SCANDINAVIAN SPORT STUDIES FORUM | ISSN 2000-088X
VOLUME FIFTEEN, 2024, 173–198

WWW.SPORTSTUDIES.ORG

Can outcomes on physical tests predict future sporting success?

A retrospective study of cross-country skiers

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Abstract

Talent identification aims to discover athletes with qualities that suggest potential future success in a specific sport. To aid in this quest, physical tests are frequently used. However, the ability of such tests to predict future sporting success remains underexplored, especially since it is rare for test results to be retrospectively analysed to determine whether those who later became successful athletes had favourable physical test outcomes in their youth. This study aims to analyse the relationship between physical test results from a young age and future sporting success in the context of cross-country skiing. A cohort design with a retrospective approach was utilised. The cohort consists of Swedish cross-country skiers (n = 193) who underwent physical tests (n = 9) before being admitted into ski high schools between 2002 and 2006. The test results of this cohort were analysed to explore their potential to predict future sporting success, using FIS-points, the official ranking and point system established by the International Ski and Snowboard Federation. Sporting success has also been analysed in relation to variables such as ski discipline (sprint and distance), sex and the relative age effect (birth quartile). In general, it can be concluded that the test results had either no correlation or a weak correlation with future sporting success across sprint and distance disciplines in cross-country skiing. Consequently, this study questions the value of physical tests as an instrument in talent identification processes.

Keywords: talent identification, physical tests, cross-country skiing, sporting success, ski high school

Introduction

In the context of sports, talent identification aims to identify athletes who possess the qualities and attributes that imply that they may excel in a particular sport or discipline in the future (Johnston et al., 2018). The talent identification process, which varies depending on the sport, typically includes a series of tests and evaluations aimed at assessing an individual's physical, technical, tactical, and psychological abilities (Baker, Schorer & Wattie, 2018; Johnston et al., 2018; Roberts et al., 2019; Sarmento et al., 2018). The evaluations of technical and tactical abilities are often conducted by coaches who rely on subjective intuition or "gut feeling", which is questionable from both reliability and validity perspectives (Christensen, 2009; Johansson & Fahlén, 2017; Roberts et al., 2019; Roberts et al., 2021).

In contrast, assessments of physical abilities are typically based on measurements derived from physical tests. These tests are commonly employed to differentiate between individuals of varying skill levels, often resulting in decisions that are driven by short-term considerations (Baker, Schorer & Wattie, 2018; Lidor, Coté, & Hackfort, 2009; Lidor et al., 2005a). However, it is uncommon for test results to be retrospectively analysed to determine whether individuals who later became successful athletes demonstrated favourable physical test outcomes during their youth (Johnston et al., 2018). This lack of retrospective analyses limits the understanding of the long-term predictive value of these tests. The present study aims to provide insight into this overlooked area of research by employing a cohort design with a retrospective approach to analyse the relationship between physical test results from a young age and future sporting success in the context of cross-country skiing, a sport that demands particularly high levels of physical attributes, such as aerobic capacity (Carlsson et al., 2012; Sandbakk & Holmberg, 2017; Holmberg, 2015; Sandbakk et al., 2016). Moreover, the correlation between performance in physical tests and future athletic ability is "very strong among both coaches and pupils" in cross-country skiing (Svensson, 2024, p. 36). The research question addressed in this study is the following:

- What is the relationship between physical test results and future competitive success in cross-country skiing?

To answer this question, we have analysed the test results of 193 Swedish cross-country skiers who underwent physical tests before being admitted

into a ski high school between 2002 and 2006. The test results have been analysed to explore competitive outcomes, i.e., sporting success. This is explored using a concept of sporting success as delineated by the ranking and scoring framework (FIS-Points) established by the International Ski and Snowboard Federation (FIS, 2023), which is further described in the methods section. Sporting success has also been analysed in relation to variables such as ski discipline (sprint and distance), sex and the relative age effect (birth quartile). These variables can influence an athlete's performance on physical tests (Lidor, Côté & Hackfort, 2009), potentially leading to disparities in competitive outcomes.

This study focuses solely on the test data of those who were admitted to ski high schools, with no data available for those who were not. Moreover, in this article, we do not address the broader admission process of ski high schools in Sweden which involves more than just physical tests, including sport-specific exercises, interviews, etc. (Andersson & Fahlström, 2023). Nevertheless, while sport schools, such as ski high schools, aim to support individuals identified as having the potential to achieve sporting success in the future (Andersson, 2024; Swedish Sports Confederation [SSC], 2012), the limitations and potential of the tests used in these admission processes, in relation to achieving or contributing to such goals, are discussed at the end of this article.

The paper proceeds through four steps. The first section addresses previous research on assessments of athletes via physical testing procedures. Then the method is presented, providing a description of the test battery used for admissions to ski high schools, along with a presentation of the statistical analyses utilised. In the final two sections, the findings are presented and discussed. In the latter, the study outlines potential directions for future research and highlights practical implications for authorities involved in talent identification, such as sports federations and coaches.

