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The Differences in Pacing Among Age Groups
of Amateur Cross-Country Skiers Depend on Performance

by
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Pacing strategies have mainly been investigated for runners, but little is known for cross-country skiers. The aim of the present study was to examine the effects of performance and age on pacing strategies in cross-country skiing. All finishers (women, n = 19,375; men, n = 86,190) in the 'Engadin Ski Marathon' (42 km) between 1998 and 2016 were analysed for the percentage change of speed at 10 km (Change A), 20 km (Change B) and 35 km (Change C). They were classified in performance groups according to quartiles of average race speed (Q1, Q2, Q3 and Q4) and in 5-year age groups (<20, 20-24, 25-29… 85-89 years). Men were faster than women by +14.3% (15.2 ± 4.0 vs. 13.3 ± 3.3 km/h; p < 0.001, η2 = 0.215). A small impact of age group × performance group interaction on Change A was shown in women (p < 0.001, η2 = 0.026) and men (p < 0.001, η2 = 0.025), where Q1 augmented and Q4 attenuated the decrease in speed with aging. However, the impact of age group × performance group interaction on Change B and C was trivial (p = 0.002, η2 ≤ 0.010). Based on these findings, it was concluded that the differences in pacing among age groups depended on the performance level. Thus, the coaches and fitness trainers working with cross-country skiers should advise their athletes to consider both age and performance.

Key words: age, endurance, master athlete, winter sport.

Introduction

Pacing strategy during an endurance event can have a significant impact on overall performance. Abbiss and Laursen (2008) described six different pacing strategies, such as negative, all-out, positive, even, parabolic-shaped and variable pacing. Generally, during endurance events, well trained athletes tend to adopt a positive pacing strategy, where the athlete progressively slows after having reached peak speed (Abbiss and Laursen, 2008). Aspects of pacing have preferably been investigated in running events of different distances in track-running from 800 m to 10,000 m (Aragón et al., 2016; Thiel et al., 2012; Tucker et al., 2006) and road running races of distance such as 5 km (Deaner and Lowen, 2016), 10 km (Lima-Silva et al., 2010), a half-marathon (Hanley, 2015), a marathon (Deaner et al., 2014; Ely et al., 2008;

Haney and Mercer, 2011; Hanley, 2016; March et al., 2011), a 100 km ultra-marathon (Knechtle et al., 2015; Lambert et al., 2004; Rüst et al., 2015; Tan et al., 2016), a 161 km ultra-marathon (Hoffman, 2014; Parise and Hoffman, 2011; Tan et al., 2016), a 173 km ultra-marathon (Kerhervé et al., 2016), in running events of different duration such as a 6-hour run (Giovanelli et al., 2016), a 24-hour run (Bossi et al., 2016), and in cross-country running (Esteve-Lanao et al., 2014; Hanley, 2014). However, limited information exists about the effect of sex, age and performance on pacing in cross-country skiing, which is one of the most popular sports in Scandinavia, central Europe and countries with cold climate such as Canada and Russia (Carlsson et al., 2016; Losnegard et al., 2016).

In cross-country skiing, different variables

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such as sex, age, a performance level and experience seem to influence pacing strategy (Carlsson et al., 2016; Losnegard et al., 2016). Regarding sex, women and men competing in 10 km and 15 km cross-country skiing races held in the World Cup, World Championships, and the Olympic Games demonstrated a positive pacing pattern shown by a decline in velocity from the first to the last lap (Losnegard et al., 2016). In longer cross-country skiing races such as the 90 km Vasaloppet, women showed a more even pacing profile than men with the same finish time, start group, age, and race experience, with men being faster in the first half of the race and women faster in the second half (Carlsson et al., 2016).

Also, the performance level has an influence on pacing in cross-country skiing. During 10 km and 15 km cross-country skiing races in the World Cup, World Championships, and the Olympic Games, slower male skiers were characterized by a quick start relative to their average velocity, with a greater decrease during the race compared with the fastest skiers (Losnegard et al., 2016).

