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1 ORIGINAL INVESTIGATION

2
3 **The impact of different competitive environments on pacing**
4 **and performance**

5
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ABSTRACT

Purpose. In real-life competitive situations, athletes are required to continuously make decisions about how and when to invest their available energy resources. This study attempted to identify how different competitive environments invite elite short-track speed skaters to modify their pacing behaviour during head-to-head competition. **Methods.** Lap times of elite 500, 1000 and 1500 m short-track speed skating competitions between 2011–2016 (n=34095 races) were collected. Log-transformed lap and finishing times were analysed with mixed linear models. The fixed effects in the model were sex, season, stage of competition, start position, competition importance, event number per tournament, number of competitors per race, altitude, and time qualification. The random effects of the model were Athlete identity and the residual (within-athlete race-to-race variation). Separate analyses were performed for each event. **Results.** Several competitive environments, such as the number of competitors in a race (a higher number of competitors evoked most likely a faster initial pace; CV=1.9-9.3%), the stage of competition (likely to most likely, a slower initial pace was demonstrated in finals; CV=-1.4-2.0%), the possibility of time qualification (most likely a faster initial pace; CV=2.6-5.0%) and competition importance (most likely faster races at the Olympics; CV=1.3-3.5%), altered the pacing decisions of elite skaters in 1000 and 1500 m events. Stage of competition and start position affected 500 m pacing behaviour. **Conclusion.** As demonstrated in this study, different competitive environments evoked modifications in pacing behavior, in particular in the initial phase of the race, emphasizing the importance of athlete-environment interactions, especially during head-to-head competitions.

KEYWORDS: Pacing strategy, Affordance, Ecological psychology, Decision-making, Sport

INTRODUCTION

The regulation of the exercise intensity over an exercise bout, a process known as pacing, is widely recognized as an essential determinant of performance.¹ In this regulatory mechanism, the sensation of fatigue and a willingness to tolerate discomfort in anticipation of future rewards appears to play a crucial role.² Yet the decision-making process involved in the regulation of exercise intensity has been shown to be rather complex. Several physiological, psychological and biomechanical variables have been revealed to influence on the outcome of pacing decisions² and performance.³ The importance of the interaction between the exerciser and environmental cues has been emphasized, in particular in the context of decision-making and pacing in head-to-head competition.^{2,4} Perceptual affordances provided by the environment can invite athletes to respond, thereby evoking in-race adaptations of pacing behavior.^{2,4} As shown before in observational and experimental studies, an opponent could be such an affordance, inviting exercisers to adjust their pacing behavior.⁴⁻⁶ For example, the presence of a virtual opponent has been revealed to improve performance.^{5,7-9} Moreover, different behavior of the opponent has been shown to invite different pacing responses.⁵

However, apart from the opponents as most obvious affordances in competition, many other external cues will be presented simultaneously to an exerciser in real-life competitive situations. Therefore, it seems likely that the response of an exerciser to an opponent is not only based on the opponent itself, but also on the context in which the opponent is presented to the exerciser. Indeed, we have already shown that a change in an exerciser's internal state, such as fatigue, alters the response to an opponent.⁹ In the present study we will explore the effect of different competitive environments on pacing and performance in short-track speed skating competitions, a sport in which it has been shown that the pacing behavior of a competitor is significantly affected by the pacing behavior of the other competitors.^{6,10,11} We hypothesize that different competitive environments, such as the number of competitors within a race, the stage of competition, and the additional possibility of time fastest qualification, could affect the chosen pacing behavior and performance when competing against others. This would demonstrate the importance of the context in which the opponent is presented to the exerciser in the decision-making process involved in pacing.

METHODS

Participants and data acquisition

Finishing and intermediate lap times were gathered for men and women from 500 m (4.5 laps), 1000 m (9 laps) and 1500 m (13.5 laps) Short Track Speed Skating World Cups, the European Championships and World Championships during the seasons 2010/11 until 2015/16. In total, 47 indoor competitions (thirty-four World Cups, six European Championships, six World Championships, and the Olympic Games) were analysed. Each short-track competition consisted of qualification stages in which a skater had to qualify for the next stage by finishing in first or second position, and the final race in which the goal was to win the event. Lap times were recorded for each competitor automatically at the finish line, using electronic time-measuring systems based on optical detectors that started automatically by the firing of a starting-gun. The International Skating Union (ISU) demands that lap times are recorded with the accuracy of at least a hundredth of a second. Therefore, for every automatic timekeeping system that was used, a certificate stating the reliability and accuracy of the system had to be presented to the referee before the competition, ensuring that all systems recorded with the accuracy of at least a hundredth of a second. No written consent was given by participants as

120 all data used are publicly available at the ISU website
121 (<http://www.sportresult.com/federations/ISU/ShortTrack/>) and no interventions occurred
122 during the data collection. The study was approved by the local ethical committee and in
123 accordance with the Declaration of Helsinki.

