Staying on track

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Elite performance development

Creating performance benchmarks for the future elites in speed skating.

Chapter 2

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Abstract

Sports performance benchmarks useful to select and guide future elites are limited in literature. The present study introduces a method to enable comparison between sports performance of different generations and creates performance benchmarks for the future elites in speed skating. 1500 m Season Best Times (SBT) of Dutch skaters (1043 females, 1812 males, age 13–26 years), who competed in at least six seasons between 1993 and 2013, were corrected for the prevailing world record (WR): rSBT= (SBT/WR)*100%. Regression analyses showed that the calendar year affected SBT ($p<0.01$), but not rSBT ($p>0.05$). Based on rSBT, performance groups were defined: elite (rSBT<110%), sub-elite (110%<rSBT<115%), high-competitive (115%<rSBT<120%), medium-competitive (120%<rSBT<125%) and low competitive (rSBT>125%). Benchmarks were based on the slowest rSBT per age of the elite group. Of the total skaters performing within the elite benchmarks, the elite performance group represented <20% up to age 16 and <50% up to age 21. An out of sample group (n=299) confirmed the usability of the benchmarks. So, by correcting time-trial performance for the prevailing WR, elite performance benchmarks can be made based on multiple generations of elite skaters. The benchmarks can be used to select and guide future elite skaters from age 13–26 years.

Keywords
Speed skating, talent development, world record, sports performance, time trial and athletic performance

Introduction

The goal of talent development programs in sports is to support and foster the future world champions throughout their youth. Though it is hard and probably impossible to predict the later world champion out of thousands of youth athletes, one thing is certain; the future world champion needs to reach an exceptional high level of performance in order to participate at the world championships to at least have a chance of winning. The question is how these elite athletes get to this high level of expertise and whether we can use their performance development as a benchmark for the future generation.

Speed skating is a time trial sport in which time needed to cover a certain distance is the ultimate performance variable. The key distance in speed skating is the 1500 m (~2 min) at which both endurance and sprint athletes can compete (Foster et al., 2004). Official competition starts at age 13 years, and the age of winning Olympic gold medals on the 1500 m is on average 26 years (Alles Met Sport, 2014). Paradoxically, although the road to expertise is long, longitudinal studies in sports are scarce. One of the few longitudinal studies in speed skating showed that from age 14 to age 18 years no more than 59% of the best performing speed skaters remained at the top of their age category (Wiersma, Stoter, Visscher, Hettinga, & Elferink-Gemser, 2017). Furthermore, performance at age 17 explained only part (9% for female and 36% for male) of performance 3–4 years later (de Koning, Bakker, de Groot, & van Ingen Schenau, 1994). Thus, even within four years, the best adult performers are not necessarily the best in earlier years, highlighting one of the great challenges for talent development programs (Barreiros, Cote, & Fonseca, 2014; Elferink-Gemser, Jordet, Coelho-E-Silva, & Visscher, 2011).

The lack of longitudinal research over more than four years can be attributed to the fact that over time athletes transfer out or quit a sport (Cobley, Schorer, & Baker, 2012). Additionally, as only a few can make it to the top, study groups become too small when the study period increases. To overcome this limitation of group size, multiple generations could be taken into account to gain insight into the longitudinal development of elite athletes. One challenge, however, is that the sport usually evolves over time, for example, by technological innovations or better training techniques that lead to improved performances (de Koning, 2010; Kuper & Sterken, 2003; Talsma, 2013). This evolution of a sport is clearly reflected in the improvement of world records (de Koning, 2010). In 1500 m speed skating, the world record for males has been improved by 11 s from 1993 to 2013 (International Skating Union, 2017). When studying performance development over multiple generations it is important to take this into account.

The present study introduced and tested a method to compare speed skating performance over multiple generations in order to provide more insight into those few who reach the elite level. To this aim, we (1) compared speed skating performance over 20 calendar years by correcting the time needed to finish the 1500 m by the prevailing world record, and (2) defined performance benchmarks within which all elite athletes perform from age 13 years onward. Finally, we (3) determined how many athletes, including those not in the elite group, performed within the elite benchmarks, and whether performance and performance development can distinguish the elites from the other athletes performing within the elite benchmarks. The ultimate goal of the present study is to provide talent programs with a data-driven and science-based tool to select and monitor those athletes who have the potential to make it to the top and, perhaps even more important, to not miss any potentials by deselecting them at a younger age.

Materials and methods

All official 1500 m speed skating results between 1993 and 2013 were obtained from the Royal Dutch Speed Skating Association (KNSB). Only the results on Dutch speed skating rinks were included to limit the influence of altitude (Koning, 2005). For each speed skater, all Season Best Times (SBT) were obtained. The study was approved by the ethics committee of Human Movement Sciences at the University of Groningen, in the spirit of the Helsinki Declaration.

Only those skaters who were in competition for at least six seasons between 1993 and 2013 and had at least one measurement at age 16 or younger were included. As speed skaters start competing in 1500 m time trials at age 13 years, and the average age of Olympic 1500 m champions is 26 years (Alles Met Sport, 2014), the age-range for inclusion of a season was set on 13–26 years. This resulted in 2993 (1102 female, 1891 male) individual skaters with 16,574 SBT's (9117 for female, 16,295 for male).