Another aspect that relates to pacing, but has not been studied in cross-country skiers yet, is the effect of age, i.e. whether younger and older skiers differ in pacing. In other sports disciplines such as running and swimming, pacing of different age groups has been investigated. For 100 km ultra-marathoners, it has been shown that younger athletes (i.e. age group 18-24 years) were slower than older athletes and older athletes did not slow down more than younger athletes (Rüst et al., 2015). In master swimmers competing in the 2014 FINA World Masters Championships in 100 m, 200 m, 400 m, and 800 m freestyle in age groups from 25-29 years to 90-94 years, pacing patterns differed by age groups for all distances with younger swimmers showing more even pacing (Nikolaidis and Knechtle, 2017b). On the other hand, it has been shown that older marathon runners adopted a more even pacing strategy than their younger counterparts (March et al., 2011). Thus, pacing in cross-country skiing would be expected to vary by age.

Although the above mentioned studies have improved our understanding of the separate effects of sex, age and performance on pacing in endurance sports, two main gaps in the relevant literature may be identified; first, the effect of age

has not been examined in cross-country skiers, and, second, no information about the impact of age×performance interaction on pacing exists. The information on the effect of age and, particularly, its interaction with the performance level would interest scientists focusing on pacing in endurance sports and coaches working with cross-country skiers in order to optimize their training and competition. Since pacing strategy is an important factor in attaining high performance standards in cross-country skiing (Losnegard et al., 2016), coaches and their athletes should focus on pacing during training considering the specific demands by sex, age and performance. Usually, coaches train athletes in small groups varying for age and performance, e.g. slow cross-country skiers differing for age, thus prescribing age- and performance-tailored exercise is a challenge. Therefore, being aware of the combined effect of age and performance on pacing would assist coaches in developing age- and performance-tailored pacing strategies. Despite the body of knowledge on pacing derived from studies on running, cross-country skiing has unique characteristics (e.g. larger muscle activity of upper limbs compared to running, human×equipment interaction) that may influence age-related differences in performance and pacing (Knechtle and Nikolaidis, 2017). Therefore, the aim of this study was to investigate whether differences in pacing strategies existed between younger and older cross-country skiers competing in a cross-country skiing race covering the distance of a marathon. Moreover, we aimed to compare the pacing strategy of cross-country skiers with similar performance and different age.

Methods

Design and procedures

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 42 km 'Engadin Ski Marathon' is an annually held cross-country ski race taking place on the second Sunday of March in the upper Engadin valley in Switzerland, Europe. Each year, between 11,000 and 13,000 skiers participate in this race. Participation is open to anyone older than 16.

The start of the race takes place in Maloja with an elevation of 1,820 m above sea level. Split

times are taken at the time stations in Silvaplana (Change A, 10 km, 1,790 m above sea level), Pontresina (Change B, 20 km, 1,805 m above sea level) and La Punt-Chamues-ch (Change C, 35 km, 1,687 m above sea level). The finish is in S-chanf at 1,670 m above sea level.

Participants

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. The initial sample included 105,587 participants. Twenty-two participants, whose information on split times was missing, were excluded from further analysis, resulting in a final sample of 105,565 participants.

Statistical analyses

Descriptive statistics (mean ± standard deviation) were used for all variables. We created performance groups according to quartiles of average race speed (Q1, Q2, Q3 and Q4) in total and within each age group. This approach allowed a 'relative' comparison among age groups, *e.g.* the faster 50-55 years athletes were compared with the faster 20-25 years athletes for pacing; however, we acknowledged that these groups differed for performance. Quartiles have been used previously to study the effect of performance on pacing in marathon runners (Nikolaidis and Knechtle, 2017a; Renfree and St Clair Gibson, 2013; Santos-Lozano et al., 2014) and triathletes (Knechtle and Nikolaidis, 2016). A two-way ANOVA examined the main effects of sex, age group, performance group and split, and the impact of performance group×split and performance group×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 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. The statistical packages IBM SPSS v.20.0 (SPSS, Chicago, USA) and GraphPad Prism v. 7.0 (GraphPad Software, San Diego, USA) were used to perform all statistical analyses. Alpha level was set at 0.05.

