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The effect of maximal speed ability, pacing strategy and technique on the finish-sprint of a sprint cross-country skiing competition

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Abstract

Purpose: The aims of this study were to investigate the contribution from maximal speed (V_{max}) and %V_{max} to the finish-sprint speed obtained in a cross-country (XC) sprint in the classical and skating style, as well as the coinciding changes in kinematic patterns, and the effect of pacing strategy on the %V_{max}. ***Methods:*** Twelve elite male XC skiers performed two 80-m V_{max} tests on flat terrain using the classical double poling and skating G3 techniques, followed by four simulated 1.4-km sprint time-trials, performed with conservative (controlled start) and positive (hard start) pacing strategies in both styles with a randomized order. In all cases, these time-trials were finalized by sprinting maximally over the last 80-m (the V_{max}-section). ***Results:*** ~85% of V_{max} was obtained in the finish-sprint of the 1.4-km competitions, with V_{max} and %V_{max} contributing similarly (R^2=51-78%) to explain the overall variance in finish-sprint speed in all four cases ($P<0.05$). The changes in kinematic pattern from the V_{max} to the finish-sprint included 11-22% reduced cycle rate in both styles ($P<0.01$), without any changes in cycle length. A 3.6% faster finish-sprint speed, explained by higher cycle rate, was found by conservative pacing in classic ($P<0.001$), whereas no difference was seen in skating. ***Conclusions:*** The V_{max} ability and the %V_{max} contributed similarly to explain the finish-sprint speed, both in the classic and skating styles, and independent of pacing strategy. Sprint XC skiers should therefore concurrently develop both these capacities, and employ technical strategies where a high cycle rate can be sustained when fatigue occurs.

Keywords: Global navigation satellite system, kinematics, pacing strategy, sprint, XC skiing.

Introduction

Sprint cross-country (XC) skiing involves a 1.0- to 1.8-km qualifying time-trial race, followed by three subsequent knockout heats where six competitors in each heat compete for the first ranks that qualify for the next round and/or for winning the final. Although maximal oxygen uptake (VO_{2max}), fractional utilization of VO_{2max} and skiing efficiency/economy are well recognized determinants of sprint XC skiing[1-3], the ability to generate a high finish-sprint speed is of additional importance for the race outcome.[4] The finish-sprint speed is determined by the combination of having a high maximal speed (V_{max}) and the ability to utilize a high fraction of V_{max} during the finish-sprint. A high V_{max} requires a high cycle rate and a concurrently long cycle length in both the classical and skating XC styles,[5,6] and the ability to utilize a high percentage of V_{max} ($\%V_{max}$) during the finish-sprint is influenced by e.g. the individual levels of fatigue.[7] Currently, the contribution from V_{max} and $\%V_{max}$ to the finish-speed at the end of an on-snow sprint race or to what extent cycle rate and/or cycle length contribute to finish-sprint speed have not yet been studied.

In the classical style, the main technique during a sprint race, and in particular in the finish-sprint, is double poling (DP)[8] where all propulsive forces are produced through the poles.[9] In the G3 skating technique, which is used in the same terrain types as DP, propulsion is generated concurrently by the leg push-off and the DP movement.[10] Although this makes G3 skating faster than DP,[11] it is not known whether there are differences between the $\%V_{max}$ utilized in a finish-sprint between these techniques and how the coinciding kinematics (i.e. cycle rate and length) may change.