Previous studies

Talent identification typically includes a range of tests and assessments to evaluate an individual's physical, technical, tactical, and psychological abilities (Baker, Schorer, & Wattie, 2018; Johnston et al., 2018; Roberts et al., 2019). While technical and tactical attributes are challenging to measure, psychological (e.g., motivation, cognitive skills) and physical attributes (e.g. strength and endurance) are viewed as quantifiable and, as a re-

sult, are often considered more reliable, particularly when justifying talent identification and selections (Andersson & Fahlström, 2023; Vaeyens et al., 2006; Van Yperen, 2009).

From a psychological perspective, emphasis is on measuring various cognitive abilities, including problem-solving skills, decision-making, spatial reasoning, memory, and attention. These abilities can indicate how effectively an individual learns and applies new information. Additionally, personality traits such as resilience, motivation, confidence, and emotional stability are assessed to understand how individuals manage stress, setbacks, and pressure in competitive environments (Sarmento et al., 2018). However, a recent comprehensive meta-analysis, containing 142 studies, revealed a lack of evidence supporting the use of psychological or cognitive testing in talent identification or selection processes (Kalén et al., 2021). In contrast to measuring various cognitive abilities, the primary purpose of physical tests is to evaluate physical attributes. In the context of talent identification, it is assumed that attributes predicting future sporting success can be discerned from a young individual's performance during these tests. This assumption has been explored by researchers such as Hafsteinsson et al. (2011), Lidor, Coté, and Hackfort (2009), Lidor et al. (2005a), Lidor et al. (2005b), and Pion et al. (2009).

Lidor et al. (2005a) aimed to identify motor, physical, and skill variables that could be used by coaches for the selection process of young handball players (n = 405) (12–13 years of age at the beginning of the testing period). The test battery included a 4x10m running test, explosive power tests (medicine ball throw and standing long jump), speed tests (a 20m sprint from a standing position and a 20m sprint with a flying start), and a slalom dribbling test. When comparing players who were eventually selected with those who were not selected, it was found that physical tests was unable to differentiate between handball players who were selected and players who were not selected. Only the slalom dribbling test (a skills test) proved to be a reliable indicator. In another sports context, Lidor et al. (2005b) explored the benefits of general physical ability tests and a judo-specific ability test during the early stages of talent identification and selection. Ten judokas, aged 12–15, were assessed three times between 1994 and 1995 on both general physical abilities and judo-specific skills. The general physical ability test included exercises such as sit-ups, push-ups, and side-to-side jumps, while the judo-specific test consisted of ten stations where participants performed skill-based tasks. After completing a 12-month training program, the judokas were ranked by two national judo coaches. Eight

years later, they were ranked again by the same coaches. The results indicated that the tests showed low or no correlation with either the 1995 or 2003 rankings.

Pion et al. (2009) investigated the link between anthropometric, physical, and motor characteristics, as assessed during talent identification in young (6-9 years) female gymnasts (n = 91). The findings revealed that 18% of gymnastics athletes who successfully passed the baseline test, consisting of motor skills and physiological measures, continued performing at the highest level of competition five years later. The authors suggest that these findings indicate the capability of test batteries to serve as a predictor of future dropout rates, rather than any other purpose.

While the studies above mostly involved athletes under the age of 15, Hafsteinsson et al. (2011) analysed data from physical tests conducted during the admissions process (from 1992 to 2002) for an athletic high school in Sweden, focusing on athletes aged 16. They studied whether these athletes (n = 207, 99 girls and 108 boys) who performed best in physical tests at the admission process were also the ones who achieved the best competition results as seniors. The results showed only weak correlations between the test results and later sports performance. Therefore, they conclude that physical tests should not be decisive in admissions to an athletic high school.

While individual studies can offer insights into specific aspects of talent identification and physical testing, reviews provide a broader perspective by synthesizing findings from multiple sources. In this context, Lidor, Coté, and Hackfort (2009) reviewed thirteen studies that examined the use of physical and motor skills tests in talent identification. The included studies analysed how athletes' test scores, both high and low, correlated with "real-world performance" indicators, such as competition results or coach rankings, to identify the best predictors of an athlete's future success in sports (p. 137). The authors highlight limitations associated with the use of such tests and suggests that, during the early stages of talent development, coaches or other relevant actors should decrease the quantity of physical and motor skills testing. However, if tests are to be used, coaches and sport scientists specializing in measurement and evaluation should cooperate to improve the effectiveness of the application and interpretation of physical skills testing at the early stages of talent development.

The primary purpose of physical testing is to evaluate physical attributes. In relation to talent identification, this kind of testing relies on the presumption that attributes that predict future sporting success can be

identified based on young individual's performance during these tests (Baker, Schorer & Wattie, 2018). However, the available literature, some of which has been mentioned above, indicates that the outcomes of the tests are influenced by the tests used, the specific sport, and the age groups involved (e.g., Sarmento et al., 2018). Hence, to contribute to existing literature this study explores the relationship between physical test results and future competitive success in cross-country skiing.

