NORWEGIAN SCHOOL OF SPORT SCIENCES

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How a change to a more controlled start pace affects biathletes with a fast-start pacing pattern

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Abstract

Purpose: In sprint biathlon with 3 equal laps, the most used pacing strategy is parabolic with the first and last lap being the fastest. However, as the best biathletes tend to have a more even pattern than the rest of the competitors, our aim was to investigate whether competitive junior biathletes with a fast-start pacing pattern increase time-trial performance by use of a more even pacing strategy.

Methods: Thirty-five biathletes, male and female (~17.5 years) performed two biathlon races of 6780 meters on roller skis, separated by 24 hours. The race consisted of 2 prone shootings, with 2260 meters between shootings. On day 1 all participants were instructed to perform a self-paced race as fast as possible. On day 2, the half with the fastest relative start pace before first shooting (relative to their average lap time) were instructed to have a more controlled opening pace before the first shooting (Intervention group; INT). The remaining participants (Control group; CON) were instructed to replicate their pacing strategy from day 1.

Results: At day 2 compared to day 1, INT increased their time before the first shooting (mean ± 95% confidence interval; 1.8% ± 0.87%, $p<0.001$, effect size; ES = 1.0), but finished with a faster overall skiing time (-0.95% ± 0.82%, $p<0.05$, ES = 0.55). CON showed no change in skiing time before the first shooting (0.1% ± 1.0%, p=0.84, ES = 0.0) or overall skiing time (0.0% ± 0.9%, p=0,98, ES = 0.0). Despite INT's improvement in skiing time, there were no significant difference in skiing improvement between groups (p=0.12, ES = 0.54). The summated Rate of Perceived Exertion (RPE) for the race as a whole were reduced for INT ($p < 0.001$). INT shot significantly better than CON on day 1 ($p<0.05$). INT had a significant lower total shooting score on day 2 (-5.8% ± 4.0%, $p<0.05$, ES = 0.74), and lower score for the first shooting (-6.9% ± 5.1%, $p<0.05$, ES = 0.72) compared to day 1. CON had no significant differences in neither summated RPE or shooting results between days (both $p>0.05$).

Conclusion: For junior biathletes with a fast start pattern, a change towards more controlled opening seems to lead to a faster skiing time and reduced summated RPE. This implies that such a strategy is beneficial for skiing performance and leads to less discomfort during the race. However, INT reduced shooting performance which implies

that an acute change in start pace could influence skiing and shooting performance differently.

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As I am writing this, my five-year journey at the Norwegian School of Sport Sciences comes to an end. I feel privileged to have been able to study at a school like this, and will look back at my time here with great joy.

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Abbreviations

RPE: Rate of Perceived Exertion

HS: hazard score

VO_{2max}: maximum rate of oxygen consumption

ES: effect size

HR: heart rate

HR_{max}: maximum heart rate

CON: control group

INT: intervention group

GNSS: global navigation satellite systems

IMU: inertial measurement unit

IBU: International Biathlon Union

FIS: International Ski Federation

1. Theory

1.1 Biathlon

Biathlon is an Olympic winter sport combining the two vastly different exercises of free technique cross country skiing, and rifle shooting. Olympic biathlon consists of a total of four individual competition formats, which are sprint, pursuit, individual, and mass start. The sprint and individual competition are both time trial events, while in mass start and the pursuit the first finisher wins the race. The main characteristic for the pursuit, is the fact that the starting order is based on results from a previous sprint competition. Details about length and shooting in the different competition formats are shown in Table 1. In addition to the individual competitions, there are two relay competitions. One consisting of four of the same sex on the same team, while the mixed relay consists of two male and two females in each team. Competitions lasts from 20 minutes to almost an hour depending on the competition format. Shooting is performed in both the prone and standing shooting in every competition. Athletes either ski 3 laps with 2 shootings or 5 laps with 4 shootings.

Table 1: *Table showing details about the different individual competitions in Olympic biathlon for different age groups and sexes. P= prone shooting, and S= standing shooting.*

	Competition format	**Competition distance (km)**	**Length of skiing loop (km)**	**Shooting sequence**	**Penalty for missed shot (s=seconds, m=meters)**
Men	Individual	20	4	P-S-P-S	60 s
	Sprint	10	3.3	P-S	150 m
	Mass start	15	3	P-P-S-S	150 m
	Pursuit	12.5	2.5	P-P-S-S	150 m
Women	Individual	15	3	P-S-P-S	60 s
	Sprint	7.5	2.5	P-S	150 m
	Mass start	12.5	2.5	P-P-S-S	150 m
	Pursuit	10	2	P-P-S-S	150 m
Junior men	Individual	15	3	P-S-P-S	60 s
	Sprint	10	3.3	P-S	150 m
	Mass start	12.5	2.5	P-P-S-S	150 m
	Pursuit	12.5	2.5	P-P-S-S	150 m
Junior women	Individual	12.5	2.5	P-S-P-S	60 s
	Sprint	7.5	2.5	P-S	150 m
	Mass start	10	2	P-P-S-S	150 m
	Pursuit	10	2	P-P-S-S	150 m

Youth men	Individual	12.5	2.5	P-S-P-S	45 s
	Sprint	7.5	2.5	P-S	150 m
	Mass start	10	2	P-P-S-S	150 m
	Pursuit	10	2	P-P-S-S	150 m
Youth women	Individual	10	2	P-S-P-S	45 s
	Sprint	6	2	P-S	150 m
	Mass start	7.5	1.5	P-P-S-S	150 m
	Pursuit	7.5	1.5	P-P-S-S	150 m

Shooting are performed in the prone and standing position with 5-shot sequences on a shooting range with 50 meters from the range to the targets. The relays are the only races where the biathletes have more than 5 shots to hit the 5 targets, where they have a total of 8 shots to hit all five targets. The target has a diameter of 45 mm in the prone position and 115 mm in the standing position. In all competitions except for the individual, a missed target is penalized with a penalty loop of 150 meters. In the individual competition, a miss is penalized with 60 seconds added to the total race time (International Biathlon Union, 2021, p. 392). The biathlon rifle is a caliber 0.22 long rifle, which must have a minimum weight of 3.5 kg, and are carried by the biathletes during the whole race.

The length of competitions depends on both sex and age. Biathletes between the age of 16 and 19 are classified as youths, while juniors are from age 20 to 22 according to the IBU rules. Above the age of 22, biathletes are classified as seniors (International Biathlon Union, 2021, p. 4).

1.2 Skiing demands in biathlon

The physical demands in biathlon is very similar to those in cross-country skiing, in the sense that courses are build with equally amounts of flat, downhill and uphill terrain, with approximately 50 % of the skiing time spent in the uphill sections of the course (Laaksonen, Jonsson, et al., 2018, p. 2). The very best biathletes need to have high maximal aerobic power, and male Olympic medalists are shown to have an oxygen uptake (VO_{2max}) of >80, while females are shown to have > 65 $mL \cdot kg^{-1} \cdot min^{-1}$ (Tønnessen et al., 2015, p. 836). Compared to cross country skiers, male Olympic winners have an average VO_{2max} just above cross country sprint skiers, and just under the distance skiers. However the female biathletes have an average VO_{2max} below both distance and sprint cross country skiers (Laaksonen, Finkenzeller, et al., 2018, p. 397).

In addition to high aerobic power, biathletes need to master the skating technique. With rapid changes in terrain, biathletes need to change between several sub-techniques throughout the race. Example of a 2.5 km skiing loop used in biathlon world cup is shown in Figure 1, from Holmenkollen arena. Cross country skiers in the sprint distance change sub-technique between 15 and 25 times per kilometer (Andersson et al., 2010, p. 593). Due to similar course profiles in biathlon and cross-country skiing, this number is probably transferable from cross-country skiers to biathletes. However, an important difference in skiing between the two sports, are the fact that biathletes are carrying their rifle on their back throughout the race. This affects the skiing technique by increasing the cycle rate, by reducing pole and leg ground contact time, regardless of what sub-technique that are used (Stöggl et al., 2014, p. 620). What effect carrying a rifle has on the choice of sub-technique remains unclear due to a lack of studies on the topic.

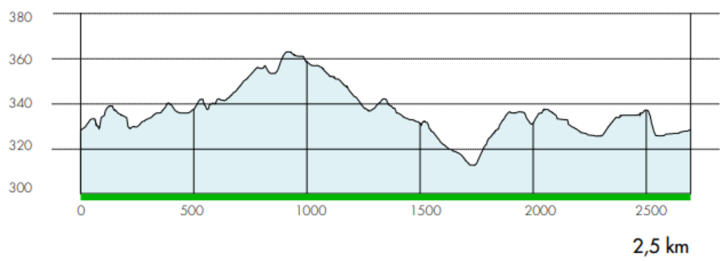

Figure 1: *Course profile from Holmenkollen arena, showing elevation in the 2.5km loop used in biathlon. Total climb in this loop is 85 meters (Oslo Kommune).*

In addition to high aerobic power, the ability to ”reload” the anaerobic capacity is of great importance, due to the constant intensities exceeding peak VO_2max in the uphill sections of the race, as shown for cross-country skiers (Karlsson et al., 2018, p. 7). As shown in Figure 1, there are rapid changes in terrain in a biathlon course as well. Joyner and Coyle (2008) proposed a model of what major variables determines performance in endurance competitions, shown in Figure 2. As the figure shows, performance depends on gross efficiency together with total energy turnover (Joyner & Coyle, 2008, p. 37).

Together these factors are the most important physical abilities a biathlete needs for maximising performance. To best maximise these abilities, tactical factors like pacing is important. Pacing will be described in detail later in the theory section. The pacing pattern a biathlete uses could have an effect on the VO_2 kinetics, in the sense that a pacing pattern with lower starting intensity could contribute to delaying the onset of the VO_2 slow component. The VO_2 slow component is a term used when an athlete exceeds ones lactate threshold, and the VO_2 continues to rise above the anticipated linear relation between VO_2 and power output, and if it fails to stabilize, will lead to fatigue (Burnley & Jones, 2007, pp. 67-68).

The importance of skiing speed in biathlon, depends on the competition format. In world cup sprints, skiing speed is shown to explain 59% and 65% of the time difference between top 10 biathletes and biathletes finishing between 21 and 30, for males and females respectively (Luchsinger et al., 2018, p. 361). For the individual race, skiing time accounted only for 42 % for males and 54 % for females between the same groups as in the sprint study (Luchsinger et al., 2019, p. 191).