Results

Sex × performance group

A large main effect of sex on mean speed was observed ($p < 0.001$, $\eta^2 = 0.215$), where men were faster than women by +14.3% (15.2 ± 4.0 vs. 13.3 ± 3.3 km/h). Also, a large main effect of performance group on speed was shown ($p < 0.001$, $\eta^2 = 0.767$). A small impact of sex×performance interaction on speed was found ($p < 0.001$, $\eta^2 = 0.031$), where sex difference was larger in the faster and smaller in the slower performance groups, *i.e.* 15.7%, 16.3%, 14.5% and 10.4% in Q1, Q2, Q3 and Q4, respectively (Table 1).

In split 1, 2, 3 and 4, similar performance- and sex-related trends as in the overall speed were observed: (*i*) men were faster than women, (*ii*) split 3 was the fastest and split 4 the slowest, and (*iii*) the sex difference decreased with decreasing performance. With regard to changes of speed, the largest effect of performance group was shown in Change A and the lowest in Change C. In Change A and B, the fastest group (Q1) changed speed the less, especially compared to Q2 and Q3.

Age group × performance group

Considering the quartiles of all participants, an age group×performance quartile association was observed, where the prevalence of the fastest quartile (Q1) decreased with increasing age in both women ($\chi^2 = 1002.48$, $p < 0.001$, $\varphi = 0.227$) and men ($\chi^2 = 6840.53$, $p < 0.001$, $\varphi = 0.282$) (Figure 1). Thus, we considered only performance quartiles calculated separately for each age group in the subsequent analyses.

The speed of women and men by split expressed as percentage of split 1 (100%) can be seen in Figure 2. A trivial main effect of age group on Change A was observed in women ($p < 0.001$, $\eta^2 = 0.006$) and men ($p < 0.001$, $\eta^2 = 0.003$), where the younger group had the smaller change (Figure 3). A small impact of age group×performance group interaction on Change A was shown in women ($p < 0.001$, $\eta^2 = 0.026$) and men ($p < 0.001$, $\eta^2 = 0.025$), where Q1 attenuated and Q4 augmented the decrease in speed with aging. In Change B, a trivial main effect of age group was observed in women ($p < 0.001$, $\eta^2 = 0.002$) and men ($p < 0.001$, $\eta^2 = 0.002$) (Figure 4). An impact of age group×performance group interaction on Change B was shown in women ($p = 0.002$, $\eta^2 = 0.002$, trivial magnitude) and

men ($p < 0.001$, $\eta^2 = 0.010$, small magnitude). In Change C, a trivial main effect of age group was observed in women ($p < 0.001$, $\eta^2 = 0.002$) and men ($p < 0.001$, $\eta^2 = 0.002$) (Figure 5). To summarise, the effect of age group on change of speed was trivial and this magnitude was similar in women and men. The magnitude of the effect of age group×performance group interaction on change of speed was similar in both sexes, except for Change B (larger in men than in women).

To sum up, a small age group×performance group interaction was observed only in Change A for both women and men and in Change B for men, whereas it was trivial in the other cases.

