

FIS INJURY SURVEILLANCE SYSTEM:



Research Report by University of Salzburg

A Qualitative Approach to Determine Key Injury Risk Factors in Alpine Ski Racing

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Abstract

In the high risk arena of the alpine World Cup ski racing, injuries are not uncommon, yet research exploring injury mechanisms is very limited. Several recent changes to equipment, course setting, snow conditions and rules have added to the complexity making it difficult to determine the key injury risk factors. The University of Salzburg research team has been mandated by the International Ski Federation to identify key risk factors and suggest a possible process of how to deal with those key risk factors. The current project utilized a qualitative research process, interviewing interest groups from the World Cup, to determine and to rank key injury risk factors that will be used to form the basis of future quantitative research and regimentation strategies.

Looking to the basic categories, SNOW, COURSE, EQUIPMENT and ATHLETE, no concrete priority concerning the risk factor can be named. But looking into several subcategories within the basic categories, a ranking of risk factors based on their potential impact on injury risk is possible. The high loading key risk factors are `System ski, binding, plate, boot (=Equipment)`, `Changing snow condition`, `Physical Aspects of the athlete`, `Speed and course setting aspects` and `Fatigue (World Cup schedule)`.

To identify and rank potential key risk factors is just one purpose of the study. Additionally, the enormous amount of information from the experts were collected and structured in form of a database. This database actually contains 1723 statements within 292 subcategories. The power of the current study is enhanced due to the fact that the content of this database will serve as an objective discussion basis for the next steps concerning injury prevention. The focus of the further process of injury prevention should be on the highest loading key risk factors as they seem to have the most potential impact. This does not mean that lower loading risk factors do not have an influence on injury prevention. Hence they should not be neglected, if their impact can be reduced easily.

Possible strategies for the key risk factors are served in the conclusion section of the current paper. A central process strategy should be the cooperative work of the responsible interest groups, FIS and the research partners in the context of evidence based regimentation changes. Therefore, the current paper should deliver an objective base.

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Introduction

Over the past decade there have been significant changes to many aspects of World Cup racing with the introduction of carving skis and water injected slopes being two of the most prominent. In an effort to create slopes that do not deteriorate as quickly as natural snow conditions, the racing hills have been injected or sprayed with water creating extremely hard durable surfaces. The introduction and subsequent refinement of side cut in ski construction has allowed ski racers to carve a line in the snow and retain speed whereas before, they primarily slid and lost speed (Sahashi & Ichino, 2001). Ski companies have been refining the equipment in an attempt to match the ski surface and ability of the athletes to turn. Some refinements include: increasing the standing height of the skier off the snow to enable them to reach greater edge angles, decreasing the lengths and increasing the side cut of the skis to allow for more ski flexion, and increasing the bending and torsional stiffness of the skis to maintain the carved turn on hard surfaces (Mössner et al., 2009).

During these rapidly changing times, the World Cup governing body, the International Ski Federation (FIS), has implemented new regulations in many aspects of equipment and race course set-up in an attempt to decrease injury rates. Some of the primary equipment regulations include restrictions on minimum ski lengths, maximum standing height off the snow, minimum ski width under the binding and minimum ski turning radius (FIS, 2009). Course setting rules have also been changed in an effort to slow the racers down primarily by increasing the number of turns in a race course (FIS, 2008). With the recent and numerous changes in equipment, course setting, snow conditions and rules and regulations it is difficult to determine the primary contributing factors to injury and if any of the regulations have made a significant impact, positive or negative, on injury rates.

There is very limited research in the area of injuries on the World Cup circuit yet what does exist certainly highlights the serious injury potential. Injury rates over the 2006/07 and 2007/08 World Cup ski racing seasons were found to be 36.7 per 100 athletes per season, where 57% of these injuries resulted in eight or more days of training and/or competition being missed (Florenes et al., 2009). More than half of these injuries (61.2%) happened during World Cup/ World Championship competitions or official training for these competitions, while only a quarter (25.1%) occurred during regular on-snow training. Of the injuries, it was determined that 58% were to the lower body, with the majority occurring in the knee (35.6%) and the lower leg (11.5%), and 11.5% were injuries in the lower back. There are four disciplines in alpine ski racing and a positive linear relationship exists between

injury rates and speed (Florenes et al., 2009). Downhill (DH), with the highest speeds, has the highest incidence of injury, followed by Super G (SG), Giant Slalom (GS) and Slalom (SL), which with the slowest speeds, has the lowest injury rate. As there was no confidential injury database prior to the 2006/07 winter season, it is unknown if these results represent an increased rate or if this is typical of years prior.

