



The Influence of a Fast Start Versus a Conservative Start Pacing Strategy on Sprint Roller Skiing Performance in Highly Trained Female Junior Skiers

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Abstract

Purpose Pacing profiles differ substantially in endurance sports with short competition duration (2–4 min). Herein, we investigated the effect of a fast start (FS) versus a conservative start (CS) pacing strategy on sprint time-trial performance in competitive junior cross-country skiers.

Methods Sixteen females (~17 years old) performed two individual self-paced 1.4 km time-trials (TT) in free technique on roller skis separated by 40 min of recovery. Skiers were instructed to perform a FS and CS pacing strategy the first ~400-m (~1 min) in a randomized order. Split and finish time was determined using radio-based photocells, while speed characteristics were collected with GNSS/IMU sensors. 1–10 Rate of perceived exertion (RPE) was collected retrospectively for 3 points during the TT. Based on mean FS and CS performance, skiers were divided into a Low- ($n=8$) and High performers ($n=8$).

Results Overall, the FS strategy induced a faster ~400-m time (56.0 ± 3.8 s) than CS (58.7 ± 3.4 s) ($P < 0.05$), but no differences in finish times were found between strategies for the group as a whole (FS: 213.3 ± 12.0 s; CS, 212.9 ± 10.3 s, $P = 0.68$). However, High performers skied faster with FS than CS (203.4 ± 7.4 s vs. 205.1 ± 7.1 s; $0.8\% \pm 0.7\%$, $P < 0.05$), whereas the Low performers skied faster with CS than FS (220.7 ± 6.1 s vs. 223.1 ± 5.0 s; $1.1\% \pm 1.0\%$, $P < 0.05$). Independent of performance level, summated RPE during the TT was higher with FS versus CS (23 ± 2 vs. 22 ± 2 , $P < 0.05$).

Conclusion Optimal pacing strategy for TT sprint skiing appears dependent of performance level. A “fast start” strategy was accompanied by higher discomfort during the time-trial.

Keywords Cross-country skiing · GNSS · Intermittent exercise · Performance · Rate of perceived exertion

Introduction

A fundamental determinant of endurance performance is to optimally distribute the energetic resources to reach the end-point of the race in the fastest possible time [1, 24, 25, 31]. This is termed “pacing” and is composed of a continuous

decision-making process based on several factors, including experience, anticipation of exercise duration/distance, information about the course profile, as well as knowledge of current physiological and psychological state [31].

A variety of pacing patterns exist, including “negative” (increase in speed/power), “even” (maintaining speed/power), “positive” / “all out” (reduction in speed/power) and different types of “parabolic” pacing profiles (“U-shaped”, “J-shaped” etc.). An even distribution of speed appears advantageous for performance in endurance sports with relatively constant course inclinations and durations of > 6 min [1, 7]. For short durations (< 30 – 60 s) an “allout” strategy seems beneficial [1] while for events lasting 1–2 min a positive pacing strategy appears advantageous [6]. For competitions with durations of 2–4 min, both positive, parabolic and even pacing patterns have been observed in different sports [6, 21, 26].

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Since pacing patterns seem to differ between sports with similar durations, sport-specific pacing profiles and their influence on performance need to be determined [6, 26]. Moreover, previous research suggests that pacing strategies in highly trained athletes should be individualized [14, 20, 26]. However, surprisingly few experimental studies have identified factors that influence individual variations in athletes. One of these aspects is performance level, and it is well documented that athletes of low- and high performance levels choose different pacing strategies, both in mass starts and time-trials [16, 17]. In long distance runners, the observed differences in pacing strategy appear to be related to physiological factors such as higher peak speed, exercise economy and velocity at lactate threshold [16]. However, to what extent pacing strategy in “middle distance events” should be based on performance level is currently not known.

Sprint cross-country skiing has a duration of ~3 min and consists of a time-trial (TT) (prologue; interval start) followed by 3 knockout heats (quarterfinal, semifinal, and final) separated by 20–60 min breaks. While the pacing during the knockout heats is influenced by the tactics of the other competitors, the overall goal of the prologue is to “race against the clock”. The average exercise intensity during sprint skiing (110%–120% of VO_{2peak}) seems to be more similar to 800-m running (110%–115% of VO_{2peak}) than 1500-m running (100%–105% of VO_{2peak}) [18, 28] despite sprint skiing being closer to the duration of a 1500 m running event. Therefore, a fast start strategy seen in 800-m running could also be the “optimal strategy” in sprint skiing despite the longer duration of the TT.

