University of Groningen

# Staying on track

Stoter, Inge

*DOI:*
10.33612/diss.113131465

**IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.**

*Document Version*
Publisher's PDF, also known as Version of record

*Publication date:*
2020

Link to publication in University of Groningen/UMCG research database

*Citation for published version (APA):*
Stoter, I. (2020). *Staying on track: the road to elite performance in 1500m speed skating*. https://doi.org/10.33612/diss.113131465

**Copyright**
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license. More information can be found on the University of Groningen website: https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment.

**Take-down policy**
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

*Downloaded from the University of Groningen/UMCG research database (Pure): http://www.rug.nl/research/portal. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.*

Download date: 27-10-2021

# General introduction

## Chapter 1

# GENERAL INTRODUCTION

Performance in sport is about giving it the best you have. Elite sport performance is about that the best you have is better than the best of your competitors. Many people can compete in a sport, but obviously only few can make it to the elite level. A long road with many years of training and competitive experience precedes elite performance. Proper guidance during that period is of great importance for later success. The ever returning questions in this regard are whom to guide from a young age onward and what goals to work on at different stages of development. To answer these questions, the present thesis aims to unravel the road to elite performance for the 1500m in speed skating. Previous elites will be studied to gain knowledge on speed skating performance, performance development and on the underlying mechanisms of performance.

Speed skating is a time-trial sport in which the ultimate performance variable is the time needed to cover a certain distance on a 400m ice-track. Individual races are skated in pairs, with each individual skating in a separate lane. Speed skaters are able to reach velocities up to 60 km/h by adopting a crouched aerodynamic position and by pushing-off in a sideward direction (figure 1). Olympic individual distances range from 500m to 10.000m. The middle distance in speed skating is the 1500m (≈2 min) at which there is a comparable contribution of the anaerobic and aerobic system to the total energy needed for the race (van Ingen Schenau, de Koning, & de Groot, 1990). The 1500m is also known as the key distance in speed skating, as both endurance

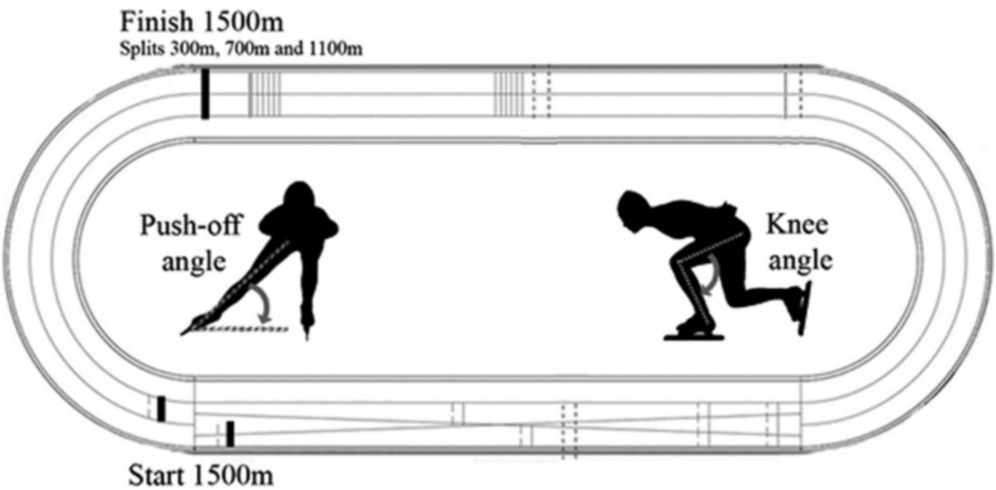



**Figure 1.** Start and finish of a 1500m speed skating competition on a 400m ice-track with illustrations of push-off angle in the frontal plane and knee angle in the sagittal plane.

and sprint athletes can prosper at this distance. Therefore, the 1500m will be the focus of the present thesis. Official 1500m competitions start at the age of 13 years, at the age of 19 speed skaters enter the senior competition and the age of winning Olympic gold medals is on average 26 years.