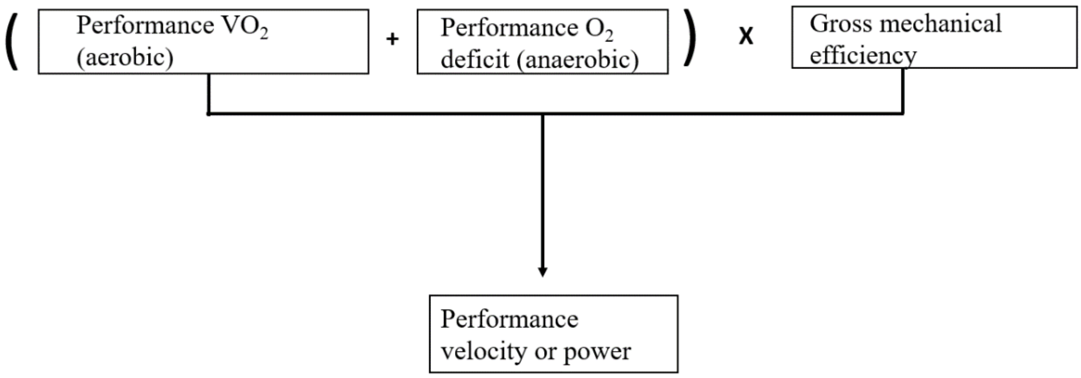

Figure 2: *Major physiological factors that interacts as determinants of performance (Figure modified from.(Joyner & Coyle, 2008, p. 37).*

1.3 Shooting performance in biathlon

In addition to skiing performance, precision on the shooting range is the other main determinant of the total performance in biathlon. Biathletes shoot 2 or 4 times each race dependent on the race format, however, each race consists of shooting in both the prone and standing position. To perform at the highest level, the number of missed hits needs to be very low. Medalists in World Championships and Olympic Games, are shown to have a hit percentage above 95% (Laaksonen, Finkenzeller, et al., 2018, p. 397). As for skiing time, shooting performance affects the final result differently on the different competition formats. In the sprint competition, penalty time accounted for 35% and 31% for males and females respectively when differentiating between the top 10, and those among the 21-30 places in the world cup (Luchsinger et al., 2018, p. 361). In the individual competition penalty time accounted for 53% and 44% when comparing the same groups as in the sprint competition (Luchsinger et al., 2019, p. 191). This increase in shooting importance is probably due to twice as many shootings combined with a penalty for missed shots of 60 seconds, which is longer than the time it takes to complete a penalty loop.

For the pursuit and mass start, it is indicated that shooting performance are more crucial in mass start than pursuit (Björklund et al., 2021, p. 102). This is likely due to the nature of the pursuit, where the biathletes are not starting with equal prerequisites for the finishing result. Despite this, shooting affects the final result more than skiing time in both race formats (Björklund et al., 2021, p. 103).

1.3.1 Prone shooting

Generally the prone shooting has a higher hit percentage than the standing shooting (Björklund et al., 2021, p. 98; Luchsinger et al., 2018, p. 361; 2019, p. 192). At rest, the most important factors for shooting performance are the stability of hold, aiming accuracy, cleanness of triggering and the timing of the triggering. These three factors together explain 80 % of the mean variance in shooting performance (Köykkä et al., 2022, p. 418). Prone shooting performance is shown not to be negatively affected by increasing intensity, although the size of the shot grouping were significantly different between rest and peak heart rate (Hoffman et al., 1992, p. 271). This indicates that shots are more spread across the target, but not enough to significantly reduce the number of hits. There is according to Köykkä et al. (2022)'s knowledge, only one study in addition to their own who looks what factors affects prone shooting performance. The other study from Sattlecker et al. (2017), focused on investigating what factors discriminate high from low score in biathlon shooting. The main findings was that forces from the rifle to the shoulder were almost 70 % greater in high scoring shooters, than the low scoring shooters at rest. The other factor discriminating high scorers from low scorers was the vertical rifle sway. In a race simulation, the main factor differentiating the shooters, was the vertical rifle sway, which is heavily influenced by increased intensity, due to increased breathing activity and heart rate (Sattlecker et al., 2017, p. 380). Together these are the performance determining factors literature says are the most important ones for biathlon prone shooting.

1.3.2 Standing shooting

Despite having larger targets in the standing position than in prone, the standing position has a higher number of misses than the prone. This is due to greater technical difficulties when shooting in the standing position (Luchsinger et al., 2018, p. 364). The increased difficulty is likely caused by the increased range of motion in the standing position, due to having only two contact points to the ground, compared to three in the prone position (Luchsinger et al., 2018, p. 364). Additionally the center of gravity is placed above the support area (Mojžiš & Paugschová, 2013, p. 296). In sprint competitions, the risk of missing a shot in the standing position are reduced for each shot throughout the series (Luchsinger et al., 2018, p. 364), which might be due to the physiological recovery when standing still.

Due to increased degrees of freedom, the main determinant for predicting high-scoring shooters in the standing position are the mean velocity of the rifle sway, and the ability to reduce the body movements the last 0,5 seconds before triggering. In addition to rifle sway, body sway also shows a relation to performance, which makes sense since increased body sway, will increase the sway of the rifle (Sattlecker et al., 2017, p. 381).

Contrary to in the prone position, aiming accuracy and timing of triggering does not show a relation to shooting performance in the standing position (Ihalainen et al., 2018, p. 1705). In the standing position, biathletes typically employ one of two different aiming strategies. These two strategies are hold, which means the biathlete employs a low velocity of the gun 0.4-0.2 seconds before firing. The other strategy called timing, are when biathletes employ a high velocity 0.4-0.2 second before triggering. These two strategies do not seem to differ in performance (Köykkä et al., 2021, p. 575). These strategies, and especially the timing strategy, might explain why aiming accuracy does not seem to affect the performance, since aiming in the timing strategy involves movement of the rifle throughout the shot.

1.4 Pacing

1.4.1 Pacing strategies

In sports where the aim is to complete a given distance in the shortest amount of time, the pacing strategy will be one of several decisive factors determining the end result. Pacing strategies describes how one distributes ones energetic resources throughout the competition (Abbiss & Laursen, 2008, p. 240). Distribution of powers includes intensity and pace during a race, and how this change throughout. Abbiss and Laursen (2008) defines 6 different pacing strategies. These strategies are; negative-, all out-, positive-, even-, parabolic-, and variable pacing. Different strategies are applied for different durations, and are also dependent on the form of movement.

Negative pacing is a strategy where the pace gradually increases throughout the duration of the competition. This strategy are often found in middle distance events, and the increase in pace often occurs at the end of the competition when athletes are aware of the remaining distance (Abbiss & Laursen, 2008, p. 241). This effect is also known as the end spurt phenomenon (Noakes, 2011, p. 28).

Positive pacing strategy is the opposite of the negative, where athletes reduces the pace throughout a race. This strategy is shown to be used both when the duration of the competition is relatively short, like a 800 meter run, as well as in ultra endurance events with durations of > 4 hours (Abbiss & Laursen, 2008, p. 243).

Even pacing strategy is a strategy where the pace is even throughout the race, or on a lap to lap basis, as in biathlon and cross country skiing. It is proposed that this strategy is the optimal for events with a prolonged duration (> 2 minutes), such as in cross country skiing (Abbiss & Laursen, 2008, p. 244; Losnegard et al., 2022, p. 4). The proposal that the even pacing at a lap-to-lap basis in cross country skiing is the most optimal strategy, makes this project interesting to determine whether this statement is correct also in biathlon (Losnegard et al., 2022, p. 4). As previously mentioned, the most common pacing strategy in biathlon is the parabolic strategy, where the pace usually is at its slowest in the middle part of a competition. This might be the result of an athlete both utilizes a positive and a negative pacing in the same competition (Abbiss & Laursen, 2008, p. 245).

All-out pacing is, as its name suggests a strategy where the athlete uses their maximum effort from start to finish. It is utilized at short durations where much of the competition time is spent accelerating, like the 100 m sprint in track and field. Variable pacing is when the pace and power output varies throughout the duration (Abbiss & Laursen, 2008, pp. 241,246). Due to the constant changes in terrain, biathletes and cross-country skiers employ a variable pacing pattern overall, since the speed changes in different terrain.

1.4.2 Choice and regulation of pacing

The athletes choice of pacing strategy is based on several factors, including previous experience, anticipation of exercise duration and distance, physiological feedback and information about the course profile (Losnegard et al., 2022, p. 1; Tucker, 2009, p. 394). Tucker (2009, p. 396) proposed a model consisting of two components for how athletes regulate pacing before and during a competition. The two components are the anticipatory-, and the feedback component. The anticipatory component depends on factors like previous experiences in exercises with similar distance and duration, physiological inputs before the start of exercise, like muscle glycogen levels or skin temperature, and psychological inputs like arousal, motivation and competitors (Tucker, 2009, p. 395). The ability to distribute energy throughout a race is something that needs to be practised and will improve as an athlete gets older and more experienced. This theory is supported by findings that older athletes utilizes a more even pacing pattern than younger cross country skiers (Sollie et al., 2020, p. 560). Pacing behaviour is shown to develop during adolescence, partly due to cognitive development (Sakalidis et al., 2021, p. 3). Cognitive skills are important for pacing due to the constant need to make decisions. In complex sports, like biathlon, there are a great number of elements which requires athletes do decide whether or not to alter their pacing (Sakalidis et al., 2021, p. 2). Examples of this are shown in Figure 3.

The feedback component on the other hand, is based on what happens during the exercise, the athletes subjective feeling. The momentary Rate of Perceived Exertion (RPE) is constantly compared to the template RPE, throughout the exercise, and if the momentary RPE is not matched with the template, the intensity needs to be altered to match the template (De Koning et al., 2011, p. 1). The template RPE is a theoretical construct, that can not be directly measured, but is made by the athlete based on previous experience and knowledge from similar durations (Tucker, 2009, p. 395) In addition, physiological changes during exercise, might alter the momentary RPE as well, which again leads to change in intensity, if it does not match the template RPE (Tucker, 2009, pp. 395-396). The concept of a template RPE, highlights the fact that pacing is a trainable skill.

Based on these two components, athletes chooses their opening pace, and accordingly creates a template RPE for how the RPE will gradually increase to its maximum at the end of the competition. The main objective with pacing in competitions with a certain duration such as biathlon is not to hit maximum RPE before the end of an exercise to prevent premature fatigue before finishing (Roelands et al., 2013, p. 302).

