**High-level biathletes with a fast-start pacing pattern improve time-trial skiing performance by pacing more evenly**

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Note: This is a summary of findings. The full text will be published in a coming article in a peer reviewed journal.

## Background

In biathlon sprint, the most common pacing pattern is a J-shaped pacing strategy with a relatively fast first lap (before prone shooting), a slower second lap (before standing shooting) and then a (slightly) faster third lap. In contrast to most other endurance sports, pacing strategy in biathlon does not only influence endurance performance, but also the preparations to the precise task of rifle shooting. In sprint competitions, the laps are interspersed by a prone and a standing shooting each consisting of 5 shots. Each target missed results in a penalty loop of ~150 m (~25 s), with penalty time explaining 31-35% of the difference between placing in the top 10 or placing between 21-30 in World Cup sprint races. In biathlon World Cup sprint competitions, faster skiing speed on laps 2 and 3 differentiates medalists from other top 20 finishers. Furthermore, compared to lower performing athletes, the best biathletes tend to have lap times closer to their average pace, indicating that they employ a more even pacing pattern. In young cross-country skiers with a fast start pacing pattern, we recently found improved skiing performance by reducing their starting pace. This was accompanied by a lower heart rate and rate of perceived exertion (RPE) during the first part of the race, in which the lower start RPE resulted in lower score of summated RPE over the race. These observations allow us to hypothesize that a more conservative pacing strategy would be beneficial for skiing performance in high level biathletes with a fast-start pacing pattern.

## Purpose

This study tested the hypothesis that biathletes with a fast-start pacing pattern would improve time-trial skiing and shooting performance by using more even pacing during a simulated sprint biathlon competition. More specifically we investigated how this change in pacing strategy influences a) time-trial roller ski performance, b) hit rate and precision of prone and standing shooting and c) rate of perceived exertion and heart rate responses.

## Methods

Thirty-eight high-level biathletes (~21 yrs., 26 males) performed an individual 7.5 km (3x2.5 km for females) or 10 km (3x3.3 km for men) sprint biathlon race on roller skis with a self-selected pacing strategy (Day 1). Prone (after lap 1) and standing shooting (after lap 2) stages were performed using paper targets with 10 standard scoring rings. Based on their pacing strategy in the first time-trial (ratio between the initial ~800-m segment pace on lap 1 and average ~800-m segment pace on laps 1-3), subjects were divided into an intervention group with the fastest starting pace (INT, n=20) or a control group with a more conservative starting pace (CON, n=18). On Day 2, INT were instructed to reduce their starting pace, while CON was instructed to maintain their Day 1 strategy. During the race, the participants wore an integrated Inertial Measurement Unit (IMU) and Global Navigation Satellite System (GNSS) unit on their back (between thoracic vertebrae 4 and 5), to capture position and speed continuously. RPE using a 6-20 scale was reported verbally during the race (after ~800 m of each lap, before (~150 m) and after 1$^{st}$ shooting (~50 m), before and after 2$^{nd}$ shooting, ~200 m before the finish) and ~30 s after crossing the finish line. A poster illustrating RPE levels 6-20 was visible to the participants before and during the race and they reported a number to one of the investigators, who recorded it. Data are presented as mean ± standard deviation (SD), except for relative differences between test days and between groups, which are presented as means ± 95% confidence intervals (CI). Paired sample t-tests were used to calculate the differences within groups from Day 1 to Day 2, while an unpaired t-test was conducted between groups for the relative differences from Day 1 to Day 2. A P-value ≤ 0.05 was considered statistically significant.

## Results

On Day 1, the overall time for INT was 28:06 ± 1:31 min (women, n=6: 26:27 ± 00:51 and men, n=14: 28:49 ± 1:08 min), while the corresponding time for CON was 26:42 ± 1:28 min (women, n=6: 24:59 ± 1:05 min and men, n=12: 27:23 ± 0:52 min). There were significant differences in overall time between groups where CON performed better than INT (*P*=0.001).