124 In total, 3414 500 m races (14036 skating performances), 3210 1000 m races (13646
125 skating performances) and 1851 1500 m races (10894 skating performances) were analysed.
126 Whereas falls and/or disqualifications could affect the lap times and positioning of the athlete
127 him/herself as well as those of the other competitors (especially for the lower placed finishers)
128 possibly leading to a misinterpretation of the results, skating performances from races with a
129 disqualification, a fall and/or races with one or more missing values were excluded. In addition,
130 outliers, defined as performances with a standardized residual >5.0, were excluded from the
131 dataset.¹² A standardized residual >5.0 means that the performance was far slower than normal
132 for the given skater. This resulted for the 500 m in 12550 of the 14036 skating performances
133 (89.4%), for the 1000 m in 12143 of the 13646 skating performances (89.0%), and for the 1500
134 m in 9402 of the 10894 skating performances (86.3%) that were examined.

135 136 **Statistical analysis**

137 The mixed linear modelling procedure in SPSS was used for the analyses of each event.
138 Finishing and lap times were log transformed before modelling, because this approach yields
139 variability as a percent of the mean (CV), which is the natural metric for most measures of
140 athletic performance.¹³ Subsequently, within- and between-athlete CV were derived by back
141 transformation into percentages of the residual and subject random effects in the mixed model.
142 Separate analyses were performed for data from each event. The fixed effects in the model were
143 Sex (men/women), Season (2010/11 up until 2015/16), Stage of competition (final, semi-final,
144 quarter-final, rep. semi-final, rep. quarterfinal, rep. heats, heats, preliminaries), Start position
145 (inner lane to outer lane), Competition importance (World Cup, European Championships,
146 World Championships, and Olympic Games), Event number per tournament (sometimes an
147 event is performed twice in one Tournament weekend, e.g. 2x 500 m event), Number of
148 competitors per race (varies from two to nine competitors), Altitude (sea-level/high altitude;
149 i.e. >1000m above sea-level), and the opportunity to qualify for the next stage as one of the
150 time fastest if not qualified via finishing position (Time qualification; no/yes). The random
151 effects of the model were Athlete identity (between-athletes differences) and the residual
152 (within-athlete race-to-race variation). The dependent variables were the natural log of the lap
153 times and finishing times in an event; analysis of these transformed variables yields coefficients
154 of variation (CV), which are variations in performance expressed as a percent of average
155 performance.¹⁴ Precision of the estimates of CV are shown as 95% confidence limits which
156 represent the limits within which the true value is 95% likely to occur. A spreadsheet was used
157 to combine and compare fixed effects and CVs.¹⁵ For the interpretation of the probability that
158 an effect was substantial or trivial, we used the following scale: < 0.5%, most unlikely; 0.5-5%,
159 very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely;
160 >99.5, most likely.¹²

161 162 **RESULTS**

163
164 Mean \pm SD of the lap times and finish times in seconds of the 500, 1000 and 1500 m event can
165 be found in Table 1.

166 167 **500 m event**

168 Fixed and random effects per lap and for the finish time can be found in Table 2 for 500
169 m races. Men were most likely faster compared to women in all laps. The fixed effect of Season
170 indicated a faster completion of the final three laps (likely to very likely substantial), while
171 differences in the first lap time over the seasons are most likely trivial. Lap times and finishing
172 times were most likely completed faster in finals, semi-finals, and quarterfinals compared to
173 the preliminary stages of the competition. The fixed effects of number of competitors within a
174 race, the competition importance, the possibility of time qualification, and the event number
175 per tournament appeared to be most likely trivial for each lap and for the finishing time. Start
176 position had a most likely substantial effect in the first lap, indicating a more inner start position
177 led to faster lap times. Interestingly, races performed at high altitude only led to a likely positive
178 effect compared to sea-level in the final lap. A more inner or outer start position did not led to
179 any likely effect on lap times or finish time.

180

181 **1000 m event**

182 Fixed and random effects per lap and for the finish time can be found in Table 3 for
183 1000 m races. Lap times and finishing times were most likely faster for men compared to
184 women. The fixed effect of Season indicated a change in chosen pacing behavior over the
185 seasons to a more conservative starting pace and faster final lap times. Except for the first lap,
186 a likely to most likely positive effect on lap times and finish time was found at high altitude
187 compared to sea level. The very likely to most likely substantial fixed effect for the number of
188 competitors within a race in the first four laps, indicates a higher number of competitors leads
189 to a faster initial pace and faster finish time compared to a lower number of competitors within
190 a race. The possibility of time fastest qualification led to a most likely positive effect on lap
191 time in the first three laps and a very likely positive effect on the finish time. The very likely to
192 most likely substantial effect of competition importance in the first four laps, appears to be
193 mainly due to differences in initial pace between the Olympic Games on one hand, and the
194 World cups, European and World championships on the other. Initial pace during the Olympic
195 Games was found to be most likely faster (1.3-6.9%). A more inner or outer start position or
196 whether it was the first or second time the event was organized in a tournament weekend did
197 not led to any likely effect on lap times or finish time. Finals, semi-finals, quarterfinals, and
198 heats were most likely leading to faster lap times in all laps compared to repechage races (1.4-
199 5.9%) and the preliminaries (0.3-5.1%).