FIS has deemed injury rates unacceptable on the World Cup ski circuit. The installed FIS Injury Surveillance System (ISS) provides already a statistical and epidemiological valuable evaluation of the actual injury status in alpine ski racing and allows an exact understanding about number, type and frequency of injuries during a World Cup Season (Oslo Sports Trauma Research Centre, headed by Prof. Roald Bahr). Furthermore an Injury-Video Analysis by a group of experts was conducted to generate a better understanding of the mechanisms behind ACL injuries. In order to define effective regimens that reduce the alarmingly high injury frequency of injuries in alpine ski racing it needs, however, a deeper understanding of skiing **specific risk factors** besides the **mechanisms behind injuries**.

For this reason, the University of Salzburg has been mandated as an independent party to research the injuries and attempt to determine if there exists specific risk factors that contribute to the injury rate and if potential solutions can be found. This research project is divided into a qualitative research phase (current paper) and a quantitative research phase (biomechanical studies; 2010/11 and 2011/12) phases over approximately three years.

Due to the fact that there are several groups with different background, knowledge and interests (Athletes, Trainers, Officials, Organizers, Equipment Companies ...) which have a common interest for injury prevention and safety in alpine ski racing, it is very important to have all these groups in one "boat" for a successful project. As a logical consequence it is absolutely necessary to systematically gather a wide range of individual views and suggestions from representatives of all involved groups. In order to get a representative picture of skiing specific risk factors and possible solutions which are discussed among the ski racing community a **qualitative questionnaire study** was performed. The objective of this qualitative interview study is to generate, together with the other ISS projects, a comprehensive discussion basis for short term regimens. Furthermore the results of the current study will be used to guide the direction of research in phase two (biomechanical research).

Methods

Interviews Participants and Organization

The qualitative analysis involved rigorous interviews of representatives from the following interest groups: athletes (12), coaches (19), officials & race organizers (12), ski equipment companies (10), and a group of topic specific experts (10) (total n=63).

Interviews took place over approximately two months with two concentrated phases during the World Cup event in Kvitfjell and the World Cup finals in Garmisch. All interviews were conducted in either German or English and lasted 40-70 minutes. All interviews were recorded using a digital voice recorder (Olympus VN-6800PC; Olympus Corporation, Tokyo, Japan) to ensure accuracy in analysis.

Interview Content

The interviews were broken down into five parts and moved from general to specific questioning as suggested by Myers and Newman (2007). This included an introduction, general and specific questions related to the injury situation and potential risk factors (**Risk Factor Analysis – RFA**) followed by a rating of risk factors (**Risk Factor Rating - RFR**) and injury prevention suggestions (**Regimentation Suggestions - RS**). The interview was semi-structured as there were prepared questions, but certain areas were examined through improvisation based on the responses of the interviewee (Fontana & Frey, 2003; Myers & Newman, 2007) with each interview ultimately covering the same material (Table1).

The first part (**RFA**) of the interview establish the interviewee's thoughts regarding the World Cup injury situation and whether or not they think there is a problem (Table1). Following this, general, detailed and specific questions were posed regarding whether they see any noticeable problems or distinct features that contribute to accidents resulting in serious injuries. The general question was left open to allow the interviewee the opportunity to address any area they consider a problem. Repetition of the question was used to draw out as many ideas from the interviewee as possible with minimal influence from the interviewer. A risk factor checklist established through trial interviews with coaches, athletes and research team members was used by the interviewer to keep track of the topics covered (Table2). The specific risk factors identified in the checklist were reduced into four basic categories

(SNOW, COURSE, EQUIPMENT, and ATHLETE) so that the interviewee was less constrained in their response. Each category not mentioned by the interviewee in the general question was asked in the detailed question (Table1). Finally, any topic from the checklist not mentioned in the previous questioning was asked in the specific section of this part of the interview.

In the third and fourth sections (**RFR & RS**) of the interview, participants were asked to identify and rank key risk factors and suggest rule changes that would help make ski racing at the World Cup level safer. In terms of rule changes, in section four, the interviewer attempted to clarify suggested changes to the rules so that little or no interpretation would be needed.