Based on previous research on youth athlete development towards elite sport performance, the International Olympic Committee (IOC) consensus statement encourages evidence-informed approaches to youth athlete development. However to do so, more scientifically based data on sport-specific tests per development phase are needed. Using ecologically valid methods, the road to elite 1500m performance will be studied in the present thesis in order to enable such evidence-informed guidance of the future elites in speed skating.

*Testing youth athletes in speed skating*

Generally, research on youth athlete development towards expertise focuses on testing various underlying, individual performance characteristics, such as anthropometric, physiological, psychological, tactical and technical characteristics (Elferink-Gemser, Jordet, Coelho-E-Silva, & Visscher, 2011). In literature, research done on performance and underlying individual performance characteristics in competitive youth speed skaters is to our knowledge limited to seven studies. Four out of seven did longitudinal research (de Koning, Bakker, de Groot, & van Ingen Schenau, 1994; Elferink-Gemser et al., 2013; Elferink-Gemser et al., 2015; Noordhof, Mulder, de Koning, & Hopkins, 2016). Performance development of high performing junior speed skaters over one year was found to be related to the psychological skills reflection, intrinsic motivation, and goal orientation (Elferink-Gemser et al., 2013; Elferink-Gemser et al., 2015). Physical and anthropometrical characteristics were studied in relation to four year performance development of the Dutch National speed skating selection, but no relations were found in a research group with 24 speed skaters (de Koning et al., 1994). The fourth longitudinal study focused on the variability in junior performance and the effect of altitude and open or closed ice rinks, but did not consider the relation with individual performance characteristics (Noordhof et al., 2016). Technical and tactical characteristics were not taken into account in the previous longitudinal studies on junior speed skaters. Technique and tactics during a 1500m race were studied in one of the three cross-sectional studies on junior speed skaters (de Koning, Foster, Lampen, Hettinga, & Bobbert, 2005). However, the study did not focus on differences in performance level, but on the experimental evaluation of the power balance model in speed skating (de Koning et al., 2005). The two other cross-sectional studies showed that better performance in high performing junior speed skaters was related with several technical, psychological, anthropometrical and physical parameters. Though, the small and homogeneous groups made it hard to draw solid conclusions (De Greeff, Elferink-Gemser, Sierksma, & Visscher, 2011; Van Ingen Schenau, De Koning, Bakker, & De Groot, 1996). As such, to better understand performance and performance development of youth speed skaters towards elite performance, more research is needed with longitudinal data and larger sample sizes.

Even though the research on the development of youth speed skaters is limited, there is a wide variety of research on performance and multi-dimensional performance characteristics in adult speed skating. Previous literature on speed skating mainly focused on physiological, technical and anthropometrical characteristics and less on psychological and tactical characteristics (Konings et al., 2015). The present thesis aims to add to the body of literature on elite athlete development by focusing on in-competition measures. The start will be studying 1500m performance development, followed by studying the underlying mechanisms of performance like pacing, technique and fatigue during the 1500m.

### *Elite performance development (chapter 2)*

One of the basic principles in unraveling the road to elite performance is to define what elite performance is. In literature however, there are more than eight definitions of elite or expert performance and even within each definition, the level which defines elite differs (Swann, Moran, & Piggott, 2015). This way the skaters classified as “sub-elites” in the one study could be the same as “elites” in another study, making results hard to compare or interpret. Both from the perspective of science as from practice, there is a clear need for a standard measure to define and interpret performance levels.

A second challenge in studying elite performance development is that only a few athletes make it to the top (i.e. Olympics or World Championships) in a specific sport. Statistical analyses over the long road of performance development is difficult with relatively small and homogenous groups. In order to expand the period of longitudinal analysis, combining information over different generations might be a solution to increase sample size. However, caution should be taken as a sport evolves over time. The evolution of speed skating is illustrated in the improvements of the world records (de Koning, 2010; Kuper & Sterken, 2003; Talsma, 2013). For example, the first speed skater to go under the two minutes on a 1500m speed skating time trial, was Ard Schenk in 1971. In the 70’s this was an exceptional performance of which many thought it would never be matched again. However, the world record is currently 1 minute and 40 seconds, 20 seconds faster than in 1971. Moreover, in the 2018-2019 season over 200 Dutch male and 18 Dutch female speed skaters finished the 1500m within two minutes. So, whether a certain end-time on a specific distance can be considered of the elite level is dependent on the era in which the athlete is performing. As such, the evolution of a sport should be taken into account when aiming to provide the future elites with scientific insight in expected performance development.