Compare performance

The present study comprises performance data over two decades. To make performances from different calendar years comparable, the present study introduces a simple method to correct for evolution in a sport (de Koning, 2010; Talsma, 2013). All SBTs were related to the prevailing world record (WR) of the corresponding sex. Meaning the official world record at the date the athlete skated his SBT. The corrected SBT will be referred to as relative Season Best Time (rSBT) and presented as percentage of the world record (see Equation 1).

$$rSBT = \left(\frac{SBT}{WR}\right) * \ 100\% \qquad \text{eq. 1}$$

The effect of the method was analysed using regression analyses before and after the correction, with SBT or rSBT as dependent variables and calendar year as an independent variable. The effect of the method was tested for the elite in age categories 16, 17 and 18 years separately, in which most skaters were represented.

Following the correction for the prevailing world record, skaters were allocated to the elite group when they have at least one SBT within 10% of the world record (rSBT<110%), meaning that they either once or multiple times reached this level, at any age. The 10% limit was based on the performance during the world cup on 10 December 2016 in Heerenveen, the Netherlands, where all competitors skated the 1500 m within 9.6% of the world record (range female 4.1–9.6%, male 4.0–8.0%) (International Skating Union, 2016). Note that due to altitude effects, the officious low-land world records are above the official world records. In 2017 this was 2.2% and 2.3% above the world record for female and male skaters, respectively. Therefore, rSBT's below 102% is not expected (Schaatsstatistieken.nl, 2017). To compare the development of elite speed skaters with their competitors, three more performance groups were defined based on the best rSBT per skater: sub-elite (110%<rSBT<115%), high-competitive (115%<rSBT<120%), medium-competitive (120%<rSBT<125%) and low-competitive (rSBT>125%). Table 1 presents the female/male distribution and the number of observations for each performance group.

Table 1. The number of speed skaters and observations for each performance group per sex.

		Elite	Sub-elite	High-comp.	Medium-comp.	Low-comp.
Female	Individuals (n)	63	116	209	212	502
	Observations (n)	651	1059	1812	1827	3768
Male	Individuals (n)	100	292	418	409	672
	Observations (n)	1054	2651	3933	3587	5070

Out of sample validation group

To validate the results of the present study, 10% of each performance group was randomly selected and excluded from the initial analyses and served as an "out of sample validation group". Using random allocation of numbers per group per sex, 6 female and 10 male elites were excluded. For the sub-elite, high-competitive, medium-competitive and low-competitive there were, respectively, 12, 21, 21 and 50 females and 29, 42, 41 and 67 males excluded from initial analyses and assigned to the out of sample group. The out of sample validation group comprises a total of 299 skaters with 2379 observations.

Elite performance benchmark

To define the characteristics of performance development of the elite group, a performance benchmark was defined based on the maximal rSBT (slowest performance) per age and per sex of the elite group at age 13–26 years. Before doing so, outliers were excluded using box-plot analyses per age category and per sex for the rSBT's of the elite group, using the interquartile range. This is the range between the upper quartile (median of upper 50%) and lower quartile (median of lower 50%). The values higher than 1.5 times the interquartile range above the median of the elite rSBT's were identified as outlier. Outliers who appeared to be the first season of a skater and/or a relative poor season for the individual skater, suggesting injury, illness or a decrease in training, were excluded from further analyses, as they were not representative for the general development of elite athletes. In total 42 outliers, 9 female and 33 male observations, were excluded from the elite performance benchmark. Benchmarks were defined for females and males separately, based on the maximal rSBT per age. As it might be that some athletes will reach the 110%WR at an early age, after which they decrease performance in the years following, the elite performance benchmark was pre-set to be monotone. A monotone elite performance benchmark means that with every successive max rSBT lower than the previous, the benchmark will decrease towards the value of this rSBT, but with every successive max rSBT higher than the previous the benchmark will remain at the same value.

Elites vs other performance groups

The total number of speed skaters who performed within the elite performance benchmarks was defined for every age category. As the number of skaters within the elite performance benchmarks can differ per age, further analyses were done for every age category separately.

The percentage of the total group within the benchmarks that are represented by the different performance groups was defined for every age category. Furthermore, one-way analysis of variance (ANOVA) was performed to define differences in performance (rSBT) and performance development of the preceding year (delta_rSBT) per group for every age. To determine differences between elites and skaters from the other performance groups, post hoc analyses with Bonferroni correction were performed.

Out of sample validation group

The reproducibility of the results was tested with the out of sample validation group by defining the percentage elites within the elite performance benchmarks, and by repeating the ANOVA's with the out of sample validation group.

For all tests, significance was set at $p < .05$. Effect sizes for ANOVA are presented as small ($\eta^2 = .01$), medium ($\eta^2 = .06$), large ($\eta^2 = .14$)(Cohen, 1988).

