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

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Abstract

Purpose: The present study explored pacing behaviour and tactical positioning during the shorter 500m and 1000m short-track competitions. ***Methods:*** Lap times and intermediate rankings of elite 500m and 1000m short-track skating competitors were collected over the season 2012/13. Firstly, lap times were analysed using a MANOVA and for each lap differences between sex, race type, final-rankings, and stage of competition were determined. Secondly, Kendall's tau-b correlations were used to assess relationships between intermediate and final-rankings. In addition, intermediate rankings of the winner of each race were examined. ***Results:*** Top-placed athletes appeared faster than bottom-placed athletes in every lap in the 500 m, while in the 1000 m no differences were found until the final four laps ($P<0.05$). Correlations between intermediate and final-rankings were already high at the beginning stages of the 500m (Lap 1: $r=0.59$), but not for the 1000m (Lap 1: $r=0.21$). ***Conclusions:*** Although 500m and 1000m short-track races are both of relatively short duration, fundamental differences in pacing behavior and tactical positioning were found. A fast start strategy seems to be optimal for 500m races, while the crucial segment in 1000 m races seems to be from the 6th lap to the finish line (i.e., after ± 650m). These findings provide evidence to suggest that athletes balance between choosing an energetically optimal profile and the tactical and positional benefits that play a role when riding against an opponent, and contribute to developing novel insights in exploring athletic behaviour when racing against opponents.

KEYWORDS: Elite athletes, Interpersonal competition, Race-analysis, Opponents, Decision-making

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 heuristic [3] and ecological [2] 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 (± 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

Championship, and one World Championship), divided over eight locations and dates were analysed. Lap times were measured using an electronic time-measuring systems based on optical detectors that started automatically by the firing of a starting-gun and that recorded automatically the reaching of the finishing line by each competitor. 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 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 all data used are publicly available at the ISU website (http://www.sportresult.com/federations/ISU/ShortTrack/) and no interventions occurred during the data collection. The study was approved by the local ethical committee.

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

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

Statistical Analysis

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

Second, tactical positioning was examined by assessing relationships between start/intermediate rankings and final-rankings. Using Kendall’s Tau-b correlations skaters’ intermediate rankings were correlated with their final-rankings. Positive correlations would indicate that respectively, top- and bottom-placed short-trackers were also ranked in top- and bottom-place in that particular lap. In contrast, negative correlations would indicate a top intermediate ranking is related with a bottom final-ranking and vice versa. Positive and negative correlations were perceived as not present/low ($r < 0.50$), moderate ($0.50 \leq r < 0.70$), or high ($r \geq 0.70$). In addition, the tactical positioning of the winner of each race was explored. Therefore, for each lap the percentage wherein the winner had skated at first, second, third, or fourth place was determined. Lastly, based on the lap times and intermediate rankings, the number of overtakings was calculated for each lap. Statistical analyses were performed using SPSS 19.0 and differences were accepted to be significant if $P < 0.05$.

<<< Insert Figure 1 about here >>>

<<< Insert Figure 2 about here >>>

Results

Pacing behaviour: lap time analysis

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

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

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

Tactical positioning: intermediate ranking analysis

Kendall's Tau-b correlations for the 500 m and the 1000 m are presented in Figure 3. In the 500 m the correlation between the starting position and final-ranking was already 0.38. During the first laps, intermediate rankings were moderately correlated with final-rankings, while high correlations were found during the last two laps of the 500 m. Until the fifth lap of the 1000 m, correlations between the start or intermediate position and final-ranking were low or not present ($r < 0.50$). From the sixth lap, the correlation between intermediate ranking and final-ranking became moderate ($0.50 \leq r < 0.70$), and during the last two laps, high correlations were found between intermediate and final-ranking of the 1000 m ($r \geq 0.70$). In addition, Table 3 shows the percentage of occasions on which the eventual race winner occupied each available position at each intermediate point.

<<< Insert Figure 3 about here >>>

<<< Insert Table 3 about here >>>

Discussion

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

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

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

As is known from studies on time trial exercise, there is a benefit of using up energy prior to the finishline rather than speeding up all the way to the finishline[8]. In addition, energy cost of variations in speed, i.e. accelerations and decelerations throughout the race, is higher compared to energy cost of an even paced profile. However, in short track speed skating races against opponents, athletes seem to choose for energetically unbeneficial speeding up towards the finishline as well as for energetically unbeneficial actions of overtaking[5]. They are balancing between choosing an energetically optimal profile, something you would do when riding a time trial, and the tactical and positional benefits that play a role when riding against an opponent. Future studies are required to analyze these tactical aspects of racing and pacing against opponents more in depth.

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

Practical applications

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

Conclusions

The present study aimed to broaden the view of pacing tactics over a range of different race durations in short-track speed skating, an athletic competition where completion time is irrelevant as long as you finish before the other competitors. In this type of competition, athletes need to pace and position themselves in such a way that they will be the first to pass the finish line. Previous research has shown that pacing tactics in the middle-distance 1500 m short-track speed skating event, involving direct competition, indicated different pacing behaviour and tactics compared to the generally shown fast start strategies in 1500 m time-trial long-track speed skating[5,6,20] The present study has shown that a fast starting strategy is still optimal in 500 m short-track speed skating, similar to time-trial sports. In contrast, 1000 m short-track speed skating was approached differently, and indicated different pacing behaviour compared to the generally shown faster start strategies in 1000 m time-trial long-track speed skating[11].

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Table and Figure Captions

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

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

Table 3. Percentages (%) in which the future winner skated at one of the four intermediate positions 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 winners already skated at first position, while only 3 % of the winners skated at fourth position.

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

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

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

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

Table 2. Mean lap times of the race winners throughout the race are presented, both in the 500 m as well as the 1000 m. In addition, mean differences between lap times of the race winners compared to the other final-rankings were shown for each lap. E.g. In lap 8 of the 1000 m the race winner was 0.4 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*

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

Table 3. Percentages (%) in which the future winner skated at one of the four intermediate positions 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 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%

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