Staying on track

Stoter, Inge

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General discussion

Chapter 6

GENERAL DISCUSSION

The present thesis aimed to unravel the road to elite 1500m performance in speed skating. Performance development and underlying mechanisms of performance were studied by cross-sectional and longitudinal studies. Based on performance development of the previous elites, short-term performance goals, needed to reach the long term goal of becoming an elite 1500m speed skater, are provided. Secondly, analyses of the underlying performance characteristics pacing, technique and muscle fatigue unravelled how to reach these short-term goals. With the gained knowledge, the present thesis enables evidence informed guidance of the future elites.

Elite performance development

In order to unravel performance development, a novel method to define performance in a standardized way was introduced in chapter 2. Standardized performance at the 1500m race was defined as the end-time divided by the prevailing world record (%WR). Comparing the 1500m end-time with the prevailing world record corrects for the evolution of the sport. Using this method it was possible to set a level for elite performance that is interpretable for future speed skaters, their coaches as well as researchers. The level of elite performance for the 1500m speed skating was set at 10 % above the world record for performance at lowland ice-tracks. Due to less air-resistance at altitude, official world records on high altitude ice-tracks are 3.2 % faster than the officious lowland world records. Taking the altitude differences into account, setting elite level performance at 110 %WR is comparable with the 2018 Olympic qualification times, which were 107.4 %WR for male skaters and 107.8 %WR for female skaters.

The new method to define standardized performance furthermore enabled comparison of different generations of speed skaters, leading to the inclusion of 63 female and 100 male elite speed skaters across 20 years (chapter 2). Their road to elite performance is described in figure 2 of chapter 2 using the average performance and performance benchmarks (upper limits) for age 13-26 years. Speed skaters who reached the elite performance level, generally performed better than their peers when they were younger, but did not develop faster than their peers (chapters 2 and 4). It is important to acknowledge that the standard deviation of performance development of the elite group was large (i.e., 1.9-3.0 %). In addition, the percentage of elite speed skaters performing within the elite performance benchmarks up to age 21 years were less than 50 % (chapter 2). These findings exemplify that not all later elites outperform their peers from a young age onward and that the road to elite performance can be different for each individual. Only average performance of the elite group is therefore not sufficient for proper goal setting for the future elites. By adding the elite performance benchmark, an upper performance level is provided which comprises all individual pathways towards elite performance from 1993-2013. In combination with the standardized performance variable future speed skaters are enabled to set age-related performance goals.

Underlying performance characteristics

The second step of the present thesis was to unravel performance by underlying performance variables measured in or around competitions. Cross-sectional and longitudinal studies were done on pacing behavior, technique and muscle fatigue in 1500m speed skating.

Pacing

In their road towards elite performance, pacing behavior differed for elite and non-elite junior speed skaters in 1500m races. Better performing female and male junior speed skaters showed a relative slower start and had a faster midsection of the race than their less performing peers (chapters 4 and 5). The overall pacing behavior of the better performing speed skaters was in line with the senior elite pacing profile (Muehlbauer, Schindler, & Panzer, 2010). Starting from17-19 years old, the later elite male speed skaters were found to develop even stronger into the direction of an elite senior pacing profile than their peers. This is exemplified by developing towards an even faster 700-1100m race section at the end of adolescence (chapter 4). The present thesis was the first to show that pacing behavior changes with age and experience in speed skating and that elite juniors outperform their peers by a better pacing behavior. Therefore, pacing behavior seems relevant for youth athletes in their road to elite performance. Chapter 3 showed that, in contrary to the longitudinal changes, instructing a faster or slower start appeared not to influence performance. Also, pacing behavior in speed skating appeared more robust than pacing behavior in cycling. This is likely related to the technical and physiological demands of speed skating.

