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Pacing Profiles in Age Group Cross-Country Skiers in the Vasaloppet 2012-2016

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Abstract

Little is known for pacing profiles in age groups cross-country skiers. The aim of the present study was to examine the effect of sex, age and calendar year on pacing strategies in the largest ski marathon in the world. All finishers (n = 66,435) in 'Vasaloppet' from 2012 to 2016 were examined for 12 different age groups (G). There was an association between age group and sex (χ^2 = 1091.1, P < 0.001; Cramer's V = 0.13, P < 0.001), where the men-to-women ratio in each age group ranged from 3.29 (in G_{20}) to 64.36 (in G_{70}). A between-within subjects analysis of variance (ANOVA) showed a sex × split interaction of small magnitude (P < 0.001, η^2 = 0.019) on speed (v) indicating sex-specific pacing strategies. A main effect of sex on v was observed (P < 0.001), where men were faster than women (12.5 ± 3.3 *versus* 10.3 ± 2.4 km·h^{-1}, respectively). There was also a main effect of split on v of large magnitude (P < 0.001, η^2 = 0.517), where all eight splits differed ($v_2 > v_3 > v_8 > v_5 > v_4 > v_7 > v_6 > v_1$). In women and men, age groups differed (small magnitude) for v (P < 0.001, η^2 = 0.015 and η^2 = 0.031, respectively), with the fastest v observed in G_{21} and G_{40}, respectively. In women and men, an age group × split interaction on v of trivial magnitude was observed (P < 0.001, η^2 = 0.005 and η^2 = 0.007, respectively). Based on these findings, it was concluded (*i*) a relatively low participation of women with increasing age, (*ii*) different pattern of pacing in women and men, and (*iii*) the age of the fastest v differed by sex.

Key Words: aerobic capacity, aging, master athlete, performance, sex

Introduction

Pacing is defined as time per distance, usually minutes per kilometer or mile (11). The pacing strategy – or a plan how to distribute an athlete's potential – is decisive for a successful athletic performance (15) and has a considerable effect on performance in different endurance sports (1, 16). Abbiss and Laursen (1) postulated six different pacing strategies such as (i) negative pacing (*i.e.* increase in speed over time), (ii) positive pacing (*i.e.* continuous slowing over time), (iii) all-out pacing (*i.e.* maximal speed possible), (iv) even pacing (*i.e.* same speed over time), (v) parabolic-shaped pacing (*i.e.* positive and negative pacing in different segments of the race) and (vi) variable pacing (*i.e.* pacing with multiple fluctuations). It should be highlighted that race duration and topography may influence pacing. For instance, due to the steep uphill in the first split of Vasaloppet, a relatively slow start should be expected. Along with others (17), Abbiss and Laursen (1) stated that athletes in endurance sports often adopt a positive pacing strategy. However, these authors (1) did not exclude the possibility that an even pacing strategy may be optimal to successfully complete an endurance event.

Very little is known for pacing in cross-country skiing (5, 13, 30) especially with regards to the variation of pacing by age group. The 'Vasaloppet' is part of the races in the long distance cup Ski Clas-

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sics and is an important competition of cross-country ski worldwide, as it is the oldest (since 1922), the longest (90 km) and with the largest participation (5).

Cross-country skiing is a sport relying mostly on aerobic energy transfer system (14). The physiological demands of cross-country skiing have been assessed in races of various distances (4, 14). Maximal oxygen uptake (VO_2max) and body fat have been suggested as main determinants of performance (3, 35). A sex effect on performance (*i.e.* faster times in men than in women) has been observed (4), which has been attributed mostly to the higher VO_2max and lower body fat in men compared to women (42). Other important physiological correlates of performance included gross efficiency, lactate threshold and upper body coordination (2). Studies have also examined the biomechanical correlates of performance (18, 27, 37). In addition to the physiological and biomechanical parameters, performance is influenced by pacing (5, 30), *i.e.* the changes of speed during a race.