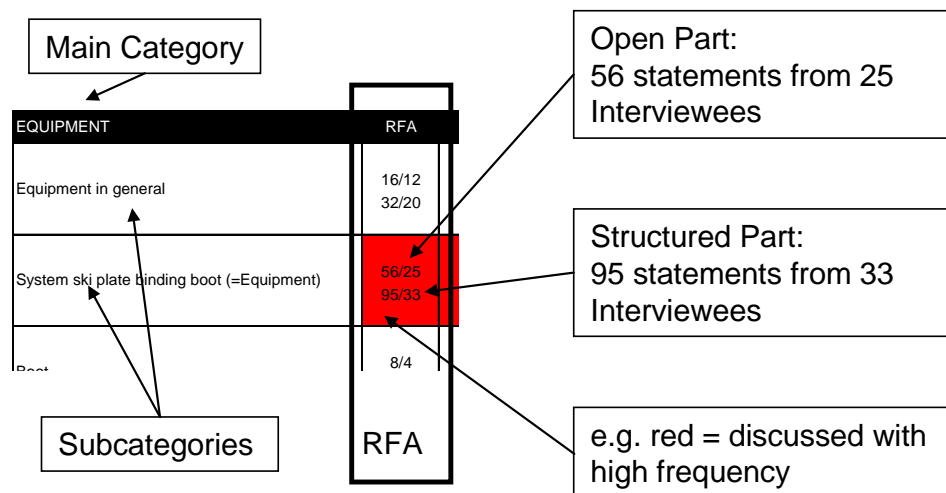
Interview Analysis

Risk Factor Analysis (RFA)

The RFA sections of the interviews (Part 1 and Part 2 in Table1) were processed with methods of qualitative research. At the beginning of the process, 15 audio taped interviews with representation from all groups, were fully transcribed word for word. Thereafter, a process of reduction was used to take the full transcripts and create statements summarizing each statement (paraphrasing). This means that a concise summary of several statements was built. Summary statements were also extracted from 25 interviews without full transcriptions using the audio files. Hence, at the moment 40 representative interviews are implemented into the analysis. Initially, hard copies of the statements were printed, cut into strips and separated into basic categories (INTRODUCTION, EQUIPMENT, SNOW, COURSE, and ATHLETE) and subcategories based on their similarities (Figure1). The coded statements were then entered into a database in their particular categories, sections and subsections. The outcome is now a structured database with in total four levels of details (Tree structure, Figure3 – Figure6) where the main discussed points based on the interviews can be extracted. On the example of the database in Figure2 Hot Spot within the category SNOW is exemplified. The database should serve a solid base for future discussions according to regulations and will be handed out to FIS as one result of the project.

For the current paper the database was summarized in form of tables containing the first subcategory of several basic categories (Figure3-7). The numbers are representing the number of statements that are collated to a particular category and the numbers of interviewees who gave a statement. The number above is the absolute frequency from the open interview part. The number below is the absolute frequency from the open and

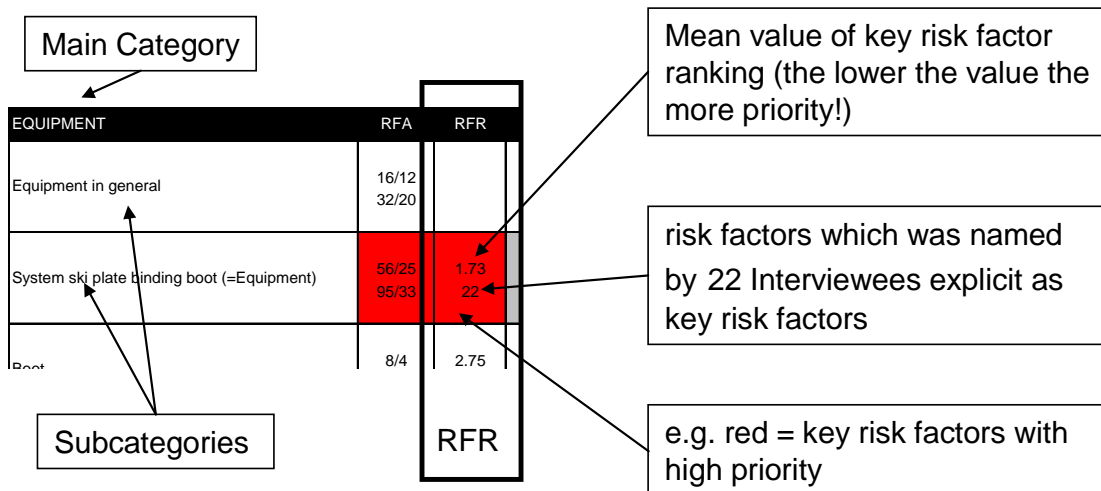
structured part (Table1). The colour code shows how often a certain risk factor was mentioned. Red means mentioned with high frequency, orange means mentioned with low but still substantial frequency. Uncoloured means risk factors, which were mentioned only by some experts or general statements about injuries.