Muscle fatigue

Pacing behavior is related to the distribution of aerobic and anaerobic energy over the race (Foster et al., 2003; Hettinga et al., 2011). Adopting a faster start needs a different distribution and was expected to cause higher muscle fatigue. Still, chapter 3 showed that an instructed faster and slower start did not influence muscle fatigue in both cycling and speed skating. The 1500m is perceived as one of the hardest distances in speed skating. It is likely that speed skaters and cyclists fatigue maximally, which was supported by the post time-trial lactate values of above 14 mmol/L (chapter 3). Though fatigue was similar for speed skating and cycling, the pacing behaviour was different. Cyclists were able to start more all-out on the bicycle than speed skaters on the ice even though they received similar instruction. Pacing behaviour appears therefore to be sport specific and might be explained by the different demands of the sport. Speed skaters have to carry their own body weight in a crouched position, whereas cyclists adopt a similar body position, are supported by a bicycle and will not change their body position during the race while staying seated even when they are fatigued. When speed skaters fatigue their body angles increase as shown in chapters 3 and 5 which has a negative influence on aerodynamics and technique. Early onset of fatigue might therefore be more detrimental for performance in speed skating than in cycling. The anticipation of this effect of fatigue in the end of the race might withhold experienced speed skaters from starting faster.

Technique

Pacing and fatigue were hypothesized to interact with technique in speed skating. Technique in speed skating is very complex to measure due to the many degrees of freedom the body has during the movement. In chapters 3 and 5 a part of the underlying performance characteristic technique was unravelled by analysing knee, hip, trunk and push-off angles. In general knee, hip and push angles increase over the race, whereas trunk angles appear to decrease in the beginning of the race after which they appear to remain similar (chapters 3 and 5). Male junior speed skaters have lower knee and push off angles than female skaters and male skaters appear to have more decay in push-off angles than female junior skaters (chapter 5). Based on cross-sectional studies, different strategies in increasing the body angles appear not to be related to better performance between peers, even when different pacing behaviours are adopted (chapters 3, 5). Juniors have already adopted similar knee angles as senior elite skaters (i.e., around 108 degrees) and adopting lower knee angles might not be beneficial for performance (chapter 5, Noordhof, Foster, Hoozemans, & de Koning, 2014). Longitudinal exploration of push-off angles suggests some improvement in overall push-off angles over competitive seasons (chapter 5). More longitudinal research is needed to confirm the new perspectives on the development of technique in speed skating.

Strengths and limitations

The present thesis focused on 'in competition' variables, measured at the highest junior performance levels. Due to the ecological valid methods, it is possible to provide practical guidelines on top of the new scientific insights concerning youth performance development. Limitations in measurement accuracy in chapter 5 (i.e., technique) and sample frequency in chapters 4 and 5 (i.e., once per 400m) are the downside of measuring in official competitions. Nevertheless, the extensive research with group sizes larger than 100 youth athletes makes the results profound. Also, skaters are used to getting feedback of performance once per lap and familiar with lap times. By presenting performance as a percentage of the world record and pacing as a percentage of the final 1500m time, values are standardized and interpretable for the future generation of speed skaters and scientists.

Concerning youth athlete development, the present thesis showed the importance of longitudinal and age-related studies, with a focus on development rather than on current performance status only (chapters 2, 4 and 5). Combining different generations in chapter 2 made it possible to include 2855 speed skaters who had at least six years of experience in competitive speed skating. With this unique sample size the performance development of elite, sub-elite and competitive speed skaters from age 13-26 years could be defined, which is also a unique age-range in sport science literature. Another strong point of the present thesis was that the development of pacing behavior in male junior speed skaters was thoroughly studied in chapter 4. To our knowledge this was the first study to show longitudinal changes in pacing behavior for adolescence. Similar results on how skaters pace the 1500m have been found for female juniors in the cross-sectional analyses of chapter 5. Unfortunately, the sample size of the longitudinal study in chapter 5 was small and no solid conclusion on longitudinal development of pacing in female juniors can be made. The same accounts for the conclusion on the longitudinal changes in technique. Nevertheless, the combination of both cross-sectional and longitudinal data made it possible to put some new perspectives on the longitudinal development and to better interpret the cross-sectional results. With the longitudinal as well as the cross-sectional data, the present thesis was able to provide general pacing, technique, and performance goals per age category and performance level. This approach is useful for scientific understanding of performance and performance development of junior athletes, as well as for practical use.

