Development of 1500m Pacing Behavior in Junior Speed Skaters: A Longitudinal Study

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Development of 1500m pacing behavior in junior speed skaters: a longitudinal study

Original investigation

Rikstje Wiersma[1]; Inge K. Stoter[1]; Chris Visscher[1] ; Florentina J. Hettinga[2] ; Marije T. Elferink-Gemser[1,3]

[1] Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

[2] Centre of Sport and Exercise Science, School of Biological Sciences, University of Essex, Colchester, UK

[3] Institute for Studies in Sports and Exercise, HAN, University of Applied Sciences, Nijmegen, The Netherlands

Corresponding author:
Inge Stoter, MSc.
Centre for Human Movement Sciences
UMCG, Sector F
A. Deusinglaan 1
9713 AV Groningen
The Netherlands
Email: i.k.stoter@umcg.nl
Tel: +31 (0) 50 361 6056

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Abstract

Purpose: Providing insight in the development of pacing behavior in junior speed skaters and analyse possible differences between elite, sub-elite, and non-elite juniors.
Methods: 1500m season best times (SBT) and corresponding pacing behavior were obtained longitudinally for 104 Dutch male speed skaters at age 13–14(U15), 15–16(U17), and 17–18(U19) years. Based on their U19 SBT, skaters were divided into elite(n=17), sub-elite(n=64), and non-elite(n=23) groups. Pacing behavior was analysed using the 0-300m, 300-700m, 700-1100m and 1100-1500m times, expressed as a percentage of final time. Mixed analyses of variance were used for statistical analyses.
Results: With age, pacing behavior generally developed towards a slower 0-300m and 1100-1500m and a faster mid-section relative to final time. While being faster on all sections, the elite were relatively slower on 0-300m (22.1±0.27%) than the sub-elite and non-elite (21.5±0.44%)($p<0.01$), but relatively faster on 300-700m (24.6±0.30%) than the non-elite (24.9±0.58%)($p=0.002$). On 700-1100m, the elite and sub-elite (26.2±0.25%) were relatively faster than the non-elite (26.5±0.41%)($p=0.008$). Differences in the development of pacing behavior were found from U17-U19 with relative 700-1100m times decreasing for the elite and sub-elite (26.2±0.31% to 26.1±0.27%), but increasing for the non-elite (26.3±0.29% to 26.5±0.41%)($p=0.014$).
Conclusions: Maintaining high speed into 700-1100m, accompanied by a relatively slower start, appears crucial for high performance on the 1500m speed skating. Generally, juniors develop towards this profile, with a more pronounced development towards a relative faster 700-1100m from U17-U19 for elite junior speed skaters. The results of the present study indicate the relevance of pacing behavior for talent development.

Key words: exercise performance, speed skating, time trial, talent development, talent identification

Introduction

In many individual time trial sports such as speed skating, an optimal energy distribution is essential for successful performance [1]. Before finishing the race, all available energy stores must be used, but not so early in a race that a meaningful slow down can occur[1]. This pacing behavior of an athlete can be characterized by the velocity profile during the race. During middle-distance events in various sports of 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[2-6]. However, how fast this fast start should be in a 1500m speed skating time trial could not be unambiguously concluded based on previous studies[4,7,8]. In elite speed skaters it appeared that better performing athletes start, in relation to total time, relatively slower on the first 0-300m, but are relatively faster on the 700-1100m section compared to less performing athletes[4]. On the other hand, modelling studies in cycling and speed skating[7] calculated that starting relatively faster than self-paced performance would result in faster finishing times[7]. Nevertheless, imposing a relatively faster start in speed skating practice did not result in faster finishing times, probably due to neurophysiological limitations related to the technical demands of speed skating[7,8]. These findings seem to indicate that though a rather fast start is important in relation to optimal pacing behavior in 1500m speed skating, the ability to maintain velocity throughout the remainder of the race might be just as, or even more important, and should be further investigated.

Most speed skaters skate their first 1500m time trial around the age of 13 years. Before transitioning to senior level (age 19 years), they progress through national competition for junior speed skaters on the 1500m classified into three age categories; 13-14 years (U15), 15-16 years (U17) and 17-18 years (U19). During these years, the athletes change over time due to influence of maturation, learning and training[9]. As literature has shown that those athletes reaching the elite level appear to be more efficient learners than non-elite athletes[10-13], there might also be a difference in the learning and development of pacing behavior for speed skaters who reach different performance levels in their later career[9]. As pacing behavior can be seen as a goal-directed process of decision-making[14] in which athletes need to decide how and when to invest their energy during the race, it could be proposed that pacing behavior is a cognitive skill that needs to be developed during adolescence, and should be incorporated in talent development programs. Furthermore, experience is known to play an important role in the development of pacing behavior[15,16] and the skill to adopt adequate pacing behavior during physical activity has been found to develop in schoolchildren during childhood from age 4 onwards[17]. The development of adequate pacing behavior is important for performance and therefore potentially of great interest for talent development programs. To our knowledge, it is unknown how pacing behavior develops during adolescence in general, and for junior speed skating athletes in particular.