Although several studies have described pacing patterns in cross-country skiing [2, 15, 17, 27, 30] only a few experimental studies have investigated the effect of pacing strategy on performance [13, 20]. Haugnes, Torvik, Ettema, Kocbach and Sandbakk [13] found that a “fast start strategy” impaired the finishing abilities in the last 100 m of the TT for elite male sprint skiers. However, they concluded that a “fast start strategy” still appeared to be the best strategy for overall performance in the ~3:30 min event, but with large individual differences. Thus, the cause of these individual variations needs further investigation.

The main purpose of the present study was to investigate differences in a fast start versus a conservative start pacing strategy on TT - sprint skiing performance and perceptual exertion in competitive female junior skiers. Moreover, we investigated whether the two pacing strategies resulted in different performance outcomes for skiers of different performance levels.

Methods

Participants

Sixteen female junior skiers participated in the project. All skiers were part of the same school and were highly trained regional-level junior athletes. Based on their average time to complete TT 2 and 3 (average time from fast start and conservative start, see Design) skiers were divided into two groups: High Performers ($n=8$) and Low Performers ($n=8$). These groups are presented in Table 1. The study was approved by the ethics committee at the Norwegian School of Sport Sciences (ref 189–170621), found advisable by the Norwegian Centre for Research Data, and conducted according to the Declaration of Helsinki. All participants gave their oral and written consent to participate, with parental consent for those under the age of 18 years.

Design

This study used a within-participants repeated-measures design to determine the effect of a fast start (FS) versus a conservative start (CS) pacing strategy on cross-country skiing sprint TT performance. All skiers used their own boots and poles and a pair of Swenor Skate rollerskis (Swenor, Sarpsborg, Norway) with wheel type 2 selected from a fleet of matched roller skis. The selected skis were used only for testing and were compared against each other (“rolling test” during downhill) to ensure similar rolling resistance. The tests were performed on a roller ski track at Geilo (Geilo, Norway, altitude 760 m above sea level). The track profile is shown in Fig. 1. The skiers performed an individual 1.4 km TT free technique roller ski session with a self-selected

Table 1 Description of the high performers and low performers skiers

Variables	High Performers ($n=8$)	Low Performers ($n=8$)
Age (years)	17.5 ± 0.8	17.3 ± 1.2
Body height (cm)	170 ± 6	170 ± 6
Body mass (kg)	64 ± 7	61 ± 5
VO_{2max} (mL/min/kg)	55 ± 4	55 ± 4
Annual training (hours)	517 ± 156	519 ± 65
Ranking of speed qualities	6 ± 3	11 ± 5*

Data are mean ± SD. Groups are based on their average time to complete time-trials 2 and 3 (average time from fast start and conservative start). VO_{2max} is maximal oxygen uptake. Annual training is the training volume in hours the year prior the the experiment. Ranking of speed qualities was based on maximal speed and conducted by coaches that work daily with the skiers. The question was “Rank the skiers from 1–16 on their ability to gain high speed over 15–20 s”.

*Significant difference between groups ($P < 0.05$)

