Section: Original Investigation

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Pacing strategy, muscle fatigue and technique in 1500m speed skating and cycling time-trials

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Abstract

Purpose: To evaluate pacing behavior and peripheral and central contributions to muscle fatigue in 1500m speed skating and cycling time-trials, when a faster or slower start is instructed. **Methods:** Nine speed skaters and nine cyclists, all competing at regional or national level, performed two 1500m time-trials in their sport. Athletes were instructed to start faster than usual in one trial and slower in the other. Mean velocity was measured per 100m. Blood lactate concentrations were measured. Maximal voluntary contraction (MVC), voluntary activation (VA) and potentiated twitch (PT) of the quadriceps muscles were measured to estimate central and peripheral contributions to muscle fatigue. In speed skating, knee, hip and trunk angles were measured to evaluate technique. **Results:** Cyclists showed a more explosive start than speed skaters in the fast-start time-trial (cyclists performed first 300m in 24.70±1.73s, speed skaters in 26.18±0.79s). Both trials resulted in reduced MVC (12.0±14.5%), VA (2.4±5.0%) and PT (25.4±15.2%). Blood lactate concentrations after the time-trial and the decrease in PT were greater in the fast-start than in the slow-start trial. Speed skaters showed higher trunk-angles in the fast-start than in the slow-start trial, while knee-angles remained similar. **Conclusions:** Despite similar instructions, behavioral adaptations in pacing differed between the two sports, resulting in equal central and peripheral contributions to muscle fatigue in both sports. This provides evidence for the importance of neurophysiological aspects in the regulation of pacing. It also stresses the notion that optimal pacing needs to be studied sport-specifically, and coaches should be aware of this.

Key words: Athletic performance, time-trial, central fatigue, peripheral fatigue, sport science

INTRODUCTION

Long-track speed skating is an intriguing sport to study: The crouched position in combination with the static gliding phase, a sideward push-off [1-4] and high velocities require high quasi-isometric muscular forces. The crouched position is important for aerodynamics and technique, as smaller knee-angles diminish air resistance [1] and is essential to increase push-off length enabling a more effective technique [5]. Often when speed skaters fatigue, they increase their body-angles [3], probably to reduce blood flow restrictions associated with the crouched position [6]. The trade-off between positive and negative aspects of changing body-angles in relation to muscle fatigue impacts the ability of speed skaters to benefit from a fast start during a 1500m time-trial. Modeling studies, which included both physiological (such as anaerobic and aerobic energy contribution) and biomechanical parameters (such as frictional energy losses) have calculated that a faster start should improve 1500m speed skating and cycling performance [3,4,7,8]. Nevertheless, imposing a faster start in 1500m speed skating resulted in slower end-times; presumably due to its impact on postural control and increasing body-angles, supposedly associated with earlier onset of muscle fatigue. [4,7] Up until now, muscle fatigue has never been quantified and analyzed in speed skating. Muscle fatigue is often defined as an exercise-induced reduction in the force-generating capacity of the neuromuscular system [9] and is generally measured by changes in maximal voluntary contraction (MVC). Both central (at or proximal to the motor neuron) and peripheral (distal from the motor neuron) mechanisms play an important regulatory role in muscle fatigue [10] and in pacing [11]. Central fatigue reflects impaired voluntary drive, whereas peripheral mechanisms are more related to changes in excitation-contraction coupling in the muscle fibers [10,12].

It is still unclear, however, to what extent muscle fatigue and technique impact on pacing and performance. Speed skating and cycling share similar characteristics such as the cyclic movement, crouched position, active muscles and maximal velocity [4,7,13,14]. The increasing body-angles, however, do not occur in cycling, as the body is supported by the bicycle, leaving only positive aspects of the crouched body position. The present study will assess muscle fatigue, pacing and technical parameters in a competitive setting. Essential to this is that subjects perform in a competitive setting, receiving pacing instructions instead of rigidly imposed pacing strategies. In this way, we include the behavioral component of pacing: though they are guided by our instructions, the athletes decide when and how much to accelerate or decelerate [15,16] . This approach will provide new valuable insights in performance of athletes in competitive settings that cannot be obtained in a laboratory design. Well-controlled laboratory studies are valuable in resolving underlying regulatory mechanisms, but need accompanying ecologically valid field studies in which the essential pillars of sports sciences psychology, physiology and biomechanics are combined [17].

