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Perceptions of experts on key injury risk factors in alpine ski racing as a function of stakeholder role and associated level of competition

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ABSTRACT

Objectives (1) To update experts' priorities of perceived key injury risk factors in alpine ski racing based on a framework and list derived 10 years ago, (2) to identify additionally emerging risk factors since then and (3) to compile a list with countermeasure suggestions.

Methods A sample of 532 expert stakeholders (athletes, coaches, team medical staff, Ski Racing Suppliers (SRS) and International Ski Federation (FIS) representatives) from the World Cup (WC), European Cup (EC) and FIS-race level participated in a cross-sectional online survey. Experts were asked to name those risk factors with the highest believed impact on injury risk and rank them according to their current priority from a predefined list. In addition, experts were encouraged to name additional (not listed) risk factors and to suggest countermeasures.

Results Regardless of stakeholder role and competition level, snow-related factors appeared to have the highest perceived priority. However, WC athletes' and coaches' perceptions were also related to equipment, while at the EC and FIS-race level fatigue and physical fitness-related factors were considered important. Athletes' perceptions were largely in agreement with SRS (ie, snow-related and equipment-related factors). At the same time, while coaches, team medical staff and FIS representatives additionally emphasised fatigue and physical fitness-related factors.

Conclusion Experts' perceptions on key injury risk factors in alpine ski racing depend on the stakeholder role and differ between the competition levels. Thus, to develop effective prevention measures and to successfully implement them, all relevant stakeholders should be given a voice, and prevention efforts should be targeted to the specific level.

Key messages

What is already known?

- Severe injuries in World Cup (WC) alpine ski racing are frequent and can have various causes.
- Knowing and understanding the perceptions of expert stakeholders is crucial for deriving and implementing successful prevention measures, and giving them a voice may help achieve better countermeasures during the implementation stages.
- At the WC level, the five main risk factor categories perceived by the experts are: the system ski, binding, plate and boot; changing snow conditions; physical aspects of the athletes; speed and course setting aspects and speed in general. However, the last expert survey was conducted 10 years ago and knowledge about the perceptions of experts competing/working at lower levels than WC is lacking entirely.

What are the new findings?

- Experts' perceptions on key injury risk factors in alpine ski racing depend on the stakeholder role and differ between the competition levels (WC, European Cup (EC), International Ski Federation (FIS)-race), which underlines that all relevant stakeholders should be given a voice for successful prevention efforts, and prevention should be targeted at the specific competition level.
- Regardless of stakeholder role and competition level snow-related factors seem to have the highest priority among all risk factors explored. In addition to snow-related factors, WC athletes' and coaches' perceptions related to equipment, while at the EC and FIS-race level fatigue and physical fitness-related factors were considered important.
- Athletes, Ski Racing Suppliers (SRS) representatives and FIS representatives additionally emphasised equipment-related factors. In contrast, coaches, team medical staff and FIS representatives additionally perceived fatigue and physical fitness-related factors as key drivers for injuries.
- The comprehensive list of perceived risk factors and suggested countermeasures provided as online supplemental file 2 may equally serve both researchers and practitioners as source of inspiration for their prevention efforts.

INTRODUCTION

Despite a decade of extensive research and prevention efforts, the risk of injuries in elite alpine ski racing is still high.[1–3] According to a recent study, the risk of suffering at least one injury during an entire season is as high as 95%, which corresponds to an absolute injury rate of 184.1 injuries per 100 athletes per season.[2] This is particularly striking

since approximately one-third of all injuries are severe (>28 days of absence in training and competition).[2] Thus, injuries, especially severe ones, are obvious in alpine ski racing and preventative action is required.

Consequently, the International Ski Federation (FIS) has recently launched a long-term project: the 'FIS Injury Surveillance and Prevention Programme' (ISPP) to prevent and reduce the number of injuries.[4] Under FIS ISPP, a group of experts, the 'Alpine Injury Prevention Working Group' works to identify the most important injury hot-spots through methodical injury surveillance and evaluation to propose effective solutions and projects for implementation. As a foundation for prioritising the work agenda and to give voice to all relevant stakeholders, the current study was designed to hear and understand alpine ski racing stakeholders' perceptions on key injury risk factors and potential countermeasures.