200

201 **1500 m event**

202 Fixed and random effects per lap and for the finish time can be found in Table 4 for
203 1500m races. Lap times and finishing times were most likely faster for men compared to
204 women. The fixed effect of Season indicated a change in chosen pacing behavior over the
205 seasons to a more conservative starting pace and faster final lap times. High altitude had a most
206 likely positive effect on the first ten lap times and the finish time compared to sea level
207 performances. The most likely substantial fixed effect for the number of competitors within a
208 race in the first seven laps indicates a higher number of competitors leads to a faster initial pace
209 and faster finish time compared to a lower number of competitors within a race. The possibility
210 of time fastest qualification led to a most likely positive effect on lap time in the first five laps
211 and a most likely positive effect on the finish time. The most likely substantial effect of
212 competition importance in the first six laps, appears to be mainly due to a differences initial
213 pace during the Olympic Games. Initial pace during the Olympic Games was found the be most
214 likely faster (3.2-8.3%) compared to the World cups, European and World championships.
215 Whether it was the first or second time the event was organized in a tournament weekend had

216 a possibly to most likely substantial effect on the first six lap times, indicating a faster initial
217 pace if it was the second time the event was organized in a weekend. The fixed effect of Stage
218 of competition indicated a slower initial pace is adopted the further in the tournament. Finals
219 are slower in the first laps compared to all other stages of competition, while semi-finals and
220 quarterfinals are starting slower compared to all other stages of competition except the finals.

221 222 DISCUSSION 223

224 The present study aimed to examine the effect of different competitive environments on
225 pacing and performance in a head-to-head structured competition, such as short-track speed
226 skating. Several competitive environments, such as the number of competitors in a race, the
227 stage of competition, the tournament, and the start position appeared to alter the pacing
228 decisions of elite short-track speed skaters. Our findings demonstrate the importance of the
229 external setting in which an opponent is presented, and highlights several novel external cues
230 that need to be incorporated in understanding the complex decision-making process involved
231 in pacing.

232 Different competitive environments appeared to affect mainly the initial phase of a race.
233 As some laps are more influenced than others, it indicates that the decision-making process
234 involved in pacing is influenced by the included variables in the present study. In this respect,
235 we have shown in a previous study that in this initial stage elite short-track speed skaters are
236 highly variables between races, however, within a race short-track speed skaters appear to
237 adjust their pace to the behavior of the other contenders.⁶ This effect of the competitive
238 environment on initial pace could be seen as well when presenting an opponent to athletes in a
239 controlled laboratory setting. Cyclists seemed to adapt their initial pace in order to keep up with
240 the pace of their virtual opponent.⁵ However, a change in pace of the opponent halfway the
241 time-trial did not have a major effect on the pacing behavior of the same cyclists.⁵ A likely
242 explanation for why external cues mainly seem to affect the decision-making of exercisers in
243 the beginning of a race could be the perceived level of fatigue of the exerciser. Variables such
244 as perceived exertion have been shown to be key components in exercise regulation,^{2,16,17} and
245 will likely accumulate throughout the race. In this perspective, a higher level of fatigue has
246 indeed been shown to alter the attentional focus from external to internal related variables.¹⁸

247 For many years, the central governor model has been the predominant theory
248 underpinning exercise regulation, arguing a subconscious governor that would set the pace and
249 protect homeostasis.^{19,20} However, the governor model has been criticized for several reasons.
250 For example, the fact that catastrophic failures of homeostasis can and do occur in athletes.^{21,22}
251 questions the existence of a governor protecting homeostasis at all costs as explained in a recent
252 review on the regulation of exercise.² The present study provides another complication for the
253 model: if pacing would be based on matching a predetermined template with the current bodily
254 state, in respect to the remaining distance ahead, this would require the exerciser/governor to
255 have thought of a template or schema for each possible combination of external cues presented
256 around the exerciser before starting to exercise. All of these templates will have to be stored
257 somewhere in the exerciser's memory, leading to a storage problem, a phenomenon that is well-
258 discussed in motor control literature.²³