Results

Compare performance

Regression analyses revealed that calendar year had a significant impact on SBT. Standardized regression coefficients for female elite speed skaters were −.569 ($p < .001$), −.614 ($p < .001$) and −.588 ($p < .001$) for age 16, 17 and 18 years, respectively, with calendar years explaining 32.3%, 37.6% and 34.6% of SBT. For male elite speed skaters, standardized coefficients were −.753 ($p < .001$), −.787 ($p < .001$) and −.761 ($p < .001$) for age 16, 17 and 18 years, respectively, with calendar years explaining 56,8%, 62.0% and 57.9% of SBT. For female and male athletes, SBT decreased (meaning improved performance) with increasing calendar years (see Figure 1).

After correcting for the prevailing world record, calendar year had no impact ($p > 0.05$) on performance (rSBT) for female and male athletes. rSBT remained constant over the calendar years within the separate age categories (16, 17 and 18 years). Figure 1 shows an example of the distribution of SBT and rSBT of the elite at age 16 years.

Elite performance benchmark

The maximal rSBTs per age, excluding the 42 outliers, are represented by the dotted black line in Figure 2. The solid black line represents the monotone elite performance benchmarks. Finally, the grey area's in Figure 2 shows the range of the elite performances within the elite performance benchmark for female and male speed skaters, with the grey solid line representing the mean rSBT per age for the elite group. The benchmark rSBT values per age are presented in Table 2 for female and Table 3 for male.

Elites vs other performance groups

Tables 2 and 3 show per age and per performance group the number of speed skaters within the elite performance benchmarks for female and male skaters. Up to age 16 years, the later elites represent less than 20% of the skaters performing within the elite performance benchmarks. From age 21 years and older, elites represent more than 50% of those speed skaters performing within the elite performance benchmarks.

Differences in performance

Table 4 shows the mean and standard deviation for rSBT for all skaters performing within the elite performance benchmarks, per age and for female and male skaters separately.
Main effects of performance groups for rSBT were found for female age 13–24 years ($P < .01$, $\eta^2 > .14$) and for males age 13–25 years ($p < .01$, $\eta^2 > .14$). Post hoc analyses revealed differences between elites and the other performance groups ($p < .05$), with better performance for the elite group, for both sexes at all ages, except for elite vs sub-elite females at age 13 and 14 years.

