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Citation: Noorbergen, Olaf S., Konings, Marco J., Micklewright, Dominic, Elferink-Gemser, Marije T. and Hettinga, Florentina (2016) Pacing Behavior and Tactical Positioning in 500- and 1000-m Short-Track Speed Skating. *International Journal of Sports Physiology and Performance*, 11 (6). pp. 742-748. ISSN 1555-0265

Published by: Human Kinetics

URL: <https://doi.org/10.1123/ijsp.2015-0384> <<https://doi.org/10.1123/ijsp.2015-0384>>

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Pacing behaviour and tactical positioning in 500m and 1000m short-track speed skating

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Article Type: Original Investigation

Running title: Pacing tactics in 500/1000m short-track speed skating

Abstract word count: 250

Text-only word count: 3207

As accepted for publication in International Journal of Sports Physiology and Performance:

<http://www.ncbi.nlm.nih.gov/pubmed/26641204>

CONFLICT OF INTEREST AND SOURCE OF FUNDING

The authors have no conflicts of interest

32 There are no sources of funding for this work

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36 **Pacing behaviour and tactical positioning in 500m** 37 **and 1000m short-track speed skating**

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Abstract

40

41 **Purpose:** The present study explored pacing behaviour and tactical positioning during the
42 shorter 500m and 1000m short-track competitions. **Methods:** Lap times and intermediate
43 rankings of elite 500m and 1000m short-track skating competitors were collected over the
44 season 2012/13. Firstly, lap times were analysed using a MANOVA and for each lap
45 differences between sex, race type, final-rankings, and stage of competition were determined.
46 Secondly, Kendall's tau-b correlations were used to assess relationships between intermediate
47 and final-rankings. In addition, intermediate rankings of the winner of each race were
48 examined. **Results:** Top-placed athletes appeared faster than bottom-placed athletes in every
49 lap in the 500 m, while in the 1000 m no differences were found until the final four laps
50 ($P < 0.05$). Correlations between intermediate and final-rankings were already high at the
51 beginning stages of the 500m (Lap 1: $r = 0.59$), but not for the 1000m (Lap 1: $r = 0.21$).

52 **Conclusions:** Although 500m and 1000m short-track races are both of relatively short
53 duration, fundamental differences in pacing behavior and tactical positioning were found. A
54 fast start strategy seems to be optimal for 500m races, while the crucial segment in 1000 m
55 races seems to be from the 6th lap to the finish line (i.e., after ± 650 m). These findings
56 provide evidence to suggest that athletes balance between choosing an energetically optimal
57 profile and the tactical and positional benefits that play a role when riding against an
58 opponent, and contribute to developing novel insights in exploring athletic behaviour when
59 racing against opponents.

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61 **KEYWORDS:** Elite athletes, Interpersonal competition, Race-analysis, Opponents, Decision-
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Introduction

Pacing has been defined as the goal-directed regulation of exercise intensity over an exercise bout,¹ in which athletes need to decide how and when to invest their energy.² In this perspective, recent theoretical frameworks from both heuristic³ and ecological² perspectives emphasized the interaction with the environment for the regulation of the exercise intensity in addition to internal characteristics such as (perceived) fatigue.^{2,3} That is, athletes may decide to alter their pacing behaviour based on both internal as well as environmental characteristics.

An important environmental characteristic that is inextricably linked to athletic sports is the presence of competition. However, the tactical decision-making processes involved in athletic competitions are still relatively unknown, especially when competing against direct opponents, such as in short-track speed skating. Moreover, direct opponents are making the tactical decision-making processes more complex compared to individual time-trial performance. In regular time-trial performance, decisions about the variation of speed over the race are mainly based on the monitoring of energy expenditure.⁴ However, when racing against direct opponents, tactical decisions about when to accelerate or decelerate during a race can also be based on avoiding collisions, drafting possibilities, motivational aspects and expectations and estimations of opponents behaviour and winning chances.² Therefore, we would like to analyse not only pacing behaviour (velocity profiles over the race), but also include an analysis of tactical positioning (rankings of athletes relative to each other) during the race.