Method

This study employs a cohort design with a retrospective approach. The cohort consists of Swedish individuals (skiers) who underwent physical tests before being admitted into a ski high school between 2002 and 2006. The results of these tests have been analysed to explore sport-specific outcomes. The empirical basis for the paper consists of data compiled and provided by the Swedish Ski Association (SSA). The data set includes 193 skiers (female n = 87, male n = 106), born between 1985 and 1991, and their outcomes on physical tests, further described below. The individuals in the data set are distributed according to Table 1.

Table 1. *The individuals in the dataset, by year of admission and sex.*

Admission year	Males		Females	
	N	%	N	%
2002	19	18.1	19	21.6
2003	20	19.0	17	19.3
2004	23	21.9	19	21.6
2005	21	20.0	16	18.2
2006	22	21.0	17	19.3
Total	105	100.0	88	100.0

Variables

The background variables analysed in this study were ski disciplines (sprint and distance), sex, relative age effect (birth quartile), and FIS points.

Relative age effect (birth quartile)

In the analysis, we examined the *relative age effect* (RAE), using birth quartiles. In brief, RAE refers to the phenomenon where children or adolescents born in the same calendar year may have reached different stages of

development. Being born early in a calendar year can provide a significant advantage due to differing relative stages of maturity (Cobley et al., 2009). This put individuals who experience delayed development, often referred to as "late bloomers", in an unfavourable position (Bloom, 2012; Helsen et al., 2000). While physical maturation and the RAE have been shown to affect the sporting performance of young athletes (Cobley et al., 2009), these elements can similarly impact performance on physical tests (Lidor, Côté & Hackfort, 2009).

FIS Points

In this study, the definition of sporting success is based on the official ranking and point system established by FIS. FIS calculates points, *Race Penalty*, for the winner in a sanctioned competition by estimating the level of competition, strength of the opposition, and the winner's margin of victory. The FIS points allocated to other participants are determined by the proximity of their time to the winning time. The winner of a competition receives the lowest number of points and others are allocated points on an ascending scale according to performance, which is measured in time (FIS, 2023).

Skiing disciplines and age categories

In cross-country skiing, sprint and distance disciplines refer to different types of races based on the length and intensity of the course. Sprint races are short, high-intensity events where skiers compete over relatively short distances, typically ranging from 0.8 kilometres to 1.8 kilometres. Sprint courses often feature multiple rounds of heats, with skiers racing head-to-head in knockout-style competitions. Distance races are longer, endurance-based events where skiers cover longer distances, ranging from 5 kilometres to 50 kilometres or more for individual races. These races can take place on various terrains, including flat tracks, hilly terrain, or even challenging mountainous courses.

Both sprint and distance disciplines are integral parts of cross-country skiing competitions, and skiers often specialize in one or the other based on their strengths, preferences, and competitive goals. In this study, therefore, we have divided variables to describe the different disciplines (sprint and distance), but also age categories (junior and senior), as follows:

- FIS Points, sprint juniors (up to 20 years of age)
- FIS Points, distance juniors (up to 20 years of age)

- FIS Points, sprint seniors
- FIS Points, distance seniors

Test battery

The test battery used during the admissions process for ski high schools in Sweden at the time of data collection included the following tests and exercises:

The treadmill running test

The treadmill running test is a fitness assessment that evaluates an individual's cardiovascular endurance, aerobic capacity, and running performance. The participant wears a breathing mask that covers both the nose and mouth to measure VO_2max (oxygen uptake) and a heart rate monitor to record heart rate. Throughout the test, the treadmill speed remains constant and is adjusted based on the runner's ability. The intensity increases gradually by increasing the treadmill's incline every minute. The duration of the test typically lasts 5–8 minutes and concludes either when the test subject feels that they have reached their maximum effort or when the test leader decides to stop the test. The test results for VO_2max are presented in litres per minute as an absolute value and in millilitres per kilogram per minute (VO_2 ml/kg/min) as a relative value, also known as the "test value".

The countermovement jump

The countermovement jump (CMJ) is a vertical jump test where the test subject rapidly lowers themselves to 90 degrees in the knee joint, or to their preferred depth, and then immediately performs a maximal jump. The entire movement occurs in one continuous motion. The CMJ is performed both without and with an arm swing (CMJa). The CMJ is a test used to measure an individual's explosiveness and leg power.

The squat jump

The squat jump (Sqjump) is executed with the feet positioned shoulder-width apart and the hands on the hips throughout the movement. Following a controlled descent to 90 degrees in the knee joint, a brief pause of a few seconds is observed to eliminate any bias effect. Subsequently, an explosive vertical jump is performed. The test is carried out both with two legs and with one leg, left (SqjumpL) and right (SqjumpR) respectively.

The squat jump is a test used to assess lower-body power and explosiveness.