Furthermore, reaching elite performance is a long-term goal and needs substantial deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993; Gladwell, 2008). To reach a long-term goal, it is advised to add specific short-term goals (Kyllo & Landers, 1995). For a junior athlete, the long term goal might be to break the world record or to become an Olympic champion. However, there is no literature on what short-term goals a junior athlete should achieve in order to stay on track for this long term goal. In order to enable evidence-based guidance of the future elites, short-term performance goals realistic for the age category and era in which the athlete competes are essential. In chapter 2, these short-term goals will be provided in relation to the long-term goal of becoming an elite speed skater in the future.

> *2) Creating performance benchmarks for the future elites in speed skating.*
> Chapter 2 introduces a method to define performance that is independent of calendar year and makes it possible to compare different generations. Using this method, elite performance will be defined. By analyzing the performance development of those who made it to the elite level, age-related elite performance benchmarks and goals will be provided for age 13-26 years.

*Underlying performance characteristics – pacing, fatigue and technique (chapters 3-5)*

Studying longitudinal performance development of elite speed skaters gains insight in the road towards elite performance and can provide short-term age-related performance goals. The follow-up question is how to reach these goals. In many individual time-trial sports such as speed skating, an optimal energy distribution within a race, so called pacing, is essential for successful performance (Abbiss & Laursen, 2008; Foster et al., 1993). Before finishing the race, all available energy stores must be used, but not so early in a race that a meaningful slow down occurs (Foster et al., 1993). This pacing behavior can be characterized by the velocity profile during the race. During middle-distance events in various sports of a similar duration to the 1500m speed skating (≈ 2min), a fast start followed by a decrease in velocity towards the end of the race is commonly observed (Foster et al., 1993; Foster, Schrager, Snyder, & Thompson, 1994; Foster et al., 2004; Muehlbauer, Schindler, & Panzer, 2010). However, how fast this fast start should be in a 1500m speed skating time-trial cannot be unambiguously concluded based on previous studies (Hettinga et al., 2011; Muehlbauer et al., 2010). Biomechanical models showed that starting faster than skaters are used to would be more beneficial for their performance, although practice shows otherwise (Hettinga et al., 2011; Muehlbauer et al., 2010). Observation of elite senior speed skaters even showed that those starting relatively slower, seem to perform better (Muehlbauer et al., 2010). The biomechanical models were also used in cycling, a sport relatively similar to speed skating concerning velocity reached, body posture and muscles used. In contradiction to the speed skaters, cyclists were able to pace their race close to the predicted optimal pacing strategy by the theoretical model (Hettinga, de Koning, Hulleman, & Foster, 2012). It might be, however, that the biomechanical models were not sport-specific enough for analyses in speed skating.

The body position in cycling is constrained and supported by the bicycle and will therefore be less affected by fatigue than in speed skating, where athletes carry their own body weight. When speed skaters fatigue they often show an increase in body angles towards a less crouched position (de Koning et al., 2005). It might be that the faster start in speed skating creates an earlier onset of muscle fatigue and therewith an earlier increase in body angles, probably affecting performance. No previous studies have been done on muscle fatigue in speed skating. Muscle fatigue is often defined as an exercise-induced reduction in the force-generating capacity of the neuromuscular system (Bigland-Ritchie, Johansson, Lippold, & Woods, 1983) and is generally measured by changes in maximal voluntary contraction. Decrease in maximal voluntary contraction can be caused by both central (at or proximal to the motor neuron) and peripheral (distal from the motor neuron) mechanisms (Gandevia, 2001). These mechanisms might also play a regulatory role in pacing (Roelands, de Koning, Foster, Hettinga, & Meeusen, 2013). To better understand pacing and why speed skaters are not able to benefit from a faster start, the interaction between pacing, muscle fatigue and technique in speed skating as well as in cycling will be studied. It might be that due to the different demands of the two sports, other pacing behaviors are more optimal for speed skating than for cycling.