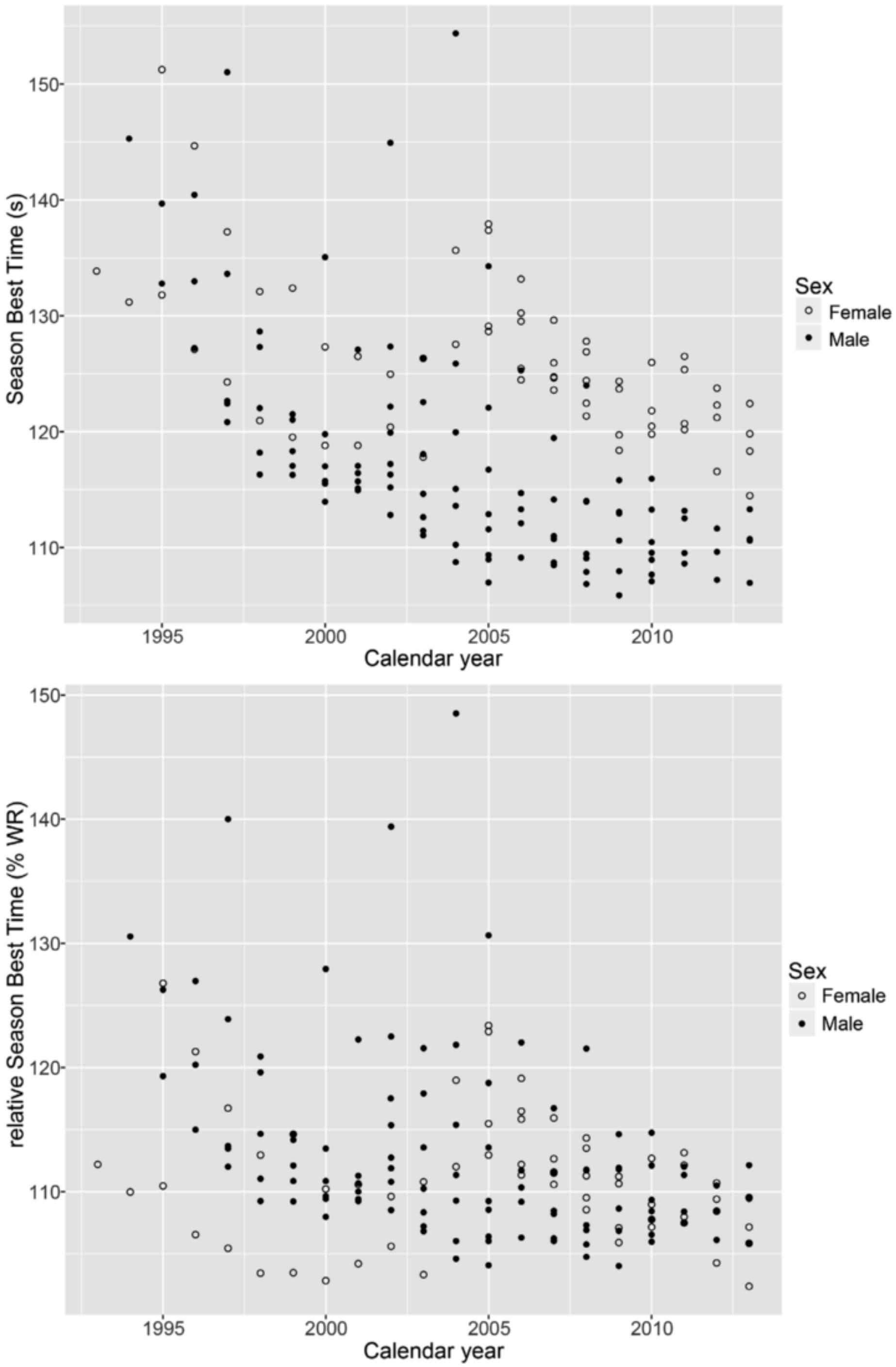

Figure 1. The relationship between calendar years and season best times (upper graph) and relative season best times (lower graph) on the 1500 m speed skating for elites age 16 years.

Differences in performance development

Table 5 shows the mean and standard deviation for development in rSBT over one year (delta_rSBT) for all skaters performing within the elite performance benchmarks, per age and for female and male skaters separately. On average, elite approached the prevailing world record with 1.9% (SD = 4.2) per year, when getting older. No differences in performance development between elite and the other performance groups were found, except for females aged 24 years ($p = .016$, $\eta^2 = .18$ elites vs sub-elites),males aged 14 years old ($p < 0.01$, $\eta^2 = 0.03$, elite vs low-competitive) and 25 years old ($p = .032$, $\eta^2 = .16$ elites vs sub-elites) with more improvement for the sub-elite and low-competitive groups. Do note that the sub-elite groups consisted of a limited number of four (female 24 years) and three (male 25 years) skaters.

Out of sample validation group

In the out of sample validation group, 100% of the performances of the female elite and 95% of the performances of male elite were within the elite performance benchmarks. The 5% of the male elite performances, which were worse than the benchmarks, were on age 13–16 years and at age 22 years. Based on the out of sample group, the percentage of the total skaters within the performance benchmarks represented by elites was not higher than 20% up to age 17 years for female and 16 years for male. From age 21 years onward elites represented 50% or more of the total number of skaters performing within the elite performance benchmarks.

ANOVA of rSBT showed main effects at all ages for female and male speed skaters ($p < .05$). Post hoc analyses showed that female elites performed better than all other groups at age 19 years old ($p < .05$). Female elites performed better than high competitive and medium-competitive speed skaters from age 14–22 and 24 years ($p < .05$). Additionally, female elites performed better than medium-competitive speed skaters at age 23 and 25 years old ($p < .05$). No differences between groups were found at age 13 years old ($p < .05$). Male elites performed better than all other performance groups at age 17, 19–23 and 25 years ($p < .05$). Male elites performed better than the high competitive, medium-competitive and low-competitive at age 14, 16, 24 and 26 years ($p < .05$). Additionally, male elites performed better than low-competitive speed skaters at age 13 ($p < 0.05$) and better than medium-competitive speed skaters at age 15 years ($p < .05$).

ANOVA of rSBT_development with post hoc analyses did not show any differences between the elite performance group and the other groups ($p > .05$).

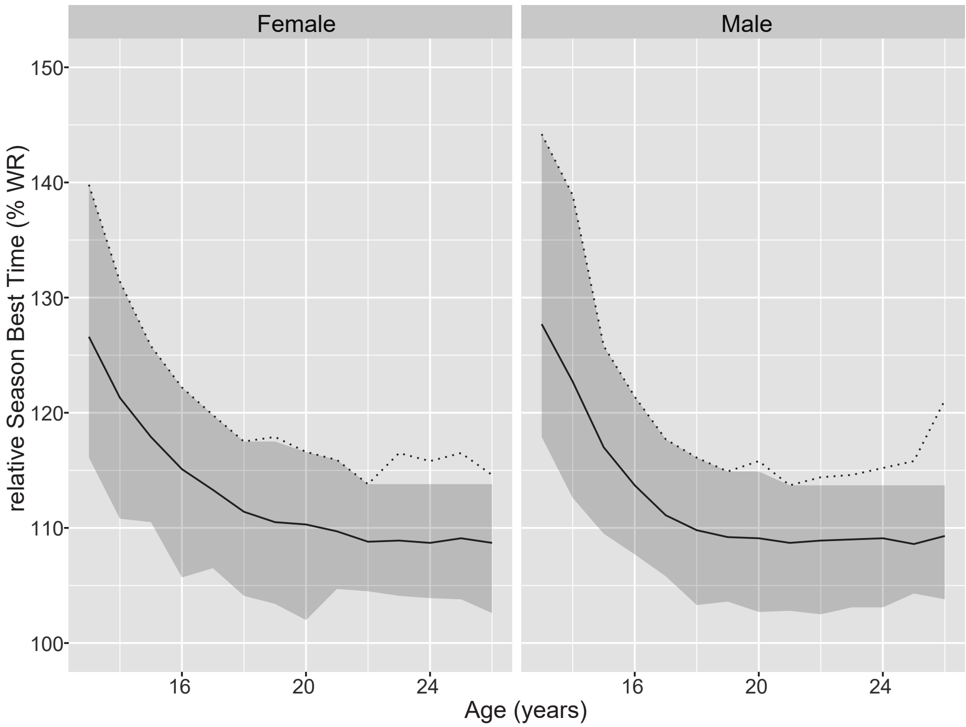

Figure 2. Performance development of female (left) and male (right) elite speed skaters on the 1500 m from age 13 to 26 years, with the black line representing the monotone elite performance benchmark, the grey solid line the mean rSBT, and the dotted line representing the max rSBT excluding outliers. The grey area represents the range of the elite performances excluding outliers.