The individual's pacing before entering the finish-sprint leads to various degrees of fatigue. Due to the competition format in XC skiing sprint, the pacing utilized during heats and thereby the subsequent grade of fatigue at the finish-sprint is decided both by each athlete's choice of effort and the competition speed. While fatigue is a complex phenomenon, encompassing reduced physiological, biomechanical and/or psychological capacities,[12,13] its presence during a XC sprint race would rationally influence the $\%V_{max}$. The presence of peripheral fatigue is confirmed by previous studies where repeated simulated XC sprint races were performed in the classical technique, in which reductions in finish-sprint speed was associated with changes in muscle activity patterns and inter-individual kinematic adaptions.[14-18] Furthermore, Vesterinen et al.[19] performed a simulated sprint on roller skis, where skiers sprinted 50-m maximally with the G3 skating technique at the beginning and in the end of 850-m heats. Compared to their V_{max}, skiers were able to use approximately 95% and 85% at the first and last part of each heat, with the reductions in speed mainly being explained by reduced cycle rate. Along the same line, Mikkola et al.[18] showed 16% decrease in the finish-sprint speed of a classical sprint race compared to close to maximal sprinting over the same distance at the beginning of the race. In skating, this has only been studied over a 20-km race, where Ohtonen et al.[20] found an 11% speed decrease in finish-sprint speed in uphill terrain that was related to lower pole forces and cycle rates, as well as decreased muscle activation. Whether the same would occur following classical and/or skating sprint races in varying terrain, and to what extent skiing kinematics (i.e., cycle length and rate) and pacing strategy would influence the finish-sprint have not yet been investigated.

Therefore, the primary aim of this study was to investigate the contribution from V_{max} and $\%V_{max}$ to the speed obtained in the finish-sprint of XC sprint competitions in classical and skating XC skiing, as well as the coinciding changes in kinematic patterns. The secondary aim was to examine the effect of pacing strategy on the $\%V_{max}$.

Methods

Participants

Twelve elite male Norwegian XC skiers, age 21.3±2.1 years, body height 183±4 cm, body mass 78.2±6.6 kg, maximal oxygen uptake (VO_{2max}) 70.7±4.2 ($mL \cdot min^{-1} \cdot kg^{-1}$), training 618.7±100.1 (h $year^{-1}$), volunteered to participate. This study was pre-approved by the Norwegian Centre for Research Data (NSD), and performed according to the Helsinki declaration. All participants were fully informed of its nature before providing their written consent to participate.

Design

Initially, all skiers were tested for VO_{2max} and maximal heart rate (HR_{max}) on two separately days. Thereafter, two 80-m V_{max}-tests were performed in a rested state on flat terrain while skiing with the classic (DP) and skating (G3) techniques. This was followed by four 1.4-km sprint time-trials (STTs) with conservative (controlled start) vs. positive (hard start) pacing strategies in both XC skiing styles (based on their own perception of intensity) in a randomized order. These were all finalized by sprinting maximally over the last 80-m (the V_{max}-section). Here, speed was tracked with a global navigation satellite system (GNSS) with integrated barometry and accompanying heart rate (HR) monitor, and the V_{max}-section was monitored by photocells and video. The snow friction and weather conditions were stable throughout the entire test day, with light-wind, light-snow, partly cloudy, air temperature of -3°C, ~60% humidity and atmospheric pressure of ~933.6 hPa. The course was covered with hard-packed mixed snow and was machine-prepared in the morning prior to testing.

Methodology

VO_{2max} was tested in an incremental uphill running test at 10.5% inclination on a 2.5 x 0.7-m motor-driven treadmill (RL 2500E, Rodby, Södertalje, Sweden), with standardized procedures published previously,[21] while employing open-circuit, indirect calorimetry with an Oxycon Pro apparatus (Jaeger GmbH, Hoechberg, Germany). Blood lactate concentration (BLa) of 5-µL-samples were taken from the fingertip and analysed by Lactate Pro LT-1710*t* kit (Arkray Inc., Kyoto, Japan). Body mass and height were measured with an electronic body mass scale (Seca model nr. 708, Seca GmbH & Co, Hamburg, Germany) and with a stadiometer (Holtain Ltd., Crosswell, UK), respectively. Rating of perceived exertion (RPE) was recorded using the 6-20 point Borg Scale.[22] HR_{max} was tested in an uphill running test described previously.[23] V_{max} was calculated based on time from two pairs of photocells with 1000 Hz resolution (TC-Timer; Brower Timing Systems, Draper, UT, USA) placed at start and finish of the V_{max}-section, 20 cm above the ground and with 300 cm between the members of each pair. A panning 50-Hz Sony video camera (Sony Handycam HDR-PJ620, Sony Inc., Tokyo, Japan) monitored the skiers in the V_{max}-section for 6 consecutive cycles in order to determine cycle rate and cycle length, and video data obtained were analysed using an open-license motion-analysis software (Kinovea version 0.8.15 for Windows).