Therefore, the purpose of the present study is to provide insight in pacing behavior of junior athletes by analysing how elite, sub-elite, and non-elite junior speed skaters pace their 1500m time trials during adolescence throughout different age categories, and whether there are differences between performance groups for the development of pacing behavior during adolescence.

Methods

Subjects

Longitudinal data of pacing behavior and performance were collected from 104 junior male speed skaters who had been active in official speed skating competitions over the past 6 years. Their mean age was 19.0 (± 0.6) yrs. at the end of the competitive season 2014/2015. Race data on the 1500m in the seasons 2010/2011, 2012/2013, and 2014/2015 were obtained, when they were in age category U15, U17, and U19 respectively. All boys were in the top 150 of the national Dutch SARA rankings of the Royal Dutch Speed Skating Association (KNSB) on the 1500m for season 2014/2015. The study was approved by the ethics committee of Human Movement Sciences at the University of Groningen, in the spirit of the Helsinki Declaration.

Procedure

Using a database from the KNSB and the skating association of Haarlem, the Netherlands, (www.osta.nl) a complete dataset was obtained, with the season best times (SBT) on the 1500m time trials for season 2010/2011 (U15), season 2012/2013 (U17) and season 2014/2015 (U19) (n= 312). Only 1500m time trials on Dutch speed skating rinks at sea-level were included to exclude the effect of altitude. Some races might have been performed on outdoor or semi outdoor speed skating rinks. Nevertheless, high quality conditions can be achieved on these artificial ice rinks in calm weather conditions. Of the SBT's, the absolute time spent on four race sections, 0-300m (S1), 300-700m (S2), 700-1100m (S3) and 1100-1500m (S4), was obtained. To operationalize pacing behavior, the absolute section times (AST) were converted into relative section times (RST) similar to Muehlbauer et al[4]. This was done by expressing section times as a percentage of the total time, leading to relative 0 – 300m (RST1), 300 – 700m (RST2), 700 – 1100m (RST3) and 1100 – 1500m (RST4) section times.

The times were measured using electronic systems and transponder systems with accuracy of one hundredth of a second[18]. Finally, the number of 1500m races the subjects skated in official competition before the moment of skating their SBT U19 were obtained as indication of their race experience on the 1500m.

As only a few can make it to the top, it is of interest for talent development to study the average versus those few who are at the end of the performance spectrum. Therefore, the present study divided the athletes into three performance groups based on the SBT's U19 and the corresponding standard deviation (SD). The sub-elite performance group (n = 64) consisted of all subjects with a SBT within one SD from the mean SBT of the entire group (SBT = SBTmean ± SD), the elite performance group (n = 17) consisted of subjects with the faster times (SBT < SBTmean – SD), and the non-elite performance group (n = 23) consisted of subjects with the slower times (SBT > SBTmean + SD). Information about the performance groups is shown in table 1.

Statistical analysis

The statistical analysis was done with IBM SPSS Statistics 20. A one-way ANOVA, with bonferroni post hoc analysis, was used to test differences between groups in SBT and race experience per age category. Mixed analysis of variance was performed for SBT, AST1, AST2, AST3, AST4, RST1, RST2, RST3 and RST4 separately, with 'age category' (U15, U17, and U19) as within-subject variable and 'performance group' as between-subject variable. If the assumption of sphericity was violated, degrees of freedom were corrected (Huynh - Feldt). A pairwise comparison with Bonferroni correction was used as post hoc test to find out which performance groups differed significantly. Additionally, 95% confidence intervals (CI) were defined for the between-subject effects. The level set for significance was $p < 0.05$.

Results

For each of the 104 speed skaters, three 1500m time trials (one in each age category) with each four race sections were analysed. There were no missing values. Descriptive statistics of the three performance groups are provided in table 1 with age, SBT, race experience and the percentage per performance group representing the fastest group within each age category. The means and standard deviations of the SBT, the absolute section times and the relative section times are shown in table 2 and 3. Figure 1 shows the development of SBT and the relative section times over the three age categories for the three performance groups.