Endurance sport events such as the 'Vasaloppet' offer a great opportunity to study exercise as a model of efficient aging by comparing performance of groups differing for age. A previous study on performance in 'Vasaloppet' compared two age groups (*i.e.* 19-39 years *versus* 40-59 years) and found similar finish times and lower race time in the third split for the older group (5). In addition to age, sex is another parameter that might influence race speed and pacing. For instance, it has been shown that in the 5 km Virginia State Championship high school cross country running race, women slowed more than men from mile one to mile two when the whole sample was considered, but when only a part of the sample was analysed (*i.e.* the fastest athletes) men slowed the mostly (9). In the 'Vasaloppet', men were faster in splits 6, 7 and 8 (in total, there are eight split times), and women in splits 2, 3 and 4, but sexes had a similar overall race time (5).

Although pacing in 'Vasaloppet' has been already the subject of a previous study (5), there are several aspects that need further research. For instance, only two age groups (*i.e.* 19-39 *versus* 40-59 years) were considered and only 800 participants were analysed (5). The examination of more age groups would allow studying performance trends across ages. Also, the consideration of the whole number of participants might result in different findings compared to examining only a number of best athletes (9). Moreover, the men-to-women ratio in the participation to this race and performance variations across calendar years have not been previously examined. Knowledge about all the above-mentioned aspects would be of great practical value for coaches and health professionals working with cross-country skiers intending to compete in very long cross-country races.

Therefore, the aim of the present study was to investigate the effect of sex, age group and calendar year on race speed and pacing in all female and male age group cross-country skiers competing between 2012 and 2016 in the 'Vasaloppet'. Before 2012, data were incomplete for all age groups and time stations.

Materials and Methods

Ethics Approval

The institutional review board of St Gallen, Switzerland, approved this study. Since the study involved analysis of publicly available data, the requirement for informed consent was waived.

The Race

The 'Vasaloppet' is the oldest and longest cross-country ski race in the world and the race with the highest number of participants. The 'Vasaloppet' is held annually since 1922 on the first Sunday of March. The race has the full distance of 90 km with start in Sälen and finish in Mora. The race has seven time stations with the first at 11 km (Smågan), the second at 24 km (Mångsbodarna), the third at 35 km (Risberg), the fourth at 47 km (Evertsberg), the fifth at 62 km (Oxberg), the sixth at 71 km (Hökberg), and the seventh at 81 km (Eldris) where split times are taken.

Data Sampling and Data Analysis

Data were obtained from the official race website http://www.vasaloppet.se/. We examined 66,514 finishers; however information on age group was missing for 79 finishers who were excluded from further analysis. All finishers (n = 66,435), 8,026 women and 58,409 men, in 'Vasaloppet' from 2012 to 2016 were classified into 12 different age groups (G) according to the records of the race: G_{20}, 19 and 20 yrs; G_{21}, 21 yrs; G_{35}, 22-35 yrs; G_{40}, 36-40 yrs; G_{45}, 41-45 yrs; G_{50}, 46-50 yrs; G_{55}, 51-55 yrs; G_{60}, 56-60 yrs; G_{65}, 61-65 yrs; G_{70}, 66-70 yrs; G_{75}, 71-75 yrs; G_{80}, 76-80 yrs. No women participated in G_{75} and G_{80}.

Statistical Analysis

Statistical analyses were performed using IBM SPSS v.20.0 (SPSS, Chicago, IL, USA) and GraphPad Prism v. 7.0 (GraphPad Software, San Diego, CA, USA). Both numerical (Kolmogorov-Smirnov test) and graphical methods (visual inspection of normal Q-Q plots) were used to test normality of data. Data were expressed as mean and standard deviations of the mean (SD). The men-to-women ratio was calculated

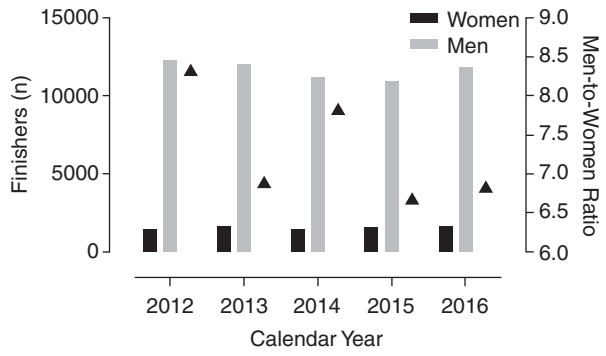

Fig. 1. Finishers by sex and year, ▲ = men-to-women ratio.