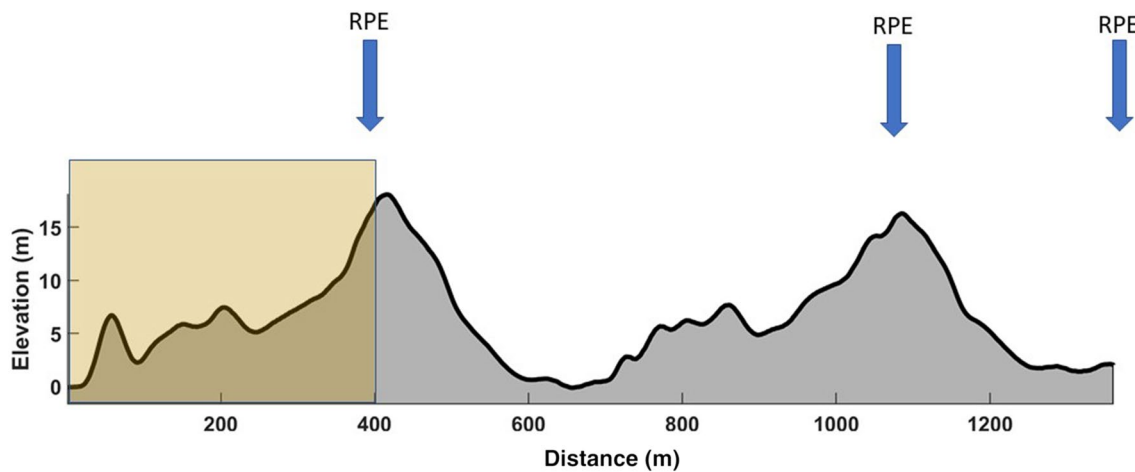


Fig. 1 Profile of the 1.4 km course, the brown area indicates the area where skiers were instructed to follow a “fast start” or “conservative start”. Arrows indicate where skiers reported their 1–10 rate of Perceived Exertion (RPE)

spacing strategy in the morning (9:00 a.m.) to act as a familiarization (TT1), followed by two TTs separated with 40 min break in the afternoon (4:00–6:00 p.m.). During the afternoon session, skiers were instructed to perform a “fast start” (FS) and a “conservative start” (CS) strategy (TT2, TT3) the first ~400-m (~1 min) in a randomized fashion. The skiers were told to pace the first ~400 m “2–3 s” faster with the FS than the CS strategy and the rate of perceived exertion (RPE) should be “slightly higher” for FS and “slightly lower” for CS at the 400-m split time compared to the TT1. Split times and finishing time were determined using radio-based photocells using a HC Timing two-way mesh radio transceiver (HC Timing, wiTiming, Oslo, Norway) with 5 sets of 500mW transmitters (start, 3 × intermediate, finish) (HC Timing, wiNode, Oslo, Norway). The velocity profiles of the TTs were determined via global navigation satellite systems (GNSS) sensors. This was collected using an Optimeye S5 (Catapult Innovations, Melbourne, Australia), validated by Gløersen, Kocbach and Gilgien [11]. The unit consisted of a 10 Hz GNSS-receiver, tracking both GPS and GLONASS data, a 3D accelerometer (100 Hz), a 3D magnetometer (100 Hz) and a 3D, 2000 °/s gyroscope (100 Hz). The course profile along the track was calculated for each athlete and lap, based on the IMU-GNSS sensors and averaged to obtain a standard course with an accompanying elevation profile. Data from the IMU-GNSS sensors were carried by the athletes were adapted to the standard course, and subsequently used to detect the speed of each athlete along the course.

The distance of 1.4 km is regularly used in competitions for this group of skiers. All skiers were familiar with the course, since they regularly used the track for training. Maximal oxygen uptake during running was determined on a separate day \pm 2 months from the test day (for protocol see

Losnegard, Schafer and Hallen [19]). VO_{2max} during running was measured at Geilo (760 m above sea level) on a treadmill (Woodway ELG, GmbH, Weil am Rein, Germany) using an automatic ergo-spirometry system with a mixing chamber (Oxycon Pro, Jaeger Instrument, Hoechberg, Germany). The system has been validated by Foss and Hallen [9] and methods are described previously by Losnegard, Schafer and Hallen [19].

A subjective ranking of the skiers' sprint ability (denoted “maximal speed”) was provided by asking the skiers' coaches to rank the skiers. This was based on the question “Rank the skiers from 1 to 16 based on their sprint ability over 15–20 s”. All skiers have the same coaches who work closely with them on daily basis.

