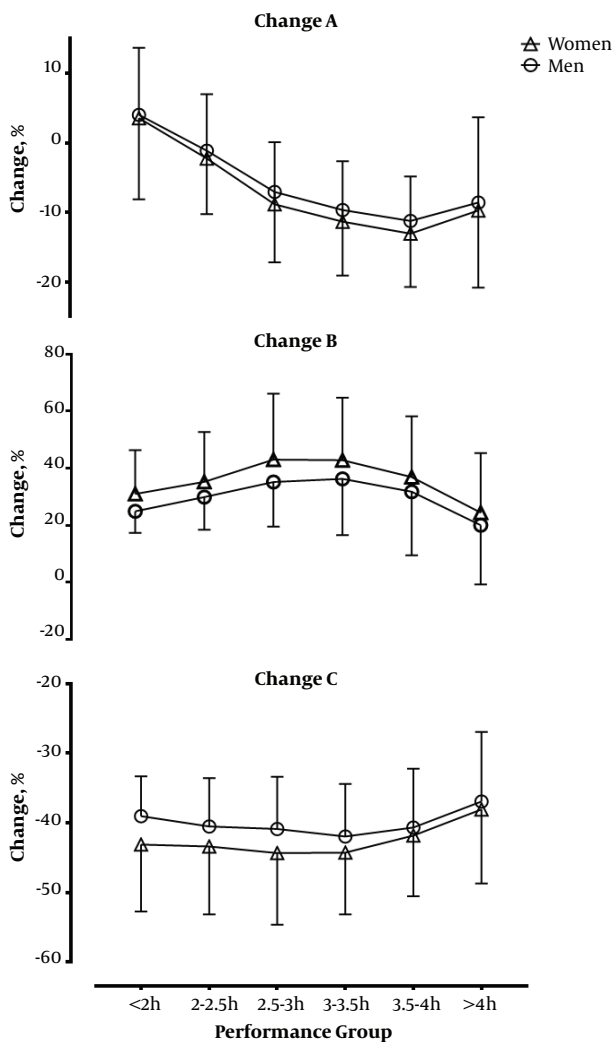
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Figure 4. Change of speed from split 1 to 2 (change A), from split 2 to 3 (change B) and from split 3 to 4 (change C) by sex and performance group. Error bars represented standard deviations.

creasing speed in this change. The pattern of pacing in the present study disagreed with a previous study in cross-country skiing which showed a positive pacing (28, 40). This discrepancy might be due to different race distance and statistical approaches in the abovementioned studies, which examined 15 km and 10 km races in men and women, respectively, and considered only the 40 fastest skiers. Another study on a small sample in skiers examined pacing during a 10 km race and found a decrease of speed during the second and third quarter of the race, which was maintained in the last quarter (41).

4.2. Variation of Change of Speed Across Performance Groups in the Last Part of the Race

Moreover, a non-linear variation of change of speed was observed across performance groups in change B and C. For instance, the fastest group seemed to have similar patterns of change of speed as the two slowest groups. However, their similarity should be due to different reasons. In the case of the fastest group this should be attributed to their relatively fast beginning and the accompanying fatigue that did not allow increasing speed in change B as much as slower groups. On the other hand, the slowest groups did not increase speed in change B as much as faster groups due their slow speed. Additionally, it might be contributed to the course profile with more ascents in the first part of the race (change A and B) but more descents in the second part of the race (change C).

4.3. Differences in Variation of Pacing by Age Groups

The last major finding was that the differences in variation of pacing by performance groups among age groups were trivial. This finding practically meant that skiers with a similar performance differing for age adopted similar pacing strategies. We would expect to find differences in pacing among skiers with similar performance and different age due to the effect of aging on performance-related anthropometric characteristics and physiological parameters. On the other hand, what we did not know was the distribution of performance groups by age groups which might influence our findings. For instance, most men of the age group 25 - 29 years were classified in the 2.5 - 3 hours performance group, whereas relatively very few athletes belonged to this performance group in the age group of 70 - 74 years. Thus, it is reasonable to assume that those athletes belonging to this performance group have an average performance and should have average physiological characteristics in age group 25 - 29 years. However, they have a high performance and should have 'exceptional' physiological characteristics in age group 70 - 74 years. Although previous research showed a decline in VO_2max of skiers

this observation should be attributed partially to sex differences in the correlation of performance to their changes with aging. For instance, in male adolescent skiers, skiing performance was related to strength and power parameters, whereas in female skiers it was related to aerobic capacity (38). Also, it has been shown that women relied less on anaerobic metabolism than men (39).