> *3) Pacing strategy, muscle fatigue and technique in 1500m speed skating and cycling time-trials.*
> In chapter 3 the effect of an instructed faster and slower start on pacing strategy, muscle fatigue and technique in both speed skating and cycling is investigated.

Research on pacing behavior is mainly done on senior athletes and it remains unknown whether pacing behavior changes during adolescence. As athletes mature, their energy systems, muscle power and anthropometrics change (de Koning et al., 1994; Malina, Bouchard, & Bar-Or, 2004), probably influencing the profile of pacing that is optimal for 1500m performance (Abbiss & Laursen, 2008; Hettinga et al., 2011). Furthermore, pacing is a goal-directed process, for which reflection, planning, monitoring and evaluation might play an important role (Elferink-Gemser & Hettinga, 2017; Smits, Pepping, & Hettinga, 2014). These psychological skills have been found related to youth athlete development at the highest performance levels (Jonker, Elferink-Gemser, de Roos, & Visscher, 2012; Jonker, Elferink-Gemser, & Visscher, 2010). To further understand the road to elite performance, the development of pacing behavior in junior speed skaters over four years will be investigated. Chapter 4 will retrospectively analyze junior speed skaters, who are at the top of their age category at age 17-18 years. High performing youth athletes, close to entering senior competition, likely develop a profile that is optimal for performance and might already push boundaries of human performance at a young age. Studying these high performing juniors is of additional interest for understanding the concept of pacing.

*4) Development of 1500-m pacing behavior in junior speed skaters: a longitudinal study.*
Chapter 4 studies the development of 1500m pacing behavior of elite junior male speed skaters from age 13-19 years with respect to the development of sub-elites and non-elites.

Speed skating distinguishes itself from most other time-trial sports with the sideward push-off and maintaining a static crouched position on one leg during the gliding phase. Technique influences the velocity of a skater and therewith performance as well as the pacing behavior (Konings et al., 2015; Noordhof, Foster, Hoozemans, & de Koning, 2013). Small knee angles towards 90 degrees reduce aerodynamic resistance and extend push-off length (de Boer et al., 1987; Konings et al., 2015; van Ingen Schenau, 1982; van Ingen Schenau, de Groot, & de Boer, 1985). However, these small knee angles, together with high quasi-isometric muscular forces during the gliding phase in speed skating, cause a restriction of blood flow (Foster et al., 1999). This results in less oxygen delivered to the working muscles (Hettinga, Konings, & Cooper, 2016). By increasing their knee angles, skaters can actively decrease the restriction of blood flow and therewith increase oxygen delivery to their leg muscles (Foster et al., 1999). However, this is disadvantageous for the aerodynamics of the skaters (de Koning et al., 2005; Noordhof et al., 2013). It might be that athletes regulate the trade-off between oxygen delivery to the working muscles and aerodynamics by changing their knee angles during the race. Previous studies on the 1500m in speed skating showed an increase in knee angles as well as push-off angles for junior (de Koning et al., 2005) and senior speed skaters (Noordhof, Foster, Hoozemans, & de Koning, 2014). The study done in juniors was limited to 8 athletes and no distinction was made between sexes (de Koning et al., 2005). To gain more insight in the possible regulation of changes in knee and push-off angles for both male and female junior speed skaters, an extensive study will be done on technical changes during the 1500m. This in relation to their pacing behavior and development towards the senior level.

*5) Changes in technique throughout a 1500-m speed skating time-trial in junior athletes:* differences between sex, performance level and competitive seasons.
In Chapter 5 changes in technique, knee and push-off angles, during a 1500-m time-trial will be investigated in elite junior speed skaters in relation to sex and performance level. Additionally, the longitudinal development of technique will be explored to provide perspectives on the development of elite junior speed skaters towards senior level.

The various studies in the present thesis all serve to define the road to elite 1500m performance and understand the underlying mechanisms of 1500m performance for junior speed skaters. Research will be done by monitoring the previous elites, in order to enable evidence-informed guidance for the future elites. The studies in this thesis apply methods that are ecological valid and useful for researchers studying performance development in other skating distances and sports.

# References


Abbiss, C. R., & Laursen, P. B. (2008). Describing and understanding pacing strategies during athletic competition. *Sports Medicine (Auckland, N.Z.), 38*(3), 239-252.