The V_{max}-tests were performed in a rested state on flat terrain using the classic (DP) and skating (G3) techniques, each separated with 5-min of light activity. Prior to testing, the skiers warmed-up according to their own individual program and were instructed to prepare and use their own ski equipment for the prevailing conditions including grinds, structure and waxing. A self-selected run-in, started from section 5 (S5; Figure 1) in order to reach the highest possible speed when entering the V_{max}-section. A 10-min recovery period followed the V_{max}-tests before each skier was instructed to perform two randomized STTs with conservative vs. positive pacing strategies using the classic (DP) and skating styles with 20-min rest in between. The skating techniques were freely chosen by the skiers, except in the finish-sprint, where the skiers were asked to use the G3 skating technique. BLa was collected at rest and immediately after the STTs together with RPE for the total course and RPE for the separate terrain sections (uphill, flat and downhill). Each STT had 1-min start intervals where drafting was prohibited to avoid the potential of skiers saving time and energy by drag.

We ensured GPS fixing, minimized inaccuracies, and determined course and elevation profiles with a Garmin Forerunner 920XT (Garmin Ltd., Olathe, KS), which was used to define a reference course, as previously described by Sandbakk et al.[24] Furthermore, each skier wore the same Garmin GPS during the STTs that collected position and HR data at a sampling rate of 1 Hz. The course was 1385-m, with varied topography based on a course profile divided into uphill, flat and downhill that made up 38, 19 and 43% of the course, respectively. The course was divided into 6 different sections (S1-S6), according to terrain topography (Figure 1). The maximal difference in elevation was 24-m with a total climb of 38-m for the entire course. The time each skier spent in a section was calculated based on virtual split times. Speed for each section was calculated by dividing the length of a section by the time elapsed within that section.

Figure 1

Temporal patterns for classic (DP) and skating (G3) techniques were determined in the V_{max}-section during the V_{max}-tests and in the end of the STTs. The cycle rate was based on frame by frame video analysis and calculated from the time between every second pole plant of the left pole for both styles. Cycle length was calculated as the average speed multiplied by the cycle time and the cycle rate was calculated as the reciprocal of cycle time.

Statistical Analysis

All data were checked for normality with a Shapiro–Wilks test and are presented as means ± standard deviation. In cases where they were not normally distributed, a nonparametric alternative was used. For V_{max} in classic and skating the coefficients of variation (CV) were <2.1% and the intraclass-correlation coefficients (ICC) >0.96. Correlations between the various parameters were analysed using Pearson's product-moment correlation coefficient test or its nonparametric counterpart, Spearman rank rho correlations, and simple linear regression was used to draw trend lines. A paired-samples t-test or their nonparametric counterpart, Wilcoxon matched pairs signed-ranks tests, were used to test for differences between conservative and positive pacing strategy using classic and skating XC skiing styles. Photocells failed to register the finish-sprint for some of the skiers because of precipitation and caused missing data with conservative pacing in classic (*n*=1), conservative pacing in skating (*n*=2) and positive pacing in skating (*n*=3), respectively. We ran all analyses with the maximum number of available participants in each case. However, the possible influence of missing data on the descriptive data presented and the statistical analyses were checked, in which close to identical values were found and none of the statistical outcomes or conclusions were influenced. Statistical significance level was set at $P < 0.05$. All statistical tests were processed using IBM SPSS statistics version 24 Software for Windows (SPSS Inc., Chicago, IL, USA) and Office Excel 2016 (Microsoft Corporation, Redmond, WA, USA).