The dip exercise

In the dip exercise (dips), the test subject assumes a dip position with their hands approximately shoulder-width apart and jumps up to the starting position. The subject then lowers themselves in a controlled manner until their shoulders are below their elbows and subsequently returns to the starting position by pushing back up. The dip exercise primarily tests upper body strength, particularly in the triceps, pectoral muscles, and deltoids.

Chin-ups

Chin-ups (chins) (or pull ups) are performed by having the test subject hang from a rail and pull their body up using their arms and back until their chin is over the rail. Chin-ups is used as a benchmark for assessing upper body strength and muscular endurance.

"Brutal bench"

The brutal bench (BrutalB) exercise primarily targets the abdominal muscles, particularly the rectus abdominis, while also engaging the hip flexors to stabilise the lower body. Brutal bench consists of hanging from the knees, usually from a bench/plinth, then performing sit-ups from this position. When used as part of a fitness assessment it can measure and test abdominal strength and endurance.

The 10 jumps test

The 10 jumps (10-jump) test involves performing a series of ten consecutive jumps, horizontally. The subject is starting on one foot and taking multiple steps to jump as far as possible within 10 steps. The 10 jumps test is used to assess and monitor an individual's lower-body explosive power and agility.

Data analysis

Data were analysed in the programme Statistical Package of Social Science (SPSS) (version 25). Statistical test methods have been utilised. The study

presents central measures (namely the mean value, median and frequency, the highest/most frequent observations) but also relationships between variables. Regarding the latter, variables have been analysed, with a primary focus on correlations, examining whether there is a relationship between different variables or not. Pearson's correlation analysis was used, and the correlations range from -1 to +1, with a positive correlation indicating that high values of one variable correspond to high values of another variable. In the case of a negative correlation, an increase in the value of one variable results in a decrease in the value of the other variable. A correlation value of 0 indicates no relationship between the variables (Gratton & Jones, 2004).

Ethical considerations

Ethical considerations for this study were conducted in accordance with the Swedish Research Council's guidelines (2024). To uphold these standards, appropriate procedures were implemented throughout the research process. This includes the anonymisation of the data to ensure that the identities of the individuals involved remain confidential. The dataset does not include names, and dates of birth are limited to the month and year, omitting the exact day to further reduce the risk of identification.

While it may be theoretically possible to infer the identity of individuals based on their birth year and year of admission to a ski high school, it is not possible to link any specific individual to a particular test result. Moreover, analyses were conducted at the group level rather than the individual level. Consequently, the integrity and confidentiality of the research subjects have been safeguarded.

Results

The results are divided into three sections. In the first section, descriptive statistics are reported with an emphasis on background variables such as sex, RAE, and FIS points. In the second section, analyses of the test results linked to sporting success (FIS points) at junior and senior level, and sprint and distance disciplines, are presented. In the third and last section an in-depth analysis of the possible correlation between obtained FIS

points and test results of the ten skiers with the lowest FIS points and the ten skiers with the highest FIS points is displayed.

Descriptive statistics

Relative age effect

The dataset comprises skiers who were born between 1985 and 1991. The dataset exhibits the following distribution of birth quartile, divided by sex (Table 2).

Table 2. *Distribution of the cohort by birth quartile and sex.*

Quartile	Male		Female	
	N	%	N	%
Jan-Mar	41	39.0	38	43.2
Apr-Jun	31	29.5	22	25.0
Jul-Sep	19	18.1	17	19.3
Oct-Dec	14	13.3	11	12.5
Total	105	100.0	88	100.0

As shown in table 2, a relative age effect was identified. Close to 70% of the individuals in this study, who were accepted into ski high schools between 2002–2006, were born during the first six months of the year, spanning from January to June.

Test results

Cross-country skiing places especially high demands on endurance-related physical variables, such as maximum oxygen transport capacity (VO_2max) (Carlsson et al., 2012; Sandbakk & Holmberg, 2017; Holmberg, 2015; Sandbakk et al., 2016). World-class cross-country skiers exhibit some of the highest VO_2max values reported. Absolute values for male and female medal winners exceeding 6.5 and 4.5 l/min have been observed, with values of 80–90 and 70–80 ml/kg/min being common for men and women, respectively (Sandbakk & Holmberg, 2017). Appropriately, the admission process to ski high schools includes a treadmill running test in which oxygen uptake capacity (VO_2max) is measured. In the table below (Table 3), the distribution of VO_2max and VO_2 ml per kilogram of body weight and minute (VO_2 ml/kg/min), divided by sex, is shown.

Table 3. *The distribution of the cohort for VO_2max and VO_2 ml/kg/min, by sex.*

	Male		Female		Total	
	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev
VO_2 ml/kg/min	65.28	3.86	55.01	4.06	60.58	6.47
VO_2max	4.54	0.50	3.25	0.33	3.95	0.78

The mean VO_2max values (4.54 for males and 3.25 for females) are consistent with those reported for junior elite skiers in Sweden (SSA, 2023). This result is notable given that the VO_2max of cross-country skiers, both male and female, generally increases with age and training, ranging from approximately 55-60 ml/kg/min at 15 years to 75-80 ml/kg/min at 25 years of age (Rusko, 1992).