INT increased their time-trial skiing performance more than CON from Day 1 to Day 2 (mean±95CI; 1.6±0.8% vs -0.4±0.9%, *P*=0.04). From Day 1 to Day 2, INT reduced their starting pace (5.0±1.5%, *P*<0.01), with reduced ratings of perceived exertion (RPE) during lap 1 (*P*<0.05). For CON, no change was found for starting pace (-0.8±1.2%) or RPE between days.

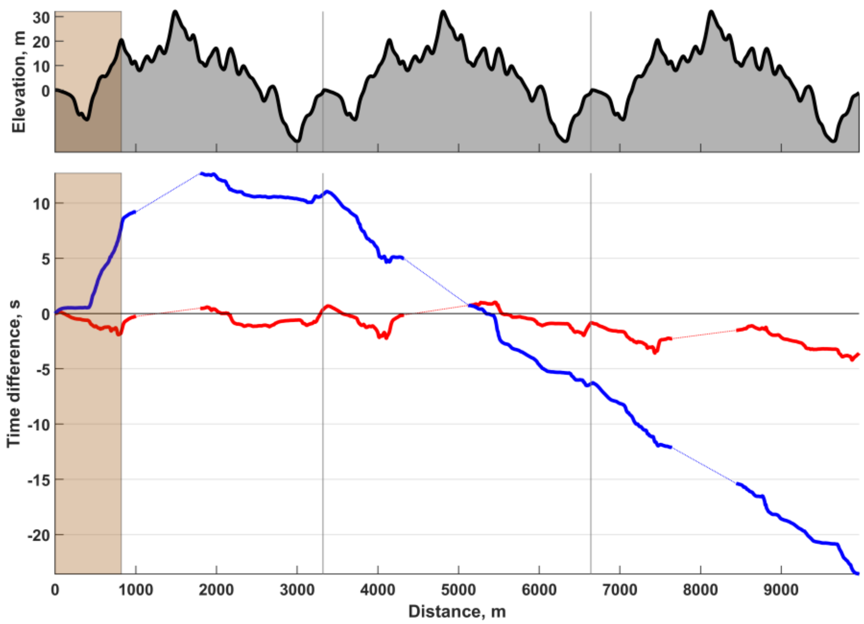


*Figure 1: Relative skiing time differences (excluding shooting) from Day 1 to Day 2 for INT (Intervention) in blue and CON (Control) in red. The thin dotted lines illustrate the segments were only the males skied. Females performed 7.5 km and males 10 km. The brown area illustrates the segment where INT were told to adjust the start pace the first lap.*

No differences in shooting performance were found within or between groups. INT performed prone shootings on Day 1 and Day 2 of 42.1 ± 3.8 and 41.8 ± 2.8 points ($P$=0.74) while the standing shootings resulted in 25.4 ± 6.0 and 24.2 ± 8.0 points ($P$=0.57). CON performed prone shootings on Day 1 and Day 2 of 42.4 ± 3.2 and 42.1 ± 3.2 points ($P$=0.70) while the standing shootings resulted in 28.6 ± 6.0 and 24.9 ± 6.2 points ($P$=0.07).

## Practical Application

The present findings demonstrate that reduced starting speed during the first ~3 min of a biathlon sprint competition substantially improves skiing performance for fast-starting biathletes. The beneficial effects of adjusting the starting pace were equal to a penalty lap (~25 s), which is substantial for overall performance. Since changing the pacing strategy did not influence shooting performance, but did reduce overall RPE, it appears that biathlon coaches and athletes would benefit from systematically evaluating individual pacing strategies and changing pacing patterns towards a more even lap-to-lap pacing for fast-starting biathletes.

## Conclusion

Biathletes with a pronounced fast-start pacing pattern benefit from using a more even pacing strategy to optimize time-trial distance skiing performance. The improved performance was reflected by faster skiing speed in all types of terrain, with no significant effect on shooting performance. In addition, the use of a more even lap-to-lap pacing strategy led to lower perceived exertion during the race.