259 Exercisers are required to decide continuously about how and when to invest their
260 available energy resources during their competition.² In this decision-making process, an
261 important role has been proposed for the interaction between the exerciser and the environment
262 surrounding the exerciser.^{2,4} At any point the external world around the exerciser presents
263 multiple invitations for actions to the exerciser, so-called affordances.^{24,25} These invitations for

264 action can arise and dissipate over time, and evoke an exerciser's decision to remain on current
265 pace, to slow down or to accelerate.² With the multitude of affordances that are presented to an
266 exerciser continuously and simultaneously, it is up to the athlete to act upon certain affordances,
267 and not on others.²⁶

268 Arguably the clearest example of how competitive environments could impact on
269 pacing behavior is illustrated by the possibility of time qualification. In some stages of some
270 competitions it was possible to qualify for the next stage not only via finishing position, but
271 also via qualification on the basis of time achieved for the time fastest skaters in that stage of
272 competition whom did not qualify via finishing position in their race. When the possibility to
273 qualify as one of the time fastest in that stage of competition was present, races in that particular
274 stage of competition started most likely faster in the 1000 m and 1500 m event compared to
275 that same stage in other competitions when the possibility of time fastest qualification was not
276 present. This faster initial pace led to very likely (1000 m event) and most likely (1500 m event)
277 faster finishing times when time fastest qualification was possible.

278 Another environmental factor that appeared to be a crucial factor for the initial pace was
279 the number of competitors competing within a race. That is, the lower the number of
280 competitors within a race the slower the adopted initial pace by the competitors compared to a
281 higher number of competitors. An effect that was especially apparent during the 1000m and
282 1500m competitions. A confounding effect of group size on performance has been reported
283 before.^{27,28} Performance of individual members of a group tend to become increasingly less in
284 a cooperative setting as the size of their group increases, and effect well known as the
285 Ringelmann effect.^{27,28} To our knowledge, this is the first time a contrary confounding effect is
286 found for group size on decision-making and performance in a competitive situation.

287 Interestingly, possibly faster finishing times were revealed over the seasons in the 500
288 m event. The faster finishing times were established mainly by a likely to very likely faster
289 completion of the final three laps rather than by a faster initial lap (most likely trivial effect
290 over the seasons). At the same time, this study once again highlights the importance of the start
291 position for 500m short-track speed skating competitions.^{11,29,30} In contrast to the 500 m event,
292 a change in chosen pacing behavior to a more conservative starting pace and faster final lap
293 times was found over the seasons for the 1000 and 1500 m event. This could be an indication
294 of an increased depth of competition over the years. That is, a similar change to a more
295 conservative initial pace was found in the final stages of the tournament in comparison to the
296 preliminary stages of the tournament during the 1500 m event. For the 500 and 1000 m event,
297 lap times and finishing times were most likely faster in finals, semi-finals, and quarterfinals
298 compared to the preliminary stages of the competition. Remarkably, during the Olympic Games
299 the skaters adopted a faster initial pace compared to World cups, European and World
300 championships, leading to faster finishing times in the 1000 m and 1500 m event. Differences
301 in pacing and performance for competition importance in the 500 m event were found to be
302 most likely trivial.

303 Noteworthy, yet not surprisingly, Sex and Altitude affected performance. Men
304 completed their races most likely faster compared to women, while races at high altitude led to
305 most likely faster finishing times compared to races at sea-level for the 1000 and 1500 m event.
306 Interestingly, the difference in finishing time between sea-level and high altitude races was
307 most likely trivial for the 500 m event. In terms of pacing, races at sea-level were most likely
308 slower in the first ten laps of the 1500 m event. For the 1000 m event all laps were likely to
309 most likely faster at high altitude, except for the first lap, while for the 500 m event only the
310 final lap was very likely faster at high altitude.

311 The possibility to benefit from the effect of drafting behind their opponent is crucial in
312 in short-track speed skating competitions, and could reduce air frictional losses up to 23%.^{31,32}
313 Therefore, adjusting your own pacing behavior based on your competitors could provide a clear
314 advantage in short-track speed skating. Whether this has an effect on the influence of the
315 competitive environment on pacing decisions is yet unclear. However, one could expect at least
316 comparable results in sports where aerodynamics play a similar prominent role, such as cycling.
317 In addition, it seems likely that a variable such as time fastest qualification could invite to adjust
318 the chosen pacing behavior in other sports such as for example running, although more
319 experimental evidence is required to support this hypothesis.