Recently, pacing behaviour and tactical positioning have been explored in the middle distance 1500 m short-track speed skating event ($\pm 2.0 - 2.5$ min), in which the beginning stages of the race were characterized by relatively slow lap times most likely due to tactical considerations.⁵ These results differed compared to the generally shown fast start strategies in middle distance 1500 m time-trial long-track speed skating.^{6,7} Up until now, not much is known regarding shorter or longer distances involving direct competition. As optimal pacing patterns are related to duration/distance,⁸ it is important to explore pacing behaviour for shorter as well as longer exercises involving direct competition.

To gain more insight into the pacing tactics during events with a relatively short duration (< 2 min), the present study will explore the pacing behaviour and tactical positioning during 500 m and 1000 m short-track speed skating competitions. Previous time-trial research suggests a fast start or positive pacing strategy is optimal for this type of competition.⁹⁻¹¹ In addition, the strong correlations that were found in short-track speed skating between starting position and finishing position during 500 m competitions suggest that tactical positioning is already important at the beginning stages of the race for 500 m races.¹²⁻¹⁴ No such correlations were found for 1000 m races. Therefore, we hypothesize that top-placed athletes skate in the foremost positions throughout the race and skate faster lap times in each lap of the 500 m. In contrast, we expect during the longer 1000 m a more tactical development of the race in which top-placed athletes skate in the more foremost intermediate positions and skate faster lap times only during the second half of the race.

Materials and methods

Subjects and events

Finishing and intermediate lap times as well as start, intermediate, and finishing positions in 500 m (4.5 laps) and 1000 m (9 laps) races were gathered from 500 m and 1000 m Short Track Speed Skating World Cups, the European Championships and World Championships during the season 2012/13. In total, ten indoor competitions (eight World Cups, one European

128 Championship, and one World Championship), divided over eight locations and dates were
129 analysed. Lap times were measured using an electronic time-measuring systems based on
130 optical detectors that started automatically by the firing of a starting-gun and that recorded
131 automatically the reaching of the finishing line by each competitor. The International Skating
132 Union (ISU) demands that lap times are recorded with the accuracy of at least a hundredth of
133 a second. Therefore, for every automatic timekeeping system a certificate stating the
134 reliability and accuracy of the system had to be presented to the referee before the
135 competition, ensuring that all systems recorded with the accuracy of at least a hundredth of a
136 second. No written consent was given by participants as all data used are publicly available at
137 the ISU website (<http://www.sportresult.com/federations/ISU/ShortTrack/>) and no
138 interventions occurred during the data collection. The study was approved by the local ethical
139 committee.

140 In total, 574 races from 500 m competitions and 545 races from 1000 m competitions
141 were analysed. However, whereas falls and/or disqualifications could affect the lap times and
142 positioning of the athlete him/herself as well as those of the other competitors (especially for
143 the lower placed finishers) possibly leading to a misinterpretation of the results, data from
144 races with a disqualification (500 m: n=81; 1000 m: n=124), a fall (500 m: n=62; 1000 m:
145 n=37) and/or races with one or more missing values (500 m: n=3; 1000 m: n=8) were
146 excluded. Lastly, to ensure consistency over the data set races with another number of
147 competitors than four (i.e. the most commonly occurring number of competitors) were
148 excluded (500 m: n=164; 1000 m: n=165). This resulted for the 500 m in 246 of 574 races
149 (46.0%; men: 132 races, women: 132 races) and for the 1000 m in 211 of 545 races (38.7%;
150 men: 114 races, women: 97 races) that were examined.

151 Each short-track competition consisted of qualification stages in which a skater had to
152 qualify for the next stage by finishing first or second, and the final race where the goal was to
153 win overall. The rankings for each lap and final-ranking were coded from 1 (leading skater)
154 to 4 (last skater). In addition, start positions were coded from 1 (inner) to 4 (outer), in line
155 with previous short-track studies.^{5,12,14,15}