Table 2. For female, the total individuals per age group, benchmark rSBT values of the elite group and the total number of speed skaters performing within the elite performance benchmarks are presented. Per performance group the number and percentage of total speed skaters within the elite performance benchmarks are presented.

Female		Bench-mark	Within benchmark					
Age (yrs)	Total (n)	rSBT (%WR)	Total (n)	E (n)	SE (n)	HC (n)	MC (n)	LC (n)
13	539	139.8	292	30 (10%)	66 (23%)	93 (32%)	67 (23%)	36 (12%)
14	771	131.4	345	43 (12%)	84 (24%)	121 (35%)	80 (23%)	17 (5%)
15	943	125.8	352	51 (14%)	96 (27%)	126 (36%)	74 (21%)	5 (1%)
16	1006	122.2	292	53 (18%)	97 (33%)	118 (40%)	24 (8%)	0
17	992	119.8	255	55 (22%)	95 (37%)	105 (41%)	0	0
18	966	117.5	182	55 (30%)	87 (48%)	40 (22%)	0	0
19	798	117.5	148	50 (34%)	76 (51%)	22 (15%)	0	0
20	648	116.6	125	50 (40%)	60 (48%)	15 (12%)	0	0
21	488	115.9	83	44 (53%)	38 (46%)	1 (1%)	0	0
22	378	113.8	50	37 (74%)	13 (26%)	0	0	0
23	269	113.8	34	29 (85%)	5 (15%)	0	0	0
24	196	113.8	31	27 (87%)	4 (13%)	0	0	0
25	148	113.8	24	23 (96%)	1 (4%)	0	0	0
26	111	113.8	19	18 (95%)	1 (5%)	0	0	0

E = Elite; SE = Sub-Elite; HC = High-competitive; MC = Medium-competitive; LC = low-competitive.

Table 3. For male, the total individuals per age group, benchmark rSBT values of the elite group and the total number of speed skaters performing within the elite performance benchmarks are presented. Per performance group, the number and percentage of total speed skaters within the elite performance benchmarks are presented.

Male		Bench-mark	Within benchmark					
Age (yrs)	Total (n)	rSBT (%WR)	Total (n)	E (n)	SE (n)	HC (n)	MC (n)	LC (n)
13	1125	144.2	611	47 (8%)	184 (30%)	226 (37%)	110 (18%)	44 (7%)
14	1439	138.9	759	67 (9%)	212 (28%)	252 (33%)	121 (16%)	107 (14%)
15	1668	125.8	596	79 (13%)	218 (37%)	226 (38%)	72 (12%)	1 (0%)
16	1774	121.4	544	90 (17%)	236 (43%)	202 (37%)	16 (3%)	0
17	1741	117.7	410	88 (21%)	226 (55%)	96 (23%)	0	0
18	1701	116.1	320	89 (28%)	201 (63%)	30 (9%)	0	0
19	1390	114.9	219	85 (39%)	134 (61%)	0	0	0
20	1088	114.9	171	78 (46%)	93 (54%)	0	0	0
21	861	113.7	127	73 (57%)	54 (43%)	0	0	0
22	654	113.7	94	61 (65%)	33 (35%)	0	0	0
23	473	113.7	69	51 (74%)	17 (25%)	0	0	0
24	374	113.7	50	39 (78%)	11 (22%)	0	0	0
25	262	113.7	28	25 (89%)	3 (11%)	0	0	0
26	230	113.7	21	20 (95%)	1 (5%)	0	0	0

E = Elite; SE = Sub-Elite; HC = High-competitive; MC = Medium-competitive; LC = low-competitive.

Table 4. Mean and SD for rSBT per age for the female and male skaters performing within the elite benchmarks, presented per performance group.