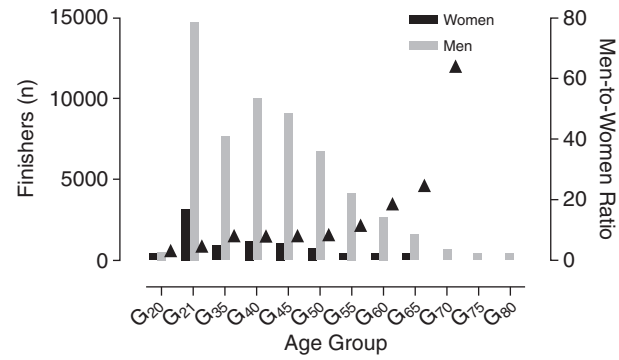

Fig. 2. Finishers by sex and age group, ▲ = men-to-women ratio.

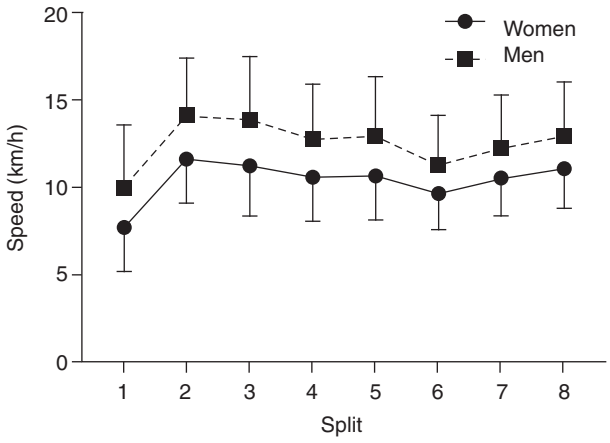

Fig. 3. Race speeds of skiers by split and sex. Error bars represent SD. All splits differed among them for race speed.

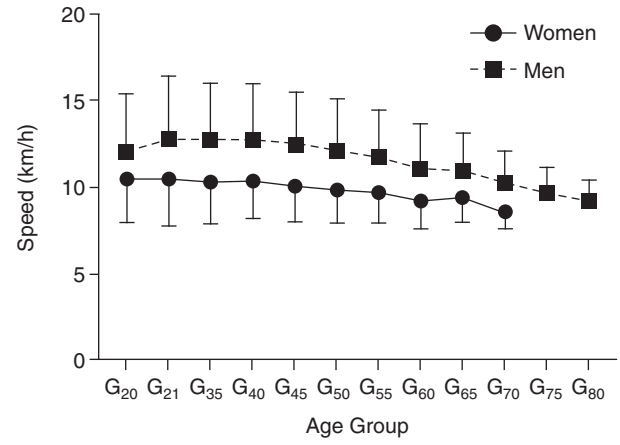

Fig. 4. Race speeds of skiers by age group. Error bars represent SD.

as the quotient of men to women finishers for each age group. A chi-square test (χ^2) examined the association between calendar year and sex, and between age group and sex. The magnitude of these associations was tested by Cramer's V. A between-within subjects analysis of variance (ANOVA) examined the main effects of split and sex, and the sex × split interaction, on race speed, where the within-subjects factor was split and the between-subjects factor consisted of sex. Also, within each sex, a between-within subjects ANOVA tested the main effects of split and age group on race speed, and the age group × split interaction, where the within-subjects factor was split and the between-subjects factor was age group. Subsequent comparisons among age groups were carried out using *post-hoc* Bonferroni test. The magnitude of the differences among groups was examined using effect size eta square (η^2) and was evaluated as following: small ($0.010 < \eta^2 \leq 0.059$), moderate ($0.059 < \eta^2 \leq 0.138$) and large ($\eta^2 > 0.138$) (7). Significance level was set at alpha = 0.05.