156 157 *Statistical Analysis*

158 To examine pacing behaviour and tactical positioning, two different statistical approaches
159 were used. First, pacing behaviour has been assessed by examining lap times using
160 MANOVA, in which lap times were added as dependent variables, and sex, final-ranking,
161 race type, and stage of competition as independent variables. Race type was classified as fast
162 or slow when the winner of the heat was respectively faster or slower than the average
163 winning finishing time. For stage of competition, final competition stages (finals, semi-finals,
164 and quarter-finals) were distinguished from non-final stages (repeated semi-finals, repeated
165 heats, heats, and preliminaries). Finally, men and women (sex), and 1st, 2nd, 3rd, or 4th final-
166 ranked athletes (final-ranking) were differentiated. In addition, a univariate ANOVA was
167 performed to examine the effect of each subtype for the finishing time. Tukey post-hoc tests
168 were performed to examine lap time differences between the final-rankings when a
169 significant effect was found for final-ranking.

170 Second, tactical positioning was examined by assessing relationships between
171 start/intermediate rankings and final-rankings. Using Kendall's Tau-b correlations skaters'
172 intermediate rankings were correlated with their final-rankings. Positive correlations would
173 indicate that respectively, top- and bottom-placed short-trackers were also ranked in top- and
174 bottom-place in that particular lap. In contrast, negative correlations would indicate a top
175 intermediate ranking is related with a bottom final-ranking and vice versa. Positive and
176 negative correlations were perceived as not present/low ($r < 0.50$), moderate ($0.50 \leq r < 0.70$),
177 or high ($r \geq 0.70$). In addition, the tactical positioning of the winner of each race was

178 explored. Therefore, for each lap the percentage wherein the winner had skated at first,
179 second, third, or fourth place was determined. Lastly, based on the lap times and intermediate
180 rankings, the number of overtakings was calculated for each lap. Statistical analyses were
181 performed using SPSS 19.0 and differences were accepted to be significant if $P < 0.05$.

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183 <<< Insert Figure 1 about here >>>

184 <<< Insert Figure 2 about here >>>

185

186 **Results**

187 *Pacing behaviour: lap time analysis*

188 Mean (SD) intermediate lap times, overall as well as within the subtypes (sex, final-ranking,
189 race type, and stage of competition), are presented for the 500 m (Figure 1) and for the 1000
190 m (Figure 2) competitions. The MANOVA revealed in both the 500 m as well as the 1000 m
191 a main effect for sex ($P < 0.001$), final-ranking ($P < 0.001$), race type ($P < 0.001$), and stage
192 of competition ($P < 0.001$). In the 500 m, an interaction effect was found for final-
193 ranking*stage of competition ($P < 0.001$), indicating smaller differences in lap times between
194 the competitors during finals compared to non-finals. In the 1000 m, interaction effects were
195 found for sex*race type ($P < 0.001$), sex*stage of competition ($P < 0.001$), race type*stage of
196 competition ($P < 0.001$), and sex*race type*stage of competition ($P = 0.004$). The interaction
197 effects in the 1000 m demonstrate that both men and women start slower in finals compared
198 to non-finals, however this difference in starting velocity between finals and non-finals was
199 relatively higher for men than women.

200 Mean (SD) finishing times, overall and for each subtype, are shown in Table 1 for
201 both distances. For both distances main effects were found for sex ($P < 0.001$), final-ranking
202 ($P < 0.001$), race type ($P < 0.001$), and stage of competition ($P < 0.001$). In addition, the
203 differences in finishing time between the first, second, third, and fourth placed skater were
204 smaller in the finals compared to the non-finals of the 500 m ($P < 0.001$). In the 1000 m,
205 differences in finishing time between men and women were lower in finals compared to non-
206 finals ($P = 0.016$).

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208 <<< Insert Table 1 about here >>>

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212 Mean lap times of the race winners and the differences in lap times compared to the
213 second, third, and fourth final-ranked skaters are presented in Table 2. In the 500 m,
214 differences in lap times were already seen after a half lap, and followed lap times remained
215 different until the finish line. In contrast, during the first five laps of the 1000 m all skaters
216 seemed to adopt the same pace. In both the 500 m as well as the 1000 m lap time differences
217 between the winners and second final-ranked skaters remained non-significant, except for lap
218 1 of the 500 m, where the winners were significantly faster than the numbers two ($P < 0.001$).