4.1. The Fastest Increased Speed in the First Part of the Race

The overall pattern of pacing (i.e. ~6% decrease of speed in Change A, ~32% increase in Change B and ~41% decrease in change C) denoted an inverse U shape. The most striking pattern was that of athletes in the < 2 hours performance group in change A which was the only group increasing speed in this change.

Figure 5. Change of speed from split 1 to 2 (change A), from split 2 to 3 (change B) and from split 3 to 4 (change C) by sex, age group and performance group. Error bars represented standard error.

with aging, this decline could be attenuated by increasing exercise stimulus (37). Moreover, older skiers might possess superior skiing economy and gross efficiency than younger skiers (42) which might offset any physiological disadvantage.

4.4. Limitations, Strengths and Practical Applications

The findings of this study should be limited by the specific characteristics of 'Engadin Ski Marathon' (e.g. race distance, change of altitude), environmental conditions (temperature, humidity and wind) and our statistical approach that used all skiers with no limitation to the top athletes in age or performance group. Thus, the results should be interpreted with caution when comparing with studies on other cross-country skiing races and using a different statistical design. On the other hand, the strength was the large number (n > 100,000) of finishers examined which allowed the analysis of performance groups

by age groups and the identification even of trivial differences. Moreover, profiling pacing strategies by sex, performance group and age group, had important practical applications to coaches and athletes, who could optimize their pacing according to the data corresponding to their sex-, age- and performance-specific characteristics. Based on our findings, future research should examine the differences in anthropometric and physiological characteristics in finishers with similar race time differing in age.

4.5. Conclusions

In summary, the findings did not confirm our hypothesis that skiers of different age groups with similar race time would pace differently. In addition, we confirmed previous findings about the effects of sex and performance on pacing. Therefore, sex and performance should be the main criteria for coaches and skiers in order to optimize their pacing strategy.

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Table 1. Mixed-Effects Regression Analysis