Table 1

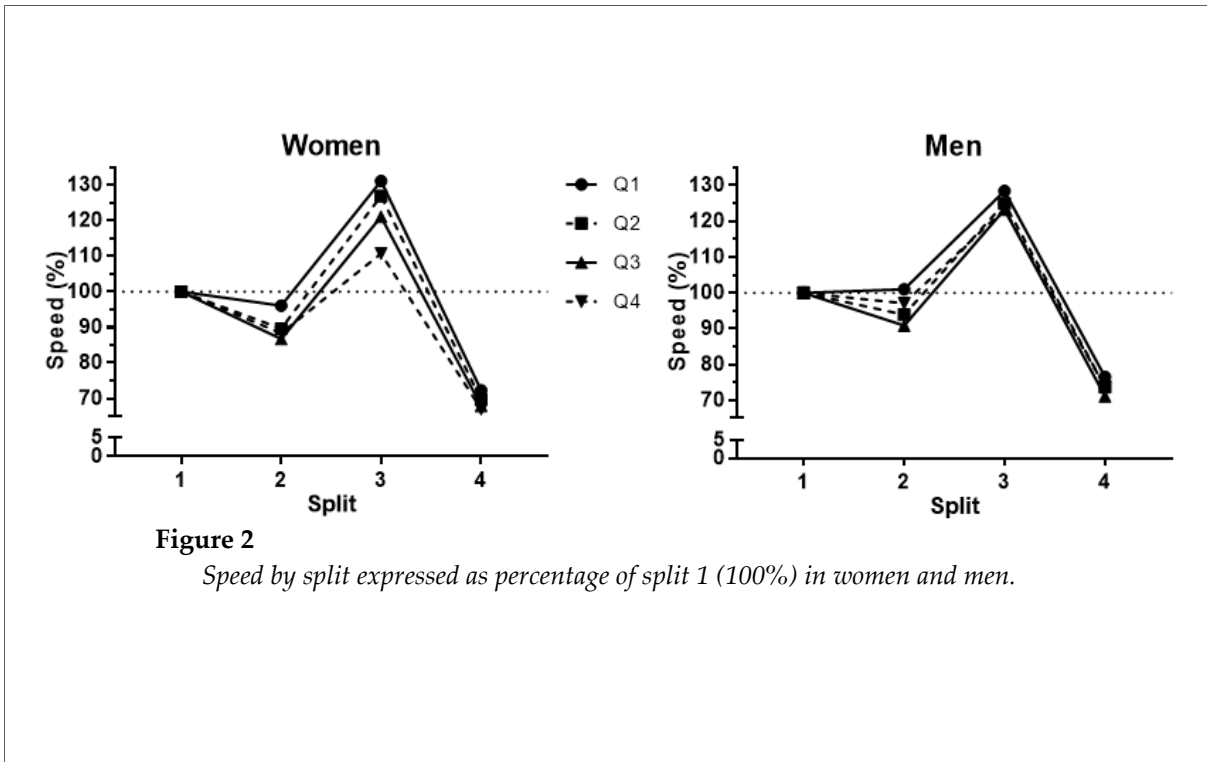*Speed and percentage change of speed by split, performance group and sex.*

	Women				Men				Effect size (η^2)		
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Performance	Sex	Interaction
Average (km/h)	17.7 ± 2.4	13.9 ± 0.6	12.0 ± 0.6	9.4 ± 1.1	20.5 ± 2.2	16.2 ± 0.8	13.7 ± 0.7	10.4 ± 1.5	0.767	0.215	0.031
Split 1 (km/h)	17.7 ± 2.2	14.5 ± 1.0	12.8 ± 1.0	10.3 ± 1.6	20.0 ± 2.2	16.4 ± 1.1	14.2 ± 1.1	10.3 ± 1.3	0.672	0.139	0.014
Split 2 (km/h)	17.0 ± 2.8	13.0 ± 1.0	11.1 ± 0.9	9.1 ± 1.2	20.2 ± 2.6	15.4 ± 1.4	12.9 ± 1.1	10.0 ± 1.4	0.692	0.184	0.035
Split 3 (km/h)	23.2 ± 3.9	18.4 ± 2.3	15.5 ± 1.9	11.4 ± 2.0	25.7 ± 3.0	20.5 ± 1.9	17.5 ± 1.9	12.7 ± 2.5	0.676	0.088	0.005
Split 4 (km/h)	12.8 ± 2.1	10.1 ± 1.0	8.7 ± 0.9	6.9 ± 1.0	15.3 ± 2.1	12.1 ± 1.1	10.1 ± 1.0	7.6 ± 1.2	0.648	0.169	0.033
Change A (%)	-4.4 ± 10.2	-10.1 ± 8.8	-12.6 ± 8.2	-10.3 ± 12.8	1.1 ± 9.4	-5.5 ± 10.1	-8.9 ± 9.7	-9.9 ± 10.9	0.071	0.018	0.005
Change B (%)	38.3 ± 20.6	43.3 ± 22.9	40.1 ± 21.0	26.0 ± 21.3	27.9 ± 9.9	33.5 ± 14.4	36.6 ± 18.8	26.7 ± 22.1	0.044	0.015	0.010
Change C (%)	-43.8 ± 10.2	-44.4 ± 9.5	-43.1 ± 8.6	-38.5 ± 10.4	-40.0 ± 6.5	-40.6 ± 7.4	-39.0 ± 9.3	-40.4 ± 7.8	0.021	0.010	0.008