Results

Participation

A chi-square test showed an association between calendar year and sex ($\chi^2 = 51.6$, $P < 0.001$; Cramer's V = 0.03, $P < 0.001$), *i.e.* the men-to-women ratio ranged from 6.69 (2015) to 8.34 (in 2012) (Fig. 1). A chi-square test showed an association between age group and sex ($\chi^2 = 1091.1$, $P < 0.001$; Cramer's V = 0.13, $P < 0.001$), *i.e.* the men-to-women ratio ranged from 3.29 (in G_{20}) to 64.36 (in G_{70}) (Fig. 2).

Sex, Split and Race Speed

A between-within subjects ANOVA showed a small sex × split interaction on speed (v) ($P < 0.001$, $\eta^2 = 0.019$) (Fig. 3). A main effect of sex on v was observed ($P < 0.001$), where men were faster than women (12.5 ± 3.3 *versus* 10.3 ± 2.4 km/h, respectively). There was also a large main effect of split on

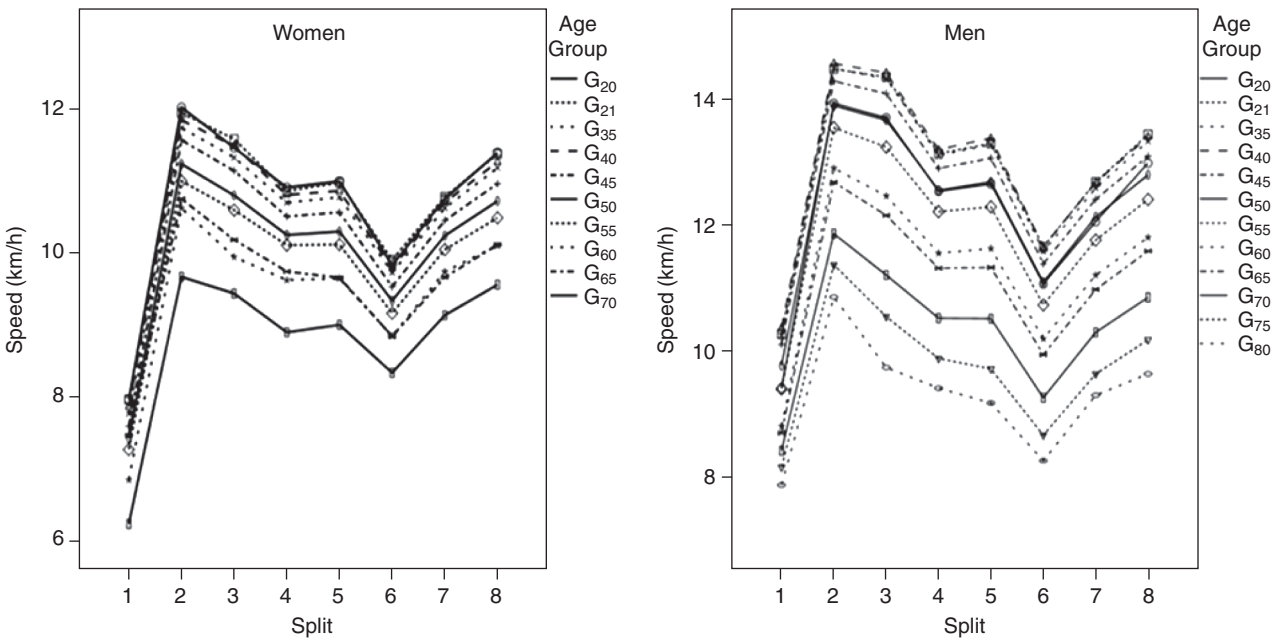

Fig. 5. Race speeds of skiers by split and age group. Circles represent means.

v ($P < 0.001$, $\eta^2 = 0.517$), where all splits differed ($v_2 > v_3 > v_8 > v_5 > v_4 > v_7 > v_6 > v_1$). Men were faster than women in each of the eight split (first: +22.3%, second: +17.4%, third: +19.0%, fourth: +16.8%, fifth: +17.1%, sixth: +14.4%, seventh: +14.3% and eighth: +14.7%). Based on the observed sex × split interaction on v, compared to men, women increased v more from the first to the second split, and decreased v more from the second to the third split.