SBT development per performance group

Figure 1.1 shows the SBT for the different performance groups in different age categories. The means and standard deviations are shown in table 2 and 3. A main effect for performance group ($F(2, 101) = 53.54$, $p < 0.01$) was found. The post hoc analysis showed significant differences between elite and sub-elite performance groups ($p < 0.01$, 95% CI [-10.67, -4.32]), between the elite and non-elite performance groups ($p < 0.01$, 95% CI [-19.38, -11.93]) and between the sub-elite and non-elite performance groups ($p < 0.01$, 95% CI [-10.99, -5.33]) with the elite performance group having the fastest SBT, followed by the sub-elite performance group. The non-elite performance group has the slowest SBT. For SBT a main effect for age category ($F(1.38, 139.80) = 199.81$, $p < 0.01$) was found, indicating a general improvement of SBT (faster) when speed skaters get older. An interaction effect of age category x performance group ($F(2.77, 139.80) = 2.77$, $p = 0.049$) was found for SBT, showing different development of SBT for the three groups from U15 to U17 ($p = 0.012$) and from U17 to U19 ($p = 0.011$). From U15 to U17 the SBT times of the three groups converge, with the higher the performance group, the lower the SBT improvement. From U17 to U19, the elite and the sub-elite performance group continued improving their SBT, whereas the non-elite performance group deteriorated in SBT.

RST1 development per performance group: How fast is their start compared to their final time?

Figure 1.2 shows RST1 (expression of 0 – 300m section time as a percentage of SBT) for the different performance groups in different age categories. The means and standard deviations are shown in table 2 and 3. A main effect for performance group ($F(2, 101) = 11.31$, $p < 0.01$) was found for RST1. Post hoc analysis showed that the elite performance group spent relatively more time in the first 300m (22.0% ± 0.24 of SBT) compared to the sub-elite (21.6% ± 0.44, $p < 0.012$, , 95% CI [0.11, 0.65]) and the non-elite (21.4% ± 0.39, $p < 0.01$, 95% CI [0.30, 0.92]) performance groups. For RST1 a main effect for age category ($F(1.71, 172.65) = 10.18$, $p < 0.01$) was found indicating relatively more time spent on the first 300m from U15 to U17 (from 21.4% ± 0.54 to 21. 7% ± 0.50 of SBT) ($p < 0.01$). No interaction effect was found for RST1 ($F(3.42, 172.65) = 1.77$, $p = 0.148$), indicating that no differences in development of the relative time spent on the first segment between the performance groups were demonstrated during adolescence.

RST2 development per performance group: How fast is their 300-700m segment compared to their final time?

Figure 1.3 shows RST2 (expression of 300 – 700m section time as a percentage of SBT) for the different performance groups in different age categories. The means and standard deviations are shown in table 2 and 3. A main effect for performance group ($F(2, 101) = 6.21$, $p < 0.013$) was found. Post hoc analysis showed differences for the elite performance group versus the non-elite performance group ($p < 0.012$, 95% CI [-0.55, -0.10]) with the elite performance group spending relatively less time from 300 – 700m (24.8% ± 0.20) compared to the non-elite performance group (25.1% ± 0.36). For RST2 a main effect for age category (F(2,

202) = 43.97, p < 0.01) was found indicating relative less time spent from 300 - 700m for older age categories (from 25.4% ± 0.45 to 24.9% ± 0.58 of SBT). No interaction effect was found for RST2 (F(4, 202) = 0.75, p = 0.560) , indicating that no differences in development of the relative time spent on S2 between the performance groups were demonstrated during adolescence.

RST3 development per performance group: How fast is their 700-1100m segment compared to their final time?