Bigland-Ritchie, B., Johansson, R., Lippold, O. C., & Woods, J. J. (1983). Contractile speed and EMG changes during fatigue of sustained maximal voluntary contractions. *Journal of Neurophysiology, 50*(1), 313-324.

de Boer, R. W., Cabri, J., Vaes, W., Clarijs, J. P., Hollander, A. P., de Groot, G., & van Ingen Schenau, G. J. (1987). Moments of force, power, and muscle coordination in speed-skating. *International Journal of Sports Medicine, 8*(6), 371-378. doi:10.1055/s-2008-1025688

De Greeff, M. J. W., Elferink-Gemser, M. T., Sierksma, G., & Visscher, C. (2011). Explaining the`performance of talented youth speed skaters.`. *Annals of Research in Sport and Physical Activity, 1*, 85-99.

de Koning, J. J. (2010). World records: how much athlete? How much technology? *International Journal of Sports Physiology and Performance, 5*(2), 262-267.

de Koning, J. J., Bakker, F. C., de Groot, G., & van Ingen Schenau, G. J. (1994). Longitudinal development of young talented speed skaters: physiological and anthropometric aspects. *Journal of Applied Physiology (Bethesda, Md.: 1985), 77*(5), 2311-2317.

de Koning, J. J., Foster, C., Lampen, J., Hettinga, F., & Bobbert, M. F. (2005). Experimental evaluation of the power balance model of speed skating. *Journal of Applied Physiology (Bethesda, Md.: 1985), 98*(1), 227-233. doi:10.1152/japplphysiol.01095.2003

Elferink-Gemser, M. T., De Roos, I. M., Torenbeek, M., Fokkema, T., Jonker, L., & Visscher, C. (2015). The importance of psychological constructs for training volume and performance improvement: a structural equation model for youth speed skaters. *International Journal of Sport Psychology., 46*(6), 726-744. doi:https://doi.org/10.7352/IJSP.2015.46.726

Elferink-Gemser, M. T., De Roos, I. M., Torenbeek, M., Idema, W., Jonker, L., & Visscher, C. (2013). Training behaviour in relation to performance development in talented speed skaters: a descriptive study. In M. J. Coelho-E-Silva, A. Cupido-Dos-Santos, A. J. Figueiredo, J. P. Ferreira & N. Armstrong (Eds.), *Children and Exercise XXVIII. The Proceedings of the 28th Pediatric Work Physiology Meeting* (pp. 263-267). London: Routledge.

Elferink-Gemser, M. T., & Hettinga, F. J. (2017). Pacing and Self-regulation: Important Skills for Talent Development in Endurance Sports. *International Journal of Sports Physiology and Performance, 12*(6), 831-835. doi:10.1123/ijspp.2017-0080 [doi]

Elferink-Gemser, M. T., Jordet, G., Coelho-E-Silva, M. J., & Visscher, C. (2011). The marvels of elite sports: how to get there? *British Journal of Sports Medicine, 45*(9), 683-684. doi:10.1136/bjsports-2011-090254 [doi]

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363.

Foster, C., deKoning, J. J., Hettinga, F., Lampen, J., Dodge, C., Bobbert, M., & Porcari, J. P. (2004). Effect of competitive distance on energy expenditure during simulated competition. *International Journal of Sports Medicine, 25*(3), 198-204. doi:10.1055/s-2003-45260

Foster, C., Rundell, K. W., Snyder, A. C., Stray-Gundersen, J., Kemkers, G., Thometz, N., . . . Knapp, E. (1999). Evidence for restricted muscle blood flow during speed skating. *Medicine and Science in Sports and Exercise, 31*(10), 1433-1440.

Foster, C., Schrager, M., Snyder, A. C., & Thompson, N. N. (1994). Pacing strategy and athletic performance. *Sports Medicine (Auckland, N.Z.), 17*(2), 77-85.

Foster, C., Snyder, A. C., Thompson, N. N., Green, M. A., Foley, M., & Schrager, M. (1993). Effect of pacing strategy on cycle time trial performance. *Medicine and Science in Sports and Exercise, 25*(3), 383-388.