Methodology

A 30 s starting interval between each skiers was used, with the skiers who were expected to ski fastest starting first. The starting order was identical for all tests. Prior to TT1 and TT2, the skiers performed a warm-up consisting of 30 min of primarily low intensity skiing incorporating 1–3 moderate intensity efforts of 1–3 min duration and 2–3 progressive sprints (> 15 s). Between TT2 and TT3 skiers performed 10 min passive rest, 15 min active rest at low intensity and then 5 min passive rest. RPE was reported directly after the TT. Before the start, athletes were instructed to note and then recall their RPE (using a 1–10 scale [10]) at the checkpoints ~400-m, ~1100-m and finish (see Fig. 1). These were reported immediately after completing each time-trial. All skiers were familiar with the RPE 1–10 system from their regular training and testing. The RPE Hazard score, which is the product of the momentary RPE and the fraction of distance remaining (%), was calculated. This score defines

the likelihood that athletes will change their effort during the competition and is associated with the need to reduce the speed to values at which homeostatic disturbances stay within acceptable limits [8]. The summated RPE Hazard score is the sum of all RPE during the TT.

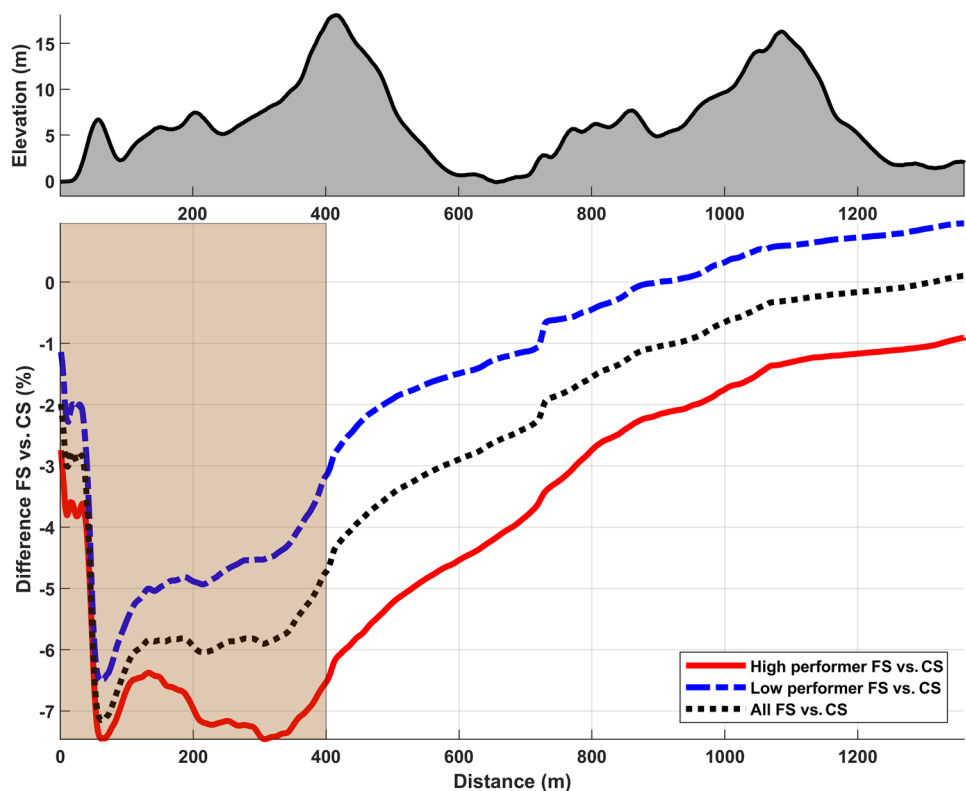
Statistical Analysis

Data are presented as mean \pm standard deviation (SD), except for relative differences between test days and between groups, which are presented as means \pm 95% confidence intervals (CI). Paired sample *t*-tests were used to calculate the differences within participants from different pacing strategies, while an unpaired *t*-test was conducted between groups for the relative differences from pacing strategies. The correlation values were obtained using Pearson product-moment correlation analysis. A *P*-value < 0.05 was considered statistically significant. Statistical analyses were performed using Microsoft Office Excel 2013 (Microsoft, Redmond, WA, USA). The magnitude of change score between groups was expressed as standardized mean differences (Cohen's *d* effect size; ES) with the formula $\left((M1 - M2) / \left(\sqrt{(SD_1^2 + SD_2^2) / 2} \right) \right)$ and for the within group comparison $\left((M1 - M2) / \left(\sqrt{(SD_1^2 + SD_2^2 - 2rS^1S^2)} \right) \right)$.

