Development of world class ski performance: Similarities and differences in pathways to expertise for freeskiers and cross-country skiers

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ABSTRACT

The overall purpose of the present study was to investigate similarities and differences in pathways to expertise for freeskiers and cross-country skiers. Specifically, 1) Entrance to the main sport, 2) Amount of training hours and organization of training, and 3) Variability in activities and content in training. Sampling athletes had to be on the highest level in their sport by competing in, e.g., the World Cup, World Championship, Olympic games, freeride World Tour. In total, 18 world-class skiers participated in the study. Eight freeskiers (age range 19-37) and ten cross-country skiers (age range 22-32 years). They answered a digital questionnaire designed to collect retrospective data describing their pathways to expertise. The first section elicits biographical information, age for entering sport and practice. The second section focused on sport-specific training, accumulated hours of training, and the distribution of organized versus self-organized training. The third section recalled the variability of activities they participated in and how they perceived the relevance of the content of different types of training for their sport-specific development. The results showed similarities in athletes' entrance to the main sport, specialization age and total amount of training. At the same time, differences were observed in their training history regarding the organization of training. In contrast to cross-country skiers, freeskiers seem to be more self-organized and more involved in additional activities besides their main sport. Interestingly, the two groups of world-class athletes representing sports with distinctive demands share several common variables in their paths to expertise, amplified by perceived specificity. Practitioners and academics should substantiate patience in expertise development, driven by a multi-disciplinary understanding of distinct and individual characteristics or conditions that may be beneficial in fulfilling varied future demands. Hence, research should explore the rationale behind and potential learning effects between sports and training content.

Keywords

constraints, diversification, specialization, self-organized learning, skill development, training organization

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Introduction

Experts are defined as exceptional performers who consistently provide superior performance on representative tasks within their domain (Ericsson & Charness, 1994). It is indisputable that to become an expert, one must practice extensively in the field they wish to excel (Newell & Rosenbloom, 1980). Domain specificity is evident in all performance development aspects, and task-specific practice's importance is well-documented (Baker & Horton, 2004; Chase & Simon, 1973; Sigmundsson et al., 2017; Singer & Janelle, 1999). Further, expertise in sports is the outcome of a rigorous process that arises from interactions among various sport-specific constraints (Baker et al., 2003; Baker & Horton, 2004; Güllich, 2017; Phillips et al., 2010). According to Phillips et al. (2010), constraints in the context of expertise acquisition are perceived as the numerous variables that shape the developmental trajectory of each expert. The possibilities and restrictions in athlete opportunities are difficult to document precisely, but research has attempted to capture the road to sports expertise through conceptual frameworks for the last 50 years (Güllich, 2017; Starkes, 2000). Roughly, the two directions can be summarized as coach-led early specialization with extensive, deliberate practice (Ericsson, 2005; Ericsson et al., 1993) and later specialization (early diversification) with a more unstructured purposeful play approach (Côté et al., 2003, 2009). However, there is no consensus or conclusive evidence that one path leads to expertise (Güllich et al., 2020). Research on pathways to skiing expertise is scarce, except for some case studies in cross-country skiing with limited generalization value (i.e., Solli et al., 2017).

All experts start their career by entering their performance domain, and previous research on former expert athletes (Barth et al., 2022; De Bosscher et al., 2023; Güllich, 2007; Güllich et al., 2022; Vaeyens et al., 2009) has shown that there is a high degree of variation in starting and specialization age. Research on causes for this variation is limited. Still, both De Bosscher et al. (2023) and Güllich (2007) have emphasized that athletes have different starting ages due to sport-specific characteristics. Several reasons contribute to athletes' starting ages and specialization ages in various sports. These reasons include demographics, geography, sports culture, significant others, sports demands, athlete identification philosophy, and coaches' developmental understanding. Research has highlighted the importance of context-specific and sport-specific data in providing valuable guidelines for determining the appropriate ages for starting and specializing in sports (Côté et al., 2007; De Bosscher et al., 2023).

An early start in sports is likely not a prerequisite for achieving expert performance in adulthood, and previous research has demonstrated that age differences can be attributed to specific demands (see De Bosscher et al., 2023; Güllich, 2007 for a comprehensive overview). Expertise research from the last 50 years has concluded with one thing: it takes many hours of diligent and relevant training to reach the expert level.