Results

The skiers' mean speed in the V_{max}-test on flat terrain was 9.3±0.6 and 10.3±0.6 $m \cdot s^{-1}$ for classical and skating XC skiing, respectively, with a mean speed difference between classical and skating of 9.9% (P<0.001). This speed difference was reflected in a significantly longer cycle length for skating compared to classical: 7.0±0.6 vs. 6.1±0.6-m (P<0.05), whereas no significant difference in cycle rate (1.48±0.09 vs. 1.54±0.12 Hz) was seen between the two styles, respectively. The mean speed during the 1.4-km STT was 5.9±0.3 vs. 6.1±0.4 $m \cdot s^{-1}$ for classical and 6.8±0.3 vs. 7.0±0.5 $m \cdot s^{-1}$ for skating XC skiing, using conservative and positive pacing, respectively. The positive pacing resulted in a significantly faster mean speed for the total course compared to the conservative pacing in classic (P<0.05; Figure 2 and Table 1), whereas no difference was seen between the strategies in skating (Figure 3 and Table 1). A comparison between classic and skating, indicates a 14.2% difference in racing speed, for both pacing strategies, respectively (P<0.001). The mean speed was significantly faster in the first flat section (S1) and uphill section (S2) with positive pacing as compared to the conservative strategy in both styles (P<0.05; Figure 2 and 3). This speed difference gradually levelled out in the subsequent terrain sections, and no significant difference was seen between the strategies in the rest of the course. A difference in HR between the two pacing strategies was only found in classic, with significantly higher mean and peak values (%HR_{max}) for the positive pacing as compared to the conservative pacing strategy (P<0.05; Figure 2 and Table 1). However, no significant difference was seen between the skiers' peak BLa level after the STT in either style. On the other hand, the skiers rated their own perception of exertion significantly higher in both styles for the total course and in all sections of terrain with positive pacing as compared to the conservative pacing strategy (P<0.05; Table 1).

Figure 2

Figure 3

The skiers achieved 86.4±5.9 and 87.0±4.9% of V_{max} in the finish-sprint with conservative pacing, while 83.0±6.0 and 84.1±4.7% was achieved when pacing positively for classical and skating XC skiing, respectively (Figure 4). The speed in the finish-sprint was 3.6% faster with the conservative pacing as compared to the positive pacing strategy in classic (P<0.001; Table 1). Although the % difference in finish-sprint speed between pacing strategies were the same for skating (Table 1), this difference did not reach statistical significance. Skiing kinematics (i.e. cycle length and rate) for classical and skating XC skiing in the finish-sprint with conservative and positive pacing strategy are presented in Table 1. Cycle rate was significantly lower with positive pacing as compared to the conservative strategy in both styles (P<0.05; Table 1), while no significant difference in the skier's cycle length was seen. The changes in kinematic pattern from the V_{max} test to the finish-sprint in the STT were reflected with significant reduced cycle rate: 14.7 vs. 10.9% with conservative pacing and 21.5 vs. 14.6% with positive pacing, for classical and skating XC skiing, respectively (P<0.01; Table 1), whereas there was no significant difference in cycle length.

Figure 4

Table 1

The correlations between the finish-sprint speed vs. V_{max} and %V_{max} are presented in Figure 5 and 6, respectively. Both the skiers' V_{max} and their ability to utilize the %V_{max} were positively correlated with the speed obtained in the finish-sprint (all P<0.05; Figure 5 and 6). The correlations between skiing kinematics and finish-sprint speed revealed that the skiers' cycle rate in classic correlated positively with the finish-sprint speed using conservative (r = 0.82, P=0.01) and positive pacing strategy (r = 0.60, P=0.05), respectively. Conversely, the skiers' cycle length in skating was positively correlated with the finish-sprint speed using conservative pacing (r = 0.76, P=0.05), and a trend was found for positive pacing (r = 0.65, P=0.056), respectively. Furthermore, when looking into the reduction in speed obtain in the finish-sprint compared to V_{max}, a trend was found between the reduction in cycle rate and the reduction in finish-sprint speed in classic using conservative and positive pacing strategy (r = 0.55 and 0.52, respectively, both P=0.08). In contrast, a trend was observed for the reduction in cycle length and the reduction in finish-sprint speed in skating using conservative (r = 0.63, P=0.052) and positive pacing strategy (r = 0.61, P=0.08).

Figure 5

Figure 6

Discussion

The present study investigated the contribution from V_{max} and $\%V_{max}$ to the finish-sprint speed obtained in a simulated XC sprint competition in the classical and skating styles, as well as the coinciding changes in kinematic patterns and the effects of pacing strategy. The main finding were that elite XC skiers obtain ~85% of their V_{max} in the finish-sprint of a 1.4-km STT, with a relatively equal contribution from V_{max} and $\%V_{max}$ to the overall variance in finish-sprint speed in both styles and pacing strategies. These reductions in speed were explained by 11-22% reduced cycle rate in both styles, without any changes in cycle length.