Age Groups, Split and Race Speed

In women, age groups differed for v ($P < 0.001$, $\eta^2 = 0.015$, small magnitude), where significant differences were observed between G_{20} and G_{55}, G_{20} and G_{60}, G_{21} with G_{45}-G_{65}, G_{35} with G_{50}-G_{60}, G_{40} with G_{50}-G_{60}, G_{45} and G_{60} (Fig. 4), in which the older groups had a slower v. In men, age groups differed for v ($P < 0.001$, $\eta^2 = 0.031$, small magnitude), where all age groups differed, except between G_{20} and G_{45}, G_{20} and G_{50}, G_{20} and G_{55}, G_{21} and G_{35}, G_{21} and G_{40}, G_{35} and G_{40}, G_{60} and G_{65}, G_{65} and G_{80}, G_{70} and G_{75}, G_{70} and G_{80}, G_{75} and G_{80}. The differences in men showed slower v in the older groups, too.

In women, a trivial age × split interaction on v was observed ($P < 0.001$, $\eta^2 = 0.005$) (Fig. 5, left). There was also a large main effect of split on v ($P < 0.001$, $\eta^2 = 0.220$), where splits differed among them, except between 3 and 8, 4 and 5, 4 and 7, 5 and 7 splits. In men, there was a trivial age × split interaction on v ($P < 0.001$, $\eta^2 = 0.007$) (Fig. 5, right). A moderate main effect of split on v was observed ($P < 0.001$, $\eta^2 = 0.120$), where all splits differed among them.

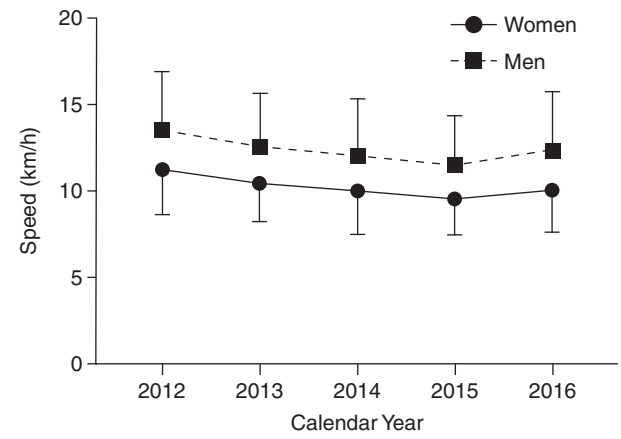

Fig. 6. Race speeds of skiers by calendar year and sex. Error bars represent SDs. All calendar years differed among them for race speed.

Calendar Year and Race Speed

A two-way ANOVA showed a trivial sex × calendar year interaction on v ($P = 0.012$, $\eta^2 < 0.001$). A small main effect of calendar year on v was observed ($P < 0.001$, $\eta^2 = 0.016$), where all calendar years differed with higher v in 2012 and lower v in 2015 (Fig. 6). In women, no age group × year interaction on v was found ($P = 0.412$, $\eta^2 = 0.005$) (Fig. 7, left), whereas such interaction was observed in men ($P < 0.001$, $\eta^2 < 0.001$, trivial magnitude) (Fig.