Future perspectives on changes in the individual, task and environment

The present thesis adds to the body of research on talent development in sport. Groningen studies are renowned for their longitudinal research to which the present thesis adds (Elferink-Gemser & Visscher, 2012; Elferink-Gemser, Wierike, & Visscher, 2018; Elferink-Gemser, Jordet, Coelho-E-Silva, & Visscher, 2011). With ecological valid methods and a universal measure of performance, the present thesis aims to provide evidence useful for the guidance of the future athletes. The present study only focused on the 1500m in speed skating, but performance development of an athlete is a dynamic interaction of individual characteristics, the task at hand, and the environment (Elferink-Gemser & Visscher, 2012; Elferink-Gemser et al., 2011; Newell, 1986). The results of the present thesis holds for the interaction of some specific individuals (junior elite speed skaters), who were good at a specific task (1500m) in a high performance environment (the Netherlands). Changing the task, environment or individual characteristics will be visible in performance, pacing, technique and muscle fatigue as well as the development of these variables. For evidence based guidance of athletes this should be taken into account. To understand the effect of differences in individual, task and environmental characteristics more research is needed.

Generally, when testing youth athletes, five individual performance characteristics are distinguished, i.e., anthropometrical, physiological, psychological, tactical, and technical characteristics. The present thesis included the tactical (i.e., pacing) and technical (i.e., body angles) characteristics, which are inter-related with the other characteristics. Anthropometrical (i.e., body segment lengths and muscle mass) and physiological changes occur during adolescence and probably influence body angles, pacing, and performance. With pacing being the distribution of available energy resources within a race, it is likely that changes in energy resources cause part of the change in pacing behavior. Research on the individual aerobic and anaerobic capacity at different ages could provide additional insight into an optimal pacing behavior per individual. Finally, the psychological characteristics are, according to previous literature, also related to pacing behavior and reaching the elite level (Abbiss & Laursen, 2008; Elferink-Gemser & Hettinga, 2017; Jonker, Elferink-Gemser, de Roos, & Visscher, 2012; Jonker, Elferink-Gemser, & Visscher, 2010). The importance of psychological variables like reflection has shown to be related with performance development over one year in speed skating (Elferink-Gemser et al., 2013; Elferink-Gemser et al., 2015). More longitudinal research is needed to gain insight in the importance of self-regulatory skills, like reflection, and goalsetting for developing pacing behavior and performance (Konings et al., 2015).

Concerning the task, the present thesis focused on the 1500m races on a 400m ice-track. However, Olympic speed skating distances range from 500m to 10.000m. Future research on different distances will contribute to translate knowledge on the 1500m in speed skating to the other distances at which a speed skaters can excel. Additionally, new team-based events entered the Olympic Program in 2006 (i.e., team pursuit) and 2018 (i.e., mass start). For the upcoming speed skating season there will even be a new international competition, called the ice-derby, on a smaller ice-track of only 220m instead of 400m. This highlights that a sport, and even the task, can change or evolve over time. Athletes and their coaches should be aware of these possible changes and need to be able to adjust in order to stay on track for elite performance in the future.

By studying the 1500m performance of junior speed skaters on lowland ice-rinks in The Netherlands, the environmental influences were kept relatively stable. However, when studying youth athletes in one country, results will have been influenced by the national selection system, the available training facilities for the various athletes, and the level and density of the Dutch junior speed skating competition. The Netherlands is the leading speed skating country of the world, winning 16 out of 42 Olympic medals in 2018 and even more (23/36) on the preceding Olympics of 2014. For the ISU World Cups every country can select a certain amount of athletes, based on their previous performances. The Netherlands is the only country that has sufficient athletes at the highest performance level, to select the maximum amount of athletes to compete at each single distance (International Skating Union, 2017). Hereby, the road to elite performance in the present thesis was investigated in the best performing country of the world, when it comes to speed skating. Though, when translating the results of the present study to other countries or sports, the competitiveness, within the country and globally, should be taken into account (Swann, Moran, & Piggott, 2015).

Practical applications: evidence-informed guidance of youth speed skaters

The findings of the present thesis can be used as an evidence base for guiding future elite speed skaters. Individual performances can be evaluated and evidence-informed short-term goals can be set for individual athletes related to their long-term goal. This can be done for performance as well as for pacing and technique during the 1500m in speed skating.