Parameter	C	SEE	P Value	Parameter	C	SEE	P Value
Total race time, s				**Split 4**			
Intercept	16675	30	< 0.001	Intercept	6.73	0.04	< 0.001
Performance group = < 2 h	-10014	87	< 0.001	Performance group = < 2 h	9.11	0.11	< 0.001
Performance group = 2 - 2.5 h	-8392	51	< 0.001	Performance group = 2 - 2.5 h	6.17	0.06	< 0.001
Performance group = 2.5 - 3 h	-6575	41	< 0.001	Performance group = 2.5 - 3 h	3.76	0.05	< 0.001
Performance group = 3 - 3.5 h	-4985	41	< 0.001	Performance group = 3 - 3.5 h	2.48	0.05	< 0.001
Performance group = 3.5 - 4 h	-3240	45	< 0.001	Performance group = 3.5 - 4 h	1.48	0.06	< 0.001
Performance group = > 4 h	0b	0		Performance group = > 4 h	0b	0	
Sex	143	17	< 0.001	Sex	-0.05	0.02	0.037
[Performance group = < 2 h] × sex	-185	45	< 0.001	[Performance group = < 2 h] × sex	0.84	0.06	< 0.001
[Performance group = 2 - 2.5 h] × sex	-204	27	< 0.001	[Performance group = 2 - 2.5 h] × sex	0.52	0.03	< 0.001
[Performance group = 2.5 - 3 h] × sex	-248	23	< 0.001	[Performance group = 2.5 - 3 h] × sex	0.50	0.03	< 0.001
[Performance group = 3 - 3.5 h] × sex	-186	23	< 0.001	[Performance group = 3-3.5h] × sex	0.21	0.03	< 0.001
[Performance group = 3.5 - 4 h] × sex	-154	25	< 0.001	[Performance group = 3.5-4h] × sex	0.05	0.03	0.117
[Performance group = > 4 h] × sex	0b	0		[Performance group = > 4 h] × sex	0b	0	
Split 1				**Change A**			
Intercept	10.04	0.04	< 0.001	Intercept	-10.86	0.33	< 0.001
Performance group = < 2 h	12.00	0.12	< 0.001	Performance group = < 2 h	13.94	0.94	< 0.001
Performance group = 2 - 2.5 h	8.23	0.07	< 0.001	Performance group = 2 - 2.5 h	7.50	0.55	< 0.001
Performance group = 2.5 - 3 h	5.47	0.06	< 0.001	Performance group = 2.5 - 3 h	0.22	0.45	0.621
Performance group = 3 - 3.5 h	3.59	0.06	< 0.001	Performance group = 3 - 3.5 h	-2.16	0.44	< 0.001
Performance group = 3.5 - 4 h	2.1	0.06	< 0.001	Performance group = 3.5 - 4 h	-4.01	0.49	< 0.001
Performance group = > 4 h	0b	0		Performance group = > 4 h	0b	0	
Sex	-0.04	0.02	0.110	Sex	1.14	0.19	< 0.001
[Performance group = < 2 h] × sex	0.12	0.06	0.064	[Performance group = < 2 h] × sex	-0.67	0.49	0.173
[Performance group = 2 - 2.5 h] × sex	0.08	0.04	0.026	[Performance group = 2 - 2.5 h] × sex	-0.02	0.30	0.936
[Performance group = 2.5 - 3 h] × sex	0.11	0.03	< 0.001	[Performance group = 2.5 - 3 h] × sex	0.65	0.49	0.009
[Performance group = 3 - 3.5 h] × sex	0.06	0.03	0.056	[Performance group = 3 - 3.5 h] × sex	0.54	0.25	0.028
[Performance group = 3.5 - 4 h] × sex	0.05	0.04	0.185	[Performance group = 3.5 - 4 h] × sex	0.68	0.28	0.013
[Performance group = > 4 h] × sex	0b	0		[Performance group = > 4 h] × sex	0b	0	
Split 2				**Change B**			
Intercept	8.84	0.04	< 0.001	Intercept	28.84	0.58	< 0.001
Performance group = < 2 h	13.73	0.12	< 0.001	Performance group = < 2 h	8.20	1.67	< 0.001
Performance group = 2 - 2.5h	8.76	0.07	< 0.001	Performance group = 2 - 2.5 h	11.75	0.97	< 0.001
Performance group = 2.5 - 3h	4.98	0.06	< 0.001	Performance group = 2.5 - 3 h	22.08	0.79	< 0.001
Performance group = 3 - 3.5h	2.97	0.06	< 0.001	Performance group = 3 - 3.5 h	20.57	0.78	< 0.001
Performance group = 3.5 - 4h	1.49	0.06	< 0.001	Performance group = 3.5 - 4 h	13.23	0.87	< 0.001
Performance group = > 4 h	0b	0		Performance group = > 4 h	0b	0	
Sex	0.07	0.02	0.003	Sex	-4.41	0.33	< 0.001

	B	SE	Sig.		B	SE	Sig.
[Performance group = < 2 h] × sex	0.15	0.06	0.021	[Performance group = < 2 h] × sex	-1.65	0.87	0.056
[Performance group = 2 - 2.5h] × sex	0.18	0.04	< 0.001	[Performance group = 2 - 2.5h] × sex	-0.96	0.52	0.066
[Performance group = 2.5 - 3 h] × sex	0.26	0.03	< 0.001	[Performance group = 2.5 - 3 h] × sex	-3.47	0.44	< 0.001
[Performance group = 3 - 3.5 h] × sex	0.17	0.03	< 0.001	[Performance group = 3 - 3.5 h] × sex	-2.15	0.43	< 0.001
[Performance group = 3.5 - 4 h] × sex	0.14	0.04	< 0.001	[Performance group = 3.5 - 4 h] × sex	-0.75	0.49	0.122
[Performance group = > 4 h] × sex	0b	0	< 0.001	[Performance group = > 4 h] × sex	0b	0	
Split 3				**Change C**			
Intercept	11.32	0.07	< 0.001	Intercept	-39.23	0.27	< 0.001
Performance group = < 2 h	19.54	0.19	< 0.001	Performance group = < 2 h	-7.96	0.77	< 0.001
Performance group = 2- 2.5 h	13.31	0.11	< 0.001	Performance group = 2 - 2.5 h	-7.07	0.45	< 0.001
Performance group = 2.5 - 3 h	9.41	0.09	< 0.001	Performance group = 2.5 - 3 h	-8.55	0.37	< 0.001
Performance group = 3 - 3.5 h	6.24	0.09	< 0.001	Performance group = 3 - 3.5 h	-7.34	0.36	< 0.001
Performance group = 3.5 - 4 h	3.28	0.10	< 0.001	Performance group = 3.5 - 4 h	-3.76	0.40	< 0.001
Performance group = > 4 h	0b	0.00		Performance group = > 4 h	0b	0	
Sex	-0.31	0.04	< 0.001	Sex	1.15	0.15	< 0.001
[Performance group = < 2 h] × sex	-0.79	0.10	< 0.001	[Performance group = < 2 h] × sex	2.92	0.40	< 0.001
[Performance group = 2 - 2.5 h] × sex	-0.29	0.06	< 0.001	[Performance group = 2 - 2.5 h] × sex	1.74	0.24	< 0.001
[Performance group = 2.5 - 3 h] × sex	-0.33	0.05	< 0.001	[Performance group = 2.5 - 3 h] × sex	2.29	0.20	< 0.001
[Performance group = 3 - 3.5 h] × sex	-0.16	0.05	0.001	[Performance group = 3-3.5 h] × sex	1.15	0.20	< 0.001
[Performance group = 3.5 - 4 h] × sex	0.02	0.06	0.656	[Performance group = 3.5 - 4 h] × sex	0.01	0.22	0.954
[Performance group = > 4 h] × sex	0b	0.00		[Performance group = > 4 h] × sex	0b	0	