1.4.3 Pacing in biathlon

In a biathlon context, the choice of a pacing strategy is complex and based on several variables that is distinctive for biathlon. At senior world cup level, skiing speed is associated with a podium finish only on lap 2 and 3 in the sprint competition when comparing lap times within the top 20 finishers (Björklund & Laaksonen, 2022, p. 6). This further enhances the importance of examining whether a more controlled opening are beneficial.

In both biathlon sprints and the individual competition, a parabolic pacing strategy seems to be the most commonly used for the best senior biathletes. More precisely a "J-shaped" pacing strategy, which means the first lap is the fastest one, with the lap or laps coming after are consequently slower, before increasing the speed in the last lap (Luchsinger et al., 2018, p. 362; 2019, p. 195). This seems also to be the case for youths, as seen by the latest youth world championship (Figure 3) (*Biathlonresults*) Despite this strategy being the most applied, there are differences in performance groups in how much pronounced their pacing strategy are. The best performing athletes tends to have lap times closer to their average pace than lower performing athletes, indicating that the best ones employs a more even pacing (Luchsinger et al., 2018, p. 362; 2019, p. 195).

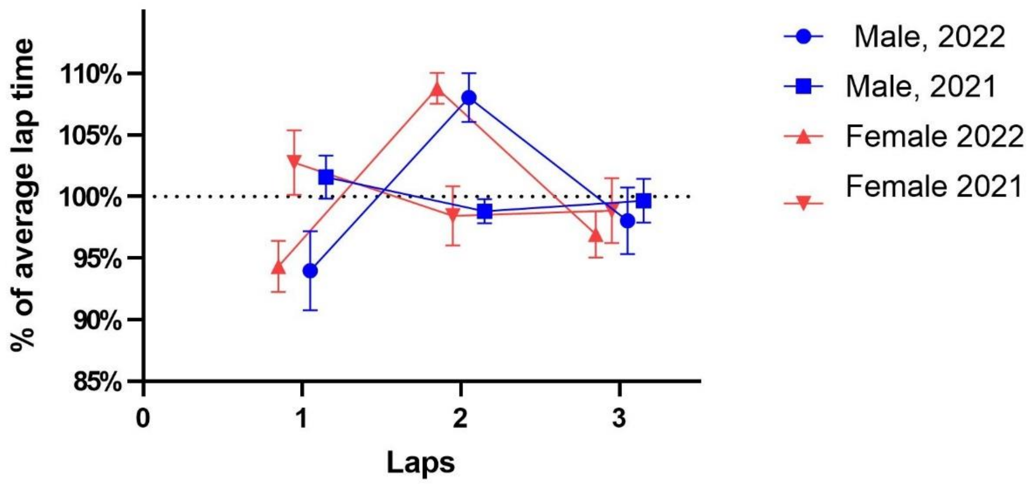

Figure 3: *Pacing index showing the average pacing pattern utilized by the top 30 finishers in the last two youth world championship sprint competition in biathlon. Pacing index is calculated as lap time/ average lap time.*

What differentiates the choice of pacing strategy in biathlon from the similar sport of cross country skiing, is obviously the repeated stops for shooting. One of the reasons biathletes employ a parabolic strategy with a fast last lap is probably due to both the end spurt phenomenon, but also to the fact that the biathletes do not need to reduce the intensity prior to a shooting. In addition to that, in competitions where missed targets are penalized by penalty loops, there is an unknown factor where the biathletes are not fully aware of the distance they are going to complete before attending the task, which may alter the pre-planned template RPE.

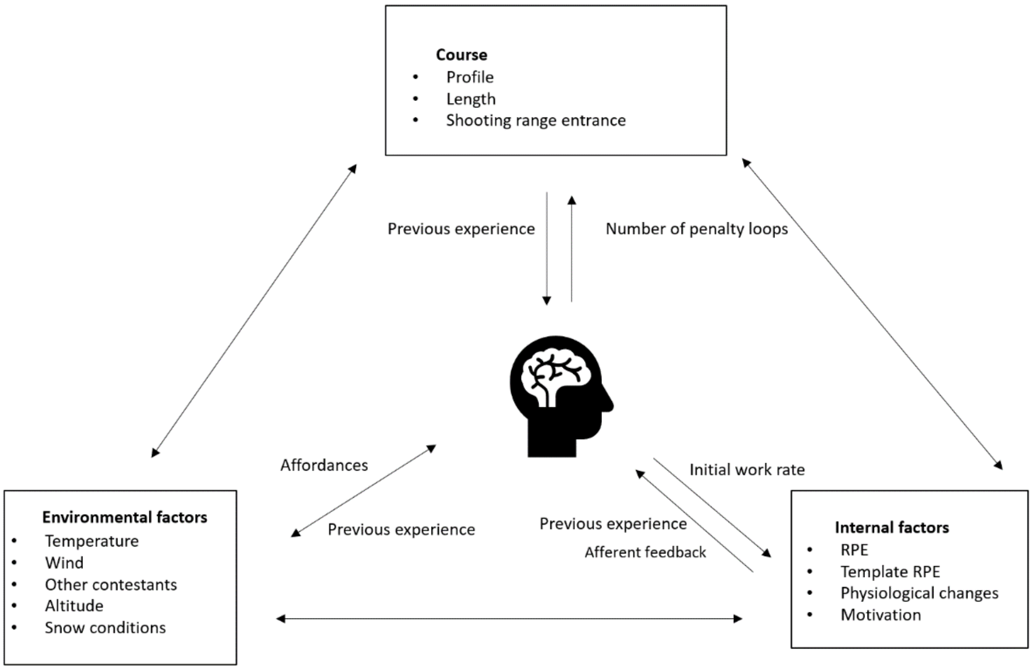

Figure 4: *Cognitive model showing some of the factors affecting the pacing strategy applied in biathletes.*

1.5 Summary

Biathlon is a complex sport requiring the physical and technical abilities found in cross country skiing, combined with the abilities to shoot precisely at intensities of 60% and 70% of HR_{max} for the prone and standing positions respectively (Hoffman & Street, 1992). In addition to the mentioned requirements, there is also a tactical aspect in biathlon in regards to distribution of energy throughout a race. What pacing pattern athletes are employing in an endurance sport have a great effect on the final result. Pacing strategies in biathlon has only ever been studied by observation, not by an intervention study. Therefore knowledge about what pacing strategy is the most optimal in biathlon are limited.

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2. Article

2.1 Abstract

Purpose: In sprint biathlon with 3 equal laps, the most used pacing strategy is parabolic with the first and last lap being the fastest. However, as the best biathletes tend to have a more even pattern than the rest of the competitors, our aim was to investigate whether competitive junior biathletes with a fast-start pacing pattern increase time-trial performance by use of a more even pacing strategy.

Methods: Thirty-five biathletes, male and female (~17.5 years) performed two biathlon races of 6780 meters on roller skis, separated by 24 hours. The race consisted of 2 prone shootings, with 2260 meters between shootings. On day 1 all participants were instructed to perform a self-paced race as fast as possible. On day 2, the half with the fastest relative start pace before first shooting (relative to their average lap time) were instructed to have a more controlled opening pace before the first shooting (Intervention group; INT). The remaining participants (Control group; CON) were instructed to replicate their pacing strategy from day 1.

Results: At day 2 compared to day 1, INT increased their time before the first shooting (mean ± 95% confidence interval; 1.8% ± 0.87%, p<0.001, effect size; ES = 1.0), but finished with a faster overall skiing time (-0.95% ± 0.82%, p<0.05, ES = 0.55). CON showed no change in skiing time before the first shooting (0.1% ± 1.0%, p=0.84, ES = 0.0) or overall skiing time (0.0% ± 0.9%, p=0,98, ES = 0.0). Despite INT's improvement in skiing time, there were no significant difference in skiing improvement between groups (p=0.12, ES = 0.54). The summated Rate of Perceived Exertion (RPE) for the race as a whole were reduced for INT (p < 0.001). INT shot significantly better than CON on day 1 (p<0.05). INT had a significant lower total shooting score on day 2 (-5.8% ± 4.0%, p<0.05, ES = 0.74), and lower score for the first shooting (-6.9% ± 5.1%, p<0.05, ES = 0.72) compared to day 1. CON had no significant differences in neither summated RPE or shooting results between days (both p>0.05).

Conclusion: For junior biathletes with a fast start pattern, a change towards more controlled opening seems to lead to a faster skiing time and reduced summated RPE. This implies that such a strategy is beneficial for skiing performance and leads to less discomfort during the race. However, INT reduced shooting performance which implies

that an acute change in start pace could influence skiing and shooting performance differently.

2.2 Introduction

Biathlon is an Olympic winter sport combining the two vastly different exercises of free technique cross country skiing, and precise rifle shooting. Olympic biathlon consists of a total of four individual competition formats, which are “sprint” (7.5 and 10 km), “pursuit” (10 and 12.5 km), “individual” (15 and 20 km), and “mass start” (12.5 and 15 km), in addition to two relay competitions. Biathletes shoot 2 or 4 5-shot series depending on the competition format, and accordingly skies 3 or 5 laps. The most frequently raced competition format in biathlon, the sprint competition, consists of three laps of skiing with two shootings. First in the prone position and then in the standing position. A missed target is penalized by a penalty loop of 150 meters.

Skiing performance in the sprint distance at world cup level is showed to explain 59% to 65% of the time difference when comparing the top 10 finishers with those finishing in the places from 21 to 30. The remaining percentages are mainly explained by missed targets (Luchsinger et al., 2018, p. 363). Although when isolating the top 20 finishers, the fundamental variable for achieving podium finishes seems to be the number of missed targets for both males and females (Björklund & Laaksonen, 2022, p. 5). Interestingly, the only lap where skiing speed does not seem to be associated with a podium finish is the first lap, when comparing podium finishers to top 20 (Björklund & Laaksonen, 2022, p. 6). However, to date, how an alteration in pacing pattern, and specifically how the start pace influences the result in a biathlon competition, is not known.

For senior cross country skiers, a positive pacing strategy seems to be the most applied strategy, although the very best male skiers tend to have a more even pacing compared to their lower performing counterparts (Losnegard et al., 2016, p. 3259). In biathlon on the other hand, a parabolic pacing strategy seems to be the most applied. More specifically a “J—shaped” strategy with the first lap being the fastest, and the subsequent laps going slower before an increase in speed on the last lap. The similarities is though that they both tend to apply a pacing pattern with a fast start. As in cross country skiing, the very best athletes tend to apply a more even pacing compared to those further down the result list. (Björklund & Laaksonen, 2022, p. 5; Luchsinger et al., 2018, p. 362; 2019, p. 195). To date there has not been done any studies on pacing for younger athletes in biathlon, although in cross-country skiing there seems to be a tendency where younger athletes demonstrate a more pronounced positive pacing strategy compared to their older counterparts (Sollie et al., 2020, p. 560). This indicates that altering the pacing pattern in youths could be beneficial due to their pronounced positive pacing.