Gandevia, S. C. (2001). Spinal and supraspinal factors in human muscle fatigue. *Physiological Reviews, 81*(4), 1725-1789.

Gladwell, M. (2008). *Outliers: The Story of Success.* San Francisco, CA: Little, Brown and Company;.

Hettinga, F. J., de Koning, J. J., Hulleman, M., & Foster, C. (2012). Relative importance of pacing strategy and mean power output in 1500-m self-paced cycling. *British Journal of Sports Medicine, 46*(1), 30-35. doi:10.1136/bjsm.2009.064261

Hettinga, F. J., De Koning, J. J., Schmidt, L. J., Wind, N. A., Macintosh, B. R., & Foster, C. (2011). Optimal pacing strategy: from theoretical modelling to reality in 1500-m speed skating. *British Journal of Sports Medicine, 45*(1), 30-35. doi:10.1136/bjsm.2009.064774

Hettinga, F. J., Konings, M. J., & Cooper, C. E. (2016). Differences in Muscle Oxygenation, Perceived Fatigue and Recovery between Long-Track and Short-Track Speed Skating. *Frontiers in Physiology, 7*, 619. doi:10.3389/fphys.2016.00619 [doi]

Jonker, L., Elferink-Gemser, M. T., de Roos, I. M., & Visscher, C. (2012). The role of reflection in sport expertise. *The Sport Psychologist, 26*(2), 224-242.

Jonker, L., Elferink-Gemser, M. T., & Visscher, C. (2010). Differences in self-regulatory skills among talented athletes: the significance of competitive level and type of sport. *Journal of Sports Sciences, 28*(8), 901-908. doi:10.1080/02640411003797157 [doi]

Konings, M. J., Elferink-Gemser, M. T., Stoter, I. K., van der Meer, D., Otten, E., & Hettinga, F. J. (2015). Performance characteristics of long-track speed skaters: a literature review. *Sports Medicine (Auckland, N.Z.), 45*(4), 505-516. doi:10.1007/s40279-014-0298-z [doi]

Kuper, G. H., & Sterken, E. (2003). Endurance in speed skating: The development of world records. *European Journal of Operational Research, 148*(2), 293-301. doi:10.1016/S0377-2217(02)00685-9

Kyllo, L. B., & Landers, D. M. (1995). Goal setting in sport and exercise: A research synthesis to resolve the controversy. *Journal of Sport & Exercise Psychology, 17*(2), 117-137. doi:10.1123/jsep.17.2.117

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation and physical activity.* (2nd ed.). Champaign, IL: Human Kinetics.

Muehlbauer, T., Schindler, C., & Panzer, S. (2010). Pacing and performance in competitive middle-distance speed skating. *Research Quarterly for Exercise and Sport, 81*(1), 1-6.

Noordhof, D. A., Foster, C., Hoozemans, M. J., & de Koning, J. J. (2013). Changes in speed skating velocity in relation to push-off effectiveness. *International Journal of Sports Physiology and Performance, 8*(2), 188-194.

Noordhof, D. A., Foster, C., Hoozemans, M. J. M., & de Koning, J. J. (2014). The association between changes in speed skating technique and changes in skating velocity. *International Journal of Sports Physiology and Performance, 9*(1), 68-76. doi:10.1123/ijspp.2012-0131 [doi]

Noordhof, D. A., Mulder, R. C., de Koning, J. J., & Hopkins, W. G. (2016). Race Factors Affecting Performance Times in Elite Long-Track Speed Skating. *International Journal of Sports Physiology and Performance, 11*(4), 535-542. doi:10.1123/ijspp.2015-0171 [doi]

Roelands, B., de Koning, J., Foster, C., Hettinga, F., & Meeusen, R. (2013). Neurophysiological determinants of theoretical concepts and mechanisms involved in pacing. *Sports Medicine (Auckland, N.Z.), 43*(5), 301-311. doi:10.1007/s40279-013-0030-4; 10.1007/s40279-013-0030-4

Smits, B. L., Pepping, G. J., & Hettinga, F. J. (2014). Pacing and Decision Making in Sport and Exercise: The Roles of Perception and Action in the Regulation of Exercise Intensity. *Sports Medicine (Auckland, N.Z.),* doi:10.1007/s40279-014-0163-0 [doi]