Individual variations in accumulated hours of training are natural. Nevertheless, the 10,000 hours rule proposed by Chase & Simon (1973)C has gained much attention. It has been used as a guideline for expertise development in several domains (Ericsson et al., 1993). Aalberg et al. (2022) stated that there are minor differences in accumulated training hours between traditional skiing events, such as cross-country, versus new skiing events, like freeride and freestyle. Macnamara et al. (2016) proclaimed that while accumulated deliberate practice is a significant predictor, it cannot explain all the variations between successful and unsuccessful athletes.

The journey from being a young talent to becoming an expert in sports is long, so athletes must take ownership of their performance development. A high level of persistent motivation is essential for success (Singer & Orbach, 1999), and unfortunately, drop-out and burnout among athletes striving to reach the top are common (Baker et al., 2009; Myer et al., 2015). The need for varied stimulation in training can arise from changes in content and training organization (Baker et al., 2003). While there is no recipe for success, especially in individual sports such as cross-country skiing and freeskiing, a certain amount of self-organized training is necessary. Previous research has shown inconsistencies in how organizational activities correlate with success (Baker et al., 2003; Güllich, 2017; Macnamara et al., 2016). An interesting point of view on this matter is how participating in other sports besides the primary sport affects development purposes (Baker et al., 2003). Current research is divided mainly because confirming causality is difficult. Güllich (2017) proclaimed that expert athletes do not differ from lower-ranked performance athletes in the accumulated amounts of sport-specific youth practice/training. However, they do vary in having more experience and involvement in other sports; hence, not only do experts spend more time in practice, but they also devote more time to specific activities they see relevant to developing the essential component skills for performance (Baker et al., 2003; Deakin & Cobley, 2003).

Transfer of training between different contexts (especially between sports activities) is complicated; research has speculated on the transfer of perceptual-motor skills, physical conditioning, and psychological skills between related sports that share standard features (Güllich, 2017). When various other sports practice is considered concerning main sports practice, the dimensions of new stimulation, information, and recognition of relevant information for learning are essential features (Bransford et al., 2000). Athletes experiencing more diverse practice designs and different skill-learning approaches can have an advantage in performance development (Davids et al., 2012), and learning transfer from other sports to the main sport has been referred to as a potential preparation for future learning (Bransford & Schwartz, 1999; Güllich, 2017).

Cross-country skiing and freeskiing are sports with considerable differences in demands for physical, technical, and motor capabilities and environment constraints for training and competition. Thus, these two sports are particularly suited to investigate and compare roads to expertise because of their contextual differences in tasks (performance characteristics) and environment (milieu, rules, regulations, etc.). Cross-country skiing can be categorized as a highly organized sport that usually follows a traditional and specified training regime influenced by a prescriptive best practice with high coach involvement (Roaas et al., 2022). Freeskiing can be categorized as a self-organized sport with little coach-led practice or organized athlete developmental programs.

The purpose of the present study is to investigate similarities and differences in pathways to expertise for freeskiers and cross-country skiers. Specifically, the study intended to explore; 1) Entrance to main sport, 2) Training hours and organization of training (specificity and variability in training), and 3) Additional activities and content in training.

Methods

Participants

Two groups of world-class winter athletes voluntarily participated in the present study: 1) Freeskiers and 2) cross-country skiers. The selection criteria of both groups were that they had to be competing on the highest level in their sport, (e.g., world cup, world championship, Olympic games, freeride World Tour). The freeskiers had to represent the Freeride World Tour and the Norwegian or Swedish Ski Federation. The cross-country skiers had to represent the Norwegian Ski Federation and Swedish Ski Federation. The sample included a total of 18 participants. Eight freeskiers (three females and five males), with an age range between 19-37 years, and with a mean age of 27.5 years (± 7,1). Ten cross-country skiers (eight females and two males), with an age range between 22-32 years, and with a mean age of 27.5 years (± 3,4).

The participants were recruited by personal contact with information about the study and a question of whether they wanted to participate. Written consent was provided to the athletes with information about the procedures, including the voluntary nature of participation and the ability to withdraw from the study at any time without providing reasons or facing any consequences. The participants received a survey link to a digital questionnaire sent by e-mail. The questionnaire was adapted from previous research (see Helsen et al., 1998; Hodges et al., 2004; Hodges & Starkes, 1996) with a few additional questions and customized adjustments. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Norwegian Social Science Data Services (NSD) with reference number 502539.

Questionnaire

The present questionnaire was designed to collect retrospective data from international word-class freeskiers and cross-country skiers. The initial section of the questionnaire was designed to elicit biographical information about the athlete and age for entering sports and practice.