A similar process was already initiated by FIS 10 years ago with a qualitative interview study involving expert stakeholders from the World Cup (WC) alpine ski racing community, which explored perceived risk factor categories and ranked them according to their impact on injury risk.[5] In total, 32 risk factor categories within the basic categories athlete, course, equipment and snow were derived from this qualitative study approach. They were subsequently ranked regarding their perceived impact on injury risk.[5] However, our knowledge of effective injury prevention has increased significantly in certain areas over the past decade (eg, course setting).[6–11] In other areas, there have been further developments and adaptations to new competition rules (eg, equipment), which may even have recently undermined the rules and led to changes in specific risk factors and injury patterns.[1 12] Accordingly, it is likely that experts' perceptions have also altered or even that new perceived risk factor categories may have emerged. Thus, there is a renewed need for an updated assessment of corresponding expert perceptions.

In this context, an important yet absent perspective are stakeholder role and competition level-dependent differences in experts' perceptions on risk factor categories, especially for younger athletes competing on the European Cup (EC) or FIS-race levels. To date, most research in alpine ski racing focused on the protection of WC athletes[13]; however, severe injuries are relatively frequent among younger athletes as well.[14–16] Accordingly, knowing and understanding the perceptions of expert stakeholders competing/working on levels lower than WC is crucial for deriving and implementing successful, specifically tailored prevention measures. Moreover, giving all relevant stakeholders a voice may help achieve better countermeasures during the implementation stages.[17]

Based on these considerations, the aims of the current study were: (1) to update experts' priorities of perceived key injury risk factor categories in alpine ski racing based on a framework derived 10 years ago; (2) to assess potential priority differences among expert subgroups in dependency of their stakeholder roles the level of competition at which they operate; (3) to identify additional emerging risk factors and (4) to compile a list with countermeasure suggestions for all risk factors reported.

Table 1 Participants' roles in alpine ski racing

Expert stakeholder group	Level/professional background
Athletes (n=298, male ASR: n=154; female ASR: n=144)	WC level athlete (n=115) EC level athlete (n=75) FIS-race level athlete (n=108)
Coaches (n=130, male ASR: n=84; female ASR: n=46)	WC level coach (n=62) EC level coach (n=31) FIS-race level coach (n=37)
TMS (n=59)	Doctor (n=21) Physiotherapist (n=36) Other (n=2)
SRS representatives (n=33)	Service men (n=9) R&D and management (n=18) Other (=6)
FIS representatives (n=12)	FIS staff for alpine competitions (n=3) Committee member (n=5) Other (n=4)

ASR, Alpine Ski Racing; EC, European Cup; FIS, International Ski Federation; FIS-race, FIS race; R&D, Research and Development; SRS, Ski Racing Supplier; TMS, team medical staff; WC, World Cup.

METHODS

Study design, setting and participants

During the off-snow season preparation period, in June 2020, an online questionnaire was sent to Alpine Sports Directors of all National Ski Associations (NSAs), FIS (ie, the FIS technical expert alpine; Atle Skaardal) and Ski Racing Suppliers (SRS) representatives (ie, the Ski Racing Supplier Association General Manager; Rudi Huber) and subsequently spread by them among the WC, EC and FIS-race level alpine ski racing communities. A reminder was sent after 4 weeks and the questionnaire closed 2 months later. Participation in this cross-sectional survey was voluntary. Inclusion criteria were: alpine ski racing athletes and coaches related to a specific FIS competition level (WC, EC, FIS-race), team medical staff, SRS representatives and FIS representatives. A total of 542 questionnaires was returned. Questionnaires were excluded if the baseline entries concerning stakeholder group and the specific level (relevant for athletes and coaches only) were not fully completed (n=10). The final analysis included 532 questionnaires completed by experts from 28 countries (table 1). Experts' perceptions were assessed and stored in encrypted form, and no health-related data were collected.

Data collection methodology

Data were collected and managed using the *REDCap* electronic data capture tool.[18 19] The questions of the online

Table 2 Framework of perceived risk factor categories within the basic categories athlete, course, equipment and snow (in alphabetic order respectively), as derived from qualitative expert stakeholder interviews 10 years ago by Spörri *et al*[5]