The current results show that elite male XC skiers obtained ~85% of their V_{max} in the finish-sprint of a simulated sprint race on snow. This is in line with comparable investigations on rollers ski and ski,[18,19] where 85% of V_{max} was obtained in the finish-sprint among elite sprint skiers. Furthermore, in a simulated 1.4-km skating STT on snow,[25] the skiers utilized ~80% of their V_{max} with the G3 skating technique during the last 20-m before the finish line. However, in the latter approach skiers aimed to ski as fast as possible throughout the entire track, and were not instructed to have a maximal finish-sprint speed as done in the current study. In the present study, we also examined the contribution from V_{max} and $\%V_{max}$ to the finish-speed after the sprints and found that V_{max} explained 51-72% and $\%V_{max}$ 54-78% of the overall variance in the finish-sprint speed across the different conditions. This clearly indicates that both factors are of high and relatively equal importance for being fast in a finish-sprint of a race both in the classical and skating styles. Overall, our results demonstrate that XC skiers need to concurrently have a high V_{max} ability and, at the same time, an ability to utilize a high fraction of V_{max} at the end of a race when being fatigued. This applies both to classic and skating, and in the cases of both conservative and positive pacing strategies.

The reduction in speed from V_{max} to the finish-sprint were reflected in 11-22% reduced cycle rate both in the classical and skating styles, whereas no significant reduction in cycle length occurred. This is in line with findings from many other locomotion, e.g. athletic events, where fatigue is mainly accompanied by reduced cycle rate.[26] In XC skiing, Zory et al.[15] and Vesterinen et al.[19]

showed a decrease in cycle rate when sprinting the finish-sprint at the end of simulated sprint races with the classic (DP) and skating (G3) styles, respectively. Furthermore, Zory et al.[16], showed that some of the upper-body muscles were affected by fatigue, in a DP sprint on snow, an aspect that might have contributed to decreased cycle rate also in this study. Additionally, the importance of the leg muscles for rapid repositioning and thereby the ability to maintain a high cycle rate in DP should also be considered.[9,27]

Cycle rate in classic was associated with finish-sprint speed, and the magnitude of reduction in cycle rate and the corresponding reduction in finish-sprint speed correlated significantly. In contrast, the reduction in cycle length in skating tended to correlate with the reduction in finish-sprint speed. This difference between the classic and skating styles is shown for the first time here, and is likely explained by the different constrains of the two skiing styles. In DP, the time for poling is highly restricted by speed,[9] with the time for propulsion being as low as ~0.2 s at high speeds.[8] This makes production of propulsion and thereby the maintenance of cycle length challenging, an aspect that may force skiers to reduce the loss of speed when fatigued by maintaining cycle rate.[5,28] In contrast, the skiers can push off when gliding in skating, and by adapting their angling of their skis they are able to maintain push-off times even at very high speeds. This allows for a greater possibility to manipulate cycle length in skating, and with this in mind, it is not surprising that the best skiers are able to maintain the longest cycles in that technique.[29] Altogether, this difference between classic and skating is of importance for coaches and athletes to be aware of, both when aiming to increase V_{max} and to prevent negative effects of fatigue on speed.

The finish-sprint speed and the ability to use a high $\%V_{max}$ in the finish-sprint requires production of high cycle rate and a concurrently long cycle length, which is dependent on the skiers' force and power production. These factors may be influenced by the levels of fatigue associated with different pacing strategies.[14-16,19] In classic, the conservative pacing strategy used in our study resulted in a 3.6% faster finish-sprint speed as compared to the positive pacing strategy. However, in skating the finish-sprint speed did not reach statistical significance although the relative difference was the same as for classic. However, cycle rate was lower with positive pacing as compared to the conservative strategy in both styles, whereas cycle length was unchanged across pacing strategies. While the influence of pacing strategy on the ability to sprint at the end of a race is examined for the first time here, the large reductions in cycle rate with more fatigue (as shown with BLa and RPE, which tended to be higher with positive pacing) may be explained by peripheral fatigue as previously found by Zory et al.[14] Overall, we find an influence of pacing strategy on the finish-sprint speed to be relatively small, but these small differences may be crucial for the final outcome of a race.