Table 2. Mixed-Effects Regression Analysis in Women

Parameter	C	SEE	P Value	Parameter	C	SEE	P Value
Total race time, s				**Split 4**			
Intercept	16336	40	< 0.001	Intercept	6.91	0.04	< 0.001
Performance group = < 2 h	-9804	113	< 0.001	Performance group = < 2 h	9.57	0.12	< 0.001
Performance group = 2 - 2.5 h	-8221	69	< 0.001	Performance group = 2 - 2.5 h	6.59	0.07	< 0.001
Performance group = 2.5 - 3 h	-6368	57	< 0.001	Performance group = 2.5 - 3 h	4.01	0.06	< 0.001
Performance group = 3 - 3.5 h	-4701	55	< 0.001	Performance group = 3-3.5 h	2.46	0.06	< 0.001
Performance group = 3.5 - 4 h	-2945	60	< 0.001	Performance group = 3.5 - 4 h	1.37	0.06	< 0.001
Performance group = > 4 h	0b	0		Performance group = > 4 h	0b	0	
Age group	81	6	< 0.001	Age group	-0.04	0.01	< 0.001
[Performance group = < 2 h] × age group	-56	27	0.036	[Performance group = < 2 h] × age group	0.08	0.03	0.005
[Performance group = 2 - 2.5 h] × age group	-58	12	< 0.001	[Performance group = 2 - 2.5 h] × age group	0.01	0.01	0.478
[Performance group = 2.5 - 3 h] × age group	-75	9	< 0.001	[Performance group = 2.5 - 3 h] × age group	0.04	0.01	< 0.001
[Performance group = 3 - 3.5 h] × age group	-78	9	< 0.001	[Performance group = 3 - 3.5 h] × age group	0.04	0.01	< 0.001
[Performance group = 3.5 - 4h] × Age group	-74	10	< 0.001	[Performance group = 3.5 - 4 h] × age group	0.03	0.01	0.011
[Performance group = > 4 h] × age group	0b	0		[Performance group = > 4 h] × age group	0b	0	
Split 1				**Change A**			
Intercept	10.55	0.05	< 0.001	Intercept	-11.83	0.38	< 0.001
Performance group = < 2 h	11.75	0.13	< 0.001	Performance group = < 2 h	17.15	1.07	< 0.001
Performance group = 2 - 2.5 h	7.96	0.08	< 0.001	Performance group = 2-2.5h	11.61	0.66	< 0.001
Performance group = 2.5 - 3h	5.01	0.06	< 0.001	Performance group = 2.5 - 3 h	4.21	0.54	< 0.001
Performance group = 3 - 3.5 h	3.12	0.06	< 0.001	Performance group = 3 - 3.5 h	0.63	0.52	0.227
Performance group = 3.5 - 4h	1.70	0.07	< 0.001	Performance group = 3.5 - 4 h	-0.77	0.57	0.175
Performance group = > 4 h	0b	0		Performance group = > 4 h	0b	0	
Age group	-0.09	0.01	< 0.001	Age group	0.35	0.06	< 0.001
[Performance group = < 2 h] × age group	0.04	0.03	0.181	[Performance group = < 2 h] × age group	-0.84	0.25	0.001
[Performance group = 2 - 2.5 h] × age group	0.05	0.01	< 0.001	[Performance group = 2-2.5h] × age group	-0.77	0.12	< 0.001
[Performance group = 2.5 - 3 h] × Age group	0.10	0.01	< 0.001	[Performance group = 2.5 - 3 h] × age group	-0.59	0.09	< 0.001
[Performance group = 3 - 3.5 h] × age group	0.09	0.01	< 0.001	[Performance group = 3 - 3.5 h] × age group	-0.38	0.08	< 0.001
[Performance group = 3.5 - 4 h] × age group	0.08	0.01	< 0.001	[Performance group = 3.5 - 4 h] × age group	-0.43	0.09	< 0.001
[Performance group = > 4 h] × age group	0b	0		[Performance group = > 4 h] × age group	0b	0	
Split 2				**Change B**			
Intercept	9.19	0.04	< 0.001	Intercept	19.36	0.81	< 0.001
Performance group = < 2 h	14.10	0.12	< 0.001	Performance group = < 2 h	13.40	2.29	< 0.001
Performance group = 2 - 2.5 h	9.19	0.07	< 0.001	Performance group = 2 - 2.5 h	12.31	1.41	< 0.001
Performance group = 2.5 - 3 h	5.12	0.06	< 0.001	Performance group = 2.5 – 3 h	23.15	1.15	< 0.001