Swann, C., Moran, A., & Piggott, D. (2015). *Defining elite athletes: Issues in the study of expert performance in sport psychology* doi:https://doi.org/10.1016/j.psychsport.2014.07.004

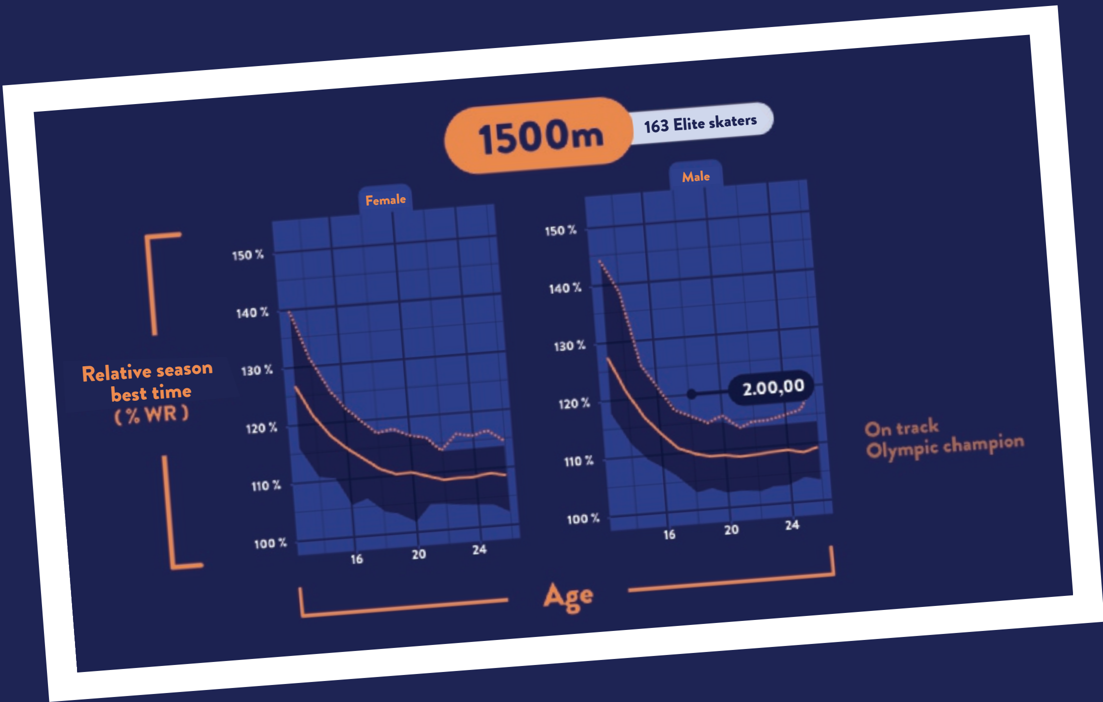
Talsma, B. G. (2013). *Performance Analysis in Elite Sports* (Doctoral dissertation). Retrieved from http://www.rug.nl/research/portal/files/14500448/Performance_Analysis_in_Elite__1.pdf

van Ingen Schenau, G. J. (1982). The influence of air friction in speed skating. *Journal of Biomechanics, 15*(6), 449-458.

van Ingen Schenau, G. J., de Groot, G., & de Boer, R. W. (1985). The control of speed in elite female speed skaters. *Journal of Biomechanics, 18*(2), 91-96. doi:0021-9290(85)90002-8 [pii]

Van Ingen Schenau, G. J., De Koning, J. J., Bakker, F. C., & De Groot, G. (1996). Performance-influencing factors in homogeneous groups of top athletes: a cross-sectional study. *Medicine and Science in Sports and Exercise, 28*(10), 1305-1310.

van Ingen Schenau, G. J., de Koning, J. J., & de Groot, G. (1990). A simulation of speed skating performances based on a power equation. *Medicine and Science in Sports and Exercise, 22*(5), 718-728.


1500m
163 Elite skaters
Female
Male
150 %
140 %
130 %
120 %
110 %
100 %
16
20
24
2.00,00
Relative season best time (% WR)
Age
On track Olympic champion