Explanation for RFA in Table3-Table7

Risk Factor Rating (RFR)

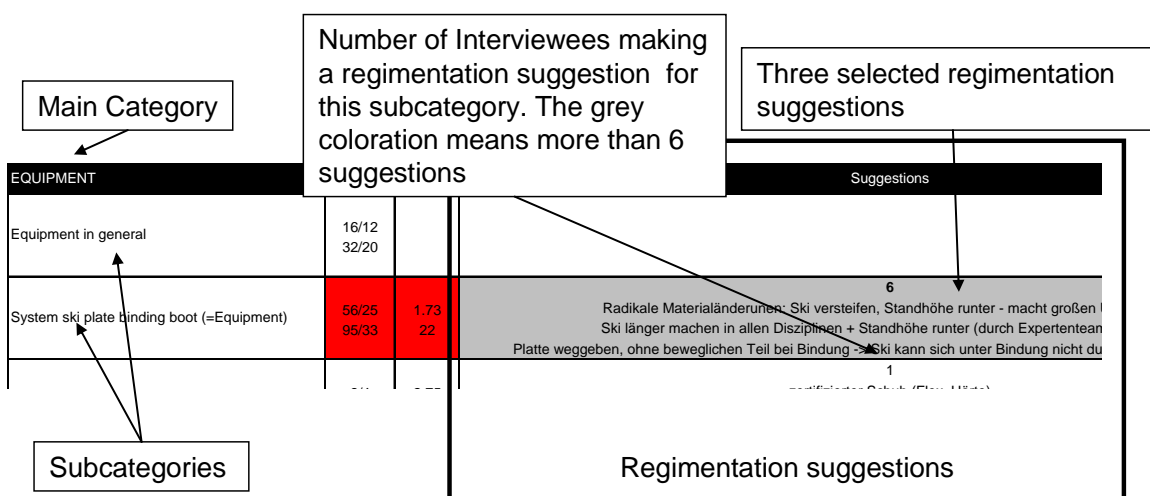
For the RFR section of the interview (Part 3 in Table1) in principal the same data processing as explained above was done (Audio file → *transcribe* → *paraphrasing*). For this analysis all 63 conducted interviews were considered. The interviewees named between one and five key risk factors, whereby the majority of the interviews named two or three key risk factors. Depending which priority the interviewee assigned each risk factor, a rank number was given to each statement. If an interview did assign the same priority to two or more key risk factors, a mean ranking number was developed and given to those statements. For the next step in the analysis, all statements were entered into categories within an Excel database. The categories have been taken over from the above mentioned database, whereas only the first subcategory was considered (RFR in Table4 to Table7). Within each category (Table3) and each subcategory (Table4 to Table7) the mean of the rank number was built. A lower value means a higher ranked risk factor. Furthermore, the frequency of how often a risk factor was named was part of the analysis. If a risk factor was named often (6 times or more), it was defined as key risk factor. The mean ranking value also explained the priority of a key risk factor within all key risk factors. Therefore, key risk factors with high priority where coloured in red and key risk factors with lower priority where orange coloured.



Explanation for RFR in Table3-Table7

Regimentation Suggestions (RS)

For the RS section of the interview (Part 4 in Table1) the first step was again finding concise summary of several regimented suggestions. All 63 interviews were considered for this analysis. Similar to the RFR section all statements were entered into categories within a excel database using the same main categories and first subcategory as in RFA and RFR. The results are presented in the Result Overview together with RFA and RFR (Table4 to Table7), whereas the total number of suggestions within a subcategory and three representative suggestions are served. If the number of suggestions within a category is six or more, the area is filled with grey. Some of the suggestions did not fit into the existing categories. Hence an additional category with four subcategories was built to present these suggestions (Table8). Additionally all suggestions of the interviewees are presented in Table8a to Table8d.