Performance group = 3 - 3.5 h	2.90	0.06	< 0.001	Performance group = 3 - 3.5 h	23.21	1.12	< 0.001
Performance group = 3.5 – 4 h	1.48	0.06	< 0.001	Performance group = 3.5 – 4 h	13.83	1.22	< 0.001
Performance group => 4 h	0b	0		Performance group => 4 h	0b	0	
Age group	-0.05	0.01	< 0.001	Age group	0.84	0.12	< 0.001
[Performance group = < 2 h] × age group	-0.09	0.03	0.001	[Performance group = < 2 h] × age group	-1.34	0.54	0.014
[Performance group = 2 - 2.5 h] × age group	-0.06	0.01	< 0.001	[Performance group = 2 - 2.5 h] × age group	-0.11	0.25	0.665
[Performance group = 2.5 - 3 h] × age group	0.02	0.01	0.115	[Performance group = 2.5 - 3 h] × age group	-0.74	0.19	< 0.001
[Performance group = 3 - 3.5 h] × age group	0.04	0.01	< 0.001	[Performance group = 3 - 3.5 h] × age group	-0.80	0.18	< 0.001
[Performance group = 3.5 - 4 h] × age group	0.02	0.01	0.020	[Performance group = 3.5 - 4 h] × age group	-0.18	0.19	0.364
[Performance group => 4 h] × age group	0b	0		[Performance group => 4 h] × age group	0b	0	
Split 3				**Change C**			
Intercept	10.93	0.09	< 0.001	Intercept	-35.52	0.37	< 0.001
Performance group = < 2 h	19.86	0.25	< 0.001	Performance group = < 2 h	-9.80	1.04	< 0.001
Performance group = 2 - 2.5 h	13.11	0.15	< 0.001	Performance group = 2 - 2.5 h	-7.46	0.64	< 0.001
Performance group = 2.5 - 3 h	9.28	0.12	< 0.001	Performance group = 2.5 - 3 h	-9.19	0.52	< 0.001
Performance group = 3 - 3.5 h	6.18	0.12	< 0.001	Performance group = 3 - 3.5 h	-8.77	0.51	< 0.001
Performance group = 3.5 - 4 h	3.17	0.13	< 0.001	Performance group = 3.5 - 4 h	-4.97	0.55	< 0.001
Performance group => 4 h	0b	0		Performance group => 4 h	0b	0	
Age group	0.01	0.01	0.311	Age group	-0.43	0.06	< 0.001
[Performance group = < 2 h] × age group	-0.30	0.06	< 0.001	[Performance group = < 2 h] × age group	1.03	0.25	< 0.001
[Performance group = 2 - 2.5 h] × age group	-0.02	0.03	0.558	[Performance group = 2 - 2.5 h] × age group	0.34	0.11	0.003
[Performance group = 2.5 - 3 h] × age group	-0.04	0.02	0.080	[Performance group = 2.5 - 3 h] × age group	0.50	0.09	< 0.001
[Performance group = 3 - 3.5 h] × age group	-0.02	0.02	0.360	[Performance group = 3 - 3.5 h] × age group	0.43	0.08	< 0.001
[Performance group = 3.5 - 4 h] × age group	0.03	0.02	0.209	[Performance group = 3.5 - 4 h] × age group	0.19	0.09	0.035
[Performance group => 4 h] × age group	0b	0		[Performance group => 4 h] × age group	0b	0	