In the last decade several studies have investigated different factors related to shooting performance, skiing performance, pacing patterns (Björklund et al., 2021; Luchsinger et al., 2018, 2019; Laaksonen, Finkenzeller, et al., 2018) and differences in skiing technique with and without carrying a rifle (Stöggl et al., 2014). However, to date, no studies have examined how a change in pacing pattern will affect skiing and shooting performance during a simulated biathlon race. A recent study in cross country skiing indicates that a change for the skiers with a fast starting pace to a more even pacing could be beneficial (Losnegard et al., 2022). Thus, it is therefore interesting to examine whether this also is evident for biathletes.

Therefore the aim of the present study was to identify how a reduction in start pace would affect those with the most pronounced positive pacing pattern, both in terms of shooting and skiing performance.

2.3 Methods

2.3.1 Participants

Fifteen male (mean age 17.5 ± 2) and twenty female (mean age 17.4 ± 1.3) biathletes were recruited in this study. Participants were recruited based on being active biathletes located at Geilo, attending the Norwegian High School of Elite Sports in Geilo, or the biathlon team, Team Geilo. Participants were informed of this project by their school coach, which again were informed about this project by the researchers. In addition, all participants signed a written consent, prior to testing. Participants over the age of 16 could sign their own written consent, while participants under the age of 16 needed their parents consent. The study was approved by the ethics committee of the Norwegian School of Sport Sciences and found advisable by the Norwegian Center for Research Data (reference number 726969). The research was conducted according to the declaration of Helsinki.

2.3.2 Overview of experimental procedures

Participants performed 2 time simulated biathlon races on 2 days separated by 24 hours. On day 1, participants performed an self-paced individual biathlon race of 6780 m on roller skis, using free technique, with 3 laps of 2260 meters with two prone shootings, using their own .22 caliber biathlon rifle. Each lap between shootings consisted of 2 equal laps of 1130 meters (Figure 1).

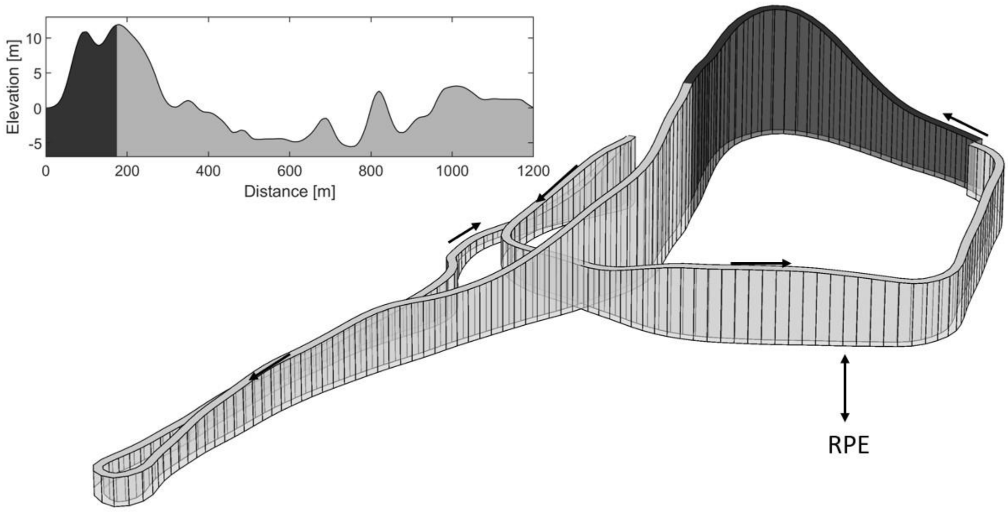


Figure 1*. Profile showing the course elevation profile of a lap of 1130 meters, and a three-dimensional map of the course. Arrows indicates the direction participants went through the course. Double sided arrow indicates where participants reported their Rate of Perceived Exertion. The black marked area are where participants in intervention group where told to reduce their speed before the first shooting on day 2.*

The race was conducted with standardized roller skis, Swenor Skate wheel type 2 (Sarpsborg, Norway) in Geilo, (Geilo, Norway, altitude 760 m above sea level), with a self selected pole length. On day 2, skiers were divided into two groups. Based on the time used on the first lap of 1.1 kilometers, relative to the individuals total race time without shooting (1lap/average of 6 laps), an “intervention group” (INT) were made of the fastest starters, with 18 of the 35 participants. The remaining participants were assigned in to a “control group” (CON) which was instructed to perform day 2 in a identical manner as day 1. The two participants who did not participate on day 2 were originally assigned into the intervention group. Therefore, we decided to move 2 participants from the control group with relatively similar positive pacing pattern, to the intervention group. On day 2 INT were told to reduce their start pace on the two laps prior to the first shooting. After the first shooting INT used a self paced strategy. CON were told to replicate the same pacing strategy that they used on day 1. The two groups possessed a similar level of shooting performance, based on shooting results from competition and test races on prone shooting from the last two years. INT averaged 76.2% hits, while CON averaged 75.6% hits ($p = 0.85$).

After each lap of 1.1 km, the participants reported their rate of perceived exertion (RPE) verbally, using a scale from 1 to 10 (Borg, 1982), which the participants were used to from their daily training. Additionally there were a poster illustrating the RPE levels from 1 to 10 visible for the skiers prior to start. Participants reported their RPE approximately 100 meters before entering the shooting range and was registered by one of their coaches. This resulted in a total of 6 RPE measures per participant, each day. The starting order was identical on both days, and the time between the two races were 24 hours.

2.3.3 Procedure

Each testing day started with the participants arriving at the stadium and shot an individual number of sighting shots at a cardboard target to adjust their aiming. Then, the global navigation satellite system (GNSS) and inertial measurement unit **(**IMU) unit, weighing 67 grams (Optimeye S5, Catapult Innovations, Melbourne, Australia) were rigidly mounted to the top of the weapon stock using double sided tape and plastic cable ties (Figure 2). The electrical targets from Megalink (Megalink Electronic Biathlon 50, Vestby, Norway) were also tested prior to the races on both days, to make sure they were functioning properly.

Figure 2. *The GNSS and IMU unit mounted to the biathlon weapon during testing.*

Participants performed a warm-up on roller skies, consisting of approximately 20 minutes of skiing in low intensity, meaning intensity-zone 1-2 according to Olympiatoppen's intensity scale (55-82 % of max heart rate (HR)), before approximately 5 minutes of skiing in moderate (82-87 % of max HR), intensity, zone 3

(Olympiatoppen, 2021). The last 10 minutes before start were also used skiing in low intensity. Due to a limited number of electric shooting targets, each participant started with a 30 second time interval, in 3 groups of 10 participants, and 1 group with 5 participants. Before start, participants were assigned to a dedicated target that they were to shoot both series on. The start and finish were at the end and start of the shooting range respectively, and participants skied through the shooting range between the laps they were not shooting, so that each lap of 1.1 km were identical, shown in Figure 6. Lap times were recorded using Racesplitter timekeeping system (Makalu Logistics Inc., Fontana, CA, USA), and were registered at the start and end of the shooting range to be able to subtract the time used while shooting to determine the time spent skiing. Each participant were told to use their own watch with a HR monitor, and wear their weapon throughout the whole race.

During shooting, a hit or a miss was blinded for the participants and no penalty loops for missed shots were given, to prevent a participant from loosing motivation over bad shooting. After each participant had shot their series, a picture were taken of the Megalink screen, and later used to analyse each series. Pictures were taken due to the software from Megalink not being able to transfer shooting data after shooting. Between day 1 and 2, split times from the first race were analysed to determine which groups participants should be assigned to, based on their pacing strategy.

On day 2 the participants were told whether they were assigned into the control or intervention group approximately 40 minutes before start. INT were then shown a graph showing how much time they lost and where they lost that time on lap 2 and 3 compared to lap 1, (example shown in Figure 3). CON were also shown a graph of their pacing, but were told to replicate that pacing strategy on day 2. Participants were told how much slower they were to go the first lap based on how much time they lost on the last two laps. The participants were told to focus on going slower in the uphill, with a focus on the longest uphill, marked with a darker color in Figure 1. The rest of day 2 were carried out the same way as day 1. In flat and downhill terrain participants in the intervention group were told to go with the same pacing and speed as day 1

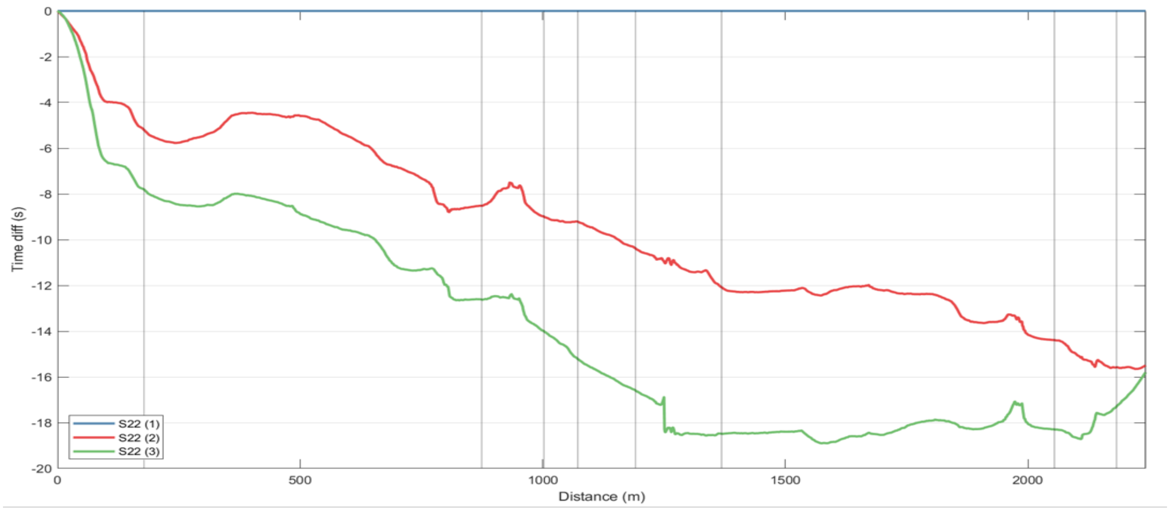


Figure 3: *Example of a graph shown to participants in INT prior to start on day 2. X-axis is the distance from start to shooting. Y-axis displays the time lost to lap 1 (blue line) The red (lap 2) and green (lap 3) line shows time-lost compared to lap 1. In this example the participant were told to slow down the first lap by approximately 6 to 8 seconds.*

2.3.4 Conditions

This study was conducted mid-August on two separate days. Day 1 had air temperatures ranging from 8°C to 11°C while day 2 had temperatures between 7°C to 13°C. Day 2 had a period with light rain, which made the asphalt wet, but it did not seem to affect skiing time. Both days had 1-4 $m \cdot s^{-1}$ wind from west. Day 2 though had some gusts of wind stronger than on day 1.