All main effects and interactions were significant at $p < 0.001$.
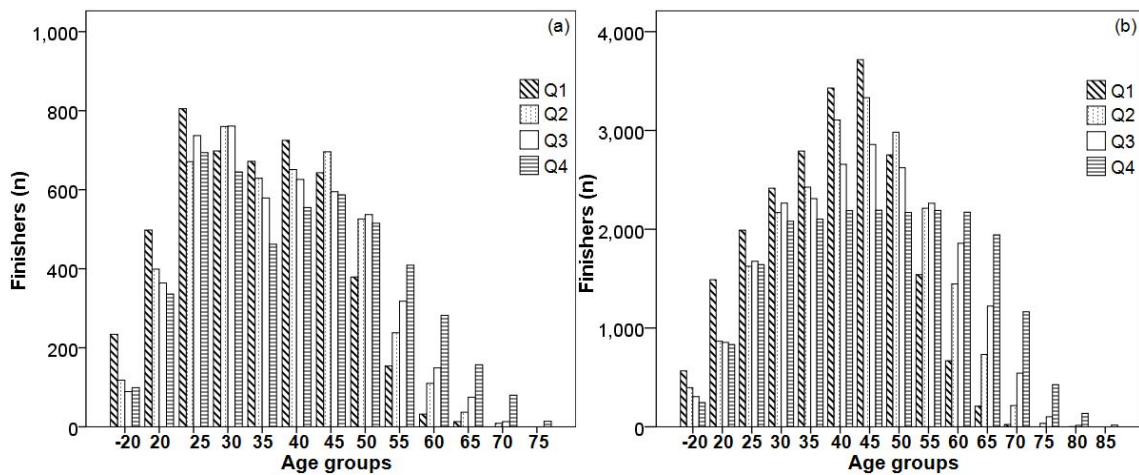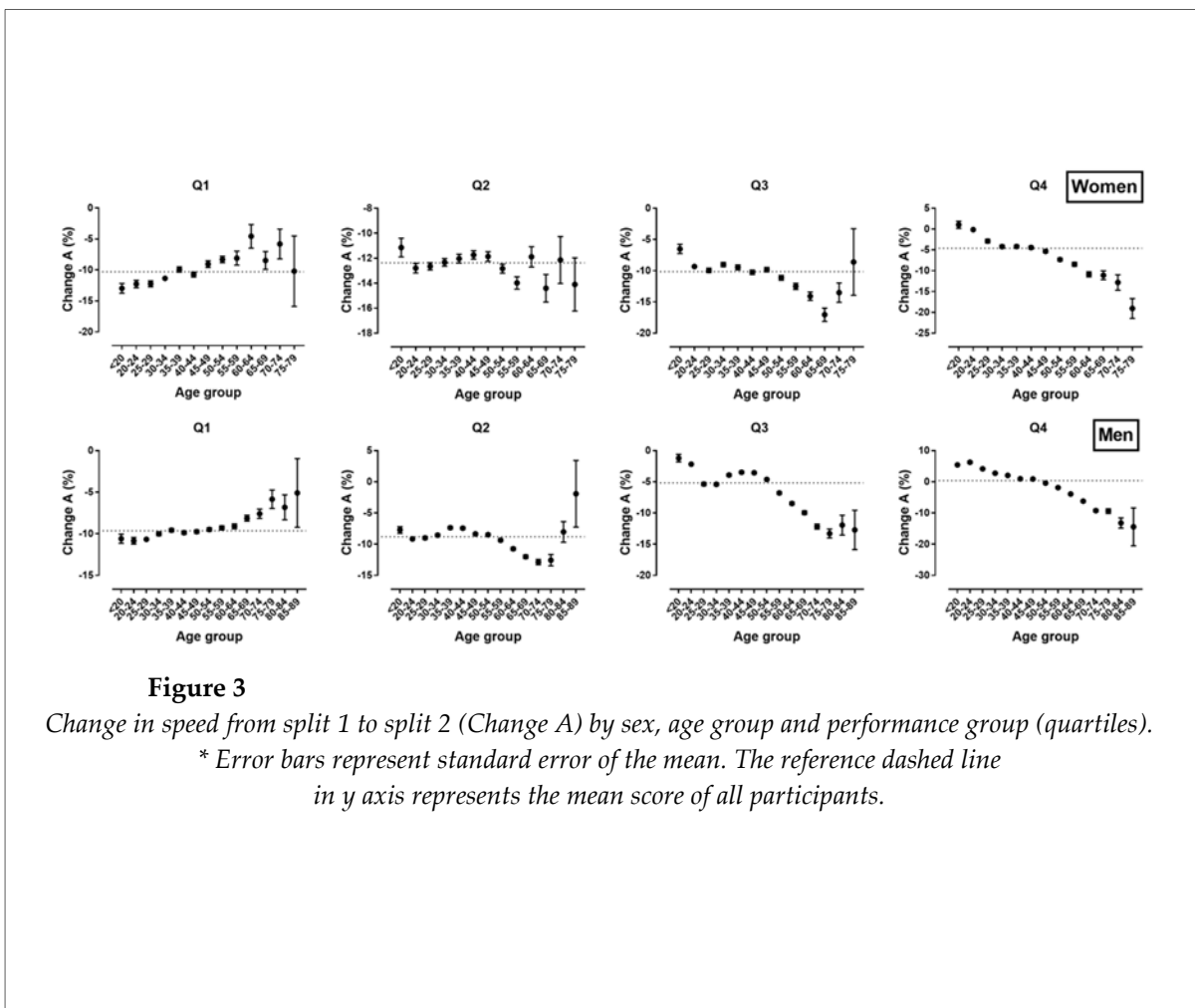