To evaluate the role of muscle fatigue in the earlier observed differences in pacing between speed skating and cycling in a realistic competitive setting, we will evaluate the contribution of peripheral and central fatigue in speed skating and cycling time-trials. We hypothesize that cyclists will perform a faster initial phase of the time-trial than speed skaters, but that the impact of pacing strategy on muscle fatigue will be the same. This will provide evidence that different behavioral adaptations depending on the nature of the sport will occur in order to result in similar neurophysiological limitations.

METHODS

Subjects. Nine well-trained male speed skaters (age:21±3yr, height:182±6cm, weight:75±6kg) and nine well-trained male cyclists (age:25±9yr, height:184±7cm, weight:78±4kg) participated and gave written informed consent. All subjects were competing at regional or national level, training at least 3 times per week. The study-protocol was approved by the institutional review board, in the spirit of the Helsinki Declaration.

Protocol. Subjects performed two 1500m time-trials in their sport of expertise. To create significantly different pacing strategies, athletes were instructed to start (first 300 m) 0.5s faster than their customary pacing strategy in the one trial (FS) and 0.5s slower in the other (SS). 0.5s is beyond the variation of 0.1s that was seen when speed skaters were instructed to go all-out compared to self-paced performance [4], but within the range of intra-individual differences seen in official time trials during one season. The remaining 1200m had to be finished as fast as possible. Each subject performed the trials in random order at the same time of day, with one week in between trials in a period with no important competitions. Subjects were requested to keep training intensity low the day before testing, refrain from caffeine 12hrs before testing and to not eat in the 2hrs preceding testing.

Speed skaters performed their 1500m-trials at an indoor 400m speed skating track in Calgary, 1035m above sea-level (n=3) or in Groningen, 5m above sea-level (n=6). To increase sample-size, data were pooled. The start was situated in the outer competition lane. Subjects were not aware of split times during the trial.

Cycling trials were performed in Calgary, on the Velotron dynafit-pro ergometer (RacerMate Inc., Seattle, Washington USA) simulating outdoor track performance, including wind resistance. The accuracy of the Velotron is 3.0% (CI=1.6-4.5%) during high intensity intervals and <1% during constant power trials.[18] A familiarization-trial was performed one week prior to the first trial. Subjects only received distance feedback.

Before (pre-trial) and after (post-trial) each time-trial blood lactate concentration (BLC) and muscle force were measured. During the time-trial, pacing strategy (velocity profiles) and technique (body-angles) were measured.

Pre-trial. Barometric pressure, ice temperature, humidity and indoor temperature were measured before every speed skating trial. For cycling, barometric pressure and indoor temperature were constant between 880-891hPa and 19-21°C.

The Lactate Pro (LP, Arkray KDK, Japan) was used to measure baseline fingertip BLC at rest [19,20], followed by baseline muscle force measurements performed on a customized chair with attached force sensor, which was calibrated before each trial. The subject was seated upright, strapped with a seatbelt across their waist, and their ankle attached to the force sensor at a 90° knee-angle. Force measurements were done on the left leg in Calgary but on the right leg in Groningen. Force measurements were repeated three times (Groningen) or two times (Calgary), with one minute rest between repetitions. Force output (N) was recorded by Windaq (Calgary) or Spike2 (Groningen) software with a frequency of 3000Hz or 500Hz respectively.

Maximal voluntary contraction (MVC), voluntary activation (VA) and potentiated twitch (PT) were obtained to quantify muscle performance. A decline in MVC (baseline vs post) indicates muscle fatigue, as a result of both peripheral and central fatigue. Peripheral fatigue was quantified by changes (baseline vs post) in PT [10], central fatigue by changes in the VA[10,21].

To determine MVC, maximal force was measured during a 5s maximal isometric contraction of the m.quadriceps femoris, with verbal encouragement. To assess VA and PT, electrical stimulation was applied to the n.femoralis to activate the m.quadriceps during and 5s after the MVC. Two stimulation pads were placed on the leg and connected to a high voltage stimulator (Digitimer DS7A(H) or 3 parallel DS7A-models). The cathode pad was placed at the distal side of the middle of the inguinal crease. The anode pad was placed 2-3cm proximal to the patella, with the knee in a bent position. Before each trial the current that evoked maximal twitch amplitude at rest was determined with stepwise current increases (minimum step: 25mA) until twitch amplitude did not increase. The current evoking the maximal twitch amplitude was used throughout the experiment.