The second section of the questionnaire focused on sport-specific training. It was designed to obtain information about accumulated hours of training and the distribution of training hours between organized versus self-organized training. Organized training is defined as training and activities organized by a coach, while self-organized training and activities are defined as training without a coach. The third section of the questionnaire asked the athletes to recall all types of activities they have participated in, and how they perceive the relevance of the content of different types of training for their sport-specific development. This includes both organized and self-organized activities and training. These activities and training are classified into three categories: team sports, individual sports and artistic sports activities. In addition, self-organized activities were divided into two subcategories: individual practice and action sports.

Data analysis

Statistical analysis was performed using Microsoft Excel (version 15.40). Results (mean, percentage and standard deviation) were compiled and used to analyze differences between the two groups. An independent *t*-test was used to determine if the data were significantly different. Statistical significance was accepted at $p < 0.05$.

Results

Entrance to the main sport

Table 1 shows the age of entering the sport, the age of first organized training in the main sport, and the age of starting with systematic training in the main sport. No significant differences were found between freeskiers and cross-country skiers in these variables ($p > 0,05$).

Table 1
Descriptive statistics for biographic information of the athletes in freeskiing and cross-country skiing.

Group	Freeskiers/Freestylers (*N* = 8)		Cross-Country skiers (*N* = 10)	
	Range	Mean (*SD*)	Range	Mean (*SD*)
Age for first unorganized training in main sport	4-16	9.25 (4.7)	4-10	5.8 (2.0)
Age for first organized training in main sport	6-16	12 (4.3)	6-16	10.6 (3.5)
Start age for systematic training in main sport	13-16	15 (1.2)	12-16	14.6 (1.3)

Training hours and organization of training: Specificity and variability in training

Figure 1 reports the estimated total mean of accumulated training hours for both sports from the athletes was 7 years until the present time of the study. Freeskiers accumulated 12,162 hours of total training, while cross-country skiers accumulated 10,698 hours of training. No significant differences were found between the two sports (p > 0,05).

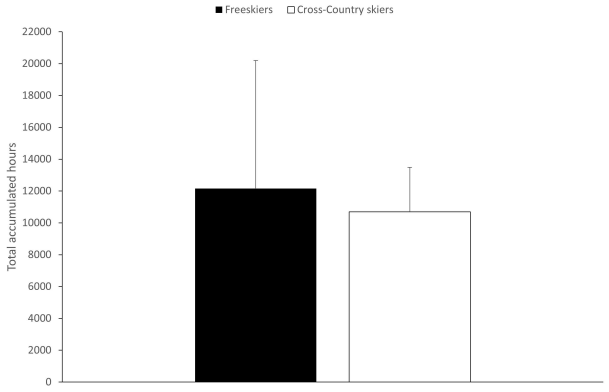

Figure 1 Total accumulated hours of training for freeskiers and cross-country skiers.

A more comprehensive way to analyze the training is to divide the accumulated training by organization, organized versus unorganized. Mean results of accumulated training for both sports and age spans are presented in Figure 2. No significant differences were found between the groups in the age span 7-15 years of age (p = >0.05). In the age span of 16+, there was a significant difference in the distribution of organized versus unorganized training between the two groups. Freeskiers spend 676 hours in other self-organized activities compared to 104 hours for the cross-country skiers (p = 0.007).

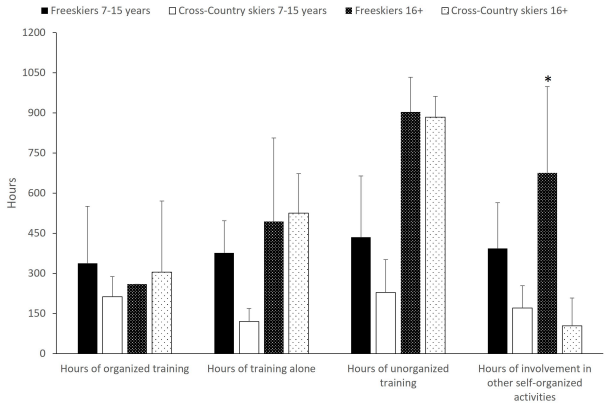

Figure 2 Total accumulated hours in organized and unorganized training.

* Indicates a significant difference between freeskiers and cross-country skiers. Freeskiers have a greater number of hours involved in self-organized activities after the age of 16 years (p = 0.007) compared to cross-country skiers.