Practical Applications

The current findings demonstrate that elite XC skiers are able to sprint at approximately 85% of their V_{max} in a finish-sprint at the end of a XC skiing sprint race, with relatively equal contributions from skiers' V_{max} and their ability to utilize a high fraction of V_{max}. This main pattern was independent of XC style and pacing strategy, with the main factor leading to reduction of speed being reduced cycle rate. Based on these findings, we would advise sprint XC skiers to concurrently develop both these capacities, and to employ technical strategies where a high cycle rate can be sustained when fatigue occurs. However, while faster skiers were able to maintain a higher cycle rate in classic, in skating, the skiers' cycle length differentiated faster from slower skiers. Although, the influence of pacing strategy on the finish-sprint speed was relatively small in this study, these small differences may be crucial for the final outcome of a race. Being aware that only a fraction of a second divides the competitors in a sprint final, our data indicate that using a conservative pacing strategy when possible would benefit the majority of skiers.

We did not examine the deeper mechanisms related to the rate of fatigue, such as force production or muscle activity patterns, during the different skiing styles or pacing strategies in the current study. This is indeed a limitation of our approach and such factors should be examined in follow-up studies. A further limitation is the relative low sample size, requiring valid and reliable data to provide robust conclusion. Therefore, we do not provide data on more detailed temporal patterns and solely include variables where we are sure that observed differences are larger than the typical variation.

Conclusions

The findings in this study highlights the importance of being able to combine a high V_{max} with a high fraction of V_{max} in the finish-sprint both in DP and G3 skating and independent of pacing strategy. Although the main factor for reduction in speed in the finish-sprint was cycle rate, slower skiers might benefit from increasing cycle rate in DP and cycle length in G3 skating in order to sprint faster at the end of a race. This difference between the styles is of importance for coaches and athletes to be aware of, both when aiming to increase V_{max} and prevent negative effects of fatigue on speed.

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Figure legend

Figure 1 - 3-dimensional illustration of the 6 sections (S1-S6) of the 1.4-km sprint time-trial (STT) ending in an 80-m finish-sprint examined in the current study.

Figure 2 - Mean speed difference and mean percentage point (pp) difference (solid lines) for 12 elite male cross-country skiers using the classic (double poling) style with conservative vs. positive pacing strategy in 1.4-km sprint time-trials (STTs), respectively.

Figure 3 - Mean speed difference and mean percentage point (pp) difference (solid lines) for 12 elite male cross-country skiers using the skating style with conservative vs. positive pacing strategy in sprint time-trials (STTs), respectively.

Figure 4 - Finish-sprint speed compared to percentage of maximal speed (%V_{max}) in an 80-m finish-sprint in the end of 1.4-km sprint time-trials (STTs) for elite male cross-country skiers using the classic (double poling) and skating (G3) techniques with conservative vs. positive pacing

strategy, respectively (mean ± SD). Significant differences between pacing strategies are indicated by * $P<0.05$.

Figure 5 - Finish-sprint speed in relationship to maximal speed (V_{max}) in an 80-m finish-sprint in the end of 1.4 km sprint time-trials (STTs) for elite male cross-country skiers using the a) classic (double poling) and b) skating (G3) techniques with conservative vs. positive pacing strategy, respectively. The data points represent the individual skiers and the lines were obtained by linear regression.

Figure 6 - Finish-sprint speed in relationship to percentage of maximal speed (%V_{max}) in an 80-m finish-sprint in the end of 1.4 km sprint time-trials (STTs) for elite male cross-country skiers using the a) classic (double poling) and b) skating (G3) techniques with conservative vs. positive pacing strategy, respectively. The data points represent the individual skiers and the lines were obtained by linear regression.