Athlete	Course
Aspects of body temperature	Bad visibility
Athlete's adaptability	Course maintenance during race
Athlete's crash behaviour	Course setting in general
Athlete's individual responsibility	Jumps
Athlete's race preparation	Level of course difficulty
Fatigue	Safety net position and spill zone
Genetics and Anthropometry	Speed and course setting aspects
Physical aspects	Speed and topographic aspects
Psychological aspects	Speed in general
Preinjury aspects	Topography in general
Skiing technique and tactics	
Equipment	**Snow**
Binding/plate	Aggressive snow conditions
Gates (panels and poles)	Changing snow conditions
Protectors and helmets	Smooth snow surface
Racing suits	Techniques of snow preparation
Ski	
Ski boot	
System ski, plate, binding, boot	

survey were posed in English, and the questionnaire was divided into five sections: (1) introduction including information on the study background and purpose; (2) completion of the personal information on the year of birth, nation, gender-focus, competition level for athletes and coaches (WC, EC, FIS-race) and stakeholder role (athlete, coach, team medical staff, SRS representative or FIS representative), and professional background for team medical staff, SRS and FIS representatives; (3) rating of the personal top 1–5 injury risk factor categories according to their perceived impact on injury risk based on the framework and predefined list with the 32 risk factor categories derived from the 2010 qualitative interview study (table 2)[5]; (4) the naming of additional risk factors (ARF) originally not reflected within one of the 32 risk factor categories (maximum of five, no minimum) and (5) the collection of countermeasures for the risk factor categories in part 3 and risk factors in part 4 of the questionnaire. The detailed questionnaire is provided as an online supplemental file 1.

Data analysis

Risk factor rating

The participants named between 1 and 5 perceived risk factor categories regarding their potential impact on injury risk. Overall, an average of 4.92 categories per participant was mentioned. 96.6% of the participants named five risk factors, 0.8% four risk factors, 1.5% three risk factors, 0.9% two risk factors and 0.2% one risk factor. In the analysis, and in accordance with Spörri *et al*[5] a rank number was given to every top 1–5 risk factor categories mentioned, with ranking number '1' given to the risk factor category with the highest impact. The average ranking number was then calculated for each risk factor category, depending on the stakeholders' priority assigned. A lower average ranking number can be interpreted as a higher potential impact on the category. The frequency of how often the risk factor was mentioned in the expert stakeholders' personal top five was reported along with this average ranking number. Then, a rank order for the frequency of mention and rank order of the assigned average ranking number was created. Finally, based on these two rank orders, an overall ranking list of risk factor categories was defined. Such risk factor rating (RFR) analysis was conducted (1) for the overall group of participants, as well as (2) for the five stakeholder subgroups and (3) for the different competition levels (only athletes and coaches considered). In the case of fewer than six mentions in the overall RFR, the risk factor category was not presented in the ranking, assuming it is not representative.

Additional risk factors

In a second part of the online survey, expert stakeholders were asked to identify all risk factors that they perceived as relevant but did not fit into one of the 32 risk factor categories derived from the 2010 qualitative interview study by Spörri *et al*.[5] As the priority rating of such ARF was, due to methodological considerations, not mergeable with those of the given 32 risk factor suggestions (rated by all vs only rated by some expert stakeholders), participants were asked to classify their potential impact on injury risk with an independent priority ranking scale as (1) *minor*, (2) *moderate* or (3) *high importance*.

Suggested countermeasures

In the final part of the survey, experts were allowed to suggest prevention measures for all risk factors mentioned in the RFR or ARF parts. If several suggestions had the same intention they were fused to one corresponding countermeasure category.

Participant and public involvement

Participants were recruited by the involvement of corresponding sports bodies (NSAs, SRS and the FIS). Overall findings were disseminated to all relevant expert stakeholder groups, FIS committees and working groups through internal research reports.

RESULTS

Risk factor rating

The stakeholders' overall perspective on key injury risk factor category priorities is presented in table 3. In total, the top five risk factor categories were 'changing snow conditions', 'system, ski, plate, binding, boot', 'fatigue', 'course maintenance during the race', as well as 'physical

Table 3 Risk factor rating (RFR): that is, stakeholders' priorities of perceived key injury risk factor categories regarding their potential impact on injury risk, for the overall group