219

220 *Tactical positioning: intermediate ranking analysis*

221 Kendall's Tau-b correlations for the 500 m and the 1000 m are presented in Figure 3. In the
222 500 m the correlation between the starting position and final-ranking was already 0.38.
223 During the first laps, intermediate rankings were moderately correlated with final-rankings,
224 while high correlations were found during the last two laps of the 500 m. Until the fifth lap of
225 the 1000 m, correlations between the start or intermediate position and final-ranking were
226 low or not present ($r < 0.50$). From the sixth lap, the correlation between intermediate ranking
227 and final-ranking became moderate ($0.50 \leq r < 0.70$), and during the last two laps, high

228 correlations were found between intermediate and final-ranking of the 1000 m ($r \geq 0.70$). In
229 addition, Table 3 shows the percentage of occasions on which the eventual race winner
230 occupied each available position at each intermediate point.

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232 <<< Insert Figure 3 about here >>>

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234 <<< Insert Table 3 about here >>>

235 Discussion

236 The present study aimed to explore pacing behaviour and tactical positioning in elite short-
237 track speed skating during 500 m and 1000 m events. In 500 m races, intermediate lap times
238 between the winner and the other competitors differed from the first half lap. Intermediate
239 rankings were moderately correlated with the final-rankings from the start of the race. This
240 seems to indicate that the start is already a crucial element of the race during 500 m short-
241 track competitions. In contrast, no differences in intermediate lap times were apparent for
242 final-rankings during the 1000 m until the sixth lap. Moreover, a low correlation between the
243 1000 m intermediate positions and final-ranking was observed until the sixth lap. In this
244 perspective, the crucial stage of 1000 m races seems to start at the 6th lap of the race (i.e.,
245 after ± 650 m).

246 The faster lap times of the winner compared to third/fourth final-ranked skaters during
247 the whole race of 500 m short-track competitions indicate a fast start strategy as the most
248 effective pacing strategy during a 500 m short-track race at the elite level. This is similar to
249 the fast start strategies adopted during the 500 m and 1000 m events in long-track speed
250 skating.⁹⁻¹¹ In addition, 63% of the race winners skated already at the first position after the
251 first half lap. Even the starting position seems important, whereas 51% of the 500 m winners
252 stood already at the inner start line. The importance of the start and starting position in 500 m
253 short-track speed skating competitions has been shown before,¹²⁻¹⁴ and is most likely related
254 to the fact that the athlete starting in the most outside position of the track needs to cover a
255 slightly longer distance to the first corner compared to the most inner starting athlete.¹²

256 Interestingly, although the duration of 1000 m short-track competitions (± 90 s) would
257 suggest a fast start (“positive”) pacing strategy for optimal performance,^{9,10} a relatively even-
258 pace seems to be adopted by the short-track skating athletes throughout the race. In contrast
259 to the 500 m, no differences in lap times between competitors within a race were found
260 during the first five laps of 1000 m competitions, indicating all athletes adopted a similar
261 pace. This group packing in the beginning stages is most likely related to the beneficial effect
262 of drafting,¹⁸ thereby saving energy for the decisive final part of the race.^{5,19} This
263 spontaneous synchronization of pacing during the beginning stages of the races was also
264 reported during the longer 1500 m short-track competitions,⁵ track cycling,¹⁶ and marathon
265 running.¹⁷ However, where the velocity during the beginning stages of the 1500 m gradually
266 increased each lap,⁵ it remained more even during the 1000 m. This could indicate that
267 bottom-ranked speed skaters expended too much energy in the first phase of 1000 m races by
268 trying to follow the pace of the others, resulting in significant slower intermediate lap times
269 from lap 6 to lap 9 (see Table 2).

270 As is known from studies on time trial exercise, there is a benefit of using up energy
271 prior to the finishline rather than speeding up all the way to the finishline⁸. In addition,
272 energy cost of variations in speed, i.e. accelerations and decelerations throughout the race, is
273 higher compared to energy cost of an even paced profile. However, in short track speed
274 skating races against opponents, athletes seem to choose for energetically unbeneficial
275 speeding up towards the finishline as well as for energetically unbeneficial actions of
276 overtaking⁵. They are balancing between choosing an energetically optimal profile,
277 something you would do when riding a time trial, and the tactical and positional benefits that

278 play a role when riding against an opponent. Future studies are required to analyze these
279 tactical aspects of racing and pacing against opponents more in depth.