Table 3. Mixed-Effects Regression Analysis in Men

Parameter	C	SEE	P Value	Parameter	C	SEE	P Value
Total race time, s				**Split 4**			
Intercept	16605	23	< 0.001	Intercept	6.83	0.03	< 0.001
Performance group = < 2 h	-10324	34	< 0.001	Performance group = < 2 h	11.34	0.05	< 0.001
Performance group = 2 - 2.5 h	-8572	29	< 0.001	Performance group = 2 - 2.5 h	7.18	0.04	< 0.001
Performance group = 2.5 - 3 h	-6747	27	< 0.001	Performance group = 2.5 - 3h	4.62	0.04	< 0.001
Performance group = 3 - 3.5 h	-5037	29	< 0.001	Performance group = 3 - 3.5 h	2.79	0.04	< 0.001
Performance group = 3.5 - 4 h	-3232	34	< 0.001	Performance group = 3.5 - 4 h	1.48	0.05	< 0.001
Performance group = > 4 h	0b	0		Performance group = > 4 h	0b	0	
Age group	48	3	< 0.001	Age group	-0.03	< 0.01	< 0.001
[Performance group = < 2 h] × age group	10	5	< 0.001	[Performance group = < 2 h] × age group	-0.12	0.01	< 0.001
[Performance group = 2 - 2.5 h] × age group	-27	4	0.070	[Performance group = 2 - 2.5 h] × age group	< 0.01	0.01	0.741
[Performance group = 2.5 - 3 h] × age group	-43	4	< 0.001	[Performance group = 2.5 - 3 h] × age group	0.02	< 0.01	< 0.001
[Performance group = 3 - 3.5 h] × age group	-43	4	< 0.001	[Performance group = 3 - 3.5 h] × age group	0.01	0.01	0.004
[Performance group = 3.5 - 4 h] × age group	-42	4	< 0.001	[Performance group = 3.5 - 4 h] × age group	0.01	0.01	0.030
[Performance group = > 4 h] × age group	0b	0		[Performance group = > 4 h] × age group	0b	0	
Split 1				**Change A**			
Intercept	10.43	0.03	< 0.001	Intercept	-10.08	0.25	< 0.001
Performance group = < 2 h	12.42	0.05	< 0.001	Performance group = < 2 h	18.80	0.39	< 0.001
Performance group = 2 - 2.5 h	8.07	0.04	< 0.001	Performance group = 2 - 2.5 h	11.19	0.32	< 0.001
Performance group = 2.5 - 3 h	5.25	0.04	< 0.001	Performance group = 2.5 - 3 h	3.72	0.31	< 0.001
Performance group = 3 - 3.5 h	3.27	0.04	< 0.001	Performance group = 3 - 3.5 h	1.01	0.33	0.002
Performance group = 3.5 - 4 h	1.77	0.05	< 0.001	Performance group = 3.5 - 4 h	0.20	0.38	0.593
Performance group = > 4 h	0b	0		Performance group = > 4 h	0b	0	
Age group	-0.06	< 0.01	< 0.001	Age group	0.20	0.03	< 0.001
[Performance group = < 2 h] × age group	-0.07	0.01	< 0.001	[Performance group = < 2 h] × age group	-1.12	0.06	< 0.001
[Performance group = 2 - 2.5 h] × age group	0.04	0.01	< 0.001	[Performance group = 2 - 2.5 h] × age group	-0.56	0.04	< 0.001
[Performance group = 2.5 - 3h] × age group	0.06	0.01	< 0.001	[Performance group = 2.5 - 3 h] × age group	-0.31	0.04	< 0.001
[Performance group = 3 - 3.5 h] × age group	0.06	0.01	< 0.001	[Performance group = 3 - 3.5 h] × age group	-0.29	0.04	< 0.001
[Performance group = 3.5 - 4 h] × age group	0.06	0.01	< 0.001	[Performance group = 3.5 - 4 h] × age group	-0.39	0.05	< 0.001
[Performance group = > 4 h] × age group	0b	0		[Performance group = > 4 h] × age group	0b	0	
Split 2				**Change B**			
Intercept	9.24	0.03	< 0.001	Intercept	15.76	0.43	< 0.001