	rSBT (%) (mean ± SD)									
`	Female					Male				
Age (y)	Elite	Sub-elite	High-comp.	Medium-comp.	Low-comp.	Elite	Sub-elite	High-comp.	Medium-comp.	Low-comp.
13	126.6 ± 6.0	127.6 ± 5.3	130.6* ± 4.8	133.2* ± 3.7	135.1* ± 3.5	127.7 ± 6.3	131.9* ± 6.1	134.7* ± 5.3	136.6* ± 4.6	139.8* ±3.9
14	121.3 ± 5.2	122.9 ± 4.1	125.0* ± 3.5	127.4* ± 2.6	129.4* ± 1.5	121.8 ± 5.5	124.4* ± 4.3	127.0* ± 3.8	129.0* ± 3.2	134.8* ±2.9
`15	117.9 ± 4.3	119.4* ± 3.0	121.6* ± 2.5	123.8* ± 1.5	125.7* ± 0.1	117.0 ± 4.0	119.6* ± 3.0	121.6* ± 2.5	123.6* ± 1.4	125.1* ±0.0
16	115.1 ± 3.5	117.2* ± 2.4	119.0* ± 1.7	121.2* ± 0.7		113.7 ± 3.2	116.6* ± 2.2	119.0* ± 1.6	120.6* ± 0.4	
17`	113.3 ± 3.2	115.6* ± 2.0	117.8* ± 1.3			111.1 ± 2.4	114.5* ± 1.5	116.7* ± 0.8		
18	111.4 ± 2.9	114.3* ± 1.4	116.5* ± 0.7			109.8 ± 2.6	113.8* ± 1.4	115.7* ± 0.3		
19`	110.2 ± 2.7	114.2* ± 1.6	116.0* ± 0.7			109.2 ± 2.4	113.0* ± 1.4			
20	110.3 ± 2.5	114.0* ± 1.5	115.8* ± 0.5			108.9 ± 2.8	112.8* ± 1.3			
21`	109.7 ± 2.8	113.5* ± 1.4	115.1* ± 0.0			108.7 ± 2.4	112.4* ± 1.1			
22	108.8 ± 2.5	112.1* ± 1.2				108.4 ± 2.2	112.2* ± 0.9			
23`	108.0 ± 2.5	112.6* ± 1.3				108.8 ± 2.5	112.0* ± 1.0			
24	108.2 ± 2.8	112.7* ± 1.5				108.5 ± 2.4	112.7* ± 1.0			
25	107.9 ± 2.5	112.7 ± 0.0				108.1 ± 2.3	112.2* ± 1.6			
26	108.1 ± 2.6	111.9 ± 0.0				107.8 ± 2.8	110.7 ± 0.0			

* indicates significant difference with the Elite Group ($p<.05$)

Discussion

The ultimate goal of the present study is to provide talent programs with a data-driven and science-based tool to select and monitor those athletes who have the potential to make it to the top and to not miss any potentials by deselecting them at a younger age. This was done by first correcting the season best times (SBT) on the 1500 m by the prevailing world record, which neutralized the effect of the evolution of speed skating times over 20 years. This simple method enabled us to compare the performance development of elite athletes over different generations. In total 163 elite speed skaters were included and formed the basis of the elite performance benchmarks. Up to age 16, the elite group represented less than 20% of the skaters, skating at or below the elite performance benchmarks. From age 21, the elite group represented more than 50% of the speed skaters performing within the benchmarks. In general, later elite skaters have a better performance than their age-matched competitors performing within the benchmarks. The elite group also remained faster over the years following, by improving performance similar to their competitors. The out of sample validation group confirmed the results, indicating that the elite performance benchmarks can be used as a reliable benchmark to monitor performance development of a small group of skaters in their pathway to elite performance.

The evolution of speed skating between 1993 to 2013 had a significant impact on the 1500 m performance. Calendar year explained 32–38% and 56–62% of differences in SBT over 20 calendar years in the age categories 16, 17 and 18 years for elite female and elite male skaters, respectively. In those 20 years, the world record improved 8.5 s for female and 11.0 s for male speed skaters (International Skating Union, 2017). Correcting SBT's for the prevailing world record (rSBT) neutralized this effect of calendar year on the performance measure. That the effect of calendar year was excluded entirely after applying this correction was above expectations, as breaking world records is not a continuous process and dependent on individuals, opportunities, new training techniques, and/or innovations like the klapskate which was introduced in 1997 (de Koning, 2010; Talsma, 2013). Previous literature used more complex calculations to exclude the effect of technological innovations and general improvement of speed skating performance over multiple generations (Talsma, 2013). Nevertheless, the statistics and Figure 1 show that correcting for the prevailing world record is a promising method to compare performance over multiple generations. With quantifying performance as a percentage of the WR, the method and results of the present study also have the poten tial to be applied at other distances and in other sports.

The present study used longitudinal data over multiple generations to get more insight into the few athletes who make it to the top. In 20 years, 63 female and 100 male Dutch speed skaters performed within 10% of the prevailing WR, reaching the pre-set "elite" level of expertise. Discussion might be raised about what the elite level is. However, the limited amount of skaters assigned as elite in a country which was world leading in speed skating at that time, shows that 10% above the world record on a low-land ice-rink does select only the best athletes of each generation. Together, the athletes of multiple generations did represent

Table 5. Mean and SD for rSBT_development (1-year change of rSBT) per age for the female and male skaters performing within the elite benchmarks, presented per performance group.