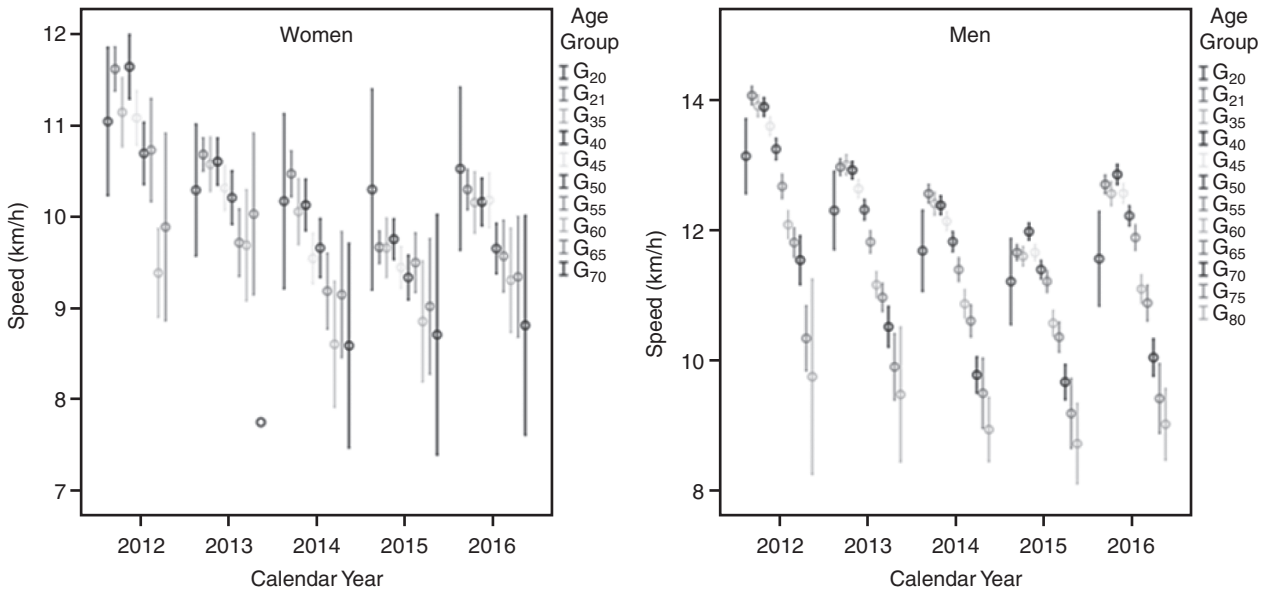

Fig. 7. Race speeds of skiers by year, sex and age group. Circles and error bars represent means and SD, respectively.

7, right).

Discussion

The main findings of the present study were that (i) the men-to-women ratio in the finishers was higher in the older age groups, indicating a relatively low participation of women compared to men with increasing age, (ii) the fastest race times were observed in G_{21} in women and in G_{40} in men, (iii) a different pattern of pacing was observed in women and men, (iv) in both sexes, there was a trivial difference in the pattern of pacing among age groups, and (v) small and trivial differences in race speed and pacing, respectively, were observed among calendar years.

Participation Trends

During the period 2012-2016, the number of women increased relative to men, as it was indicated by the men-to-women ratio. This observation was in agreement with the existing literature. For instance, female participation in endurance and ultra-endurance races is generally lower compared to men (8) but increased in the last decades (34). We also found an increase in the men-to-women ratio with increasing age which has also been recently reported for age group breaststroke swimmers aged 25-29 to 95-99 years and competing between 1986 and 2014 in the FINA (Fédération Internationale de Natation) World Masters Championships (24).

Differences in Pacing between Women and Men

An important finding was the different pattern of pacing (*e.g.* a larger increase of speed from the first to the second split in women than in men and a larger decrease from the second to the third split). The faster speed observed in men than in women should be attributed to sex differences in performance characteristics. For instance, it has been shown that men needed less time to complete a short time trial and revealed a lower fractional utilization of VO_2max (33). In addition, a comparison between sexes indicated that men had higher power output, VO_2peak and lean mass (19). Sex differences in pacing in 5 km running race have been attributed to psychological aspects of decision making, *e.g.* over-confidence, risk perception and willingness to tolerate discomfort (9).

Comparison of Pacing among Age Groups

A further finding was a trivial difference in the pattern of pacing among age groups. The trivial magnitude of the age group × split interaction on race speed in both sexes indicated that the statistical significance ($P < 0.001$) of this finding should be attributed to the very large number of participants, rather than to the existence of different pacing strategies among age groups. Since the pacing had multiple fluctuations, it should be classified as variable pacing (1). A major characteristic of the pacing in Vasaloppet was the relatively slow first split, which was due to the difficult terrain (uphill) and the difficulties to pass other participants (5). Considering

the race without the first split, a parabolic-shaped pacing was observed, a positive pacing (increased race time and decreased speed) till the sixth split and a negative pacing (decreased race time and increased speed) in the last two splits.