2.3.5 Data analyses

Course profile and elevation were calculated based on the data from several GNSS-units. For two participants on day 1, time from the GNSS unit were used to determine lap times due to an error made when recording two participants entering the shooting range at the same time. This was calculated by dividing lap times from all participants to their own time determined by the GNSS unit, to find the average margin of error between the two systems. This average margin of error were subtracted from the time obtained from the GNSS-unit, to determine their lap times as precisely as possible. HR data from the participants personal watches was collected after both days of testing, and subsequently synchronized with data from the GNSS-unit. On day 1, 28 participants submitted their HR data, and 22 submitted their data for day 2. Due to measurements errors, only 18 of 28 on day 1 and 11 of 22 were usable. Due to this, HR measurements are not used in the results in this study.

To determine the quality of shooting results, both number of hits were used, as well as the number of points each shooting series acquired. Each shot were given points between 0.0 and 10.9, by the Megalink system. A target in a prone shooting is 45 mm in diameter (International Biathlon Union). A score of 8.2 equals to 45.6 mm and is the score closest to 45 mm, and was therefore used as the threshold for defining a shot as a hit or a miss.

For analyses done on the size of shot grouping, we used custom computer program (written in Matlab R2021a; Math-Works, Inc, Natick, MA) where all shots manually were placed on a graphical representation of the target, based on the pictures of each shooting series. From this a midpoint from the 5 shots were found. To determine the size of the shot grouping in a series, the average distance between the midpoint and the shots were calculated. A picture of the computer program is shown in Appendix 1.

2.3.6 Statistical analysis

Data are presented as mean ± standard deviation. Statistical analyses were performed using Microsoft Office Excel 2019 (Microsoft, Redmond, WA, USA). To calculate the difference within groups from day 1 to day 2, a paired sample t-test was used. To calculate the relative differences between groups from day 1 to day 2, an unpaired t-test were used. A P-value of ≤ 0.05 was considered statistically significant. To calculate whether or not there was a correlation between shooting time and shooting results, and HR at the shooting range entrance and shooting results, a Pearson correlation analysis was conducted, also in Microsoft Office Excel 2019. Figures were created using Graphpad (GraphPad Software, Inc., USA), Microsoft Office PowerPoint 2019 (Microsoft, Redmond, WA, USA), and Matlab.

Hazard Score (HS) was calculated by multiplying the remaining fraction of the race by the current RPE, while summated HS was calculated by adding the HS values for each lap (Binkley et al., 2021, p. 4). Cohen’s D effect size (ES) was used to calculate the magnitude of change within groups and across the two groups, and was calculated in Microsoft Office Excel 2019.

2.4 Results

2.4.1 Skiing performance

INT had a significant increase in the first lap-time on day 2 compared to day 1 ($p < 0.01$) (Table 1 and Figure 4) and a significant reduction in overall skiing time on day 2 compared to day 1. Overall Time (Mean ± SD) was reduced from 18:39 ± 01:44 to 18:29 ± 01:49 (mean ± 95% confidence interval; -0.95% ± 0.82%, $p < 0.05$, ES = 0.55), while CON had the same average finishing times both days (18:33 ± 02:00 on day 1, and 18:33 ± 02:03 on day 2, $p = 0.98$, ES = 0.005). There was no significant difference in change score between INT and CON, but ES was = 0.53, which suggests a moderate effect. Lap times for both days are shown in Table 2. CON had no difference in finishing times for both days, and there was no difference in start pace between days. Absolute changes in seconds within the groups between days are shown in Figure 4, while every participant's absolute change from day 1 to day 2 is shown in Figure 5. Thirteen out of 18 participants improved their finishing time in INT, while 9 out of 15 participants improved their skiing time in CON. Pacing patterns utilized are illustrated in Figure 6.

When examining sexes isolated, there were no significant differences, neither within or across groups in skiing time from day 1 to day 2.

Table 1: *Average lap times ± standard deviation for CON and INT for all 3 laps for both days. Shooting time not included.*

	Control group (n=15)			Intervention group (n=18)		
	Lap 1	**Lap 2**	**Lap 3**	**Lap 1**	**Lap 2**	**Lap 3**
Day 1 (mm:ss)	06:11 ± 00:42	06:14 ± 00:39	06:08 ± 00:41	06:05 ± 00:33	06:19 ± 00:34	06:15 ± 00:37
Day 2 (mm:ss)	06:11 ± 00:42	06:15 ± 00:41	06:07 ± 00:41	06:12 ± 00:35 **	06:12 ± 00:39 **	06:07 ± 00:38 *

Note: Data are mean and SD. ** = significant change compared to INT on day 1. ** = significant change compared to INT on day 1 and a significant change score from day 1 to day 2 compared to CON.*

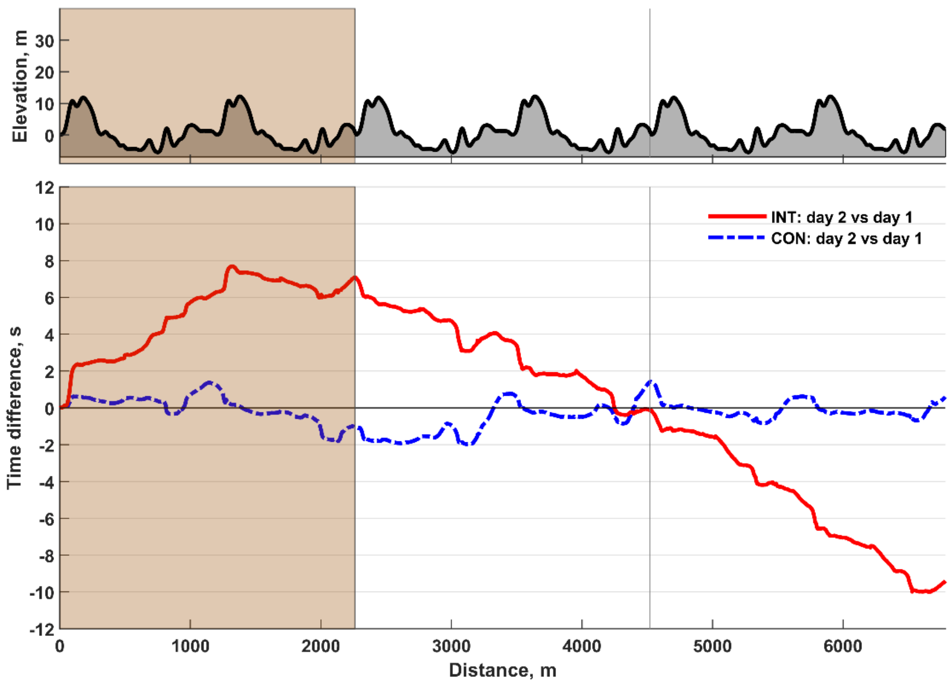


Figure 4: *Absolute average time difference between days, at each point in the course. The marked area of the course represents where INT were told to reduce their pace. The red represents INT, and the blue line represents CON. The vertical gray lines represent where shooting found place. INT indicates intervention, CON indicates control.*

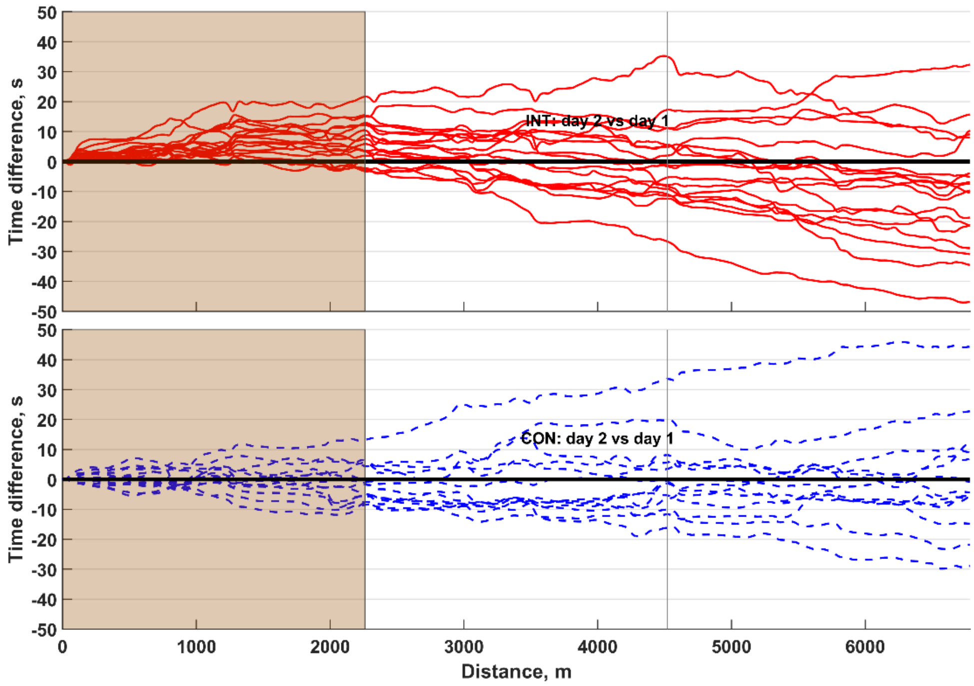


Figure 5: *Absolute time difference at each point in the course for every individual. INT in red and CON in blue. The marked area of the course represents where INT were told to reduce their pace. The vertical gray lines represent where shooting found place. INT indicates intervention, CON indicates control.*