Perceived priority	Key injury risk factor category	Mentions in RFR	Rank	Mean rank RFR	Rank	∑Rank points
1	Changing snow conditions	322	1	2.53	1	2
2	System ski, plate, binding, boot	193	4	2.80	3	7
3	Fatigue	225	2	2.85	6	8
4	Course maintenance during race	128	7	2.79	2	9
5	Physical aspects	176	5	2.92	10	15
5	Aggressive snow conditions	127	8	2.87	7	15
5	Bad visibility	194	3	2.99	12	15
8	Smooth snow surface	82	12	2.80	4	16
9	Techniques of snow preparation	129	6	3.08	15	21
10	Athlete's race preparation	64	15	2.88	8	23
10	Athletes' crash behaviour	67	14	2.90	9	23
12	Speed and course setting aspects	83	11	3.08	16	27
13	Skiing technique and tactics	123	9	3.13	19	28
14	Course setting in general	70	13	3.09	17	30
14	Athletes' individual responsibility	48	19	2.94	11	30
16	Psychological aspects	85	10	3.24	21	31
16	Protectors and helmets	24	26	2.83	5	31
18	Binding/plate	29	24	3.03	14	38
19	Ski	35	23	3.09	17	40
19	Athletes' adaptability	60	17	3.27	23	40
21	Preinjury aspects	61	16	3.36	25	41
22	Racing suits	13	30	3.00	13	43
22	Speed and topographic aspects	42	21	3.26	22	43
24	Jumps	53	18	3.74	30	48
24	Level of course difficulty	45	20	3.60	28	48
26	Genetics and anthropometry	37	22	3.49	27	49
27	Speed in general	29	24	3.48	26	50
28	Gates (panels and poles)	20	28	3.30	24	52
29	Safety net position and spill zone	22	27	3.95	31	58
30	Topography in general	7	31	3.71	29	60
31	Aspects of body temperature	19	29	4.05	32	61
	Ski boot	≤6		3.17		

aspects' of the athletes, 'aggressive snow conditions' and 'bad visibility' equally on the fifth place.

Table 4 highlights the expert stakeholders' category priorities in dependency of the competition level. Expert stakeholders' risk factor perceptions from all three competition levels (WC, EC and FIS-race) concerned 'changing snow conditions' to be highly important. Additionally, WC athletes and coaches prioritised equipment-related risk factors, while the focus of EC and FIS-race athletes and coaches was more on 'fatigue' and 'physical aspects'.

Table 5 summarises the perceived category priorities of the expert stakeholders in dependency of their stakeholder role within the alpine ski racing community based on the sum of rank points. All stakeholder groups expressed a perceived priority for snow-related factors. Athletes, SRS representatives and FIS representatives additionally emphasised equipment-related factors. In contrast, coaches, team medical staff and FIS representatives also perceived fatigue and physical fitness-related factors as key drivers for injuries. FIS representatives only prioritised speed and course-setting related aspects.

Additional risk factors

Sixty-five suggestions were given and these suggestions were summarised into nine ARF, which were not part of the original list derived from the 2010 qualitative

Table 4 Risk factor rating (RFR), that is, stakeholders' top three priorities of perceived key injury risk factor categories regarding their potential impact on injury risk per level in dependency of the competition level

Perceived priority	Key injury risk factor category	Mentions in RFR	Rank	Mean rank RFR	Rank	∑Rank points
WC level						
1	Changing snow conditions	122	1	2.30	2	3
2	System ski, plate, binding, boot	71	2	2.71	5	7
3	Aggressive snow conditions	51	6	2.66	4	10
EC level						
1	Fatigue	59	1	2.43	1	2
2	Changing snow conditions	59	1	2.51	2	3
3	Physical aspects	35	5	2.76	6	11
3	Bad visibility	44	3	2.88	8	11
FIS-race level						
1	Changing snow conditions	83	1	2.58	5	6
2	Physical aspects	51	4	2.53	3	7
3	Course maintenance during race	41	6	2.57	4	10

EC, European Cup; FIS-race, International Ski Federation (FIS) race; WC, World Cup.

interview study by Spörri *et al*.[5] These were: 'environmental influences'; 'forced jury decisions'; 'lacking athlete-/stakeholder voice'; 'level differences'; 'medication'; 'parallel events'; 'race organisation'; 'warm-up slopes' and 'ski edge tuning'. 'Ski edge tuning' for the injury risk factor category 'ski' was suggested with the justification that skis are prepared by factories in the WC competition, in contrast to the EC and FIS-race level competitions where athletes are using edge machines to sharpen the skis leading to a too aggressive setup. Notably, 'forced jury decisions' were suggested to substantiate that races should be cancelled when certain weather conditions are met and that athletes should be FIS priority, in contrast to, for example, television broadcast.