280 A potential limitation of this study might be that positional and time data of both
281 qualification races and finals were included from finals as well as non-finals. Results of this
282 study have shown that the stage of competition might influence lap times, and therefore, race
283 tactics. Short-track athletes then possibly have different race tactics in finals compared to
284 non-finals. Future research on this topic needs to further explore differences in tactics
285 between finals and non-finals.

286

287 **Practical applications**

288 Though both analysed distances in the present study are of relatively short duration (>2 min),
289 our findings indicate that 500 m and 1000 m short-track speed skating races should be
290 approached differently. During 500 m a fast starting strategy from the beginning of the race
291 seems to be optimal, whereas race winners appeared to be faster and positioned themselves in
292 the leading position throughout the whole race. This makes the start crucial and possibly even
293 decisive for successful 500 m performance. In contrast, in 1000 m short-track competitions,
294 athletes are advised to save energy throughout the race in order to be able to maintain pace or
295 overtake their opponent in the final stages of the race. In this perspective, athletes might
296 profit from another intermediate position than the first in the beginning of the race as it
297 significantly reduces air frictional losses due to the effect of drafting. With only four laps
298 remaining it is advised to attempt to occupy one of the foremost positions, as performance is
299 strongly correlated to a foremost intermediate position after the 6th lap of the race (i.e. after \pm
300 650 m).

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302

303 **Conclusions**

304 The present study aimed to broaden the view of pacing tactics over a range of different race
305 durations in short-track speed skating, an athletic competition where completion time is
306 irrelevant as long as you finish before the other competitors. In this type of competition,
307 athletes need to pace and position themselves in such a way that they will be the first to pass
308 the finish line. Previous research has shown that pacing tactics in the middle-distance 1500 m
309 short-track speed skating event, involving direct competition, indicated different pacing
310 behaviour and tactics compared to the generally shown fast start strategies in 1500 m time-
311 trial long-track speed skating^{5,6,20}. The present study has shown that a fast starting strategy is
312 still optimal in 500 m short-track speed skating, similar to time-trial sports. In contrast, 1000
313 m short-track speed skating was approached differently, and indicated different pacing
314 behaviour compared to the generally shown faster start strategies in 1000 m time-trial long-
315 track speed skating¹¹.

316

317 **Acknowledgements**

318 No sources of funding were used to assist in the preparation of this article. The authors have
319 no potential conflicts of interest that are directly relevant to the content of this article.

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384 **Table and Figure Captions**

385

386 **Table 1.** Mean (SD) finishing times for overall performance as well as each subtype ('sex',
387 'final-ranking', 'race type' and 'stage of competition') in the 500 m and 1000 m (N =
388 number of short-track athletes).

389

390 **Table 2.** Mean lap times of the race winners throughout the race are presented, both in the
391 500 m as well as the 1000 m. In addition, mean differences between lap times of the race
392 winners compared to the other final-rankings were shown for each lap. E.g. In lap 8 of the
393 1000 m the race winner was 0.4 sec faster than the 4th final-ranked athlete.

394

395 **Table 3.** Percentages (%) in which the future winner skated at one of the four intermediate
396 positions was shown in each lap of the 500 m as well as the 1000 m. E.g. in lap 1 of the 500
397 m 63 % of the winners already skated at first position, while only 3 % of the winners skated
398 at fourth position.

399

400 **Figure 1.** Mean (SD) lap times during the 500 m short-track speed skating, overall and for
401 each subtype ('Sex', 'Race Type', 'Final-ranking', 'Stage of Competition').
402 *Significant main effect for the subtype in that particular lap (p<0.05)
403 † Lap 1 is only the lap time for the first ½ lap

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405 **Figure 2.** Mean (SD) lap times during the 1000 m short-track speed skating, overall and for
406 each subtype ('Sex', 'Race Type', 'Final-ranking', 'Stage of Competition').
407 *Significant main effect for the subtype in that particular lap (p<0.05)

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409 **Figure 3.** Kendall's tau-b correlations of all intermediate rankings with the final-rankings
410 from the 500 m and 1000 m.