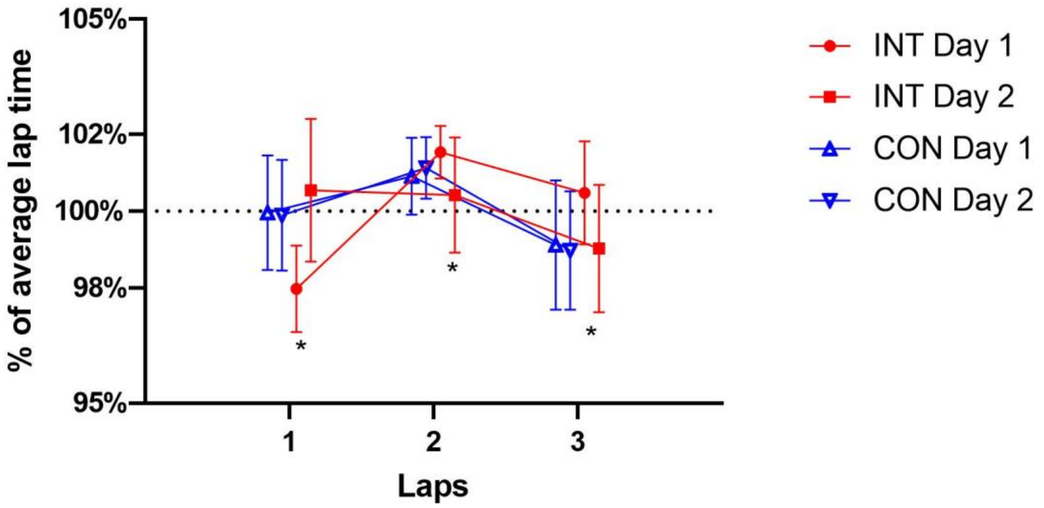
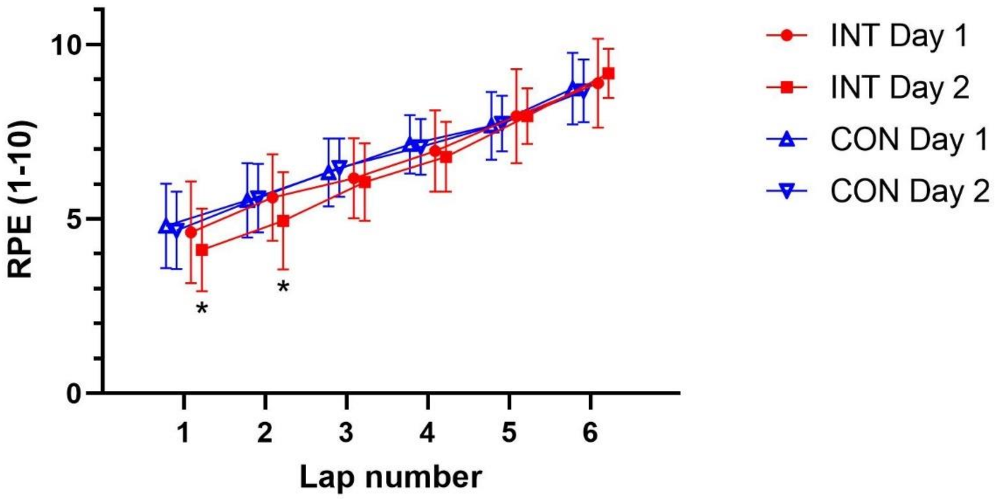


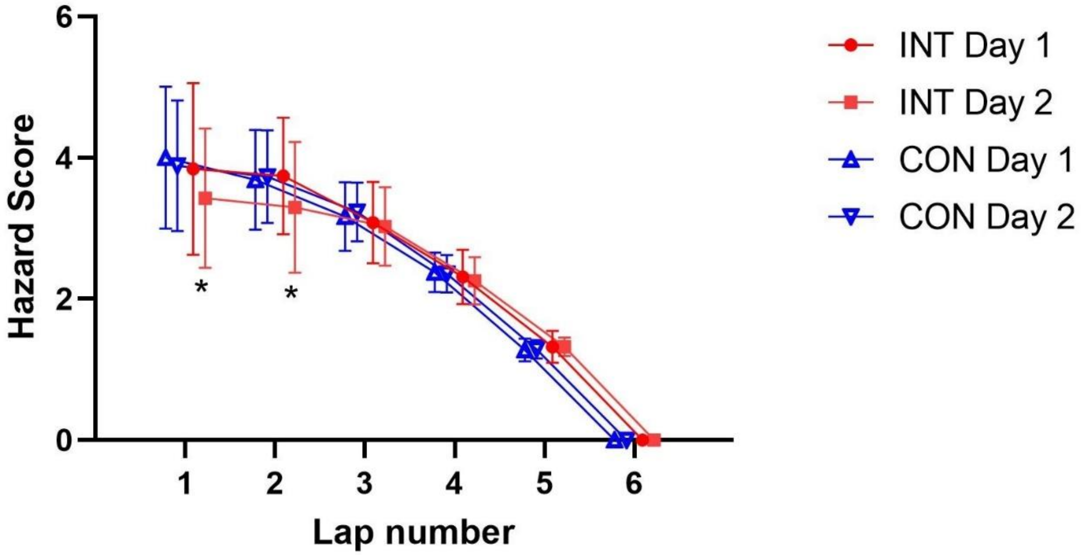
Figure 6: *Pacing index, showing how the groups distributed their pace throughout the race in relation to their respective relative pace. The index is calculated as lap time/average lap time.* ***Note:*** ** = significantly different from day 1 to day 2 for INT. INT indicates intervention, CON indicates control.*

2.4.2 Rate of Perceived Exertion

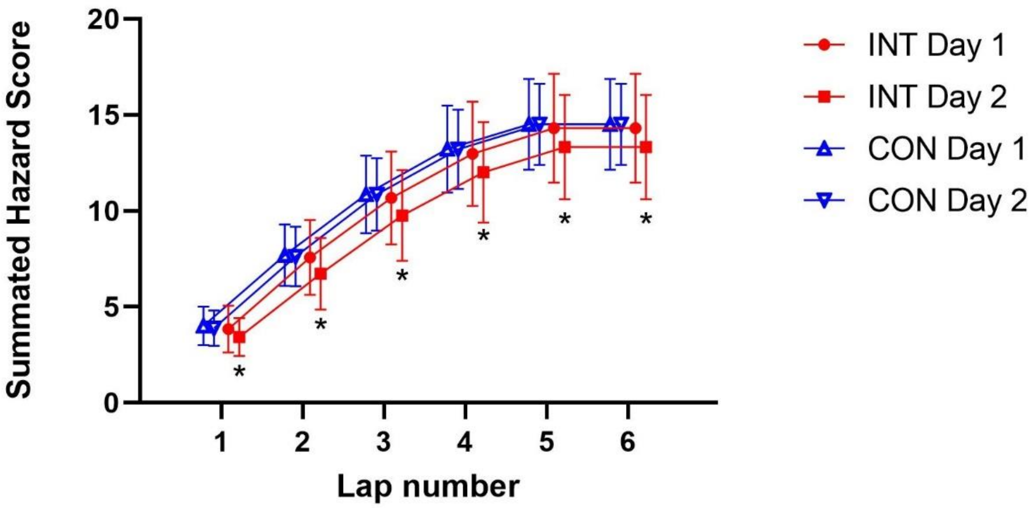
Figure 7 shows the RPE (a), Hazard Score (b) and Summated Hazard score (c) for both groups and both days. INT displayed a lower RPE and Hazard Score for the two first measurements on day 2, compared to day 1 ($p < 0.05$). For the Summated Hazard score, INT had significantly lower values for all 6 measurement points ($p < 0.05$). The summated RPE reported at the end of each lap was lower in INT at day 2, compared to day 1 ($p < 0.001$). CON had no significant changes from day 1 to day 2, in any of the measured RPE values. There were no relevant differences in RPE between sex, in neither of the groups nor days.


10
5
0
RPE (1-10)
*
*
1
2
3
4
5
6
Lap number
INT Day 1
INT Day 2
CON Day 1
CON Day 2

(a)


6
4
2
0
Hazard Score
*
*
1
2
3
4
5
6
Lap number
INT Day 1
INT Day 2
CON Day 1
CON Day 2

(b)



(c)

Figure 7: *RPE (a), Hazard Score (b) and Summated Hazard Score (c), based on reported RPE at the end of each lap. All measurements are taken at the same place, but groups are differentiated for visual reasons.* ***Note:*** ** = significantly different from day 1 to day 2 for INT. INT indicates intervention, CON indicates control.*

2.4.3 Shooting performance

Shooting results are shown in Table 3, with both average points and average number of hits per series, (hit = > 8.1 points). INT shot a significantly higher score than CON on day 1 for the first series and for both series combined (both $p < 0.05$). INT shot a significantly lower score on the first series (-6.9% ± 5.1% $p < 0.05$, ES = 0.72) on day 2, and for both series combined (-5.8% ± 4.0%, $p < 0.05$, ES= 0.74) , compared to INT on day 1. In addition, INT had a significantly higher change score from day 1 to day 2 compared to CON, on the first series ($p < 0.05$, ES = 0.31) and both series combined ($p < 0.05$, ES = 0.71). CON had no difference between the days ($p > 0.05$, ES = 0.006). Shot grouping shows the average distance between the midpoint of each series and each shot. A higher score indicates a bigger spread of shots. There were no significant differences, neither between groups, nor between days inside the two groups, despite INT having a significantly lower number of points hit on day 2.

When isolating sexes, males in INT only had a significant change in the first series between days, while females in INT only had a significant change for the second series between days ($p < 0.05$). In both cases the changes were to a lower number of points on day 2. In CON, males showed no significant difference between days, while females had a significantly higher score for the first series on day 2 compared to day 1 ($p < 0.05$). Females in INT also had a significantly lower change score from day 1 to day 2, compared to females in CON, while males showed no difference between groups in change score.

Table 3: *Average points (mean ± SD), hits and average distance from shots to midpoint of the series (distance is shown in numbers of points away) per series, for both groups both days. All series are prone shootings.*

	Control group (n=15)		**Intervention group (n=18)**	
	1st shooting	**2nd shooting**	**1st shooting**	**2nd shooting**
Day 1 (points)	41.7 ± 2.4	42.5 ± 3.4	44.5 ± 3.5*	44.0 ± 2.3
Day 2 (points)	42.4 ± 3.9	41.8 ± 3.8	41.3 ± 3.7**	42.0 ± 3.7**
Day 1 (hits)	3.1 ± 1.0	3.4 ± 0.9	3.5 ± 0.8	3.7 ± 0.8
Day 2 (hits)	3.4 ± 1.0	3.0 ± 1.3	3.1 ± 1.2	3.1 ± 1.3
Day 1 (shot grouping)	1.98 ± 0.49	2.12 ± 0.67	1.82 ± 0.47	1.83 ± 0.51
Day 2 (shot grouping)	2.18 ± 0.87	2.03 ± 0.56	2.1 ± 060	2.01 ± 0.50

Note: ** = Significantly different to CON (p = 0.003). ** = Significantly different change score from day 1 to day 2 compared to CON (p < 0.05).*

2.5 Discussion

This study shows that an individually adjusted reduced starting pace in those who employ a fast start pacing pattern, resulted in a reduction of the total skiing time in biathlon sprint in young biathletes. The reduced starting pace also resulted in a lower overall rate of perceived exertion. However, surprisingly, a more controlled start pace also resulted in a lower number of points gained on the shooting range.