As mentioned earlier, the test battery utilised during the admission process also incorporates assessments of strength (Andersson & Fahlström, 2023). The outcomes of these tests, at the group level, are outlined in the table (4) provided below.

Table 4. *The distribution of the cohort for SqJump left, SqJump right, SqJump, CMJ, CMJ(a), Dips, Chin-ups, Brutal bench, and 10-jumps, by sex.*

	Male		Female		Total	
	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev
SqJump L	18.7	3.3	13.5	2.7	16.3	4.0
SqJump R	19.2	4.8	13.8	3.0	16.7	4.9
SqJump	34.2	4.5	26.3	4.1	30.5	5.9
CMJ	35.8	5.2	27.6	3.9	32.0	6.2
CMJ(a)	42.5	5.7	32.1	4.7	37.7	7.3
Dips	12	6	4	3	8	6
Chins	9	4	2	3	6	5
BrutalB	18	5	14	5	16	5
10-jump	25	2	21	1	23	2

The table shows results from nine physical tests, the first five tests show jump hight in centimetres, the next three number of repetitions (reps) and 10-jump the total jump length in meters. It is important to emphasize that the purpose of this study isn't to assess the quality of the test results, but rather to examine their correlation with the attained FIS points, thereby evaluating the tests' predictive capacity for future sporting success. Hence, to ascertain any correlation between test outcomes and subsequent sporting performances (measured by FIS points), correlation analyses have been conducted.

Sporting success (FIS Points)

As mentioned earlier, the definition of sporting success in this study is based on the ranking and point system of the International Ski Federation (FIS, 2023). Below, the individuals in this study have been divided into several groups based on obtained FIS points (0-100, 100-200, 200-300, 300-400 and 400-) (Table 5, overleaf). Bear in mind that the most successful skiers have the lowest FIS points.

Table 5. *The distribution of the cohort for grouped FIS points, junior and senior, sprint and distance, by sex.*

		Male		Female		Total	
		N	%	N	%	N	%
Junior sprint FIS points	0-100	5	4.9	3	3.7	8	4.3
	100-200	29	28.2	22	26.8	51	27.6
	200-300	50	48.5	34	41.5	84	45.4
	300-400	15	14.6	18	22.0	33	17.8
	400-	4	3.9	5	6.1	9	4.9
	Total	103	100	82	100	185	100
Junior distance FIS points	0-100	7	7.0	8	9.8	15	8.2
	100-200	70	70.0	44	53.7	114	62.6
	200-300	19	19.0	22	26.8	41	22.5
	300-400	4	4.0	4	4.9	8	4.4
	400-	0	0	4	4.9	4	2.2
	Total	100	100	82	100	182	100
Senior sprint FIS points	0-100	18	28.6	11	23.4	29	26.4
	100-200	23	36.5	15	31.9	38	34.5
	200-300	17	27.0	9	19.1	26	23.6
	300-400	5	7.9	10	21.3	15	13.6
	400-	0	0	2	4.3	2	1.8
	Total	63	100	47	100	110	100
Senior distance FIS points	0-100	32	48.5	23	46.0	55	47.4
	100-200	24	36.4	15	30.0	39	33.6
	200-300	7	10.6	7	14.0	14	12.1
	300-400	2	3.0	4	8.0	6	5.2
	400-	1	1.5	1	2.0	2	1.7
	Total	66	100	50	100	116	100

A relatively limited number of individuals scored lower than 100 FIS points during their junior years (referring to those who achieved the best competitive outcomes in FIS-events). Most junior skiers scored in the range of 100-300 points.

In the senior category, most of the individuals are within the FIS point range of 0 to 200. Note that the senior group comprises roughly half the number of participants compared to the youth group. This discrepancy arises due to the absence of certain individuals who held FIS points as juniors but were no longer enlisted as seniors, likely indicating that they stopped skiing on a high national and international level.

Analysis of relationships between test results and sporting success

While the section above provides descriptive insights, the following analysis reveal correlations between test results and future sporting success (FIS-points).

Table 6 demonstrates the correlation, that emerged from the test results, between oxygen uptake capacity (VO_2max and VO_2 ml/kg/min) and sporting success on junior and senior level (age category), and in sprint and distance disciplines.