320

321 **Practical applications**

322 Previously, we demonstrated that the behavior of the other contenders in the race is an
323 important affordance in elite short-track speed skating competitions.⁶ That is, elite short-track
324 speed skaters adjust their pacing response during competition heavily based on the actions and
325 pacing behavior of the other competitors in their race.⁶ However, the adopted pace by the
326 competitors during a race appeared to vary widely between races. The present study revealed
327 that part of this variability per race could be related to the context in which a race is presented.
328 Several competitive environments, such as the number of competitors in a race (a higher
329 number of competitors evoked most likely a faster initial pace), the stage of competition (likely
330 to most likely, a slower initial pace was demonstrated in finals), the possibility of time
331 qualification (most likely a faster initial pace) and competition importance (most likely faster
332 races at the Olympics), altered the pacing decisions of elite skaters in 1000 and 1500 m events.
333 In addition, the stage of competition and start position affected pacing behaviour in the 500 m
334 event.

335

336 **Conclusions**

337 A multitude of external cues, inviting for action, are presented continuously and
338 simultaneously to an exerciser during a competition. As demonstrated in this study, different
339 competitive environments impacted on pacing behavior, in particular in the initial phase of the
340 race. This emphasizes the importance of athlete-environment interactions, especially during
341 head-to-head competition. To understand the decision-making involved in pacing both the
342 internal state of the exerciser as well as the external world around the exerciser need to be
343 considered.

344

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348 commercial or financial relationships that could be construed as a potential conflict of interest.

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442 **Tables**
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Table 1. Mean \pm SD of the lap times and finish times in seconds of the 500, 1000 and 1500 m event

	500m	1000m	1500m
Lap 1	7.33 \pm 0.35	13.72 \pm 0.99	9.73 \pm 1.06
Lap 2	9.33 \pm 0.38	10.42 \pm 0.80	13.16 \pm 1.68
Lap 3	8.88 \pm 0.39	10.07 \pm 0.66	12.14 \pm 1.48
Lap 4	9.02 \pm 0.41	9.83 \pm 0.53	11.60 \pm 1.26
Lap 5	9.27 \pm 0.44	9.66 \pm 0.46	11.10 \pm 1.06
Lap 6		9.54 \pm 0.46	10.66 \pm 0.84
Lap 7		9.49 \pm 0.49	10.30 \pm 0.65
Lap 8		9.57 \pm 0.57	10.06 \pm 0.55
Lap 9		9.80 \pm 0.66	9.89 \pm 0.49
Lap 10			9.75 \pm 0.48
Lap 11			9.66 \pm 0.51
Lap 12			9.66 \pm 0.60
Lap 13			9.80 \pm 0.71
Lap 14			10.08 \pm 0.84
Finish time	43.82 \pm 1.81	92.09 \pm 4.18	147.59 \pm 7.93

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462 **Table 2.** Random (\bar{x}/\div 95% CI) and fixed effects (\pm 95% CI) per lap and for the finish time
 463 for 500m short-track speed skating races.
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	Lap 1	Lap 2	Lap 3	Lap 4	Lap 5	Finish time
Random effects						
Between-athlete	2.1 \bar{x}/\div 1.08	2.0 \bar{x}/\div 1.08	2.6 \bar{x}/\div 1.08	2.7 \bar{x}/\div 1.08	2.7 \bar{x}/\div 1.08	2.5 \bar{x}/\div 1.07
Within-athlete	2.3 \bar{x}/\div 1.01	2.0 \bar{x}/\div 1.01	2.1 \bar{x}/\div 1.01	2.3 \bar{x}/\div 1.01	2.8 \bar{x}/\div 1.01	1.8 \bar{x}/\div 1.01
Fixed effects						
Sex	7.5 \pm 0.2 ^{MS}	6.2 \pm 0.1 ^{MS}	6.3 \pm 0.2 ^{MS}	6.3 \pm 0.2 ^{MS}	6.1 \pm 0.2 ^{MS}	6.4 \pm 0.1 ^{MS}
Season	0.0 \pm 0.3 ^{MT}	1.0 \pm 0.2 ^{PS/PT}	1.3 \pm 0.3 ^{VS}	1.2 \pm 0.3 ^{LS}	1.2 \pm 0.3 ^{LS}	1.0 \pm 0.2 ^{PS/PT}
Stage of Competition	-0.8 \pm 0.5 ^{LT}	-1.1 \pm 0.4 ^{PS/PT}	-1.4 \pm 0.4 ^{VL}	-1.3 \pm 0.5 ^{LS}	-1.2 \pm 0.6 ^{PS/PT}	-1.1 \pm 0.4 ^{LS}
Start position	-2.2 \pm 0.2 ^{MS}	0.0 \pm 0.2 ^{MT}	-0.1 \pm 0.2 ^{MT}	-0.1 \pm 0.3 ^{MT}	-0.2 \pm 0.3 ^{MT}	-0.4 \pm 0.2 ^{MT}
No of ST	-0.1 \pm 0.3 ^{MT}	-0.3 \pm 0.2 ^{MT}	-0.1 \pm 0.2 ^{MT}	-0.1 \pm 0.3 ^{MT}	-0.1 \pm 0.3 ^{MT}	-0.1 \pm 0.2 ^{MT}
Altitude	0.1 \pm 0.2 ^{MT}	0.6 \pm 0.1 ^{MT}	0.8 \pm 0.2 ^{VT}	0.9 \pm 0.2 ^{PS/PT}	1.2 \pm 0.2 ^{VS}	0.8 \pm 0.1 ^{MT}
Competition importance	0.1 \pm 0.3 ^{MT}	0.5 \pm 0.4 ^{MT}	0.2 \pm 0.4 ^{MT}	0.1 \pm 0.4 ^{MT}	0.0 \pm 0.5 ^{MT}	-0.2 \pm 0.5 ^{MT}
Event No. per tournament	-0.1 \pm 0.1 ^{MT}	-0.1 \pm 0.1 ^{MT}	-0.1 \pm 0.1 ^{MT}	0.1 \pm 0.1 ^{MT}	0.1 \pm 0.1 ^{MT}	0.0 \pm 0.1 ^{MT}
Time qualification	-0.0 \pm 0.3 ^{MT}	-0.1 \pm 0.2 ^{MT}	-0.2 \pm 0.3 ^{MT}	-0.2 \pm 0.3 ^{MT}	-0.1 \pm 0.4 ^{MT}	-0.1 \pm 0.2 ^{MT}