Two main factors might account for different pacing strategies among age groups. On the one hand, the older groups would be expected to exhibit a larger decline in their performance during the race due to lower aerobic capacity (28). On the contrary, the younger groups would be supposed to show larger decline in their performance during the race according to their initial higher race speed (25, 40). Based on our findings, it was concluded that these two factors offset each other resulting in a similar pacing strategy among age groups. Furthermore, other factors, such as changes in ski track due to changes in weather (*i.e.* since the older age groups are slower, they pass across a particular point much later than their younger counterparts and may face different weather conditions) may also influence pacing among age groups.

Best Performance Earlier in Life for Women

A further important finding was that the fastest race time was observed in G_{21} in women and in G_{40} in men. Overall, women achieved their fastest race time ~20 years earlier in life than men. This difference is very exceptional when compared to other endurance and ultra-endurance athletes. In elite marathoners, women (29.8 ± 4.2 years) were older than men (28.9 ± 3.8 years) (21). In Ironman-triathlon, women and men peak at a similar age of ~32-33 years with no sex difference (46). Similarly, women and men 100-km ultra-marathoners achieved their fastest race time at the same age of ~35 years (6).

A very likely explanation for this difference between women and men in 'Vasaloppet' could be the difference in anthropometric and physiological characteristics. Female endurance athletes have a lower skeletal muscle mass (36) and a higher body fat (26) compared to male endurance athletes. A higher percentage of slow twitch muscle fibres and higher anaerobic threshold and low percentage of body fat have been observed in elite cross-country skiers (12, 20, 38).

Regarding physiological characteristics, very large correlations between skiing speed and oxygen uptake do exist (31). Cross country skiers are char acterized by extremely high VO_2max where values of ~6 l/min and 88 ml/kg/min have been reported (17). VO_2max correlated largely with ranking in ski races (35). Thus, the higher VO_2max in men (22, 33) explains their faster race speed compared to women. Another physiological characteristic associated with performance is gross efficiency, the quotient of work rate by metabolic rate (2). In addition to the abovementioned anthropometric and physiological differences between women and men, sex differences have also been reported about technical characteristics such as cycle length (43).

Differences in Performance between Editions

We found an overall faster speed in 2012 and a slower speed in 2015. It has been supported that performance in outdoor sports such as cross-country ski might reach asymptotic limits and occasionally might benefit from technological advances (10). However, lower speeds might also be attributed to environmental conditions such as cold, wind and the type of snow (47). Moreover, the decrease of the speed across years might be attributed to changes in participation. Although the overall participation was similar in both 2012 and 2016, there was an increase of women participants (probably slower than the average) and a decrease of men participants (probably faster than the average) across years that were reflected to a decreased men-to-women ratio.

Limitations, Strength and Practical Applications

This study has some limitations since anthropometric and physiological characteristics (39) as well as training aspects (23, 43) of these more than 66,000 finishers are not known. Furthermore, environmental conditions (47) and race equipment (20) might considerably influence race outcome. 'Vasaloppet' is a race performed in a relatively flat terrain, which implies the increased use of the upper-body dominant technique of double poling; thus, the present findings should not be generalized to races with large elevations. Moreover, this race is characterized by a large number of participants, which results in large delays in the start, *i.e.* the start has been given, but many athletes stand in a queue waiting behind other skiers. In this large field of athletes, drafting is possible but has not been considered in our analysis. Drafting can have a considerable influence on performance where weaker athletes can draft behind faster athletes (41). For athletes and coaches, women were faster at a younger age compared to men in this 90-km cross-country skiing race. In addition, the trivial magnitude of the age group × split interaction on race speed suggested that all age groups adopted a similar pacing strategy and thus, there was no need for specific pacing guidelines for the older age groups. It was assumed than in races with large elevations, the additional muscle work might influence differently the pacing of age groups. The findings on the differences in race speed among age groups would be

important for coaches in order to develop age-tailored training programs.

In summary, in 'Vasaloppet' held between 2012 and 2016, the number of women increased relative to men but their number decreased relative to men in the older age groups and women achieved their fastest race time at an earlier age (G_{21}) compared to men (G_{40}). It was also concluded that age groups showed similar pacing suggesting a lack of aging effect on this performance-related parameter.

Conflict of Interests

The authors declare that there are no conflicts of interests.

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