Explanation for RFR in Table3-Table7

Results

Risk Factor Analysis (RFA)

Overview

In this evaluation part the most mentioned risk factors of the database are described qualitative using example statements. See Figure3-7 for an overview of the quantification of the statements within the basic categories SNOW, COURSE, EQUIPMENT, and ATHLETE. The numbers in the brackets represent the number of statements that are collated to a particular category or subcategory. The first number is the absolute frequency from the structured interview section. The second number is the absolute frequency from the open interview section (see page 9 and Table1).

The main goal of the RFA-analysis is to get a content overview about the main statements concerning risk factors discussed among the skiing community. This analysis only shows which risk factors are mainly discussed and does not show how these risk factors are related to injury frequency. If a risk factor is frequently discussed, it does not automatically mean that it is a key risk factor or an injury hotspot.

The colour code shows how often a certain risk factor was mentioned and is consistent in the text and Table3-7. **Red bold** means mentioned with high frequency, **orange bold** means mentioned with low, but still substantial, frequency. The other risk factors were mentioned only by some experts.

General Statements

The majority of the interviewed experts are of the opinion that there is actually an **evident injury problem** in alpine ski racing, despite the fact that risk is inherent to ski racing. Based on the experience of the experts the number of injuries did not increase dramatically in recent years, but the pattern of injuries changed in a new direction.

„Unfälle passieren heute mit mehr “Gewalt“ als noch vor 15 Jahren: Wenn der Ski einmal falsch belastet wird oder man aus der Balance gerät, entstehen durch plötzliches Greifen des Skis enorme Kräfte.“

„Wenn sich ein Athlet einen Kreuzbandriss ohne Sturz zuzieht, dann ist es offensichtlich, dass etwas nicht stimmt.“

Furthermore the experts remarked that injuries have a bad **influence on the image** of the sport.

“Parents will not want their children to ski if there is a good chance they will ruin both knees.”

„Unfälle und Verletzungen sind für die Skiindustrie kontraproduktiv, weil wir mit dem Skisport Produktwerbung machen und sich die Kunden schon wundern, wenn die Geräte so gefährlich sind.“

“If the big stars of the sport are injured people will stop watching it.”

In terms of **injury prevention** some experts pointed out that risk reduction should not reduce the attractiveness of the sport.

“It is very hard to find the balance between spectacular show and minimal risk.”

On the other hand, some experts are of the opinion that only **radical changes** will solve the injury problem, due to an “optimization cycle” that optimizes the small changes in one key area by adaptations in the other key areas.

„Wenn wir den Sport retten wollen, dann müssen alle Opfer bringen und es braucht radikale Änderungen.“

„Das Optimierungsstreben ist ein grundsätzliches Problem: Athlet und Material werden sich immer anpassen, sodass der Kurs schnellst möglich bewältigt wird. Deshalb braucht es radikale Änderungen, wenn sie etwas bewirken sollen.“

Therefore, the contrast of **group specific interests** and the disagreement of the involved groups make efficient injury prevention difficult.

“If we trying to slow the athletes down, the equipment companies are going to keep trying to find ways to speed them up- they want to win.”

„Der Läufer wird nur wertgeschätzt wenn dieser ganz vorne mit fährt (Medien, Ausrüster etc.) was den Leistungsdruck auf den Läufer und damit seine Risikobereitschaft erhöht.“

“Business gets in the way of injury prevention sometimes where we run races in unsafe conditions because we have to satisfy business.”

“It needs communication between all parties which way to go.”

About **competition rules** there were only very few statements pointing out that rule changes don't automatically solve the problem.

Snow

In the basic category SNOW the majority of the interviewed experts see the main problem in **‘Changing snow conditions within one run’**, because it makes it very difficult for the athlete to adapt immediately and the equipment setup and preparation does not fit all of the different conditions.

“A mix of injected and aggressive snow on the same slope is a problem for injury as it is hard to set up the equipment for both situations.”