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433 **Table 1.** Mean (SD) finishing times for overall performance as well as each subtype ('sex',
 434 'final-ranking', 'race type' and 'stage of competition') in the 500 m and 1000 m (N =
 435 number of short-track athletes).

	500 m		1000 m		
	Mean	N	Mean	N	
Overall	43.96 (1.83)	1056	91.28 (3.77)	844	
Sex	Men	42.68 (1.31)	528	89.15 (3.08)	456
	Women	45.24 (1.30)	528	93.80 (2.85)	388
Final-ranking	1st	43.36 (1.57)	264	90.68 (3.51)	211
	2nd	43.61 (1.60)	264	90.89 (3.53)	211
	3rd	44.00 (1.68)	264	91.25 (3.67)	211
	4th	44.85 (2.08)	264	92.30 (4.16)	211
Race type	Fast	43.33 (1.68)	572	89.29 (2.76)	508
	Slow	44.72 (1.71)	484	94.28 (3.04)	336
Stage of Competition	Finals	43.35 (1.46)	332	89.36 (3.07)	248
	Non-finals	44.23 (1.91)	734	92.08 (3.75)	596

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454 **Table 2.** Mean lap times of the race winners throughout the race are presented, both in the 500 m as
 455 well as the 1000 m. In addition, mean differences between lap times of the race winners compared to
 456 the other final-rankings were shown for each lap. E.g. In lap 8 of the 1000 m the race winner was 0.4
 457 sec faster than the 4th final-ranked athlete.

	Lap 1	Lap 2	Lap 3	Lap 4	Lap 5	Lap 6	Lap 7	Lap 8	Lap 9
500 m									
Mean lap times (sec) of race winner:									
1st	7.2	9.3	8.8	9.0	9.2				
Difference in lap time (sec) with race winner:									
2nd	+0.1*	0.0	0.0	0.0	0.0				
3rd	+0.2*	+0.1*	+0.1*	+0.1*	+0.1*				
4rd	+0.4*	+0.2*	+0.2*	+0.3*	+0.4*				
1000 m									
Mean lap times (sec) of race winner:									
1st	13.4	10.3	10.0	9.8	9.6	9.5	9.4	9.4	9.5
Difference in lap time (sec) with race winner:									
2nd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+0.1	0.0
3rd	0.0	0.0	0.0	0.0	0.0	0.0	+0.1*	+0.1*	+0.2*
4rd	+0.1	0.0	0.0	0.0	+0.1	+0.1*	+0.2*	+0.4*	+0.7*

458 * Significant post-hoc effect in lap times for 1st final-ranked athlete compared to 2nd, 3rd, and 4th (P<0.05)

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484 **Table 3.** Percentages (%) in which the future winner skated at one of the four intermediate positions
 485 was shown in each lap of the 500 m as well as the 1000 m. E.g. in lap 1 of the 500 m 63 % of the
 486 winners already skated at first position, while only 3 % of the winners skated at fourth position.

500 m	Start ^a	Lap 1	Lap 2	Lap 3	Lap 4	Finish
1st	51%	63%	70%	78%	87%	100%
2nd	22%	26%	21%	17%	12%	0%
3rd	16%	8%	8%	4%	1%	0%
4th	10%	3%	1%	0%	0%	0%

1000 m	Start ^a	Lap 1	Lap 2	Lap 3	Lap 4	Lap 5	Lap 6	Lap 7	Lap 8	Finish
1st	39%	36%	36%	43%	47%	55%	62%	74%	89%	100%
2nd	23%	27%	29%	28%	29%	27%	26%	20%	9%	0%
3rd	24%	21%	23%	19%	15%	12%	9%	5%	1%	0%
4th	15%	17%	12%	9%	9%	6%	3%	1%	0%	0%

487 ^a At the start of the races 1st = the most inner starter and 4th = the most outer starter.

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