2.5.1 Skiing performance

As instructed beforehand, participants in INT were able to increase their skiing time prior to the first shooting on day 2. Importantly, all participants were instructed to employ a more controlled start pace, not a “slow” start. In addition, the participants were told to focus mainly on reducing their speed in the uphill sections of the course (marked in dark on Figure 1)**,** and maintaining the approximately same pace on the flat and downhill sections between days. This is due to the high O_2-demand in uphills where athletes frequently apply intensity above their peak VO_2-max (Karlsson et al., 2018, p. 7). By reducing the effort at these sections of the course, one might be able to delay the O_2 – deficit that athletes obtain during uphill sections. Additionally, it is shown that the uphill sections are the main determinant of overall cross-country skiing performance (Sandbakk et al., 2011, p. 953). Since both cross-country skiing and biathlon has the same amount of uphill climb in a race (International Biathlon Union, 2021, p. 10; Skiforbund, 2018, p. 48), we assume that this is similar in cross-country skiing and biathlon events. The more controlled start pace resulted in a reduction in skiing time, which is similar to what has been found in junior cross-country skiing (Losnegard et al., 2022, p. 3). It has been shown that gross efficiency and cycle length on roller skies are reduced after high-intensity exercise (Grasaas et al., 2014, p. 22). The more controlled start pace may therefore contribute to a smaller reduction in gross efficiency or that the onset of the reduction comes later in the race compared to day 1.

A controlled start pace resulted in a more evenly paced race for INT compared to their own self-paced race, as shown in Figure 6. On day 1, INT employed a “J-shaped” pacing, with the first lap being the fastest one, and the second being the slowest. This is the same pacing strategy that top 30 athletes, both male and female world cup level biathletes tend to apply in sprints (Luchsinger et al., 2018, p. 362). However, younger athletes tend to apply a even more positive pacing pattern than their older counterparts (Sollie et al., 2020, p. 560). At the sprint distance in the 2022 youth world championship, it was clear to see that the same pacing strategy as in the present study was applied (*Biathlonresults*)**.** One reason why it might be the most applied pacing strategy in biathlon sprint could be due to the increased difficulty related to standing shooting. This is shown by the average number of hits, which even on world cup level are lower in standing than in the prone position (Luchsinger et al., 2018, p. 364). Biathletes might therefore attend this task with a lower intensity than in prone shooting. Interestingly, the participants employed a “J-shaped” pacing strategy, despite not shooting in a standing position on the second shooting. It is unclear why. It might be because of the accumulated fatigue from the first lap, combined with the awareness of a new shooting coming up, leads to a more controlled pace on the second lap.

The improvement in overall skiing time was not influenced by sex. CON had the same average skiing time on both testing days, which indicated that conditions did not change between days. CON also had similar pacing patterns both days when comparing lap times. Pacing is a skill that is both psychological and physiological, and they both develop significantly throughout puberty and towards adulthood (Elferink-Gemser & Hettinga, 2017, p. 832). Development of pacing behaviour differs from athletes during adolescence (Wiersma et al., 2017, p. 1229). Different development of pacing behaviour might partly explain why some participants had a more even pacing strategy than others prior to instructions, and therefore were assigned to CON.

A more even pacing strategy is often referred to as the most optimal strategy for competitions with a prolonged duration (Abbiss & Laursen, 2008, p. 244). Cross-country skiing and biathlon differs from other endurance sports due to the constant change in terrain, speed, applied techniques and thereby frequent shift in intensity. Therefore, the overall pacing has to be examined based on lap times to determine what type of pacing pattern athletes has employed, rather than the momentary speed. Despite this, it has been suggested that a more evenly lap-to-lap paced race are beneficial for cross-country skiing as well, at both senior and junior level (Losnegard et al., 2016, p. 3259; Losnegard et al., 2022, p. 4). The present study strengthens the idea that a more even pacing strategy is beneficial also for skiing performance for biathletes.

2.5.2 Rate of Perceived Exertion

Followed by a reduced skiing time on day 2, INT had a reduction in RPE. Both RPE and HS prior to the first shooting were significantly lower on day 2 compared to day 1. HS can give information about whether an athlete is at risk of premature fatigue, or is able to increase their speed later on in the race, in order to be within acceptable limits of homeostatic disturbances (De Koning et al., 2011, p. 2). Therefore, a reduction in HS early on in the race on day 2 for INT implies that the risk for premature fatigue is reduced. The reduction in RPE prior to first shooting resulted in a reduction on the summated HS for all measurements throughout the race on day 2. These findings are in line with what has been found in cycling time trails with different opening-pace strategies. Here they found that whilst HS may be similar at some specific time points during the trail, the summated HS, will be higher with a faster start (Binkley et al., 2021, p. 11). This is in line with the present study, since HS are relatively similar between groups after the first shooting, but the summated HS is significantly lower in INT from day 1 to day 2 at all laps.

2.5.3 Shooting performance

On day 1, INT shot significantly better than CON for the first series, and the summated number of points gained shooting from both series. These findings are surprising since the two groups did not differ in shooting performance based on the two previous seasons prone shooting results that were collected by the participants coaches**.**

On day 2 there were no significant differences between the two groups, but as INT had superior shooting at day 1, INT had a significant decrease in number of points hit from day 1 to day 2. When only looking at whether a shot was a hit or a miss, there were no significant differences, neither between groups, nor between days within the groups. It has previously been found that change in HR does not have a significant impact on the shooting results (Hoffman et al., 1992, p. 272). It has been suggested that biathletes find individual strategies to deal with increased fatigue while shooting, and therefore no general predictor of shooting could be discovered when comparing shooting at rest to shooting after skiing (Sattlecker et al., 2015, p. 38). The same research-group found that vertical rifle movement and shoulder force were discriminating factors differencing low from high performers at prone shooting at race-load. The athletes main task in a race-like shooting situation were to control the vertical movement of the rifle (Sattlecker et al., 2017, p. 380). A rifles vertical movement is highly dependent on HR and breathing activity, and it would therefore seem logical that shooting at a lower intensity would be a less challenging task. Despite a lack of valid HR measurements in this study, it is fair to assume that that the intensity on the first shooting for INT on day 2 was a similar or lower than on day 1 due to the reduction in skiing speed**.** The assumed lower intensity does not explain the reduction in shooting performance.

Taken together, it seems like INT for some reason overachieved on the shooting range on day 1, since there were no obvious reason these shooters would perform better than CON based on previous results. In addition the two groups had very similar shooting results on day 2. Since the number of hits did not significantly decrease from one day to the other for INT, the practical implication in a race would be small. However, it is fair to assume that hitting a lower number of points while shooting indicates that the chance of a missed target increases.

Another aspect which may impact shooting results in this study is the fact that participants did not see whether a shot hit or missed the target during shooting. This may have lead to the participants not adjusting their aim, or their lying position after one or two bad shots, since no visual feedback were given to them.

The reduced points hit might also come from the fact that the biathletes had to focus on a new task that they were unaccustomed to, which could affect participants in INT's ability to focus solely on shooting. Another explanation might be that the intensity INT shot their series in on day 2 were different from what they are used to. This, though, does not explain why INT shot worse for the second series as well as the first, since they were free to go at their desired intensity on lap 2 and 3.

When looking at shot grouping, there were no significant differences between groups, although INT had a slight increase (15.5% ± 15.4%, $p=0.09$, $ES = 0.43$) in the average distance from shots to the series middle point with. Since this value was calculated based of each series' individual middle point, a series with a low number of points might end up with a low average distance from middle point, if the whole series is skewed to one direction.

2.5.4 Limitations

A potential limitation in this study is the fact that the participants were divided into groups based solely on their pacing strategy. This ended up resulting in INT having a significantly higher amount of points on day 1's shooting, despite previous results indicating that there were no differences in the groups. In a future study, shooting results should also be considered when dividing into two groups, to eliminate the risk of uneven shooting results going in to day 2. On the other hand that could result in a participant with a positive pacing ending up in CON, while an other participant with a more evenly pacing ending up being assigned to INT.

The fact that heart-rate data collected in this study were too poor to use in the analysis is a limitation. Using standardized equipment on all participants might have eliminated this problem, and possibly given some answers to why shooting results in INT ended up the way they did.

The fact that this study was carried out on roller skies instead of on-snow skis might be a limitation, since biathlon is a winter sport and is carried out on skis. Roller ski performance is however highly correlated to distance FIS points (Talsnes et al., 2021, p. 14), which indicates that roller skis is a valid measurement for on-snow skiing. Females and males skied the same distance in this study, which is longer than youth females are used to in their competitions, which might affect their pacing strategy due to lack of experience in the distance. However there were almost equally many females and males ending up in INT solely based on their pacing pattern, which indicates that females did not pace their race much different than males did.

Total climb on the course in this study was about 199 meters, which is slightly less than the minimum requirement for total climb in biathlon. According to the competition rules for youths made by the International Biathlon Union (IBU), a biathlon sprint of 7500 meters should contain a minimum of 210 meters climb (International Biathlon Union, 2021, p. 10). Due to the course available in this study, this was not feasible, but the difference between this study and the rules are small, which indicates the course was quite representative of a race-course. This also implies that the results are generalizable to some degree.

In a competition where missed targets are penalized, it might affect the pacing strategy due to an unknown length of the race. This is not taken into account in this study due to the uncertain results it would bring.

There was a bit more wind on the shooting range on day 2, but due to CON shooting similar results both days, it is unlikely that it affected INT more than CON. However, uneven wind conditions will always be an uncertainty when shooting outdoors.

2.6 Conclusion

For youth biathletes that tend to employ a fast start pace, a reduction in skiing speed in the first lap seems to be beneficial for improving skiing time in the sprint competition. With such a strategy, the biathletes also perceive the race as less exhausting while still skiing faster. Despite this, it seems that shooting results for some reason are negatively affected with a slower first lap.