Results

The familiarization TT was performed in 215.8 ± 11.6 s with the first 400-m completed in 57.0 ± 3.6 s. The RPE was 6.8 ± 1.1 at 400-m, 7.9 ± 0.8 at 1100-m and 8.4 ± 0.6 at finish. The influence of FS and CS strategy is shown in Fig. 2 and individual responses are shown in Fig. 3. The FS strategy induced a faster 400-m time than CS (56.0 ± 3.8 s vs. 58.7 ± 3.4 s, $P < 0.05$), but there were no differences in finish times for the group as a whole (FS: 213.3 ± 12.0 s; CS: 212.9 ± 10.3 s; $P = 0.68$, ES = 0.04). However, dividing the group into High- and Low performers showed that the High performers skied faster with FS than CS (203.4 ± 7.4 s vs. 205.1 ± 7.1 s; $0.8\% \pm 0.7\%$), whereas the Low performers skied faster with CS than FS (220.7 ± 6.1 s vs. 223.1 ± 5.0 s; $1.1\% \pm 1.0\%$) (all $P < 0.05$, comparison between groups; $P < 0.05$, ES = 1.5). Both groups had the same relative start pace (400 m time relative to the 1400 m time) for FS ($\sim 26\%$) and CS ($\sim 28\%$). There were no significant order effects between the TT2 and TT3, independent of pacing strategy (213.0 ± 11.6 and 213.2 ± 10.7 s, respectively). The correlation between performance (taken as the average time from FS and CS) and the relative difference between FS and CS was $r = 0.49$ ($P = 0.05$) and shown in Fig. 4.

Fig. 2 The relative time difference between fast start (FS) and conservative start (CS) for High performers ($n = 8$), Low performers ($n = 8$) and both groups together (All). The brown area indicates the area where skiers were instructed to follow a fast start or conservative start