VA was quantified by use of equation 1 [22,23]. The underlying principle is that an imposed electrical stimulation delivered to the motor nerve of muscles that perform a MVC will evoke an increase in muscle activation when the voluntary activation is submaximal [21,24]. The force evoked by the imposed electrical stimulation on top of the MVC is the interpolated twitch (IT), the force evoked by the electrical stimulation 5s after MVC is PT.

$$VA\ (\%) = (1 - IT / PT) \cdot 100 \qquad [eq.\ 1]$$

After baseline measurements, athletes performed a 10min low intensity warm-up including two brief accelerations. Cyclists warmed-up on the bicycle, whereas speed skaters had a 5min off-ice warm-up followed by a 5min on-ice warm-up.

Time-trial. Mean velocities per 100m were obtained during all time-trials. For cycling this was obtained by the ergometer. For speed skating, infrared timing gates (TC timing system, Brower, USA in Calgary; HL 2-31 Photocell, TAG Heuer professional timing, Switzerland in Groningen) were placed at the entry and exit of every corner to measure split times for every straight and curve.

Changes in speed skating technique were determined by changes in knee-, hip- and trunk-angles (figure 1) measured at every straight. One high resolution camera, located in the middle of the 400m track, filmed the speed skater in the sagittal plane. Body-angles were taken over 5 frames with the left leg in gliding phase and the right leg in recovery phase with close to 90° knee-angle (figure 1) and corrected for viewing angle.

Post-trial. Within 2-4min after completion of the time-trial, force measurements were repeated. The percentage decrease of the post-trial measurement relative to baseline was used to quantify the amount of muscle fatigue present after the trial. Additionally, BLC was measured seven times at intervals of 5min starting 5min after the subject had finished his time-trial. BLC-post, including all seven BLC measurements after the time trial, and BLC-max, being the highest post-BLC value, were obtained. All subjects performed a 10min active cycling recovery, starting 20min after time-trial completion.

Statistics. The highest VA, PT and mean MVC of the baseline and post force measurements were used for analysis. Velocity and body-angles were analyzed per lap for 0-300m, 300-700m, 700-1100m and 1100-1500m, as is common in speed skating. Pearson's correlation coefficients were calculated to determine the relationship between BLC-max and VA, PT and MVC. Further statistical analysis was done with mixed analysis of variance (ANOVA), with 'strategy' (FS vs SS) as within-subject variable and 'sport' (cycling vs speed skating) or 'location' (Calgary vs Groningen) as a between-subject variable. For statistical analysis of mean velocity per lap, BLC-post and force measurements the within variable 'lap' or 'time' (before vs after or time after trial) was added to the mixed ANOVA. Body-angles were tested in speed skating only, with a two-way repeated measures ANOVA with 'strategy' and 'lap' as within-subject variables. When the assumption of sphericity was violated, degrees of freedom were corrected (Greenhouse-Geisser). When a three-way interaction effect was found, a post hoc analysis was performed with a two-way repeated measures ANOVA. Planned contrasts (repeated; T_1-T_2, T_2-T_3, etc.) were used on the main and two-way interaction effects involving lap or time.

RESULTS

External conditions: In speed skating no interaction effects of strategy x location or main effect for trial were found for ice temperature, indoor temperature and barometric pressure. There were main effects for location for ice temperature ($F(1,7)=36.489; p=0.001$), indoor temperature ($F(1,7)=261.241; p<0.001$) and barometric pressure ($F(1,7)=1368.7; p<0.001$), showing lower mean ice temperatures (-6.9 ± 0.1°C;-5.6 ± 0.9°C), higher indoor temperatures (15.1 ± 0.7°C;4.1 ± 3.9°C) and lower barometric pressures (884 ±

6hPa;1022 ± 12hPa) in Calgary than in Groningen respectively. These differences were deemed inconsequential since athletes performed both time-trials in the same location.