Table 6. *The correlation between age categories, disciplines, and oxygen uptake capacity (VO_2max and VO_2 ml/kg/min), by sex*

		Male		Female	
		VO_2 ml/kg /min	VO_2max	VO_2 ml/kg /min	VO_2max
Junior sprint FIS points	Pearson Correlation	-.153*	-.177*	-.280*	-.330**
	Sig. (2-tailed)	0.038	0.016	0.011	0.002
	N	184	184	82	82
Junior distance FIS points	Pearson Correlation	-.292**	-.221**	-.272*	-.191
	Sig. (2-tailed)	0.000	0.003	0.013	0.085
	N	183	183	82	82
Senior sprint FIS points	Pearson Correlation	-.240*	-.268**	-0.216	-0.173
	Sig. (2-tailed)	0.011	0.004	0.139	0.240
	N	111	111	48	48
Senior distance FIS points	Pearson Correlation	-.200*	-0.131	-0.173	0.034
	Sig. (2-tailed)	0.031	0.158	0.224	0.815
	N	117	117	51	51

As observed in the table above, there is no explicit relationship between measured VO_2max, VO_2 ml/kg/min and FIS points. This implies that the oxygen uptake capacity measured prior to admission to a ski high school

does not predict future sporting success (FIS points) within the analysed cohort. The results indicate that differences around the mean value are low, suggesting that the values of the skiers are relatively similar. The women's values on junior level are slightly higher than for the men. In general, however, there is a low correlation between oxygen uptake capacity and FIS points.

The following tables (Tables 7 and 8, overleaf) demonstrates the correlation between outcomes on strength tests and FIS points. The female group is shown in Table 7 and the male group in Table 8.

As revealed in the tables, the test results from Sqjump show low correlations with future sporting success (FIS-points), with slightly more pronounced results observed among junior male participants. Overall, the correlations are modest, underscoring the limited capacity of testing strength to predict future sporting success. Thus, the analysis suggests that there is minimal variation in the tests concerning FIS points, except for male sprinters and senior female sprinters.

While the results show low correlations between the outcomes of the tests and future sporting success, it is worth noting that there may be individual nuances in the cohort that are not apparent in the various mean values. Therefore, in the next section, to further explore potential correlations between future sporting success (FIS points) and test results an in-depth analysis is presented.

Table 7. *Correlation in the female group between different age categories (junior- senior), type of discipline (sprint, distance) and SqJump, CMJ, CMJ (a) Dips, Chins, BrutalB and 10-jumps.*

		Sq Jump V	Sq Jump H	Sq Jump	CMJ	CMJ (a)	Dips	Chins	BrutalB	10-jump
Sprint jun	Pearson Correlation	-.314*	-.285*	-.362**	-.355**	-.336**	-.321*	-0.071	-.377**	-.399**
	Sig. (2-tailed)	0.012	0.024	0.004	0.005	0.007	0.019	0.612	0.002	0.003
	N	63	63	63	62	63	53	54	63	54
Dist jun	Pearson Correlation	-0.204	-0.187	-0.134	-0.086	-0.093	-0.142	-0.022	-0.119	-0.197
	Sig. (2-tailed)	0.107	0.140	0.292	0.502	0.464	0.307	0.875	0.351	0.154
	N	64	64	64	63	64	54	55	64	54
Sprint sen	Pearson Correlation	-.408*	-0.221	-.364*	-.382*	-.397*	-0.346	-0.340	-.383*	-0.325
	Sig. (2-tailed)	0.015	0.201	0.031	0.023	0.018	0.061	0.066	0.023	0.069
	N	35	35	35	35	35	30	30	35	32
Dist sen	Pearson Correlation	-0.064	-0.050	-0.012	-0.044	-0.065	-0.236	-0.267	-.339*	0.105
	Sig. (2-tailed)	0,700	0,761	0,940	0,791	0,693	0,179	0,127	0,035	0,550
	N	39	39	39	39	39	34	34	39	35

Table 8. *Correlation in the male group between different age categories (junior-senior), type of discipline (sprint, distance) and SqJump, CMJ, CMJ (a), Dips, Chins, BrutalB and 10-jump.*

		Sq Jump V	Sq Jump H	Sq Jump	CMJ	CMJ (a)	Dips	Chins	BrutalB	10-jump
Sprint jun	Pearson Correlation	-0.071	-0.076	0.038	0.011	-0.077	-0.031	-0.173	-0.205	-0.005
	Sig. (2-tailed)	0.531	0.503	0.735	0.924	0.498	0.784	0.134	0.069	0.967
	N	80	80	80	80	80	78	76	79	64
Dist jun	Pearson Correlation	0.045	0.145	.247*	.258*	0.219	0.002	0.060	-0.057	0.213
	Sig. (2-tailed)	0.693	0.202	0.028	0.022	0.052	0.986	0.606	0.618	0.090
	N	79	79	79	79	79	78	76	79	64
Sprint sen	Pearson Correlation	-0.110	-0.068	-0.106	-0.171	-0.233	-0.144	-.293*	-.343*	-0.249
	Sig. (2-tailed)	0.435	0.628	0.450	0.222	0.094	0.312	0.041	0.013	0.112
	N	53	53	53	53	53	51	49	52	42
Dist sen	Pearson Correlation	0.038	0.244	0.199	0.200	0.196	-0.013	-0.089	-0.144	0.125
	Sig. (2-tailed)	0.785	0.075	0.149	0.146	0.157	0.927	0.532	0.300	0.425
	N	54	54	54	54	54	53	51	54	43

In-depth analysis

To further explore potential correlations between FIS points and test results, we present four tables (9–12) highlighting the top ten skiers with the lowest FIS points and the ten skiers with the highest FIS points. The tables include juniors and seniors in sprints and distance and is divided by sex. Note that there are skiers included in the dataset who participated in the physical tests, got admitted to ski high schools, but ultimately did not attain any FIS points; consequently, they are not included in the in-depth analysis below.