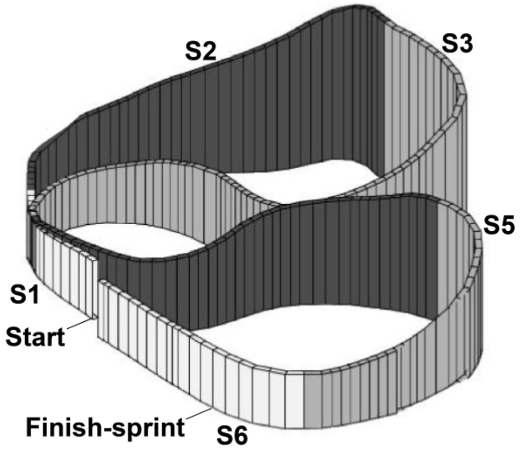
Table 1. Performance and physiological characteristics of 12 elite male cross-country skiers during 1.4-km sprint time-trials (STTs) ending in an 80-m finish-sprint using the classic (double poling) and skating styles with conservative and positive pacing strategies, respectively (mean ± SD).

	Conservative pacing	**Positive pacing**
CLASSIC		
BLa$_{pre}$ (mmol·L^{-1})	10.1 ± 4.7	9.0 ± 2.0
BLa$_{peak}$ (mmol·L^{-1})	13.1 ± 4.1	14.5 ± 2.8
Heart rate mean (%HR$_{max}$)	82.0 ± 3.7	84.3 ± 2.5*
Heart rate peak (%HR$_{max}$)	87.4 ± 3.7	89.0 ± 2.6*
Total (Borg 6-20)	17 ± 1	19 ± 1**
Uphill (Borg 6-20)	17 ± 1	19 ± 1**
Flat (Borg 6-20)	16 ± 2	17 ± 2*
Downhill (Borg 6-20)	14 ± 3	15 ± 2*
Race time (s)	234 ± 11	226 ± 15*
Finish-sprint (m·s^{-1})	8.0 ± 0.9$^{\#\#}$	7.8 ± 0.9$^{*,\#\#}$
Finish-sprint cycle length (m)	6.0 ± 0.4	6.1 ± 0.7
Finish-sprint cycle rate (Hz)	1.35 ± 0.14$^{\#\#}$	1.28 ± 0.15$^{*,\#\#}$
SKATING		
BLa$_{pre}$ (mmol·L^{-1})	9.8 ± 2.7	8.8 ± 4.5
BLa$_{peak}$ (mmol·L^{-1})	13.0 ± 2.3	14.3 ± 3.4
Heart rate mean (%HR$_{max}$)	84.4 ± 2.9	84.2 ± 5.5
Heart rate peak (%HR$_{max}$)	89.1 ± 3.1	89.2 ± 5.2
Total (Borg 6-20)	17 ± 1	19 ± 1**
Uphill (Borg 6-20)	18 ± 2	19 ± 2*
Flat (Borg 6-20)	16 ± 2	18 ± 1**
Downhill (Borg 6-20)	14 ± 3	16 ± 2*
Race time (s)	203 ± 8	200 ± 15
Finish-sprint (m·s^{-1})	8.9 ± 0.7$^{\#\#}$	8.7 ± 0.8$^{\#\#}$
Finish-sprint cycle length (m)	6.6 ± 0.7	6.8 ± 0.7
Finish-sprint cycle rate (Hz)	1.35 ± 0.10$^{\#\#}$	1.29 ± 0.11$^{*,\#\#}$

Significant difference between conservative and positive pacing, $^{*}P < 0.05$; $^{**}P < 0.01$.

Significant different from the maximal speed (V$_{max}$) test, $^{\#}P < 0.05$; $^{\#\#}P < 0.01$.

BLa$_{pre}$ Rest blood lactate, BLa$_{peak}$ Peak blood lactate.



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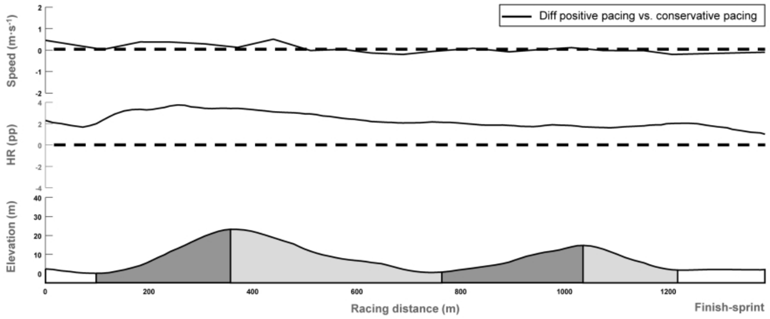