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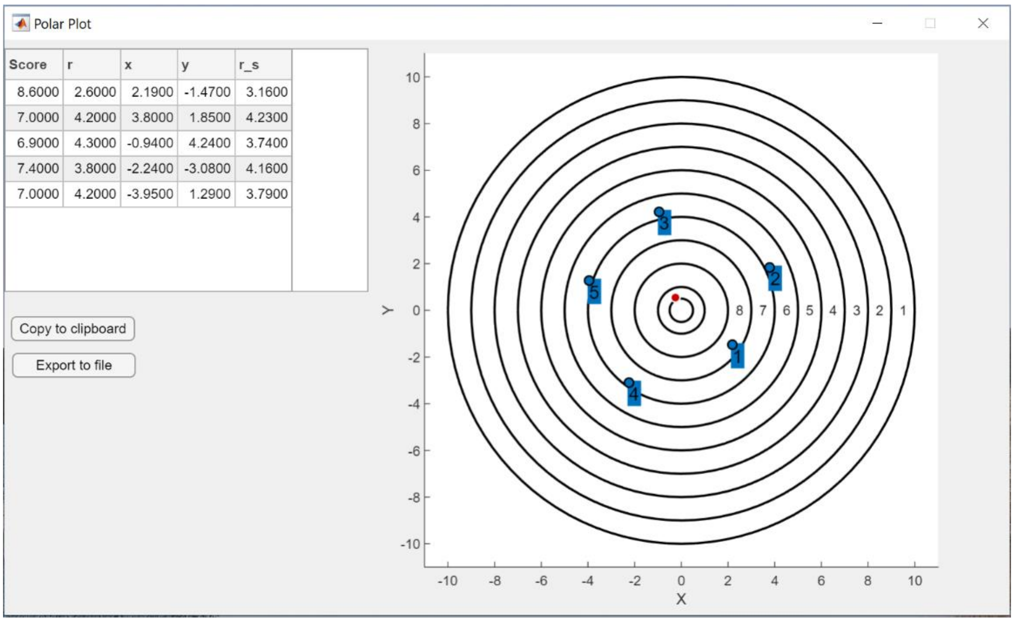
Appendices

Appendix 1

Picture of the Mathlab - program used to quantify the size of shot grouping.



Appendix 2

Example of a photo from the Megalink screen, used to find points of each shooting and shot grouping.

Attachments

I Godkjenning fra etisk komité ved Norges idrettshøgskole

II Informert samtykkeskriv

III NSDs godkjennelsesbrev

Thomas Losnegard
Institutt for fysisk prestasjon

OSLO 10. juni 2021

Søknad 189 – 170621 – Åpningshastighetens effekt på prestasjon på liggende skyting i skiskyting og total prestasjon

Vi viser til søknad, prosjektbeskrivelse, informasjonsskriv og innsendt melding til NSD.

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, har leder av komiteen på fullmakt fra komiteen konkludert med følgende:

Vurdering

Deltakerne er godt trente utøvere og testene som skal gjennomføres er ikke mer belastende enn en hard treningsøkt eller en konkurranse. Komiteen forutsetter at det gjennomføres en screening som sikrer at deltakere som pga sykdom, skader eller lignende ikke bør inkluderes. I tillegg bør det etableres en form for beredskap dersom det oppstår skader under gjennomføringen av testene.

Vedtak

På bakgrunn av forelagte dokumentasjon finner komiteen at prosjektet er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har komiteen lagt følgende forutsetning til grunn:

- *Vilkår fra NSD følges*
- *Det gjennomføres en screening av deltakerne*
- *Det etableres en form for beredskap for eventuelle skader under gjennomføring av testene*

Komiteen forutsetter videre at prosjektet gjennomføres på en forsvarlig måte i tråd med de til en hver tid gjeldende tiltak ifbm Covid-19 pandemien.

Komiteen gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon. Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

NIH NORGES IDRETTSHØGSKOLE

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NORGES IDRETTSHØGSKOLE

Vil du delta i forskningsprosjekt om løpsstrategi i skiskyting?

Dette er en forespørsel om å delta i et forskningsprosjekt der formålet er å se på betydningen av ulike åpningsstrategier i skiskyting, og dets effekt på prestasjonen i skyting og på ski. I dette informasjonsskrivet vil jeg beskrive prosjektet og hva en deltakelse vil innebære for deg som forsøksperson.

Formål

Skiskyting er en kompleks idrett som krever en kombinasjon av langrenns- og skyteferdigheter på et høyt nivå. Innfor litteraturen er det gjort flere studier som ser på løpsstrategi i langrenn, men innenfor skiskyting er litteraturen mangelfull. Det er ved flere anledninger vist at skiløpere har en tendens til å åpne hardt for så å senke hastigheten utover i konkurransen. De aller beste har en tendens til å ha jevnere fart gjennom hele konkurransen, og derfor vil vi undersøke om en jevnere fart med en roligere åpning også vil være gunstig for skiskyttere. Derfor vil vi over to dager se om utøvere som vanligvis går med en rask åpningsfart ville hatt fordel av å redusere denne farten.

Hva deltakelse i studien innebærer

Deltakelse i prosjektet innebærer to testløp på to dager. Testløpene går på rulleski med en total distanse på 6 km med to liggende skytinger. På dag 2 vil vi dele opp deltakerne i to ulike grupper basert på åpningshastigheten fra dag 1. Deltakere får utdelt en GPS-enhet av typen Catapult, som festes på hjelmen. Det bes også om at deltakere i prosjektet bruker pulsbelte gjennom begge løpene, med tilhørende pulsklokke med GPS-funksjon.

For så pålitelige resultater som mulig, bes deltakere om å forberede seg til testløpene som man ville forberedt seg til en vanlig konkurranse.

Hvorfor får du spørsmål om å delta?

Du får spørsmål om å delta på dette prosjektet da du er elev ved Norges Toppidrettsgymnas (NTG) i Geilo og er aktiv skiskytter.

Fordeler og ulemper med å delta på prosjektet

Som deltaker i prosjektet får man et innblikk i idrettsforskning og hvordan dette foregår. I tillegg vil du kunne få personlige opplysninger om GPS-data fra løpene som kan være nyttig kunnskap å ta med seg videre med tanke på løpsstrategier fremover. Du vil også være med på å tilføre ny kunnskap om skiskyting.

Deltakelse i prosjektet innebærer to testløp på to dager. I tillegg er deltakelsen fysisk krevende, da det kreves maksimal innsats. Eventuelle farer ved deltakelsen i dette prosjektet er høy fart på rulleski.

Opplysninger om deltakere

Opplysningene som registreres om deg skal kun brukes slik som beskrevet i hensikten med prosjektet. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert. Du har også rett til å få innsyn i sikkerhetstiltakene ved behandling av opplysningene.

Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger (avidentifisert). En tallkode knytter deg til dine opplysninger gjennom en navneliste. Det er kun forskerne i prosjektet som har tilgang til denne listen. Prosjektet vil avsluttes 31.12.2022, men av dokumentasjonshensyn oppbevarer vi opplysningene dine til 31.12.2027. Opplysningene dine lagres elektronisk hos Norges idrettshøgskole, og bare forskerne i prosjektet har tilgang. Den 31.12.2027 anonymiseres opplysningene ved at navnelisten destrueres. Det vil ikke være mulig å gjenkjenne den enkelte deltaker i den endelige masteroppgaven.

Frivillig deltakelse

Deltakelse i prosjektet er helt frivillig, og man kan når som helst trekke seg fra prosjektet uten å oppgi noen grunn. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg. Det vil ikke påvirke ditt forhold til skolen, trener eller lærer om du ikke ønsker å delta.

Godkjenninger

Prosjektet gjennomføres etter godkjenning av lokal-etisk komite ved Norges Idrettshøgskole. Prosjektet meldes også inn til Norsk senter for forskningsdata (NSD). Norges Idrettshøgskole er ansvarlig forskningsinstitusjon og prosjektleder er Thomas Losnegard. Alle opplysninger behandles basert på ditt samtykke.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvor kan jeg finne ut mer?

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- Norges Idrettshøgskole ved prosjektleder Thomas Losnegard
    - E-post: thomasln@nih.no
    - Telefon: 23262377

- Vårt personvernombud: Rolf Haavik
  - E-post: personvernombud@nih.no
  - Telefon: 90733760

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Samtykkeerklæring

Jeg har mottatt og forstått informasjonen om dette prosjektet.

Jeg samtykker til:

å delta i prosjektet og at mine opplysninger behandles og oppbevares frem til prosjektet er avsluttet

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(dato) (signatur deltaker)

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(dato) (signatur prosjektmedarbieder)

NORSK SENTER FOR FORSKNINGSDATA

NSD sin vurdering

Prosjekttittel

Åpningshastighetens effekt på prestasjonen i liggende skyting i skiskyting samt total prestasjon

Referansenummer

726969

Registrert

02.06.2021 av Øyvind Nøstdahl Gløersen - oyvindgl@nih.no

Behandlingsansvarlig institusjon

Norges idrettshøgskole NIH / Institutt for fysisk prestasjonsevne

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Thomas Losnegard, thomasl@nih.no, tlf: 99734184

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Even Granrud, even.granrud@gmail.com, tlf: 94174658

Prosjektperiode

01.07.2021 - 31.12.2022

Status

30.06.2021 - Vurdert

Vurdering (1)

30.06.2021 - Vurdert

Det er vår vurdering at behandlingen vil være i samsvar med personvernlovgivningen, så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet den 29.06.2021 med vedlegg, samt i meldingsdialogen mellom innmelder og NSD.

Behandlingen kan starte så snart godkjennelsen foreligger fra NHI etiske komite.
NSD forutsetter at godkjennelsen lastes opp i meldeskjemaet på siden «Tillatelser» når den foreligger

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å

lese om hvilke type endringer det er nødvendig å melde:
https://www.nsd.no/personverntjenester/fylle-ut-meldeskjema-for-personopplysninger/melde-endringer-i-meldeskjema
Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige frem til 31.12.2022.

LOVLIG GRUNNLAG UNGDOMMER UNDER 17 år
Prosjektet vil innhente samtykke fra foresatte til behandlingen av personopplysninger om ungdommen. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som foresatte kan trekke tilbake. Ungdommene vil også samtykke til deltakelse.

Lovlig grunnlag for behandlingen vil dermed være foresattes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

For alminnelige personopplysninger vil lovlig grunnlag for behandlingen være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 a.

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen:

- om lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet.

DE REGISTRERTES RETTIGHETER
NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18) og dataportabilitet (art. 20).

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

Microsoft, skylagring er databehandler i prosjektet. NSD legger til grunn at behandlingen oppfyller kravene til bruk av databehandler, jf. art 28 og 29.

For å forsikre dere om at kravene oppfylles, må prosjektansvarlig følge interne retningslinjer/rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Gry Henriksen
Tlf. Personverntjenester: 55 58 21 17 (tast 1)