Table 9. *Test results for the 10 skiers with lowest and highest FIS points in sprints for juniors, divided by sex.*

	Lowest and highest FIS points, junior sprint		Lowest and highest FIS points, junior sprint	
	Male (lowest)	Male (highest)	Female (lowest)	Female (highest)
	Mean	Mean	Mean	Mean
VO_2 ml/kg body weight/minute	65.07	67.57	60.13	53.81
VO_2max	4.87	4.19	3.47	3.14
SqJump	35.7	31.8	29.5	26.5
CMJ	39.9	34.6	30.5	28.3
Dips	12	11	8	4
Chin-ups	13	8	4	2
BrutalB	23	16	20	13
10 steps jump	26.60	25.36	21.51	20.68

As shown in the table above, the high performing (low FIS-points) female junior sprinters had better results in all physical tests, particularly the treadmill-test which measures VO_2max. The highest performing male junior sprinters showed better results in the strength tests, though they had lower oxygen uptake values than athletes in the lower performing group (highest FIS points).

Table 10. *Test results for the 10 skiers with lowest and highest FIS points in distance for juniors, divided by sex.*

	Lowest and highest FIS points, junior distance		Lowest and highest FIS points, junior distance	
	Male (lowest)	Male (highest)	Female (lowest)	Female (highest)
	Mean	Mean	Mean	Mean
VO_2 ml/kg body weight/minute	67.22	65.09	59.35	53.75
VO_2max	4.70	4.34	3.44	3.16
SqJump	31.9	36.3	28.6	24.9
CMJ	33.1	37.3	29.1	26.8
Dips	7	13	6	4
Chin-ups	10	11	4	3
BrutalB	19	18	19	14
10 steps jump	24.88	24.53	21.88	20.94

The best performing, i.e. the lowest FIS-Points, female junior distance skiers had better overall test results. The results for the male distance skiers, however, differed from the sprinters. The male junior distance skiers had better oxygen uptake values but lower or equal test results on strength tests as the lower performing group (highest FIS points).

Table 11. *Test results for the 10 skiers with lowest and highest FIS points in sprints for seniors, divided by sex.*

	Lowest and highest FIS points, senior sprint		Lowest and highest FIS points, senior sprint	
	Male (lowest)	Male (highest)	Female (lowest)	Female (highest)
	Mean	Mean	Mean	Mean
VO_2 ml/kg body weight/minute	68.19	64.28	55.89	55.22
VO_2max	4.76	4.47	3.41	3.22
SqJump	32.9	35.9	29.6	29.9
CMJ	32.3	37.6	31.5	32.4
Dips	18	13	5	3
Chin-ups	10	12>	3	1
BrutalB	23	20	19	12
10 steps jump	23.30	23.88	22.35	22.82

An analysis of the correlations between test results and FIS points in senior sprints does not show the same differences as shown above concerning

the junior results. Regarding VO_2 ml/kg/min, the higher performers (i.e. the lowest FIS-Points), both male and female, had better values. The strength test results varied: in the leg strength tests (SqJump and CMJ), the lower performing group had better results than the higher performing group. However, it should be noted that the comparisons do not show that the tests vary in any systematic way with FIS Points.

Table 12. *Test results for the 10 skiers with the lowest and highest FIS points in distance for seniors, divided by sex.*

	Lowest and highest FIS points, senior sprint		Lowest and highest FIS points, senior sprint	
	Male (lowest)	Male (highest)	Female (lowest)	Female (highest)
	Mean	Mean	Mean	Mean
VO_2 ml/kg body weight/minute	68.19	65.89	55.89	55.40
VO_2max	4.73	4.44	3.41	3.21
SqJump	32.9	35.7	29.6	32.0
CMJ	32.3	38.7	31.5	32.4
Dips	18	11	5	4
Chin-ups	10	13	3	4
BrutalB	23	19	19	13
10 steps jump	25.15	25.03	22.35	24.95

An analysis of the correlations between test results and FIS points for senior distance skiers, as shown in table 12, illustrates a similar picture as for senior sprints (table 11). The test results for VO_2 ml/kg were higher for the best performing skiers, both male and female. Otherwise, there were no differences in test results between the groups.

Discussion

Talent identification aims to discover athletes with qualities that suggest potential future success in a specific sport (Johnston et al., 2018). To aid in this quest, physical tests are used (Baker, Schorer & Wattie, 2018; Johnston et al., 2018; Roberts et al., 2019; Sarmento et al., 2018). However, the ability of such tests to predict future sporting success remains underexplored, especially since it is rare for test results to be retrospectively analysed to determine whether those who later became successful athletes had favora-

ble physical test outcomes in their youth (Johnston et al., 2018). Therefore, this study explored the relationship between physical test results done at a young age and future competitive results in cross-country skiing. In general, the results showed weak or no correlations between physical tests and future sporting success (FIS points). In this section, we will discuss the results and provide insights for future research.