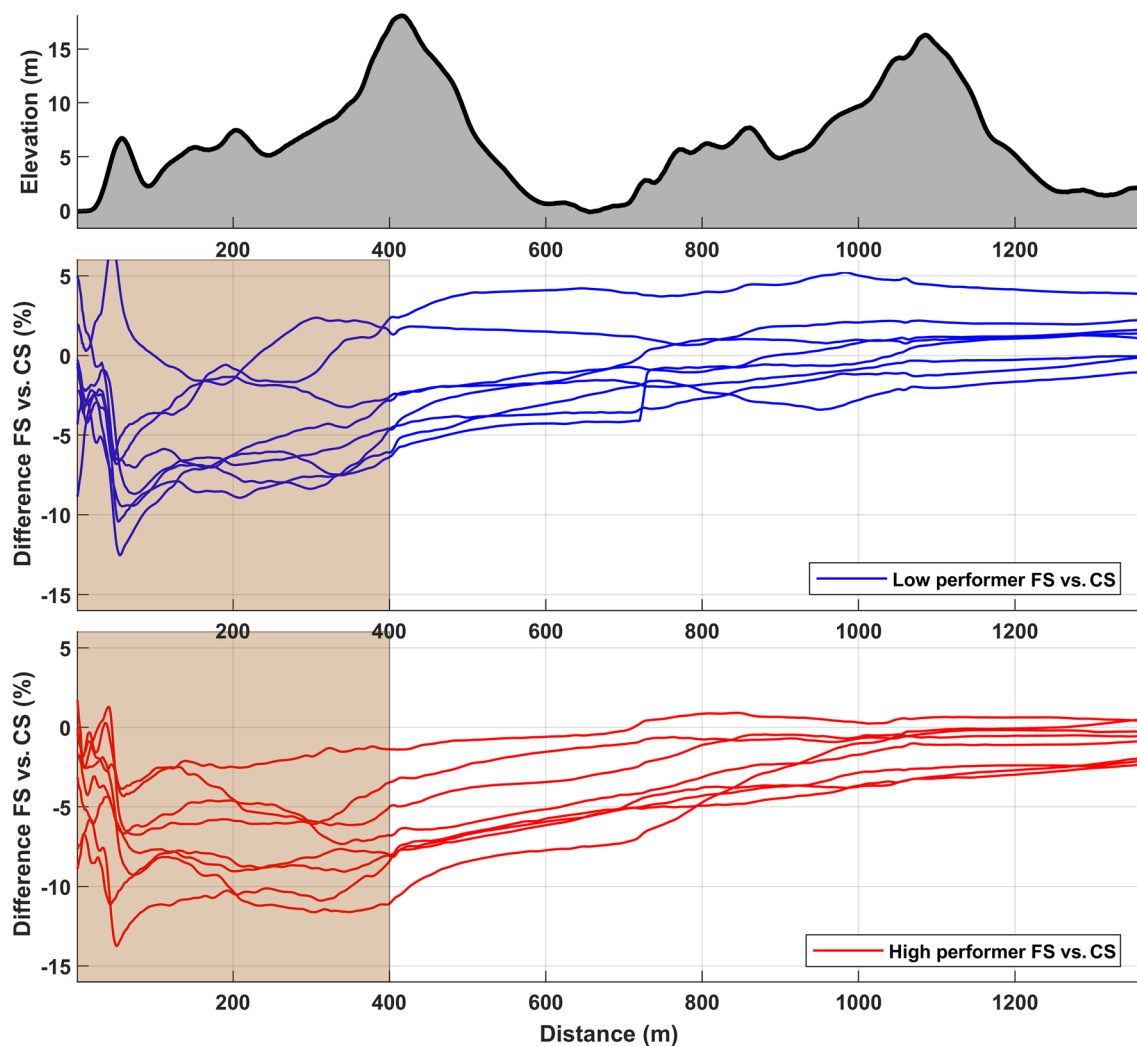


Fig. 3 The individual relative time difference between fast start (FS) and conservative start (CS) for High performers ($n=8$) and Low performers ($n=8$). The brown area indicates the area where skiers was instructed to follow a fast start or conservative start

There were no differences between the High- and Low performers with regards to age, body mass, height, VO_{2max} or annual training volume, but a significant difference in the ranking of maximal speed from the coaches (Table 1).

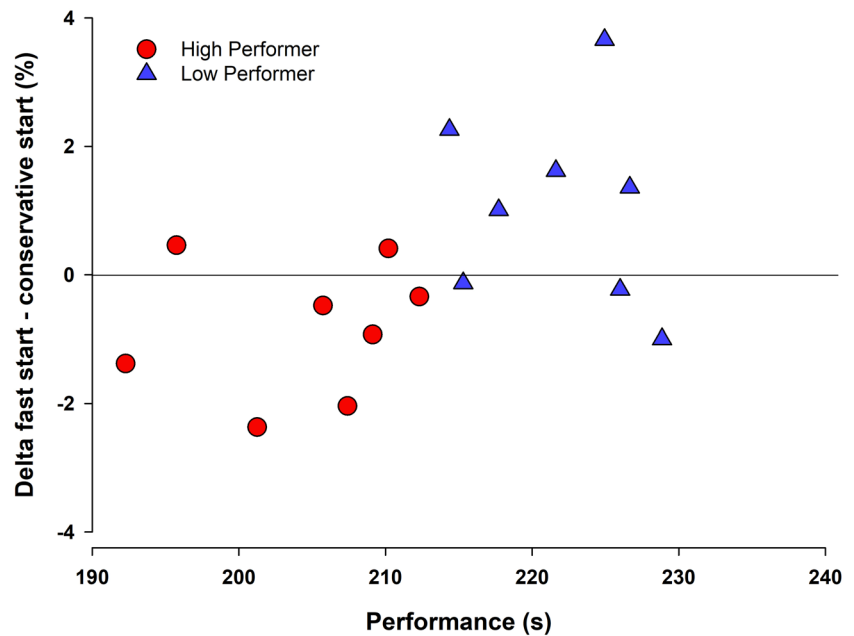
The RPE and RPE Hazard score is shown in Fig. 5. There were no differences between groups in RPE or RPE Hazard Score or Summated RPE Hazard score for either FS or CS. However, both groups displayed a higher RPE and RPE Hazard score at 400-m for FS than CS, with no differences between strategies at 1100-m or finish. Thus, the Summated RPE was higher during FS than CS strategy (23 ± 2 vs. 22 ± 2 , $P < 0.05$).