Suggested countermeasures

The suggested countermeasures for all risk factors mentioned in the RFR or ARF parts are presented in an online supplemental file 1. The top five risk factor categories that received the most prevention suggestions were 'fatigue'; 'changing snow conditions'; 'physical aspects'; 'ski, plate, binding, boot' and 'bad visibility'. For 'fatigue' most countermeasure suggestions included recommendations for adjusting the organisation and competition schedule. Experts stated that the race schedule is too busy and does not allow for enough rest. Especially allrounders, who participate in more than one discipline, have an overscheduled competition calendar. It was suggested to avoid 'changing snow conditions' by providing the same snow conditions throughout the course (ie, using the same snow preparation techniques, such as water injection, from top to bottom) to help athletes to find an appropriate equipment setup. To avoid injuries resulting from the risk factor category 'physical aspects', injury screenings and a certain minimum physical condition have been suggested, especially for younger athletes. For the risk factor category 'ski, plate, binding, boot', a large group of stakeholders suggested a less aggressive setup. Finally, regarding the risk factor category 'bad visibility', stakeholders stated that the races should be cancelled if the visibility is too bad, and blue dye should be used more often.

DISCUSSION

Expert stakeholders' perceptions on injury risk factor categories differ between the WC, EC and FIS-race level

Regardless of competition level affiliation, snow-related factors were perceived to have the highest priority among all risk factors explored. In addition to snow-related factors, WC athletes' and coaches' perceptions related to equipment, while at the EC and FIS-race level fatigue and physical fitness-related factors were considered important. To date, there is no research on competition level-dependent stakeholder perception on injury risk factors in alpine ski racing. Nevertheless, snow-related factors are a recurring theme throughout the skiing community, given that alpine ski racing has to deal with a changing and uncontrollable outdoor environment.[5] Moreover, at the top level, that is, WC alpine ski racing, it is entirely plausible that equipment and its setup play a key role in performance enhancement and sportive success, which is why corresponding limits are constantly being explored. This also applies to finding the optimal aggressiveness in the ski-snow interaction, characterised by direct force transmission (beneficial for performance) and difficulty getting the ski off its edge once the ski is carving (injury-promoting).[20] In contrast, it is understandable that on lower levels, for example, FIS-race level, physical aspects are perceived by expert

Table 5 Risk factor rating (RFR), that is, stakeholders' priorities of perceived key injury risk factor categories regarding their potential impact on injury risk in dependency of their role within the alpine ski racing community

Perceived priority	Key injury risk factor category	Mentions in RFR	Rank	Mean rank RFR	Rank	∑Rank points
Athletes						
1	Changing snow conditions	181	1	2.60	2	3
2	Course maintenance during race	82	6	2.56	1	7
3	System ski, plate, binding, boot	97	4	2.69	4	8
3	Bad visibility	134	2	2.81	6	8
Coaches						
1	Changing snow conditions	83	1	2.29	2	3
2	Fatigue	57	2	2.77	7	9
3	Aggressive snow conditions	39	6	2.69	5	11
TMS						
1	Fatigue	30	1	2.67	7	8
2	Physical aspects	24	3	2.54	6	9
3	Changing snow conditions	28	2	2.79	10	12
SRS representatives						
1	Changing snow conditions	22	1	2.18	5	6
2	System ski, plate, binding, boot	17	2	2.88	12	14
2	Techniques of snow preparation	15	3	2.80	11	14
FIS representatives						
1	Athletes' individual responsibility	4	3	1.50	4	7
2	System ski, plate, binding, boot	3	5	1.33	3	8
3	Athlete's race preparation	3	5	2.67	9	14
3	Fatigue	3	5	2.67	9	14
3	Speed and course setting aspects	4	3	3.00	11	14
3	Smooth snow surface	2	10	1.50	4	14

FIS, International Ski Federation; SRS, Ski Racing Supplier; TMS, team medical staff.

stakeholders as of higher importance for the causation of injury, compared with the WC level. As WC athletes are professionals, they train more targeted than EC and FIS-race athletes, making it likely that deficits in physical aspects play a greater role for EC and FIS-race athletes. In addition, EC and FIS racers often compete within race series of different levels and therefore complete a higher number of events than WC athletes, who mainly compete in the highest level events. This may have a significant impact on overall fatigue.

Expert stakeholders' perceptions on injury risk factor categories depend on their roles

Comparable to the level-specific ranking, all stakeholder groups prioritised snow-related factors. Athletes, SRS representatives and FIS representatives additionally emphasised equipment-related factors. Contrastingly, coaches, team medical staff and FIS representatives additionally perceived fatigue and physical fitness-related factors as key drivers for injuries. This may reflect the interests, different backgrounds and areas of expertise among different stakeholder groups. It is important to be aware that when interviewing expert perceptions, but ultimately also when implementing injury prevention measures, the understandings and attitudes of individual stakeholders may vary and that knowledge of such contextual factors is crucial to effective prevention.[21] Therefore, it is essential to involve all relevant stakeholders to develop a comprehensive and total picture of health protection for athletes.