Figure 1.4 shows RST3 (expression of 700 – 1100m section time as a percentage of SBT) for the different performance groups in different age categories. The means and standard deviations are shown in table 2 and 3. A main effect for performance group (F(2, 101) = 8.68, p < 0.01) was found. Post hoc analysis showed significant differences for the elite performance group versus the non-elite performance group (p < 0.01, 95% CI [-0.52, -0.13]) and for the sub-elite performance group versus the non-elite performance group (p < 0.018, 95% CI [-0.33, -0.04]), with the elite (26.1% ± 0.13) and the sub-elite (26.3% ± 0.27) performance groups spending relatively less time from 700 – 1100m compared to the non-elite performance group (26.4% ± 0.26). For RST3 a main effect for age category (F(1.94, 196.11) = 21.65, p < 0.01) was found indicating relative less time spent on the 700 – 1100m in U17 compared to U15 (26.4% ± 0.35 to 26.2% ± 0.31 of SBT) (p < 0.01). For RST3 an interaction effect of age category x performance group (F(3.88, 196.11) = 2.72, p = 0.032) was found from U17 to U19 (p = 0.014). Results showed relative less time spent on 700 – 1100m for the elite (from 26.1% ± 0.19 to 26.0% ± 0.18) and the sub-elite (from 26.2% ± 0.33 to 26.1% ± 0.28) performance groups, whereas the non-elite performance group spent relative more time in 700 – 1100m (from 26.3% ± 0.29 to 26.5% ± 0.41).

RST4 development per performance group: How fast is their 1100-1500m segment compared to their final time?

Figure 1.5 shows RST4 (expression of 1100 – 1500m section time as a percentage of SBT) for the different performance groups in different age categories. The means and standard deviations are shown in table 2 and 3. No significant main effect for performance group was found (F(2, 101) = 0.71, p = 0.495), indicating that the relative 1100 – 1500m section times were not different for the different performance groups. For RST4 a main effect for age category (F(2, 202) =23.47, p < 0.01) was found indicating relative more time spent on 1100 – 1500m for older age categories (from 26.8% ± 0.65 to 27.5% ± 0.86 of SBT). No interaction effect was found for RST4 (F(4, 202) = 0.82, p = 0.513), indicating that no differences in development between the performance groups were demonstrated during adolescence.

Discussion

The purpose of the present study was to provide insight in pacing behavior of junior athletes by analysing how elite, sub-elite, and non-elite junior speed skaters pace their 1500m time trials during adolescence throughout different age categories, and whether there are differences between performance groups for the development of pacing behavior during adolescence. Our results showed that pacing behavior changes with age during adolescence and that there are differences between performance groups in pacing behavior. While being fastest on all sections, elite speed skaters spent relatively more time, expressed as a percentage of the 1500m final time, on the start (S1) and relatively less time on the midsections (S2 and S3) of the race compared to sub-elite and non-elite speed skaters. When they mature, the pacing profiles of the athletes generally develop towards the profile as demonstrated by the elite group. The data showed that from U17 to U19, the development of pacing behavior was different for the performance groups, with the elite and sub-elite speed skaters developing more towards pacing behavior characterized by a relatively faster S3, while the non-elite speed skaters develop towards a relatively slower S3. For elite performance on the 1500m, it appears important to make sure that a high speed can be maintained well into the third section of the race. Even if this means that the first 300m of the race needs to be performed relatively slower than in previous performances. Again, it has to be acknowledged that relatively slow for the elite group still means with faster absolute times than the speed skaters from the other performance groups.

The present study showed that during adolescence, pacing behavior of speed skaters changed over time. To our knowledge, the development of pacing behavior in junior athletes has not been studied before. Only one study has been conducted on the development of pacing behaviors in young individuals in general, and included schoolchildren up to the age of 12[17]. The present study is therefore the first to describe the development of pacing behavior in youth athletes. The general trend visible in the present study is that athletes develop to faster absolute section times and final times (see table 3). However, expressed as a percentage of final time, relative section times develop towards a relatively slower start and relatively faster S2 and S3 over time (figure 1) throughout their development.

Independent of the development, elite junior speed skaters showed different pacing behaviors throughout adolescence compared to non-elite junior speed skaters. While being faster on all sections, elite junior speed skaters demonstrate a relatively slower start, followed by a relatively faster midsection. These results are in accordance with the study of Muehlbauer et al.[4] who showed that the best performing senior elite speed skaters are relatively slower on the start, but are better able to maintain high velocities in S3 than the less performing senior elites. Together with the observed development of the athletes towards a relative slower start and final round as well as the relatively faster midsection, it therefore appears that junior speed skaters develop towards the pacing behavior shown at senior elite level. This development is found in all performance groups during adolescence. However, the elite junior athletes demonstrated a pacing behavior that was already more skewed towards the profile related to elite performance from age 13-14 years onwards. Moreover, differences in development were found in S3 at the later stage of adolescence, with a more pronounced development towards a faster S3 for the better performing groups from U17 to U19. The elite junior athletes thus do not only start with a pacing behavior that is more similar to elite performance at age 13-14 years, but also distinguish themselves by a more pronounced development towards an elite performance pacing behavior in the last phase of adolescence. These results of the developmental nature of pacing behavior during adolescence towards pacing behavior of senior elites, provide evidence that pacing behavior is a skill associated with optimizing performance and therefore needs to be incorporated in talent development programs. The ability to maintain high speeds well into the third section of the race could be further explored in relation to training. As pacing behavior is suggested to be based on the distribution of energy resources, the aerobic and anaerobic capacity of an individual are of importance for optimal pacing too[1,7]. Whether the elite speed skaters have developed better pacing behaviors throughout their adolescence or whether they are physically predisposed for the 1500m and adapted their specific pacing behavior based on their changing physical capability during adolescence remains to be further investigated.