Data from chapter 2 is used to provide practical guidelines for the future elites, which is presented in table 1 of the present chapter. The average performance and performance benchmarks of the previous elites are shown in table 1 for the ages 13-26 years. Both standardized performance as well as absolute 1500m end-times for 2019 are provided. In hindsight these juniors were on the right track to elite performance, but they did not follow the same path. For example, the average elite performance at age 15 years for females is 117.9 %WR, which is 2 minutes and 9 seconds using the world record of 2019. At age 15 years there was an elite female speed skater that needed 125.8 %WR to finish the 1500m, which is equal to 2 minutes and 18 seconds when using the 2019 world record (table 1). Though she was not close to the average performance of the elite group at age 15 years, she was still able to reach the elite performance level at a later age. By providing these upper performance benchmarks, a broad range of 1500m times which have let to elite performance are presented. Concerning the selection of athletes it is advised to not only support the best junior athletes in the here and now, but to evaluate all within the elite performance benchmark in order to not miss any talent. Note that up to age 21 years, less than 50 % of the previous speed skaters performing within the elite performance benchmark made it to the elite performance level (Chapter 2). Therefore, considering performance time only, is not sufficient. Comparing the performance development in the years preceding the selection moment with the performance development of the previous elite in table 1 can give additional insight in the performance potential of the specific athlete. Furthermore, research and practice should look for additional talent markers to select the right athletes for a selection programme. Though with the standardized performance variable, performance can be monitored and evaluate at every age using table 1 below. Also, short- and long-term performance goals can be set based on the performance development of the previous elite. Last but not least, the provided percentages on how many skaters performed within the elite performance benchmarks per age and made it to the elite performance level is new evidence for coaches to work with.

For example, a speed skating association might aim to have 3 male speed skaters of each age category reaching the elite performance level of 110 %WR. Based on the results of the present thesis, they are advised to support at least 14 to 15 speed skaters at age 17 years and 7 to 8 speed skaters at age 20 years who perform within the corresponding elite benchmarks. This because at age 17 years, 21-22 % of the skaters performing within the elite performance benchmarks will probably make it to the elite performance level. At age 20 years around 40-46 % (male/female) of those performing within the elite performance benchmark will be able to skate within 110 %WR in their later speed skating career (see table 1).

More in-depth analyses of the 1500m performance can be done using the methods to quantify pacing behavior and technique. By comparing the patterns of pacing and technique of future speed skaters to the patterns of the previous elites, presented in chapters 4 and 5, performance can be evaluated and new performance goals can be set.

For example, based on the performance benchmark a male skater of 18 years is expected to skate within 116.1 % of the prevailing world record in order to be able to have a chance at reaching the elite performance level. To optimize performance in competition, the athlete and coach can reflect on the performance by comparing the pacing behavior and body angles with the best performing 17-18 years old of the previous generation (Chapters 4 and 5). The best performing 17-18 years old male athletes in the season 2014-2015 used 22.07 %, 24.63 %, 25.98 % and 27.29 % of the end-time for respectively the 0-300m, 300-700m, 700-1100m and 1100-1500m race sections as can be seen in table 2. In chapter 5 knee and push-off angles were found to be around 100-115 degrees and 48-54 degrees respectively for high performing male junior speed skaters. Knee angles increase every lap, whereas push-off angles increase in the first three laps and remain similar in the last lap for junior speed skaters.

Table 1. Elite Performance (fastest, average and upper benchmarks) for the 1500m in speed skating per age for female (F) and male (M) speed skaters in % above WR (%WR) and in time (m:ss), taking the 2019 world records of 109.83 seconds for female and 100.17 seconds for male as a reference. Additionally, the representation of later elites in the benchmarks per age as a percentage of the total number of speed skaters performing within the elite performance benchmark.