Figure 1

Distribution of overall performance (speed, km/h) quartiles by age group in women (a) and men (b)

Figure 2
Speed by split expressed as percentage of split 1 (100%) in women and men.

Figure 3
Change in speed from split 1 to split 2 (Change A) by sex, age group and performance group (quartiles).
* Error bars represent standard error of the mean. The reference dashed line
in y axis represents the mean score of all participants.

Figure 4

Change in speed from split 2 to split 3 (Change B)
by sex, age group and performance group (quartiles).
* Error bars represent standard error of the mean.
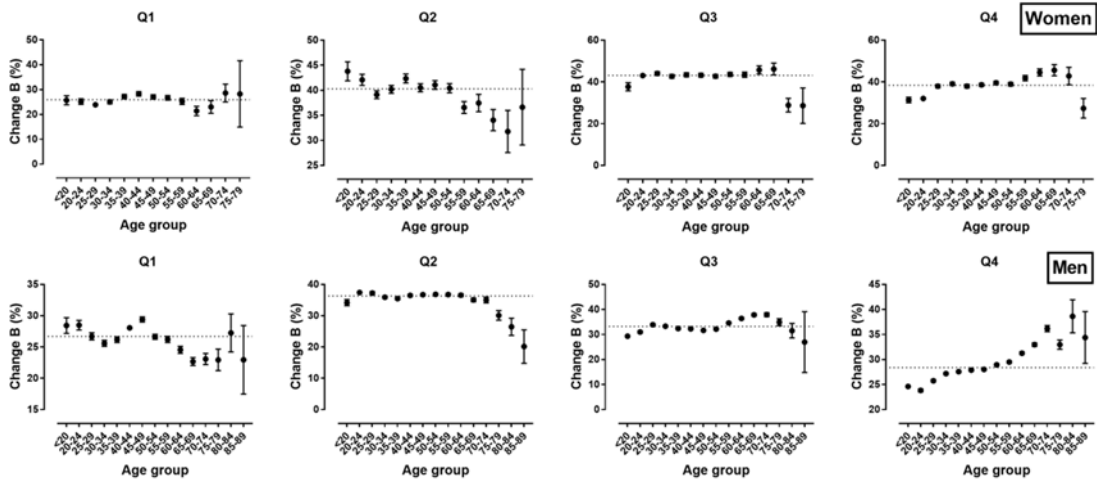*The reference dashed line in y axis represents the mean score of all participants.*

Figure 5

Change in speed from split 3 to split 4 (Change C) by sex, age group
and performance group (quartiles).
* Error bars represent standard error of the mean.
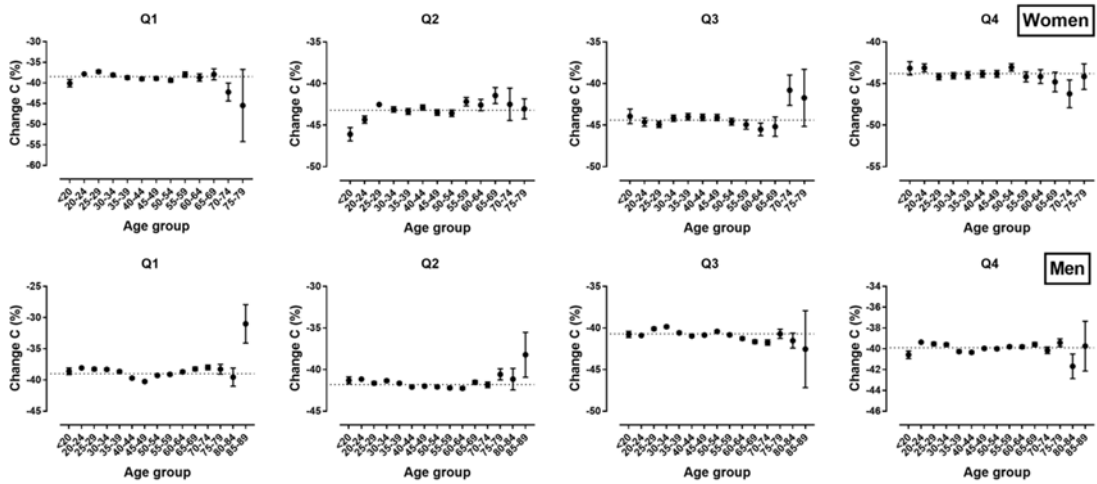*The reference dashed line in y axis represents the mean score of all participants.*

Discussion

The main findings of the present study were that (*i*) men were faster than women and the sex difference was larger in the faster and smaller in the slower performance groups, (*ii*) the largest effect of performance group was shown in Change A and the lowest in Change C, where in Change A and B, the fastest group (Q1) changed speed the less, especially compared to Q2 and Q3, and (*iii*) a small age group×performance group interaction was observed only in Change A for both women and men and in Change B for men.

Difference in pacing between faster and slower skiers

A major finding was that the fastest skiers (Q1) changed their speed less in the beginning of the race (*i.e.* Change A and B) compared to slower skiers (Q2 and Q3). Particularly, Q1 was the only group that decreased the least (women) or increased slightly (men) its speed in Change A, whereas the other groups decreased speed. In Change B, Q1 showed the smaller increase of speed compared to Q2 and Q3, which should be attributed to the relatively superior performance of fast skiers in the first two splits.