Start- and end-times: Start-times at 0-300m and 1500m end-times are presented (table 1). For start-times, an interaction effect of strategy x sport ($F(1,16)=5.276; p=0.035$) was found, with similar start-times in SS for both sports, but relatively faster start-times in FS for cyclists than for speed skaters.

For end-times, neither a strategy x sport interaction-effect ($p=0.46$), nor main effects of sport ($p=0.37$) and strategy ($p=0.28$) were found, revealing no differences in end-times for sports or trials.

Velocity. Mean velocities per lap are presented (table 2). To provide more insight into the variation during the time-trial, velocity profiles for FS and SS are also presented per 100m for speed skating and cycling (figure 2).

An interaction effect of strategy x lap x sport ($F(2.019,32.304)=7.126; p=0.003$) was found. Post hoc analysis yielded interaction effects of strategy x lap for speed skating ($F(1.434, 11.476)=11.118; p=0.004$) and cycling ($F(1.733,13.862)=20.392; p<0.001$), suggesting different pacing strategies for FS and SS in both sports. In speed skating, the planned contrasts showed a different strategy x lap interaction for lap 1 to 2 and 2 to 3, showing a relatively faster start in FS than in SS and a greater decrease in mean velocity from lap 2 to 3 in FS than in SS. Planned contrasts in cycling showed a different strategy x lap interaction from lap 1 to 2, indicating a relatively faster first lap in FS than in SS.

Force measurements. Results of force measurement at baseline and post-trial as well as the percentage decrease (post-trial relative to baseline) in force measurements are presented (table 3).

No strategy x time (baseline vs post) x sport interactions were found for MVC ($p=0.91$), VA ($p=0.24$) and PT ($p=0.46$). Additionally no interaction effects were found for

MVC ($p=0.37$;$p=0.65$;$p=0.19$), VA ($p=0.50$;$p=0.32$;$p=0.80$) and PT ($p=0.14$;$p=0.56$;$p=0.07$) for strategy x sport, time x sport nor strategy x time, respectively.

Main effects of sport were found for MVC ($F(1,16)=6.186$;$p=0.024$) and PT ($F(1,16)=6.044$;$p=0.026$), indicating higher average values in speed skating than in cycling. No main effect was found for VA ($p=0.70$).

Main effects of strategy were only found for MVC ($F(1,16)=6.940$;$p=0.018$) , indicating higher MVC values in SS than in FS. No main effects for strategy were found for VA ($p=0.39$) nor PT ($p=0.16$).

Main effects of time were found for MVC ($F(1,16)=20.256$;$p<0.001$), VA ($F(1,16)=5.708$;$p=0.030$) and PT ($F(1.16)=40.364$;$p<0.001$). Lower measurements were found post-trial than at baseline, indicating the occurrence of general muscle fatigue (MVC) with both central (VA) and peripheral (PT) fatigue contributing.

Percentage decrease in force measurements

The percentage decrease did neither result in a strategy x sport interaction effect nor a main effect for sport for MVC ($p=0.62$;$p=0.26$ respectively), VA ($p=0.24$;$p=0.32$, respectively) and PT ($p=0.06$;$p=0.32$ respectively).

A main effect of strategy was found for the decrease in PT ($F(1,16)= 4.981$;$p=0.04$), showing a greater percentage decrease in FS (29.2±14.9%) than in SS (21.7±15.0%), indicating a stronger contribution of peripheral fatigue to muscle fatigue in FS than in SS. No main effects of strategy were found for the decrease in both MVC ($p=0.26$) and VA ($p=0.32$).

Blood Lactate Concentration. Baseline BLC and BLC-post are presented in figure 3. Baseline BLCs yielded no strategy x sport interaction ($p=0.29$), no main effect for sport ($p=0.36$) nor strategy ($p=0.11$). For BLC-post, 5-35min after the trials, no three-way ($p=0.728$), nor two-way interaction effects nor a main effect for sport ($p=0.06$) were found.

Main effects for strategy (F(1,16)= 6.112;p=0.025) and time (F(6,96)=194.977;p<0.001) were found, indicating higher BLC-post values after FS than after SS and decreases in BLC-post starting 10min after finishing the trial across both sports.