The present study was based on a unique sample of athletes, as all 104 athletes remained in speed skating competition over six years during adolescence and were within the Dutch top 150 at age 17-18 years old, competing at a very high level. As came forward from a recent review of literature[19], not many studies have explored the development of talent-related characteristics in youth skaters, and we are the first to longitudinally explore pacing behavior in youth athletes in this context. Nevertheless, experience of the performance groups differed, which might influence the development of pacing behavior. Being able to learn from previous experiences and use them to form and continuously update an adequate performance template has been mentioned in literature as an important aspect of optimizing pacing behavior[20]. For novices, experience on a certain distance improves performance over six consecutive time trials, however it is unknown when this effect of experience dissolves[20]. The deterioration of performance for non-elite after U17, together with an average increase of race experience of this group from 21 to 30 races, reveals that more experience is not necessarily related to better performance. Therefore, it is assumed that experience only was of limited effect on our results. Nevertheless, more research is needed on the influence of experience on pacing behavior.

Practical applications

The study provides practical information which may be used as a benchmark by coaches and athletes to optimize athlete development. For example, a male speed skater in the category U19 might compare his pacing behavior with the pacing behavior of U19 elite junior speed skaters, who spend 22.1% of total race time on S1, 24.6% on S2, 26.0% on S3 and the remaining 27.3% on S4. The skater can, if necessary, adjust his pacing strategy towards the profile of the elite junior speed skaters, keeping in mind his own physiological predisposition, and monitor whether changes in pacing strategy improve his performance

Conclusion

The present study showed that during adolescence pacing behavior generally develops towards a relatively slower start and final round and a relatively faster mid-section (all expressed relative to final times) of the race compared to previous performances. For optimal performance, it seems crucial to be able to maintain high speed well into the third section, even if this means that the first 300m of the race needs to be performed relatively slowly to ensure that speed can be maintained throughout the race. Elite speed skaters distinguish themselves from non-elite speed skaters by doing so from an early age onwards and even more pronounced in the later phase (from U17 to U19) of their adolescence. Results of the present study provide support for the notion that pacing behavior is relevant for talent development.

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References

1. Foster C, Snyder A, Thompson NN, Green MA, Foley M, Schrager M. Effect of pacing strategy on cycle time trial performance. *Med Sci Sports Exerc*. 1993;25(3):383-388.

2. Foster C, De Koning JJ, Hettinga F, et al. Pattern of energy expenditure during simulated competition. *Med Sci Sports Exerc*. 2003;35(5):826-831.

3. Foster C, Dekoning J, Hettinga F, et al. Effect of competitive distance on energy expenditure during simulated competition. *Int J Sports Med*. 2004;25(3):198-204.

4. Muehlbauer T, Schindler C, Panzer S. Pacing and performance in competitive middle-distance speed skating. *Res Q Exerc Sport*. 2010;81(1):1-6.

5. Sandals LE, Wood D, Draper SB, James DV. Influence of pacing strategy on oxygen uptake during treadmill middle-distance running. *Int J Sports Med*. 2006;27(1):37-42.

6. Thompson K, MacLaren D, Lees A, Atkinson G. The effect of even, positive and negative pacing on metabolic, kinematic and temporal variables during breaststroke swimming. *Eur J Appl Physiol*. 2003;88(4-5):438-443.

7. Hettinga FJ, De Koning JJ, Schmidt LJ, Wind NA, MacIntosh BR, Foster C. Optimal pacing strategy: From theoretical modelling to reality in 1500-m speed skating. *Br J Sports Med*. 2011;45(1):30-35.

8. Stoter IK, MacIntosh BR, Fletcher JR, Pootz S, Zijdewind I, Hettinga FJ. Pacing strategy, muscle fatigue and technique in 1500m speed skating and cycling time-trials. *Int J Sports Physiol Perform*. 2015.