Discussion

We investigated differences between a fast start (FS) versus a conservative start (CS) strategy on TT sprint skiing performance of competitive junior female skiers. The main finding was that the High performers skiers benefit from a FS strategy while for the Low performers skiers, a more CS strategy appears to be the best choice. Independent of performance level, the FS strategy was accompanied by a higher summated RPE Hazard Score, implying higher discomfort during the TT.

For the group as a whole, no differences in roller ski TT performance were observed between the FS vs. the CS strategy. However, in line with previous studies [4,

Fig. 4 The correlation between performance (taken as the average time from FS and CS) and the relative difference between FS and CS ($r=0.49$, $P=0.05$)



[14, 20, 26] our findings suggest that the choice of pacing strategy in competitive athletes should be individualised. An important factor to take into account when choosing pacing strategy is performance level [16]. In the present study, the High performers benefited from the FS strategy, whereas the Low performers benefited from the CS strategy. Importantly, both groups appear to have the same relative start speed and reported similar RPE the first 400-m, which suggests that the difference between the two groups lies in the ability to maintain performance during the last ~2 min of the TT.

A numerous physiological and technical abilities has been attributed to influence optimal pacing strategy in high-level athletes [4, 16]. In the present study, VO_{2max} was not different between the groups and could not explain the differences in performance or the best pacing strategy. Another determinant of sprint skiing performance, at least within a heterogeneous group of skiers (sprint and distance), is maximal speed [29]. In 800-m runners, Bellinger, Derave, Lievens, Kennedy, Arnold, Rice and Minahan [4] showed that pacing was related to the runners maximal speed. More specifically, the runners with the fastest maximal speed had the fastest 800-m time when the pacing behavior was self-selected (hence, a typical fast start strategy) but was not evident when the pacing was set to a slower start pace. The authors therefore emphasise that 800-m runners with a high maximal speed are best suited to successfully adopt a positive pacing strategy. In the present study, the subjective ranking from the coaches indicates that the High performers had higher maximal speed compared to the Low performers. Although such subjective rankings should be taken with caution, we propose that speed qualities could explain some of

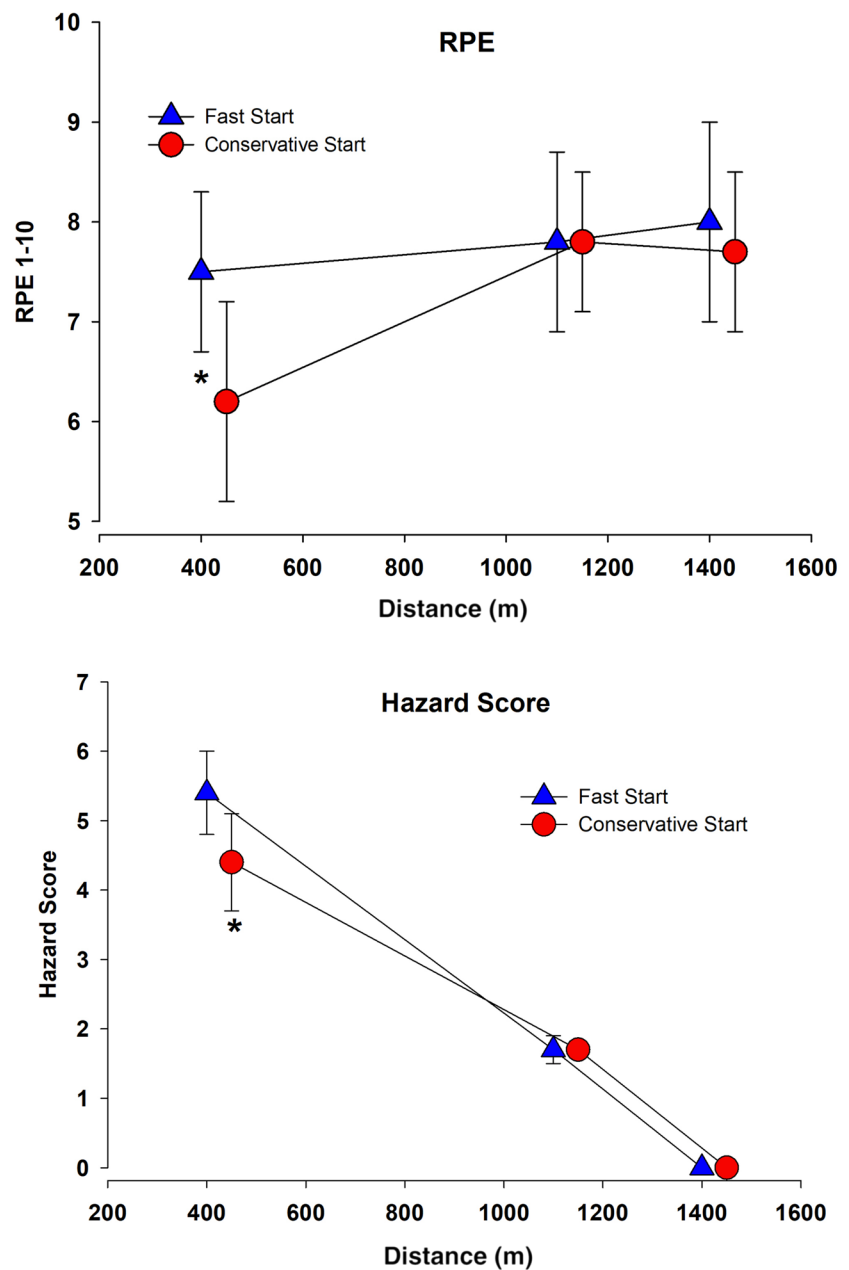
the variations in types of “optimal” pacing in sprint skiing for junior female skiers. However, this should be confirmed in future studies that include objective measures of maximal speed.