^{MS} most likely substantial; ^{VS} very likely substantial; ^{LS} likely substantial; ^{PS} possibly substantial; ^{PT} possibly trivial; ^{LT} likely trivial; ^{VT} very likely trivial; ^{MT} most likely trivial.

465 **Table 3.** Random (x/÷ 95% CI) and fixed effects (± 95% CI) per lap and for the finish time for 1000m short-track speed skating races.

	Lap 1	Lap 2	Lap 3	Lap 4	Lap 5	Lap 6	Lap 7	Lap 8	Lap 9	Finish time
Random effects										
Between-athlete	1.5 x/÷1.12	1.2 x/÷1.16	1.0 x/÷1.17	0.8 x/÷1.16	0.8 x/÷1.15	1.4 x/÷1.11	2.5 x/÷1.09	3.2 x/÷1.08	3.4 x/÷1.09	1.6 x/÷1.09
Within-athlete	5.4 x/÷1.01	6.2 x/÷1.01	5.0 x/÷1.01	3.8 x/÷1.01	3.1 x/÷1.01	2.8 x/÷1.01	3.1 x/÷1.01	3.8 x/÷1.01	4.8 x/÷1.01	2.6 x/÷1.01
Fixed effects										
Sex	5.0 ±0.3 ^{MS}	5.5 ±0.3 ^{MS}	5.9 ±0.3 ^{MS}	6.4 ±0.2 ^{MS}	6.9 ±0.2 ^{MS}	6.9 ±0.2 ^{MS}	6.9 ±0.2 ^{MS}	6.9 ±0.3 ^{MS}	6.7 ±0.3 ^{MS}	6.4 ±0.2 ^{MS}
Season	-2.1 ±0.6 ^{MS}	-1.2±0.7 ^{PS/PT}	-0.1 ±0.5 ^{MT}	0.5 ±0.4 ^{VT}	0.7 ±0.3 ^{LT}	1.1±0.3 ^{PS/PT}	1.2 ±0.4 ^{LS}	1.4 ±0.5 ^{LS}	1.4 ±0.6 ^{LS}	0.2 ±0.3 ^{MT}
Stage of Competition	-2.0 ±1.2 ^{VS}	-1.6 ±1.4 ^{LS}	-1.8 ±1.1 ^{LS}	-1.7 ±0.9 ^{VS}	-1.7 ±0.7 ^{VS}	-1.4 ±0.6 ^{LS}	-1.4 ±0.7 ^{LS}	-1.4 ±0.9 ^{LS}	-1.3±1.1 ^{PS/PT}	-1.6 ±0.6 ^{VS}
Start position	-0.5±1.3 ^{PS/PT}	0.2 ±1.5 ^{LT}	0.2 ±1.2 ^{LT}	0.2 ±1.0 ^{LT}	0.0 ±0.8 ^{VT}	0.0 ±0.7 ^{VT}	-0.2 ±0.8 ^{VT}	-0.3 ±1.0 ^{VT}	-0.8±1.2 ^{PS/PT}	-0.1 ±0.7 ^{MT}
Number of shorttrackers	3.8 ±1.1 ^{MS}	3.9 ±1.2 ^{MS}	3.4 ±1.0 ^{MS}	1.9 ±0.7 ^{VS}	0.8 ±0.6 ^{PS/PT}	0.1 ±0.5 ^{MT}	-0.4 ±0.6 ^{VT}	-0.9±0.7 ^{PS/PT}	-0.9±0.9 ^{PS/PT}	1.5 ±0.5 ^{VS}
Altitude	0.2 ±0.3 ^{MT}	1.1 ±0.4 ^{LS}	1.5 ±0.3 ^{MS}	1.7 ±0.2 ^{MS}	2.0 ±0.2 ^{MS}	1.9 ±0.2 ^{MS}	1.7 ±0.2 ^{MS}	1.5 ±0.2 ^{MS}	1.4 ±0.3 ^{VS}	1.4 ±0.2 ^{MS}
Competition importance	1.6 ±1.1 ^{VS}	2.2 ±1.2 ^{MS}	1.9 ±1.0 ^{MS}	1.3 ±0.8 ^{VS}	0.5 ±0.6 ^{MT}	0.3 ±0.6 ^{MT}	0.0 ±0.6 ^{MT}	-0.4 ±0.7 ^{MT}	-0.7 ±0.9 ^{MT}	0.8 ±0.5 ^{LT}
Event No. per tournament	0.5 ±0.3 ^{MT}	0.7 ±0.3 ^{LT}	0.9 ±0.3 ^{LT}	0.8 ±0.2 ^{VT}	0.6 ±0.2 ^{MT}	0.2 ±0.2 ^{MT}	0.0 ±0.2 ^{MT}	-0.1 ±0.2 ^{MT}	-0.1 ±0.3 ^{MT}	0.4 ±0.1 ^{MT}
Time qualification	-2.6 ±1.0 ^{MS}	-2.6 ±1.2 ^{MS}	-2.3 ±1.0 ^{MS}	-1.1±0.8 ^{PS/PT}	-0.7 ±0.6 ^{LT}	-0.3 ±0.6 ^{MT}	-0.4 ±0.6 ^{MT}	-0.2 ±0.8 ^{MT}	-0.6 ±1.0 ^{VT}	-1.3 ±0.5 ^{VS}