As revealed in the section outlining descriptive results, the relative age effect was identified in the examined group, showing that nearly 70% of the skiers in the data, admitted to ski high schools between 2002 and 2006, were born between January and June. This suggests that the skiers who were admitted had advanced in their physical development when they were assessed prior to acceptance into a ski high school. Importantly, due to the asynchronous progression of chronological age and biological maturity, a younger athlete's performance on tests may be adversely influenced by their biological maturity, particularly when compared to the norms of their chronological age (Lidor, Côté & Hackfort, 2009). Our results show that there is a potential for bias towards individuals born earlier in the year, potentially putting late bloomers at a disadvantage in the admission to ski high schools (Bloom, 1985; Cobley et al., 2009; Helsen et al., 2000). Therefore, there is good reason to consider how to take RAE into account while utilising physical tests in talent identification processes, such as the admission to ski high schools.

Further, this study showed weak or no correlations between physical tests done at a young age and future sporting success (FIS points). Overall, based on the data in this study, it can be said that physical tests have no or low correlation with later skiing success in high level competitions, both on junior and senior level and across sprint and distance disciplines in cross-country skiing. These findings align with previous research, which, across various sports, also suggests, that general physical tests performed at a young age are unlikely to offer any predictive utility for later results on the senior elite level (Johnston et al., 2018; Hafsteinsson et al., 2011; Lidor, Côté & Hackfort, 2009; Lidor et al., 2005a; Lidor et al., 2005b). This raises questions about whether other tests can be developed to use in talent identification scenarios.

While the test battery (including the treadmill-test and CMJ-test) analysed in this study is standardised, and regularly used to document the status of individuals in terms of oxygen uptake (VO_2max) and strength, the tests are general in its nature. Thus, they are lacking specificity tailored to the discipline of cross-country skiing. Thus, while the tests have high valid-

ity as general physical tests, they, based on the analysis in this study, cannot be used to predict future success in cross-country skiing. Instead other sport-specific tests, such as treadmill roller skiing (Carlsson et al., 2012; Holmberg, 2015; Sandbakk et al., 2016), could be more relevant when trying to identify future ski talents. Additionally, tests could be developed for use in real-world, non-laboratory environments, such as ski tracks, where they are easy to replicate and adaptable to various training environments. While such tests are already used in ski high schools, to set a standard for what is needed in terms of performance (see Svensson, 2024) they could also be applied in admission processes, to assess abilities beyond physical performance, such as technical skills, i.e. skiing technique.

While the lack of retrospective analysis limits the understanding of the long-term predictive value of physical tests, this study offers valuable insight and a step forward in understanding this phenomenon. However, further work needs to be done. Future studies should adapt retrospective and prospective designs to explore if and how test batteries can predict future sporting performance. In these cases, researchers should report and control for differences in participant age, sex, and specific sport to ensure that peripheral factors do not influence the results. Moreover, with a larger amount of data and more parameters, it will (or might be) possible to use multivariate analysis to show significant factors for success and even to indicate factors that have no long-term significance at all.

Practical implications

While this study shows that general physical tests cannot be used to predict future performance in cross-country skiing, we suggest that the SSA, and potentially other sports federations, either evaluate their test batteries or reduce the number of physical tests used in talent identification, such as the admission process to sport schools. However, if tests are to be used, they should have clearly established minimum requirements, and skiers should be informed of these prior to the tests.

While our results show that physical tests have limited predictive power regarding future sporting success, they could potentially serve as an indicator of the physical condition of young athletes, such as of applicants at the time of admission to ski high schools. The tests could serve as a starting point for an individual development plan for each admitted skier. The

tests could also be periodically repeated during subsequent years in the ski high school to monitor training status and progression.

Limitations

An important limitation in this study is the low number of individuals in the data set studied (n = 193), which makes it impossible to generalise and conclude that physical tests cannot predict future sporting success. The focus of this study was to analyse the correlation between test results and future sporting success (FIS points). However, since only the test results for the cross-country skiers who were admitted to ski high schools have been studied, they cannot be compared to the test results of the other applicants, as such data is not available.

Conclusion

In summary, this study showed that there are no or weak correlations between physical tests done at a young age and future success as a professional skier (FIS points). Consequently, this study, along with previous research, questions the value of physical tests as an instrument in talent identification processes (e.g., Johnston et al., 2018; Hafsteinsson et al., 2011; Lidor, Côté & Hackfort, 2009). However, while currently used tests are unreliable in predicting future sporting success, they can assist coaches in evaluating the physical abilities of young prospects. The information gathered from these tests can be valuable for assessing the current physical condition of talented athletes and for designing tailored training programs to help them reach their potential.

Declaration of conflicting interests

We declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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