Speed skaters had a BLC-max of 14.5±1.7mmol·L^{-1} in FS and 14.8±1.4mmol·L^{-1} in SS. Cyclists had a BLC-max of 16.3±1.8mmol·L^{-1} in FS and 15.1±1.8mmol·L^{-1} in SS. For BLC-max no strategy x sport interaction (p=0.07) was found and no main effects for strategy (p=0.33) nor sport (p=0.14).

BLC-max was significantly correlated with percentage decrease in MVC (r=.518, p=0.025) and percentage decrease in PT (r=.556, p<.001), but not with percentage decrease in VA (r=.315, p=.062).

Body-angles. For the speed skaters, body-angles and k_1 are presented (figure 2). Unfortunately, one subject did not have a full data set for the body-angles. No strategy x lap interaction effects were found for knee- (p=0.13), hip- (p=0.93) and trunk-angles (p=0.39). Main effects for lap were found for knee- (F(3,21)=86.486;p<0.001), hip- (F(3,21)=16.176, p<0.001) and trunk-angles (F(3,21)=24.181;p<0.001). Contrasts showed increasing knee-angles in all laps, increasing hip-angles in all laps except for lap 3-4 and decreasing trunk-angles from lap 1-2 (figure 2). Additionally, a main effect for strategy was found for trunk-angles (F(1,7)=12.280;p=0.010) with higher trunk-angles in FS than in SS. No main effect of strategy was found for knee- (p=0.74) and hip-angles (p=0.27).

DISCUSSION

The present study is the first to report data on muscle fatigue in speed skating. It was shown that both peripheral and central mechanisms contribute to muscle fatigue in 1500m speed skating as well as in cycling time-trials. However, consistent with previous reports investigating cycling and speed skating separately [4,7], the present study showed a relatively more explosive start in FS for cyclists compared to speed skaters. We can thus conclude that as hypothesized, cyclists and skaters adapted different behavioral approaches to pacing while receiving equal instructions, and while contributions of muscle fatigue did not differ between sports. This provides evidence for the importance of neurophysiological aspects involved in regulatory mechanisms responsible for pacing, as suggested in a recent literature review [11].

Speed skaters were not willing to sacrifice their crouched position and chose a less explosive strategy, while knee-angles followed the same profile throughout FS as well as SS. FS resulted in slightly higher trunk angles compared to SS. Possibly, speed skaters started less explosively to maintain speed at the end of the race, consistent with the proposal that maintaining body posture and coordination is more important in speed skating than in cycling. This was further supported by the greater loss of skating velocity in lap 2-3 in FS compared to SS, while mean velocity over the last two laps did not differ.

The present design uniquely combines neurophysiological and biomechanical measures in a realistic competitive setting as advised in a recent literature review on speed skating [17], while leaving room for the behavioral pacing responses of the athletes to these given instructions as an outcome measure. We do realize that our choice to study behavior in a setting that is as close to competitive performance as possible, consequently led to some limitations of the study as well. We chose to use two different groups of athletes (cyclists and speed skaters), to have them all perform in their sport of expertise. Though this is very realistic, it does prevent a repeated measures design with sport as a within factor. To increase our limited subject number, a common problem in sport science, we pooled measurements at different locations. As temperature has been shown to affect processes associated with muscle fatigue and pacing [11], differences need to be noted here: the 6 Groningen skaters performed the time-trial at lower temperatures than the cyclists and 3 Calgary skaters, which might explain the relatively high variability in the muscle fatigue measurements. In addition, skaters were tested on different legs, while asymmetry has been shown in speed skating [26].

However, muscle fatigue measurements were all performed off ice, in a room temperature environment, and on the same leg before and after exercise. We believe that these limitations are important to note, but at the same time, have limited impact. The study provides interesting and novel outcomes on behavioral pacing adaptations in relation to neurophysiological measures in a realistic sport setting.