9. Elferink-Gemser MT, Jordet G, Coelho-E-Silva MJ, Visscher C. The marvels of elite sports: How to get there? *Br J Sports Med*. 2011;45(9):683-684.

10. Anshel, Mark H and Porter, Anne and others. Efficacy of a model for examining self-regulation with elite and non-elite male and female competitive swimmers. *International journal of sport psychology*. 1996;27(3):321-336.

11. Cleary TJ, Zimmerman BJ. Self-regulation differences during athletic practice by experts, non-experts, and novices. *Journal of Applied Sport Psychology*. 2001;13(2):185-206.

12. Jonker L, Elferink-Gemser MT, Visscher C. Differences in self-regulatory skills among talented athletes: The significance of competitive level and type of sport. *J Sports Sci*. 2010;28(8):901-908.

13. Toering TT, Elferink-Gemser MT, Jordet G, Visscher C. Self-regulation and performance level of elite and non-elite youth soccer players. *J Sports Sci*. 2009;27(14):1509-1517.

14. Smits BL, Pepping G, Hettinga FJ. Pacing and decision making in sport and exercise: The roles of perception and action in the regulation of exercise intensity. *Sports Medicine*. 2014;44(6):763-775.

15. Mauger AR, Jones AM, Williams CA. Influence of feedback and prior experience on pacing during a 4-km cycle time trial. *Med Sci Sports Exerc*. 2009;41(2):451-458.

16. Micklewright D, Papadopoulou E, Swart J, Noakes T. Previous experience influences pacing during 20 km time trial cycling. *Br J Sports Med*. 2010;44(13):952-960.

17. Micklewright D, Angus C, Suddaby J, St Clair Gibson A, Sandercock G, Chinnasamy C. Pacing strategy in schoolchildren differs with age and cognitive development. *Med Sci Sports Exerc*. 2012;44(2):362-369.

18. International Skating Union. Special regulations and technical rules, speed skating and short track speed skating. https://knsb.nl/wp-content/uploads/sites/98/2014/10/Internationaal-reglement-Speed-Skating-en-Short-Track-Speed-Skating.pdf. Updated 2014. Accessed Feb/12, 2016.

19. Konings MJ, Elferink-Gemser MT, Stoter IK, van der Meer D, Otten E, Hettinga FJ. Performance characteristics of long-track speed skaters: A literature review. *Sports Medicine*. 2015;45(4):505-516.

20. Foster, Carl and Hendrickson, Kirsten J and Peyer, Karissa and Reiner, Brigette and Lucia, Alejandro and Battista, Rebecca A and Hettinga, FJ and Porcari, JP and Wright, Glenn and others. Pattern of developing the performance template. *Br J Sports Med*. 2009;43(10):765-769.

Figure captions

Figure 1: Season best time, SBT (1.1), relative 0 – 300m sector time, RST1(1.2), relative 300 – 700m sector time, RST2 (1.3), relative 700 – 1100m sector time, RST3 (1.4) and relative 1100 – 1500m sector time, RST4 (1.5) for the different age categories and performance groups, with lines representing means, error bars representing standard deviation, ‘a’ representing main effect performance group, ‘b’ representing main effect age category and ‘c’ representing interaction effect of age category x performance group.