Figure 3 shows the distribution of training hours in main sport versus other sports in the ages 7-15 years and 16+ years. In the age span 7-15 years athletes from both sports accumulated 63% of their total training in their main sport, and 37% were other sports. From the athletes who were 16+ years old, freeskiers accumulated 75% of the training in their main sport, while

25% in other sports. Cross-country skiers perceived as much as 98% of total accumulated training as sport specific to their main sport, while only 2% in other sports. The number of accumulated hours of sport-specific training in main sport was significantly higher for cross-country skiers compared to freeskiers (p = 0.009), and vice versa in the comparison in the amount of training in other sports (p = 0.009).

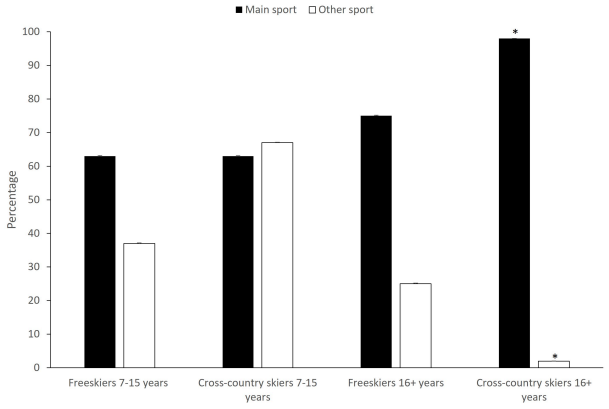

Figure 3 Distribution of training hours in main sport versus other sports in the age 7-15 years and 16+ years.

* Indicates a significant difference between freeskiers and cross-country skiers. Cross-country skiers accumulate significantly more training hours in the main sport (p = 0.009) and significantly lower amounts in other sports (p = 0.009) compared to freeskiers.

Additional sports activities and content in training

Mean result of total number of activities the athletes have been involved in for both age spans and the organization of these are presented in Figure 4 and Figure 5. Figure 4 shows how many activities the athletes have participated in and whether they perceive these activities as relevant or general for performance development in their main sport. Both freeskiers and cross-country skiers declined in the number of activities perceived as relevant from 7-15 years compared to 16+ years (see Figure 4). This is followed by an increase in participation in activities considered as general for their main sport from 16+ years.

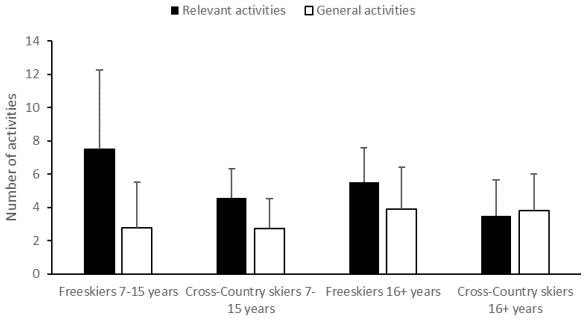

Figure 4 Number of activities considered relevant or general in the main sport.

Figure 5 shows the number of additional activities outside the main sport. There was no significant difference in involvement in the number of activities between freeskiers compared to cross-country skiers at any age. Participation increases for self-organized activities for freeskiers and cross-country skiers beyond 16+ years. While freeskiers participate in other organized activities in both age spans, cross-country skiers only participate in these activities between 7 and 15 years of age.

Figure 5 Number of additional activities outside the main sport.

Table 2 presents the specific additional activities that freeskiers and cross-country skiers have participated in. An equal number of freeskiing and cross-country skiing athletes have participated in organized sports such as football, handball and hockey. The most commonly performed individual activity for both freeskiers and cross-country skiers was cycling (including all

types of cycling). In addition, both groups of athletes reported participation in a wide range of other individual activities. Individual practice of strength training and balance training were commonly reported for both groups and as expected, freeskiers reported greater participation in action sports compared to cross-country skiers. Only a few athletes reported participation in artistic sports activities.

Table 2
Involvement in additional organized and self-organized activities.