This finding is most probably due to the hilly course with ascents and descents and the length of the race. The third split has a length of 15 km and a descent from 1,805 to 1,687 m above sea level, which might explain that this section was the fastest in the race. The last section has a length of 7 km and a descent from 1,687 to 1,670 m above sea level. Most probably the athletes were exhausted after the first 35 km and therefore not able to increase speed compared to the first split which has also a descent from 1,820 to 1,790 m above sea level. Another explanation might be that despite the descent during the third split that one would expect to result in increased speed, this split included many changes of altitude (ascents and descents). Such changes in altitude might induce counteracting forces, such as increased potential energy on uphill slopes, air resistance and friction between skis and snow, slowing race speed (Carlsson et al., 2016).

It is well known for runners that high and low performance runners adopt different pacing strategies (Lima-Silva et al., 2010). In female marathoners competing in the Women's Marathon Championship, the fastest runners were the fastest in all segments, and differences in speed between faster and slower athletes increased throughout the race. The fastest runners ran at lower relative speeds than other runners for the first two 5 km segments, but at higher relative speeds after 35 km (Renfree and St Clair Gibson, 2013). In athletes competing in Olympic and World Championship marathons, female and male medallists maintained even-paced running from 10 km onwards, whereas slower finishers dropped off the lead pack at approximately half-distance (Hanley, 2016). Also in athletes competing in World Half Marathon Championships, the best men and women largely maintained their split speeds between 5 km and 15 km, whereas slower athletes decreased speeds from 5 km onwards (Hanley, 2015).

Difference in pacing between younger and older skiers

A further important finding was that the fastest skiers attenuated the decrease in speed with increasing age at the beginning of the race (*i.e.* Change A), whereas the slowest skiers had a more pronounced decrease in speed with increasing age. This observation was of great practical importance, because it indicated that performance groups paced differently according to their age. This observation was partially in agreement with research in marathon running suggesting that the older athletes are better pacers (Nikolaidis and Knechtle, 2017a). This was observed in the present study only for the fast cross-country skiers.

Although the young fast skiers maintained their speed at the beginning, the old fast skiers decreased it. This observation should be attributed to the fact that older fast skiers, despite being the fastest in their age group, were slow compared to the younger fast skiers, and it was a result of age differences in performance (Knechtle and Nikolaidis, 2017); thus, the old fast skiers followed a pacing strategy adopted by slow skiers.

Limitations, strengths and practical implications

The main limitation of the present study was the definition of performance groups, which relied on quartiles. Thus, the comparison of a particular quartile (*e.g.* Q1) among age groups implied that these groups differed in absolute performance (*i.e.* race time). Furthermore, large delays in the start might appear due to the large number of participants. On the other hand, the strength of the study was that this "relative" approach in performance allowed the comparison of more even groups. If we had created performance groups according to the race time instead, it would have not been possible to

consider all age groups, because the older one would have missed very fast race times. Although coaches and cross-country skiers would be more interested in performance analysis by race time groups, the analysis by quartiles provided the opportunity to add theoretical knowledge on differences among age groups. Future studies should examine pacing in the 'Engadin Ski Marathon' using more splits to provide more details on the variation of pacing by sex, age and performance level.

Conclusions

In summary, previous studies had highlighted the role of sex and performance. Based on the findings of the present study, it was shown that younger fast skiers paced differently compared to older fast skiers. Therefore, sex, age and performance level should be considered by coaches and their athletes in order to adopt an optimum pacing strategy in cross-country skiing. The findings have practical implications for coaches and fitness trainers working with cross-country skiers, since these professionals prescribe exercise for athletes varying for sex, age and performance. The older fast cross-country skiers had more even pacing than the younger athletes, whereas the older slow cross-country skiers had less even pacing compared to their younger counterparts. Thus, the age-related differences among age groups depend on the performance level, and coaches and fitness trainers should advise their athletes accordingly.

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