^{MS} most likely substantial; ^{VS} very likely substantial; ^{LS} likely substantial; ^{PS} possibly substantial; ^{PT} possibly trivial; ^{LT} likely trivial; ^{VT} very likely trivial; ^{MT} most likely trivial.

467 **Table 4.** Random (x/÷ 95% CI) and fixed effects (± 95% CI) per lap and for the finish time for 1500m short-track speed skating races.

	Lap 1	Lap 2	Lap 3	Lap 4	Lap 5	Lap 6	Lap 7	Lap 8	Lap 9	Lap 10	Lap 11	Lap 12	Lap 13	Lap 14	Finish time
Random effects															
Between-athlete	2.5 x/÷1.12	2.0 x/÷1.18	1.8 x/÷1.20	1.4 x/÷1.22	1.1 x/÷1.25	0.8 x/÷1.30	0.5 x/÷1.37	0.6 x/÷1.27	0.7 x/÷1.21	1.4 x/÷1.12	2.7 x/÷1.09	4.0 x/÷1.08	5.0 x/÷1.08	5.2 x/÷1.08	1.4 x/÷1.11
Within-athlete	8.4 x/÷1.02	10.7 x/÷1.02	10.3 x/÷1.02	9.0 x/÷1.02	7.7 x/÷1.02	6.2 x/÷1.02	4.8 x/÷1.02	4.1 x/÷1.02	3.6 x/÷1.02	3.2 x/÷1.02	3.4 x/÷1.02	4.0 x/÷1.02	4.8 x/÷1.02	6.0 x/÷1.02	3.5 x/÷1.02
Fixed effects															
Sex	4.5 ^{MS} ±0.5	6.6 ^{MS} ±0.6	7.1 ^{MS} ±0.5	7.1 ^{MS} ±0.5	7.4 ^{MS} ±0.4	6.8 ^{MS} ±0.3	6.5 ^{MS} ±0.2	6.1 ^{MS} ±0.2	6.1 ^{MS} ±0.2	6.3 ^{MS} ±0.2	6.0 ^{MS} ±0.3	5.7 ^{MS} ±0.3	5.5 ^{MS} ±0.4	4.9 ^{MS} ±0.5	6.4 ^{MS} ±0.2
Season	-6.5 ^{MS} ±1.0	-5.1 ^{MS} ±1.2	-3.9 ^{MS} ±1.2	-2.6 ^{MS} ±1.0	-1.2 ^{PS/PT} ±0.9	-0.2 ^{VT} ±0.7	0.6 ^{LT} ±0.6	1.1 ^{PS/PT} ±0.5	1.4 ^{VS} ±0.4	1.4 ^{VS} ±0.4	1.6 ^{VS} ±0.5	1.6 ^{VS} ±0.6	1.8 ^{VS} ±0.7	2.0 ^{VS} ±0.8	-0.9 ^{PS/PT} ±0.5
Stage of Competition	0.6 ^{PS/PT} ±1.5	2.3 ^{LS} ±1.8	1.3 ^{PS/PT} ±1.7	-0.1 ^{LT} ±1.5	-1.4 ^{PS/PT} ±1.4	-1.7 ^{LS} ±1.0	-1.6 ^{LS} ±0.8	-1.4 ^{LS} ±0.7	-1.4 ^{LS} ±0.6	-1.3 ^{LS} ±0.6	-1.3 ^{LS} ±0.6	-1.5 ^{LS} ±0.7	-1.6 ^{LS} ±0.8	-1.7 ^{LS} ±1.0	-0.7 ^{LT} ±0.6