A mean BLC-max of 14-16mmol·L^{-1} in all time-trials indicated that they were performed with maximal effort [27] and the decrease in MVC indeed confirmed the presence of muscle fatigue. The present paper also demonstrated that both peripheral and central mechanisms contributed to muscle fatigue in all time-trials. Nevertheless, the decreases in VA (central fatigue [10]) were relatively small compared to decreases in MVC and PT (table 4). For all force-related variables, the 4min delay between end of trial and the force measurements should be kept in mind. As some recovery is likely, muscle fatigue mechanisms could thus not be estimated to their full extent [25,28]. Speculation about the recovery from central and peripheral fatigue is difficult as recovery of muscle fatigue is task dependent and no data comparing cycling and speed skating is present at the moment. We did establish that, conform previous literature [25], greater (peripheral) fatigue was associated with greater metabolic demand, as confirmed by the association between BLC and PT and muscle fatigue. Differences between trials were found in post-trial BLC and PT. BLC-post was higher after FS than after SS and peripheral fatigue (PT) was more evident after FS. FS thus seemed to cause somewhat more homeostatic disturbance and peripheral fatigue than SS. Future studies aimed at understanding fatigue, pacing and recovery in different sports are recommended.

Practical Applications

The present study provides evidence that both peripheral and central contributions of muscle fatigue are involved in the regulatory process of pacing. It seems that athletes of the different sports adapt their strategy differently when responding to similar instructions, resulting in a similar level of muscle fatigue. It stresses the notion that optimal pacing needs to be studied sport-specifically, and coaches should be aware of this. It is advised to further explore muscle fatigue, pacing and technique under controlled and standardized laboratory settings to place alongside these unique field data.

CONCLUSION

Both peripheral and central mechanisms contributed to muscle fatigue in 1500m speed skating as well as in cycling. While contributions of muscle fatigue were not different between sports, behavioral pacing adaptations differed, with a more explosive start for cyclists than for speed skaters. Speed skaters presumably anticipated muscle fatigue, homeostatic disturbance and the subsequent deleterious effect on their technique, and adapted their behavior to the nature of the sport in order to complete the time-trial with similar neurophysiological limitations as in cycling. This provides evidence for the importance of neurophysiological aspects involved in regulatory mechanisms responsible for pacing.

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Figure 1: Trunk angle (θ1), hip angle (θ2) and knee angle (θ3).

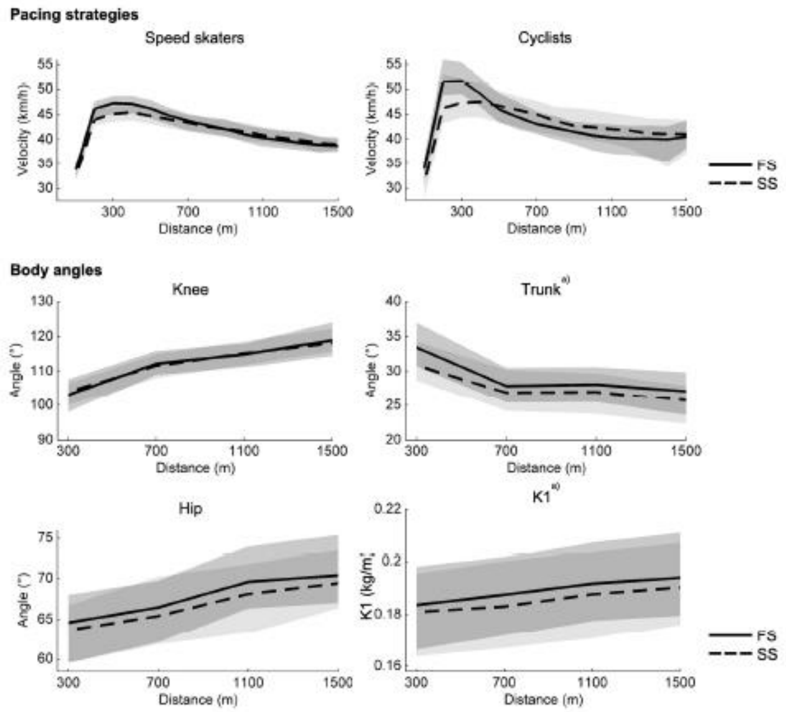

Figure 2: Velocity (pacing) profiles for the fast start (FS) and slow start (SS) 1500m time-trials in speed skating (n=9) and cycling (n=9). Body angles for speed skating (n=8); knee-, trunk- and hip-angles per lap and k1. Solid (fast-start) and dashed (slow-start) lines represent mean velocity and shades represent ± SD. [a)] represents a main effect for strategy ($p<0.05$).