Potential change of perception over the last decade

Compared with our previous study with qualitative interviews collected in 2010,[5] it appears that expert stakeholders' perceptions on key injury risk factor categories have changed over the past decade. A direct comparison, however, was not possible due to the different data collection methods and a more diversified target group (including the EC and FIS-race levels). While 'changing snow conditions', 'system ski, plate, binding, boot' and 'physical aspects' seem to have an unchanged high perceived priority, it looks like the risk factors 'fatigue' and 'course maintenance during the race' have increased in perceived priority. In contrast, it seems that 'course

setting' and 'speed' have lost attention within the alpine ski racing community. In addition, ARF have emerged, such as 'environmental influences'; 'forced jury decisions'; 'lacking athlete-/stakeholder voice'; 'level differences'; 'medication'; 'parallel events'; 'race organisation'; 'warm-up slopes' and 'ski edge tuning'.

Prevention measure suggestions

A scientifically and practically very useful outcome of the current study is the systematic compilation of potential prevention measures suggested by the expert stakeholders. In this regard, the risk factor categories 'fatigue'; 'changing snow conditions'; 'physical aspects'; 'ski, plate, binding, boot' and 'bad visibility' received the most attention in terms of countermeasure suggestions. For 'fatigue' most countermeasure suggestions pointed in the direction of race schedule and organisation adaptations. It is plausible that injuries are more likely to happen when athletes are fatigued (either within race,[22] or over the season[5]). 'Changing snow conditions' were considered avoidable by providing the same snow conditions from top to bottom. This is fully in line with our previous investigation from 2010.[5] Especially when conditions change during a run, snow conditions challenge the athletes and SRS representatives to choose and adapt their equipment setup and technique. Regarding 'physical aspects', injury screenings and certain minimum criteria for physical fitness have been suggested. Physical aspects are indeed known to be a key driver for injury risk in alpine ski racing.[23–29] Moreover, also in many sports other than alpine ski racing, the benefits of physical fitness-related injury prevention programmes have been demonstrated.[30–32] Concerning the 'ski, plate, binding, boot' category, several stakeholders suggested a less aggressive setup as one of the most promising approaches. Thus, in alpine ski racing, this remains one of the greatest prevention challenges to be addressed.[5 33] Regarding 'bad visibility', particularly measures related to appropriate jury decisions and race cancellations despite external pressures have been suggested. Poor visibility is a known relevant key component of events leading to ACL injuries in alpine ski racing.[34] The proposed measures certainly seem plausible, although difficult to optimise given the high level of professionalism in the sport at the WC level.

Study limitations

There are some limitations one should be aware of when interpreting the study findings. First, the methodological approach taken does not allow or claim to verify whether the perceived injury risk factors are 'true' risk factors. For this purpose, further aetiological studies are needed to confirm their status as being injury risk factors. Second, to obtain as integrated a picture as possible, experts from different stakeholder groups were involved in this study; however, sample sizes of the different expert stakeholder groups are not equally distributed. Accordingly, major emphasis has been laid on the analysis and interpretations of the subgroup-specific (ie, level-dependent and role-dependent) results, which can be considered being highly representative for the corresponding stakeholder subgroups. At the same time, the overall rankings must be interpreted with caution. Third, as the alpine ski racing community is a close-knit group of stakeholders that travels around the world together, there is some risk that they will answer questions similarly or in a way that they believe will be accepted and liked by their peers (social desirability bias).

CONCLUSION

This study demonstrated that expert stakeholders' perceptions on key injury risk factor categories in alpine ski racing depend on their role and differ between the competition levels (WC, EC, FIS-race). Generally, snow-related factors were prioritised by stakeholders. In addition, WC stakeholders, athletes and SRS representatives highlighted equipment-related injury risk factor categories, while EC and FIS-race level stakeholders, coaches, team medical staff and FIS representatives prioritised fatigue and physical fitness-related injury risk factor categories. Thus, to develop effective prevention measures and to successfully implement them, all relevant stakeholders should be given a voice, and prevention efforts should be targeted to the specific level.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

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Data availability statement All data relevant to the study are included in the article or uploaded as supplemental information. Additional data from the digital database of the "Risk Factor Rating", "Additional Risk Factors" and "Countermeasure Suggestions" parts of this study is presented in the online supplemental file 2.

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