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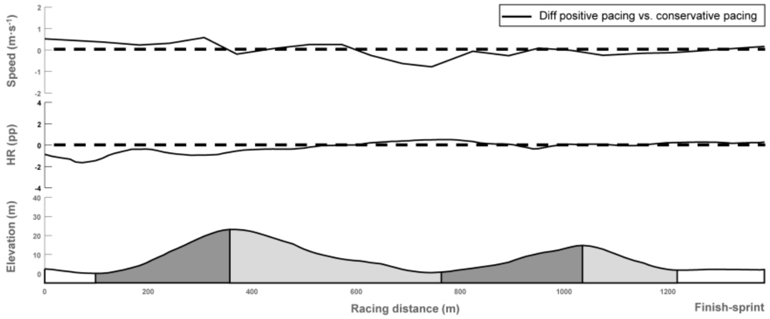

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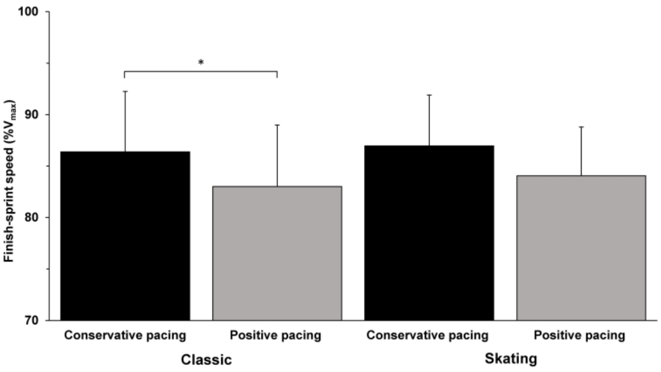

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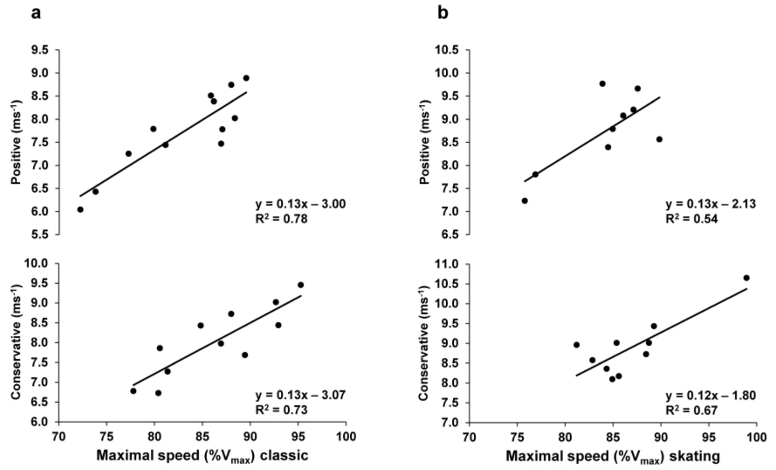

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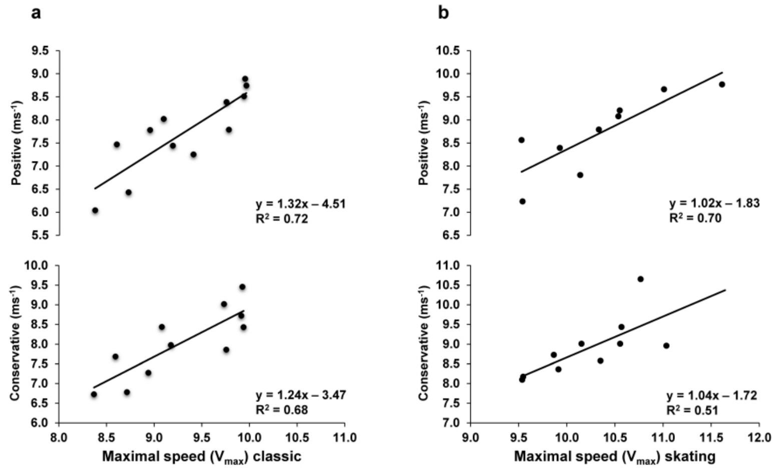

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