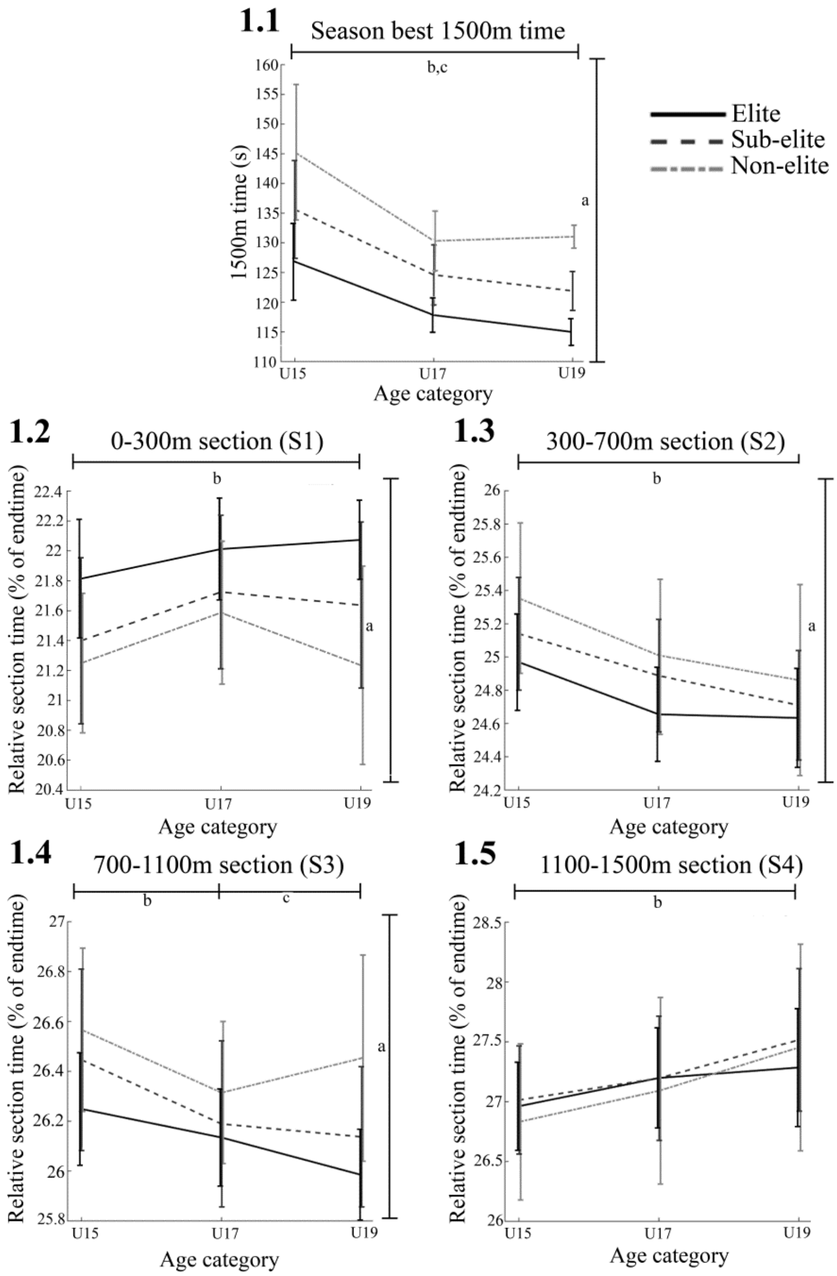

Table 1: Age, season best time (SBT), race experience and percentage representing fastest group at different age categories (U15, U17 and U19) for the three performance groups (elite, sub-elite and non-elite).

	Elite (n = 17)			**Sub-elite (n = 64)**			**Non-elite (n = 23)**		
	U15	**U17**	**U19**	**U15**	**U17**	**U19**	**U15**	**U17**	**U19**
Age (yrs.)	15.25 ± 0.55	17.25 ± 0.55	19.25 ± 0.55	15.91 ± 0.56	17.91 ± 0.56	18.91 ± 0.56	15.93 ± 0.63	17.93 ± 0.63	18.93 ± 0.63
SBT (s) ** elite-sub-non	126.82 ± 6.45 **	117.82 ± 2.89 **	114.97 ± 2.27 **	135.61 ± 8.26 **	124.59 ± 5.05 **	121.90 ± 3.30 **	145.25 ± 11.41 **	130.32 ± 5.02 **	131.02 ± 1.93 **
Race experience (No. of 1500m races) * elite-sub-non ** elite-sub-non	20.65 ±7.19 **	44.94 ±11.24 **	61.8 ± 14.1 **	12.75 ±8.60 *	30.78 ±14.07 **	45.3 ± 15.6 **	8.04 ±6.12 *	21.48 ±8.66 **	30.4 ± 9.7 **
Percentage representing fastest group in age category	58.8%	64.7%	100%	41.2%	35.3%	0%	0%	0%	0%

Values are expressed as mean ± SD. * $p<0.05$ and ** $p< 0.01$. Elite-sub-non refers to a significant post hoc difference between elite and sub-elite skaters, between elite- and non- elite skaters, and between sub-elite and non-elite skaters.

Table 2: Season best times (SBT), absolute section times (AST1, AST2, AST3 and AST4) and relative section times (RST1, RST2, RST3 and RST4) per performance group (elite, sub-elite and non-elite).