	rSBT_development (%) (mean±SD, n)									
	Female					Male				
Age (yrs)	Elite	Sub elite	High comp.	Medium comp.	Low comp	Elite	Sub elite	High comp.	Medium comp.	Low comp.
14	−6.4 ±3.5 n = 30	−5.8 ±5.5 n = 68	−7.2 ± 5.4 n = 95	−7.0 ± 5.6 n = 65	−7.1 ±7.7 n = 15	−8.5 ± 7.5 n = 51	−8.6 ± 5.3 n = 190	−9.4 ± 6.1 n = 234	−9.2 ± 5.2 n = 105	−11.9* ± 7.0 n = 87
15	−3.6 ± 3.3 n = 42	−4.5 ± 3.6 n = 89	−4.6 ± 4.7 n = 118	−4.9 ± 4.3 n = 68	−7.5 ± 3.6 n = 5	−5.4 ± 4.0 n = 69	−5.2 ± 4.0 n = 207	−5.3 ± 3.7 n = 219	−4.9 ± 3.4 n = 71	−6.3 ± 0.0 n = 1
16	−2.9 ± 2.9 n = 50	−2.5 ± 2.5 n = 95	−3.1 ± 3.0 n = 116	−3.5 ± 2.6 n = 23		−3.5 ± 2.8 n = 81	−3.3 ± 2.6 n = 226	−3.1 ± 4.0 n = 199	−3.9 ± 2.8 n = 15	
17	−1.9 ± 2.2 n = 55	−1.6 ± 2.4 n = 94	−2.1 ± 2.6 n = 105			−2.4 ± 2.4 n = 88	−2.0 ± 2.1 n = 226	−2.3 ± 2.1 n = 96		
18	−1.8 ± 2.5 n = 55	−1.2 ± 2.0 n = 87	−1.1 ± 2.2 n = 40			−1.6 ± 1.9 n = 89	−1.1 ± 2.1 n = 201	−1.5 ± 1.2 n = 30		
19	−1.3 ± 2.4 n = 50	−0.9 ± 2.7 n = 76	−2.7 ± 2.3 n = 22			−0.7 ± 2.0 n = 85	−1.1 ± 2.1 n = 134			
20	−0.3 ± 2.6 n = 50	−0.5 ± 2.0 n = 59	−1.9 ± 1.8 n = 14			−0.3 ± 1.9 n = 78	−0.7 ± 1.8 n = 93			
21	−0.2 ± 3.0 n = 44	−1.4 ± 2.1 n = 38	−3.0 ± 0.0 n = 1			−0.2 ± 2.6 n = 73	−0.7 ± 1.7 n = 54			
22	−0.3 ± 2.6 n = 37	−1.3 ± 1.7 n = 13				−0.1 ± 2.1 n = 61	−0.7 ± 1.6 n = 33			
23	−0.9 ± 2.7 n = 29	−1.4 ± 2.5 n = 5				0.1 ± 2.5 n = 51	−1.1 ± 1.7 n = 18			
24	−0.2 ± 2.1 n = 27	−4.5* ± 7.5 n = 4				0.0 ± 1.6 n = 39	0.2 ± 1.0 n = 11			
25	−0.5 ± 1.9 n = 23	−1.4 ± 0.0 n = 1				0.2 ± 1.8 n = 25	−2.6* ± 4.2 n = 3			
26	−1.4 ± 3.0 n = 18	−2.0 ± 0.0 n = 1				−0.1 ± 2.0 n = 20	−1.2 ± 0.0 n = 1			

*indicates significant difference with the Elite Group ($p < .05$)

large enough groups to investigate longitudinal performance development of elite athletes over 13 years, which was limited to four years in previous literature (de Koning et al., 1994; Wiersma et al., 2017). Do note that longitudinal statistical analyses could not be done in the present study as multiple generation were included and in competition period could differ per individual from 6 to 13 years. Nevertheless, with the analyses done per age category, the present study was able to build up an indication of the average performance and performance development of the previous elite.

The performance pathway of the elite group was characterized by a fast improvement in performance from age 13–16 years (rSBT_development −6.4 to −2.9%), minor improvement from age 16–19 years (rSBT_development −1.9 to −1.2%), and only a slight improvement from age 19–24 years (rSBT_development −0.1 to −0.6%). The fast development up to 16 years might be explained by the influence of the adolescent growth spurt, or peak height velocity, which occurs around age 11–13 years for girls and 13–15 years for boys (Beunen & Malina, 1988; Philippaerts et al., 2006). During the growth spurt, athletes become taller and stronger very rapidly, which influences their performance. The tempo and timing of the growth spurt varies between individuals (Beunen & Malina, 1988; Philippaerts et al., 2006), which is why performance before age 16 years is unstable and not necessarily representative for later performance.

This can also be seen in Tables 2 and 3, which show that up to age 16 the elite group represents less than 20% of the total athletes performing within the elite performance benchmarks. Though female elite speed skaters, in general, perform better than their competitors after age 15 and male elite speed skaters from age 13 years, the present study recommends talent programs to support all athletes performing within the elite performance benchmarks. This to exclude the possibility that potential elite athletes are prematurely deselected. Based on the elite performance benchmarks a broad group of skaters is suggested to be supported up to age 16 years, with less than 20% reaching elite level of expertise. Nevertheless, this group will narrow down fast towards age 21 years, with more than 50% of the athletes reaching the elite level of expertise once in their career.