	Elite 1500m performance (fastest)				Elite 1500m performance (average)				Elite 1500m Performance Benchmarks (upper limit)				Representation elites in benchmark	
Age (yrs)	Standardized performance (%WR)		2019 end-time (m:ss)		Standardized performance (%WR)		2019 end-time (m:ss)		Standardized performance (%WR)		2019 end-time (m:ss)		Percentage of total (%)	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M
13	119.0	119.0	2:10.7	1:59.2	126.6	127.7	2:19.0	2:07.9	139.8	144.2	2:33.5	2:24.5	10	8
14	112.8	112.7	2:03.9	1:52.9	121.3	121.8	2:13.2	2:02.0	131.4	138.9	2:24.3	2:19.1	12	9
15	110.6	110.5	2:01.5	1:50.7	117.9	117.0	2:09.5	1:57.2	125.8	125.8	2:18.2	2:06.0	14	13
16	107.3	108.5	1:57.8	1:48.7	115.1	113.7	2:06.4	1:53.9	122.2	121.4	2:14.2	2:01.6	18	17
17	105.7	107.2	1:56.1	1:47.4	113.3	111.1	2:04.4	1:51.3	119.8	117.7	2:11.6	1:57.9	22	21
18	104.1	104.1	1:54.3	1:44.3	111.4	109.8	2:02.4	1:50.0	117.5	116.1	2:09.1	1:56.3	30	28
19	103.4	103.3	1:53.6	1:43.5	110.2	109.2	2:01.0	1:49.4	117.5	114.9	2:09.1	1:55.1	34	39
20	102.0	103.3	1:52.0	1:43.5	110.3	108.9	2:01.1	1:49.1	116.6	114.9	2:08.1	1:55.1	40	46
21	102.4	102.7	1:52.5	1:42.9	109.7	108.7	2:00.5	1:48.9	115.9	113.7	2:07.3	1:53.9	53	57
22	103.4	103.6	1:53.6	1:43.8	108.8	108.4	1:59.5	1:48.6	113.8	113.7	2:05.0	1:53.9	74	65
23	103.5	102.5	1:53.7	1:42.7	108.0	108.8	1:58.6	1:49.0	113.8	113.7	2:05.0	1:53.9	85	74
24	102.9	103.1	1:53.0	1:43.3	108.2	108.5	1:58.8	1:48.7	113.8	113.7	2:05.0	1:53.9	87	78
25	103.8	103.4	1:54.0	1:43.6	107.9	108.1	1:58.5	1:48.3	113.8	113.7	2:05.0	1:53.9	96	89
26	102.6	103.8	1:52.7	1:44.0	108.1	107.8	1:58.7	1:48.0	113.8	113.7	2:05.0	1:53.9	95	95

Table 2. Pacing profiles per age category for the 1500m in speed skating for female and male junior speed skaters, taking the current 1500m world record (2019) of 109.83 seconds for female 100.17 seconds for male speed skaters as a reference.

	Female		Male			
	Age (yrs)	World record		Age (yrs)		World record
	15-18		13-14	15-16	17-18	
End-time (m:ss.hh)	2:09.05	1:49.83	2:19.14	2:01.61	1:56.30	1:40,17
End-time (s)	129.05	109.83	139.14	121.61	116.30	100.17
Standardized End-time (%WR)	117.5	100	138.9	121.4	116.1	100
0-300m (s)	27.87	24.74	30.35	26.77	25.67	22.91
0-300m (% end-time)	21.60 %	22.53 %	21.81 %	22.01 %	22.07 %	22.87 %
300-700m (s)	31.98	26.95	34.74	29.99	28.64	24.27
300-700m (% end-time)	24.78 %	24.54 %	24.97 %	24.66 %	24.63 %	24.23 %
700-1100m (s)	33.79	27.97	36.52	31.78	30.21	25.20
700-1100m (% end-time)	26.18 %	25.47 %	26.25 %	26.13 %	25.98 %	25.16 %
1100-1500m (s)	35.40	30.17	37.51	33.08	31.74	27.79
1100-1500m (% end-time)	27.43 %	27.47 %	26.96 %	27.20 %	27.29 %	27.74 %

Keeping these race profiles of pacing and technique in mind, individual interventions can be done. Trainer and athlete are leading in this, but decisions can be supported by chapters 2, 4 and 5. When all goes well, the 18 year old male later elite speed skater is expected to improve performance with on average 1.6 %WR in one year (chapter 2). But maybe, with the evidence-informed approach this can become higher.

Concluding remarks

The evidence provided in the present thesis can help understand 1500m performance and set age-related performance goals. Additionally, it provides profiles of pacing and technique with which performance might be improved. The provided knowledge should help the future elites not only to improve their own performance but also to keep pushing boundaries. In their turn, the future elites can help researchers to push boundaries in the knowledge of human performance. This way, sport and science can evolve hand in hand.

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