Gross efficiency was not established, but from a theoretical perspective it could explain some of the variations between groups. It has been demonstrated that gross efficiency is negatively affected by high-intensity work and that the recovery of gross efficiency after such work is relatively slow [3, 12, 22]. Moreover, fatigue clearly affects the skier’s technique [23, 32], and from a practical point of view high level skiers might be able to maintain their movement pattern better during a state of fatigue than low level skiers. Taken in consideration the differences in the ranking of maximal speed, the High performers in the present study may have a higher “speed reserve” (speed in time-trial relative to the maximal speed) during the first part of the TT. Thus, it could be suggested that the High performers might maintain gross efficiency better after a fast start (but at similar relative intensity) compared to the Low performers, and thereby better maintain skiing speed during the final part of the race. However, to our knowledge, these mechanisms have rarely been investigated, and should therefore be followed up in future studies.

Practical Application

In intermittent endurance sports such as cross-country skiing it is practically difficult to use objective external (e.g. speed) or internal markers (e.g. heart rate) to continuously evaluate and adjust exercise intensity. We recently demonstrated that the simple, but applied, rating of perceived exertion

Fig. 5 1–10 Rate of perceived exertion (RPE) (upper) and RPE Hazard Score (lower) at 400 m, 1100 m and finish (1400 m) for fast start and conservative start. The RPE Hazard score is the product of the momentary RPE and the race distance remaining (%). * Significantly different between strategies ($P < 0.05$)



(RPE) with calculations of RPE “Hazard Score (HS)” (e.g., product of the momentary RPE and the fraction of distance remaining) and accumulated RPE during the time-trial (“Summated RPE”) [5, 8] combined with split times, could provide meaningful data regarding skiers’ pacing strategies [20]. Such information is likely of even greater importance when multiple races are held on the same day, such as sprint skiing. An important aspect of sprint skiing performance is the ability to maintain performance over four heats with recovery periods of ~60–40–20 min. Independent of performance level, the FS strategy induced a higher RPE/RPE Hazard score at 400-m, with no differences at 1400-m and finish. Thus, this implies a higher risk of premature fatigue

than with a CS, but with potentially greater gain for faster skiers who’s overall performance appears to benefit from a “fast start” strategy.

Conclusion

Pacing strategy during time-trial sprint skiing for female juniors seems dependent of the performance level. However, for all skiers, a fast start strategy was associated with higher summated RPE, and thus, higher discomfort during the time-trial.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest The authors have no relevant financial or non-financial interests to disclose. All authors contributed to the study conception, data collection and design. Material preparation and analysis were performed by [Thomas Losnegard] and [Jan Kocbach]. The first draft of the manuscript was written by [Thomas Losnegard] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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