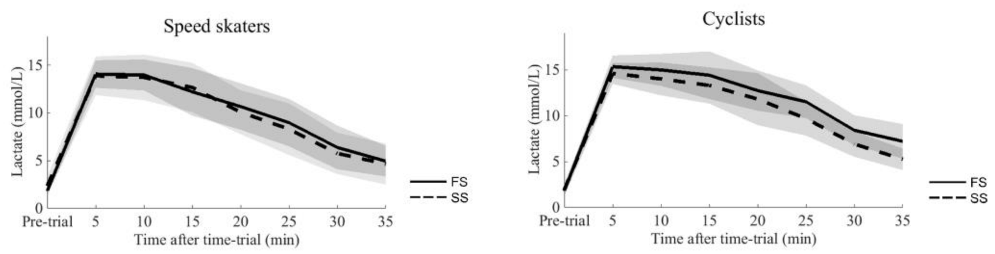

Figure 3: Blood lactate concentrations (BLC) for the fast start (FS) and slow start (SS) trials in speed skating and cycling.

Table 1: 0-300m split-time and 0-1500m end-times for the fast start (FS) and the slow start (SS) trials in speed skating and cycling.

	Speed skating n=9		**Cycling** n=9	
	Time (s)		Time (s)	
	FS	SS	FS	SS
0-300m [a)]	26.18 (0.79)	27.27 (0.79)	24.70 (1.73)	27.41 (3.00)
0-1500m	129.5 (4.1)	130.4 (3.5)	127.5 (6.9)	127.6 (7.0)

Values are mean (SD). [a)] represents a strategy x sport interaction effect.

Table 2: Mean velocities per lap for the fast start (FS) and the slow start (SS) trials in speed skating and cycling.

	Speed skating n=9		**Cycling** [a)] n=9	
	Vmean ($km \cdot h^{-1}$)		Vmean ($km \cdot h^{-1}$)	
	FS	SS [b)]	FS	SS [b)]
0 - 300m	42.31 (1.18)	40.56 (1.23)	45.68 (3.30)	41.48 (4.80)
300 - 700m	45.30 (1.41)	44.60 (1.52)	45.65 (2.64)	46.26 (2.74)
700 - 1100 m	41.51 (1.75)	41.94 (1.60)	41.25 (2.26)	42.73 (3.19)
1100 - 1500 m	39.34 (1.74)	39.59 (1.25)	40.20 (2.68)	41.27 (2.93)

Values are mean (SD). [a)] Represents a strategy x lap x sport interaction effect and [b)] represents a strategy x lap interaction effect.

Table 3: Maximal voluntary contraction (MVC), voluntary activation (VA) and potentiated rest twitch (PT) of speed skaters and cyclists before (baseline) and after (post) the fast start (FS) and slow start (SS) trials.

		Both trials			FS	SS
		Baseline	Post	Decrease (%)	Decrease (%)	Decrease (%)
MVC (N)	Speed skaters	642 (196)	581 (174)	8.6 (12.3)	9.8 (15.9)	7.4 (8.1)
	Cyclists	488 (81)	413 (101)	15.5 (16.1)	18.4 (15.3)	12.4 (17.2)
	All subjects	565 (167)	497 [a] (164)	12.0 (14.5)	14.1 (15.8)	9.9 (13.3)
VA (%)	Speed skaters	86.9 (10.3)	85.5 (10.7)	1.4 (4.9)	0.4 (4.9)	2.3 (5.0)
	Cyclists	89.5 (7.3)	86.1 (9.3)	3.4 (4.9)	4.0 (6.2)	2.8 (3.5)
	All subjects	88.2 (8.9)	85.8 [a] (9.9)	2.4 (5.0)	2.2 (5.7)	2.6 (4.2)
PT (N)	Speed skaters	249 (65)	164 (52)	24.8 (13.9)	25.1 (14.2)	24.4 (14.5)
	Cyclists	199 (39)	134 (47)	26.1 (16.8)	33.3 (15.2)	18.9 (16.0)
	All subjects	224 (58)	149 [a] (51)	25.4 (15.2)	29.2 (14.8)	21.7 [b] (15.0)

Values are mean (SD). [a] represents a main effect for time and [b] represents a main effect strategy.