Performance group = < 2 h	15.44	0.05	< 0.001	Performance group = < 2 h	7.05	0.65	< 0.001
Performance group = 2 - 2.5 h	9.39	0.04	< 0.001	Performance group = 2 - 2.5 h	13.12	0.54	< 0.001
Performance group = 2.5 - 3 h	5.35	0.04	< 0.001	Performance group = 2.5-3 h	19.39	0.52	< 0.001
Performance group = 3 - 3.5h	3.15	0.04	< 0.001	Performance group = 3 - 3.5 h	19.45	0.55	< 0.001
Performance group = 3.5 - 4 h	1.69	0.05	< 0.001	Performance group = 3.5 - 4 h	12.83	0.64	< 0.001
Performance group => 4 h	0b	0		Performance group => 4 h	0b	0	
Age group	-0.04	< 0.01	< 0.001	Age group	0.57	0.05	< 0.001
[Performance group = < 2 h] × age group	-0.29	0.01	< 0.001	[Performance group = < 2 h] × age group	-0.16	0.10	0.109
[Performance group = 2 - 2.5 h] × age group	-0.05	0.01	< 0.001	[Performance group = 2 - 2.5 h] × age group	-0.41	0.07	< 0.001
[Performance group = 2.5 - 3 h] × age group	0.02	0.01	< 0.001	[Performance group = 2.5 - 3 h] × age group	-0.57	0.07	< 0.001
[Performance group = 3 - 3.5h] × age group	0.02	0.01	< 0.001	[Performance group = 3 - 3.5 h] × age group	-0.42	0.07	< 0.001
[Performance group = 3.5 - 4 h] × age group	0.01	0.01	0.094	[Performance group = 3.5 - 4 h] × age group	-0.13	0.08	0.107
[Performance group => 4 h] × age group	0b	0		[Performance group => 4 h] × age group	0b	0	
Split 3				**Change C**			
Intercept	10.61	0.05	< 0.001	Intercept	-34.47	0.20	< 0.001
Performance group = < 2 h	19.59	0.08	< 0.001	Performance group = < 2 h	-5.17	0.30	< 0.001
Performance group = 2 - 2.5 h	13.27	0.06	< 0.001	Performance group = 2 - 2.5 h	-6.38	0.25	< 0.001
Performance group = 2.5 - 3 h	8.95	0.06	< 0.001	Performance group = 2.5 - 3 h	-6.44	0.24	< 0.001
Performance group = 3 - 3.5 h	5.99	0.06	< 0.001	Performance group = 3 - 3.5 h	-6.88	0.25	< 0.001
Performance group = 3.5 - 4 h	3.29	0.07	< 0.001	Performance group = 3.5 - 4 h	-4.70	0.29	< 0.001
Performance group => 4 h	0b	0		Performance group => 4 h	0b	0	
Age group	0.01	0.01	0.052	Age group	-0.33	0.02	< 0.001
[Performance group = < 2 h] × age group	-0.31	0.01	< 0.001	[Performance group = < 2 h] × age group	0.45	0.05	< 0.001
[Performance group = 2 - 2.5 h] × age group	-0.08	0.01	< 0.001	[Performance group = 2 - 2.5 h] × age group	0.38	0.03	< 0.001
[Performance group = 2.5 - 3 h] × age group	-0.03	0.01	< 0.001	[Performance group = 2.5-3h] × age group	0.33	0.03	< 0.001
[Performance group = 3 - 3.5 h] × age group	-0.01	0.01	0.273	[Performance group = 3-3.5 h] × age group	0.24	0.03	< 0.001
[Performance group = 3.5 - 4 h] × age group	0.01	0.01	0.489	[Performance group = 3.5 - 4 h] × age group	0.12	0.04	0.001
[Performance group => 4 h] × age group	0b	0		[Performance group => 4 h] × age group	0b	0	