Start position	-1.3 ^{PS/PT} ±1.2	0.6 ^{PS/PT} ±1.5	0.2 ^{LT} ±1.7	0.1 ^{LT} ±1.3	0.0 ^{LT} ±1.1	0.0 ^{VT} ±0.9	-0.1 ^{VT} ±0.7	-0.1 ^{MT} ±0.6	-0.1 ^{MT} ±0.5	-0.2 ^{MT} ±0.5	-0.2 ^{MT} ±0.5	-0.3 ^{VT} ±0.6	-0.4 ^{LT} ±0.7	-0.7 ^{LT} ±0.9	-0.1 ^{MT} ±0.5
Number of shorttrackers	5.0 ^{MS} ±1.6	7.9 ^{MS} ±2.1	9.3 ^{MS} ±2.1	8.3 ^{MS} ±1.8	7.0 ^{MS} ±1.5	5.9 ^{MS} ±1.2	3.9 ^{MS} ±0.9	1.7 ^{VS} ±0.8	0.5 ^{LT} ±0.7	-0.1 ^{MT} ±0.6	-0.5 ^{LT} ±0.6	-0.8 ^{PS/PT} ±0.8	-0.8 ^{PS/PT} ±0.9	-0.6 ^{LT} ±1.1	3.7 ^{MS} ±0.7
Altitude	3.3 ^{MS} ±0.6	4.5 ^{MS} ±0.8	4.8 ^{MS} ±0.8	4.8 ^{MS} ±0.7	4.7 ^{MS} ±0.6	3.7 ^{MS} ±0.5	2.6 ^{MS} ±0.4	2.0 ^{MS} ±0.3	2.0 ^{MS} ±0.3	1.6 ^{MS} ±0.2	0.8 ^{VT} ±0.3	0.2 ^{MT} ±0.3	-0.1 ^{MT} ±0.4	-0.1 ^{MT} ±0.5	2.6 ^{MS} ±0.3
Competition importance	3.5 ^{MS} ±1.8	3.5 ^{MS} ±2.2	3.1 ^{MS} ±2.1	2.2 ^{MS} ±1.9	2.0 ^{MS} ±1.6	2.1 ^{MS} ±1.3	0.7 ^{LT} ±1.0	0.8 ^{LT} ±0.8	0.8 ^{LT} ±0.7	0.9 ^{LT} ±0.7	0.7 ^{VT} ±0.7	0.4 ^{MT} ±0.8	0.4 ^{VT} ±1.0	0.1 ^{MT} ±1.2	1.6 ^{MS} ±0.7
Event No.per tournament	0.8 ^{LS} ±0.4	1.0 ^{PS/PT} ±0.6	1.4 ^{LS} ±0.5	1.8 ^{MS} ±0.5	1.4 ^{VS} ±0.4	1.1 ^{PS/PT} ±0.3	0.8 ^{VT} ±0.3	0.6 ^{MT} ±0.2	0.2 ^{MT} ±0.2	-0.3 ^{MT} ±0.2	-0.3 ^{MT} ±0.2	-0.5 ^{MT} ±0.2	-0.5 ^{MT} ±0.3	-0.4 ^{MT} ±0.3	0.5 ^{MT} ±0.2
Time qualification	-3.9 ^{MS} ±1.3	-5.0 ^{MS} ±1.6	-4.4 ^{MS} ±1.6	-3.5 ^{MS} ±1.4	-2.6 ^{MS} ±1.3	-1.4 ^{LS} ±1.0	-0.5 ^{VT} ±0.8	-0.5 ^{MT} ±0.7	-0.2 ^{MT} ±0.6	-0.3 ^{MT} ±0.6	0.0 ^{MT} ±0.6	0.1 ^{MT} ±0.7	0.0 ^{MT} ±0.8	-0.2 ^{MT} ±1.0	-1.8 ^{MS} ±0.6

^{MS} most likely substantial; ^{VS} very likely substantial; ^{LS} likely substantial; ^{PS} possibly substantial; ^{PT} possibly trivial; ^{LT} likely trivial; ^{VT} very likely trivial; ^{MT} most likely trivial.