Activity	# of Freeskiers	# of Cross-Country Skiers	Activity	# of Freeskiers	# of Cross-Country Skiers
Organized			Self- organized		
Team sports			**Individual practice**		
Football	3	3	Strength training	7	9
Handball	1	1	Balance training	7	5
Hockey	2	2	Tennis		1
Rugby	1				
Individual Sports			**Action sport**		
Athletics	5	3	Climbing		1
Swimming	2	3	Trampoline	1	
Cross country skiing	1		Skateboard	6	
Alpine skiing	6	2	Surfing	6	2
Cycling*	7	6	Water activities**	2	
Gymnastics	4	3			
Biathlon	1				
Cross country running	3	5			
Artistic Sport Activities					
Dance		1			
Ballet		1			

Discussion

An appropriate coherence between constraints over many years of training is essential for skill development and expert performance. In line with former research, the present study shows that domain specificity is evident (Chase & Simon, 1973; Sigmundsson et al., 2017), and that the pathway to expertise is multifaceted (Güllich, 2017; Phillips et al., 2010).

Previous research (Barth et al., 2022; De Bosscher et al., 2023; Güllich et al., 2022) has shown variation in starting and specialization age. However, the results indicate no significant difference between freeskiing and cross-country athletes when they enter the sports domain. Although several reasons can contribute, athletes in this study are part of similar national sports cultures, the same geographics and demographics that affect starting ages and specialization age, illustrated by athletes who began unorganized training before entering systematic training. The current results shows that athletes in both sports participated in numerous activities in addition to their main sport at an early

age, and based on that it is reasonable to assume that athletes probably have had a playful, unorganized entrance into sports. Between the ages of 7 and 15 years, athletes in both sports accumulated 63% of their total training in their main sport and 37% in other sports. The systematic specialization started for freeskiers at 15 years of age and for cross-country skiers at 14.6 years of age, this result is in line with former research on specialization (De Bosscher et al., 2023; Güllich et al., 2022). Based on data from this study, the need for specialized training at a young age to become an adult expert is not supported. These findings are in line with the results of other studies (Baker et al., 2003; Berry et al., 2008; Coutinho et al., 2016; Güllich, 2007; Güllich et al., 2022), which suggest that sampling different sports during the early years can provide a solid foundation for expert development.

It takes a long time to progress from being a youthful talent to becoming an expert in sports, and similar to former research, this study demonstrated that expert athletes have accumulated extensive hours of training (Chase & Simon, 1973; Ericsson et al., 1993; Güllich, 2007). There were minor differences in accumulated training hours between freeskiers (average 12,162 hours) and cross-country skiers (average of 10,698 hours). Variation in accumulated training for attaining expertise has been shown in other studies (Helsen et al., 1998; Hodges & Starkes, 1996; Tucker & Collins, 2012), indicating that rigid thoughts about training quantity should fade, especially training quantity demands for young athletes. Quality of training (training content and performance execution) is probably more significant for development, but previous research has shown inconsistencies in how the organization of activities correlates with success (Baker, 2003; Güllich, 2017; Macnamara et al., 2016). With increase in athletes age, specialization and autonomy in training organization become apparent. In our study, athletes after the age of 16 differed prominently in activity content. Cross-country skiers accumulated 98% of their activity in the main sport, whereas freeskiers accumulated 75%. It is likely believed that during the off-season, freeskiers engage in a wider variety of training activities; this could be linked to the necessity of varied stimulation through changes in content and training organization (Baker et al., 2003). At the same time, cross-country athletes continue to perform activities in the main sport (i.e., roller skiing). This is accentuated by time spent in training categorized as organized (coach-led) or self-organized (athlete-led); no significant difference was found between the groups aged 7-15. However, after age of 16, there was a significant difference in the distribution of organized versus self-organized training between the two groups. Freeskiers spend 676 hours yearly in self-organized activities compared to only 104 hours for cross-country skiers.

The present results indicate different approaches to performance development. It is a difference in how freeskiers versus cross-country skiers organize their training, and an interesting point of view on this matter is how participating in other sports relevant to primary sports intervenes (Baker et al., 2003). The results from this study demonstrate that as the athletes get older, the total number of activities considered as highly relevant for main sport decreases; the number of general activities increases from 7-15 years compared to 16+ years. This may indicate that the athletes focus more on specificity in training content; however, the expert athletes seemingly enjoy movement and participation in various activities. Nevertheless, they do not consider these activities as highly relevant for their main sport, especially when the athletes get older and the demands for training specificity increase. The present findings align with Güllich (2017), who proclaimed that expert athletes have more experience and involvement in other sports they see as relevant for development and enjoyment at a young age.