The present study is the first that used longitudinal data (over 20 years) to analyse a large group of elite athletes, resulting in a solid benchmark for talent development programs to select the number of athletes to support at different ages. The out of sample group confirmed that the elite performance benchmarks are useful for skaters outside the study group as 100% female elite and 95% male elite measures were within the elite performance benchmarks. Another strong point of the study is that all speed skaters had at least six years of experience, due to which results are less influenced by drop-outs and therewith easier to interpret.

Practical implications

Due to the correction of SBT by the prevailing world record, the present study provides an easy method to compare performance over different generations. Coaches can use the average rSBT's per age per performance group to monitor their athlete's development and to set realistic goals over longer periods of time (i.e., 1–13 years). The results of the present study can also be used to define the number and level of athletes to be supported in talent programs. For example, to remain with one female athlete, who performs within 110% of the WR in the future, sport associations are advised to select and support at least five females who skate within 122.2% of the prevailing WR at age 16, as the elite group represented 18% of the within benchmark group at this age. After selection, the results of the present study can be used to monitor the yearly development of the athletes needed to perform within 110% of the WR. Even when the WR changes in the future, the results of the present study remain relevant for practice, as performance is defined as a percentage of this changing world record and will therewith adjust to the evolution of the sport.

Conclusions

The method of correcting the 1500 m SBT for the prevailing world record neutralized the effect of evolution of speed skating over 20 years. This makes it possible to use the presented benchmarks for future generations. In order to support all speed skaters who are able to reach an elite level of speed skating (on a low-land ice-rink within 10% of the prevailing world record), the present study recommends to support all athletes performing within the presented elite performance benchmarks, which will be a broad group of skaters up to age 16 and narrows down towards age 21 years. The benchmarks of the present study can be used as a data-driven and science-based tool to decrease the chance of missing out any potential later elite athletes and to monitor performance development of the future generation from age 13 to 26 years.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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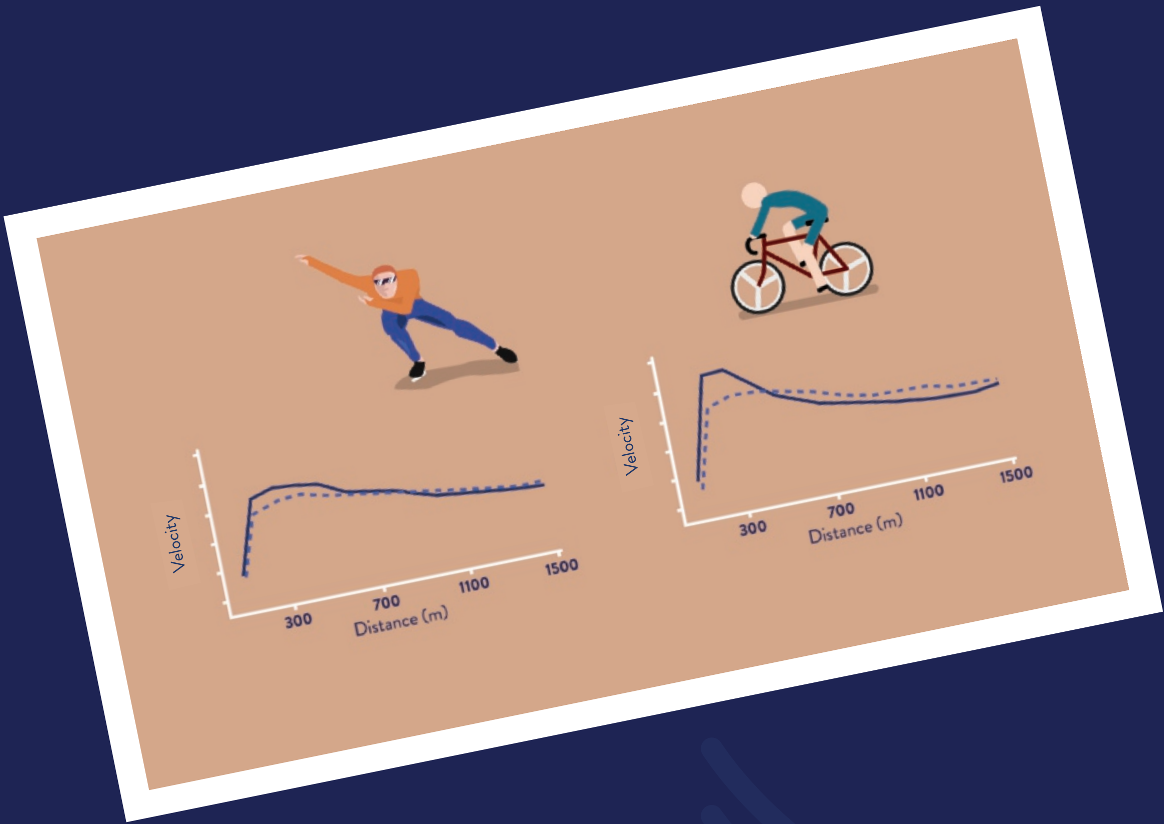

Velocity
300
700
1100
1500
Distance (m)
Velocity
300
700
1100
1500
Distance (m)