	Elite (n = 17)	**Sub-elite (n = 64)**	**Non-elite (n = 23)**
	Average	Average	Average
SBT (s) a, elite-sub-non	119.9 ± 3.4	127.4 ± 5.0	135.5 ± 5.1
AST1 (s) a, elite-sub-non	26.3 ± 0.6	27.5 ± 0.9	28.9 ±1.1
RST1 (%) a, elite-(sub, non)	22.0 ± 0.2	21.6 ± 0.4	21.4 ± 0.4
AST2 (s) a, elite-sub-non	29.7 ± 0.9	31.8 ± 1.5	34.0 ±1.6
RST2 (%) a, elite-non	24.8 ± 0.2	24.9 ± 0.3	25.1 ± 0.4
AST3 (s) a, elite-sub-non	31.3 ± 0.9	33.5 ± 1.6	35.9 ± 1.6
RST3 (%) a, elite-(sub, non)	26.1 ± 0.1	26.3 ± 0.3	26.4 ± 0.3
AST4 (s) a, elite-sub-non	32.5 ± 1.2	34.7 ± 1.3	36.7 ± 1.3
RST4 (%)	27.2 ± 0.3	27.2 ± 0.4	27.1 ± 0.6

Values are expressed as mean ± SD. [a] represents main effect performance group. Elite-sub-non refers to significant post hoc differences between elite and sub-elite skaters, between elite and non-elite skaters, and between sub-elite and non-elite skaters. Elite-(sub, non) refers to significant post hoc differences between elite and sub-elite skaters and elite and non-elite skaters, not between sub-elite and non-elite skaters.

Table 3: Season best times (SBT), absolute section times (AST1, AST2, AST3 and AST4) and relative section times (RST1, RST2, RST3 and RST4) for each performance group (elite, sub-elite and non-elite) per age category (U15, U17 and U19).

	Elite (n = 17)			Sub-elite (n = 64)			Non-elite (n = 23)		
	U15	U17	U19	U15	U17	U19	U15	U17	U19
SBT (s) b, U15-U17-U19 c, U15-U17-U19	126.8 ± 6.5	117.8 ± 2.9	115.0 ± 2.3	135.6 ± 8.3	124.6 ± 5.1	121.9 ± 3.3	145.3 ± 11.4	130.3 ± 5.0	131.0 ± 1.9
AST1 (s) b, U15-U17-U19	27.7 ± 1.1	25.9 ± 0.5	25.4 ± 0.4	29.0 ± 1.4	27.1 ± 0.9	26.4 ± 0.8	30.8 ± 2.2	28.1 ± 1.0	27.8 ± 0.9
RST1 (%) b, U15-U17	21.8 ± 0.4	22.0 ±0.3	22.1 ± 0.3	21.4 ± 0.6	21.7 ± 0.5	21.6 ± 0.6	21.3 ± 0.5	21.6 ± 0.5	21.2 ± 0.7
AST2 (s) b, U15-U17-U19	31.7 ± 1.8	29.1 ± 0.8	28.3 ± 0.5	34.1 ± 2.4	31.0 ± 1.5	30.1 ± 1.0	36.9 ± 3.3	32.6 ± 1.6	32.6 ± 0.9
RST2 (%) b, U15-U17-U19	25.0 ± 0.3	24.7 ±0.3	24.6 ± 0.3	25.1 ± 0.3	24.9 ± 0.3	24.7 ± 0.3	25.4 ± 0.5	25.0 ± 0.5	24.9 ± 0.6
AST3 (s) b, U15-U17-U19 c, U15-U17-U19	33.3 ± 1.8	30.8 ± 0.8	29.9 ± 0.7	35.9 ± 2.6	32.6 ± 1.6	31.9 ± 1.1	38.6 ± 3.3	34.3 ± 1.6	34.7 ± 0.8
RST3 (%) b, U15-U17 c, U17-U19	26.2 ± 0.2	26.1 ± 0.2	26.0 ± 0.2	26.4 ± 0.4	26.2 ± 0.3	26.1 ± 0.3	26.6 ± 0.3	26.3 ± 0.3	26.5 ± 0.4
AST4 (s) b, U15-U17	34.2 ± 1.9	32.1 ± 1.1	31.4 ± 1.1	36.6 ± 2.2	33.9 ± 1.5	33.5 ± 1.1	39.0 ± 2.6	35.4 ± 1.5	35.6 ± 1.2
RST4 (%) b, U15-U17-U19	27.0 ± 0.4	27.2 ± 0.4	27.3 ± 0.5	27.0 ± 0.5	27.2 ± 0.5	27.5 ± 0.6	26.8 ± 0.7	27.1 ± 0.8	27.5 ± 0.9

Values are expressed as mean ± SD. ^{b} represents main effect age category and ^{c} represents interaction effect of age category x performance group. U15-U17-U19 refers to significant post hoc differences for all age categories. When only two age categories are named post hoc differences were limited to the indicated age categories.