Unlocking the secrets behind the transfer of training is complex and difficult to prove objectively (Oppici & Panchuk, 2022). The present findings show that freeskiers participate in several activities that require high levels of balance, risk-taking, and knowledge about the terrain or environment, as needed in their main sport. Regarding perceived transfer, two highly

rated activities by freeskiers were alpine skiing and cycling (including mountain biking). Both sports share many similarities as freeskiing. For instance, all three sports are high-speed technical events where the athletes must anticipate the terrain. These findings could be linked to the positive transfer of perceptual-motor skills, physical conditioning, and psychological skills, as proclaimed by Güllich (2017). Athletes need different stimulation and information (Bransford et al., 2000), yet relevant; this could be found in high training variability that adapts their repertoire of motor strategies, fitting the situation and environment in which they practice and perform. Additionally, several sports require many of the same physical characteristics. The link to alpine skiing is most evident for freeskiers, where inspiration about training from a scientific point of view could be found (i.e., Gilgien et al., 2018). Activities such as strength and balance training, action sports activities such as skateboarding and surfing, were commonly reported by freeskiers as being relevant and used for performance development.

The more traditional sport, cross-country skiing, has extensive research on what kind of training affects performance development the most (Moen et al., 2016; Sandbakk & Holmberg, 2017; Stöggl et al., 2010, 2018). In our study, cross-country ski experts rated cycling and cross-country running as the most used and relevant sports. Superficial evaluation of demands in these activities compared to cross-country skiing tells us that participation in these cyclical endurance activities, which require high levels of VO_2-max and low-intensity training, similar to cross-country skiing, could be positive regarding endurance capacity. The cross-country skiers rated strength and balance training highly, and the findings indicate that expert athletes' additional activities have similar features or physical capacities. Both freeskiers and cross-country skiers, intentionally or unintentionally, choose to add training activities that contain some specificity related to their main sport.

Practical implications

What characterizes expert performers is that they have done the right thing on their path to excellence; addressing what other athletes should be doing to achieve the same outcome is probably futile. However, in the process of becoming as good as possible, athletes and coaches should work open-minded in order to cope with variations between sports and individual constraints. Hence, a multi-disciplinary approach to content, stimulation, and organization is necessary in order to optimize ski training. Instead of saying, "This is what we have always done", perhaps the more playful self-organized entrance and mindset could generate new resources into development, prolonged into adulthood, yet with an unmistakable thought of what the training gives you (i.e., specificity). Athletes, coaches and researchers would benefit from discussing the content and execution of training more critically regarding variations between sports and individual constraints. Training in different environmental conditions with a broader spectrum of practice design may benefit future performance development.

Limitations and future studies

Research on expert performance will always be limited by uncertainty, and the current retrospective survey has limitations. Methodologically, the research is based on a retrospective questionnaire involving limitations of athletes' accuracy in recalling past information about their organization and content in training from seven years of age until adulthood. Furthermore, it is difficult to establish a large sample sizes with statistically solid power with only world-class athletes. This is based on the fact that the inclusion criteria are restricted to top-ranked elite-level performers, the total sample size has to be relatively modest. Reflections concerning theoretical issues are essential in every scientific approach. Because many frameworks (see introduction) are somewhat conceptual, it is easy to find similarities and differences from current propositions. However, the aim of this study was not to test conceptual theoretical frameworks, and there are no

clear indications from our study to confirm former academic content. Yet, there are striking resemblances with some former theoretical findings. We propose that future expertise studies could benefit from longitudinal research designs underpinned by a solid connection to its key stakeholders that consider the microstructure of practice content, environmental constraints and individual differences to nuance the development of sports expertise in freeskiing and cross-country skiing. Our study indicates that practitioners within each discipline should be more patient on defining the road to expertise. The future of skiing is uncertain. As a result, focusing on specific and individual aspects or conditions may be advantageous in meeting varying future demands and provide more understanding within each discipline.

Conclusion

The present study investigated similarities and differences in pathways to expertise for freeskiers and cross-country skiers. In conclusion, freeskiers and cross-country skiers share similarities regarding the age of entrance to their main sport (and specialization age) and total accumulated hours of training. However, the two groups differed in training organization; whereas freeskiers have more self-organized training hours, cross-country skiers spend more training hours in their main sport. Freeskiers has longer and greater participation in additional sport activities. Both groups accentuate specificity in training content and harvest from perceived transferable content in different activities, i.e., freeskiers from action sports and cross-country skiers from endurance activities.

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Data availability statement

All relevant data are within the paper.