„Wechselnde Verhältnisse innerhalb des Laufes sind für den Läufer sehr schwer um sich anzupassen.“

„Wenn auf einer aggressiven Piste einige Kurven vereist sind, dann muss das Setup so eingestellt werden, dass man auf Eis fahren kann. Dadurch wird das Material auf nicht vereisten Stellen noch aggressiver.“

Some experts also mentioned the difficulty to adapt the equipment setup to particular snow conditions due to changing snow conditions between different avenues and runs.

„Die Anpassung des Setups auf die jeweiligen Schneebedingungen ist ein Problem. Es ist jedoch schwierig bis unmöglich das Setup wöchentlich zu ändern und ständig auf jede Piste neu einzustellen.“

„Es gibt kaum Fahrer, die ihr Setup speziell auf bestimmte Bedingungen einstellen (können), das Setup wird meistens einmal abgestimmt und dann immer gefahren.“

„Im Zeitraum der Amerikarennen häufen sich die Stürze. Dies hat mit den unterschiedlichen Trainingsbedingungen während der Vorbereitungszeit auf den Gletschern zu tun, da die Materialeinstellung auf den“ gutmütigen“ Gletscher Schnee nicht für den aggressiven Amerika-Schnee passen.“

A second important risk factor according to the experts seems to be **‘Aggressive snow conditions’**, whereby cold temperature, low humidity and artificial snow seem to be the driving factors. These conditions lead to a more direct force transmission at the ski-snow interaction.

“Aggressive snow is dangerous because the equipment reacts and carves really well – too much energy is going into the athlete.”

“On aggressive snow where things react faster there is less room for error on the aggressive equipment.”

„Das Grundphänomen ist der technische Schnee, der sich aufgrund der kleineren Kerngröße anders verhält als der Naturschnee. Er hat eine höhere Dichte wodurch man schneller eine höhere Festigkeit und Härte erreicht. Es entstehen keine Bruchstellen mehr, die Energie aufnehmen könnten. Er ist aggressiv und verzeiht keine Fehler mehr.“

„Sehr trockene Luft und extreme Kälte führen zu extrem aggressiven und gefährlichen Schnee- und Pistenverhältnissen.“

„Ist die Luftfeuchtigkeit über 70 Prozent, ist auch eine gewisse Feuchtigkeit auf der Schneeoberfläche vorhanden, sodass trotz kalten und aggressiven Kunstschneebedingungen Fahrfehler nicht so direkt auf Ski und Körper des Fahrers transferiert werden.“

A majority of the experts, therefore, see water prepared slopes as a golden standard of **‘Techniques of snow preparation’**, due to the fact that injected slopes lead to less direct force transmission. However it has to be accepted that it is very difficult to prepare a perfect slope because the weather cannot be controlled.

“Icy snow conditions are safer than aggressive snow because the equipment does not react as fast.”

“Injected snow allows for energy to be released without going so much into the body of the athlete.”

„Auf vereisten Pisten sind weniger Verletzungen zu beobachten, da vereiste Pisten weniger aggressiv sind und ein Verschneiden weniger begünstigen. Andererseits steht dies im Kompromiss mit Mikro-Traumen und chronischen Problemen aufgrund der harten Piste.“

„Balkenpräparierung ist sinnvoll und sollte immer verwendet werden.“

„Exakt die gleiche Schneepräparierung kann je nach Witterungsbedingungen, Temperatur und Luftfeuchtigkeit zu sehr unterschiedlichen Resultaten führen. Dies macht es sehr schwierig immer eine perfekte Piste zu präparieren.“

Some experts pointed out that it makes no sense to inject all slopes on the women's side.

„Damen könne den Gripp und den Druck nicht aufbringen um komplett vereiste Strecken fahren zu können, daher kann man sie nicht so vereisen.“

„Im Damenbereich darf es nicht zu eisig sein, denn das ist kontraproduktiv für die Sicherheit.“

„Speziell für Damen wird die Piste, die mit Injektionsbalken präpariert wird viel zu hart und glatt für Abfahrt und Super-G.“

„Beim Grossteil der technischen Disziplinen im Damenweltcup wird mit dem Balken präpariert und es entsteht eine gute, kompakte und harte Piste. Die Balkenpräparierung ist somit in den technischen Disziplinen wünschenswert, nicht aber in den Speed Disziplinen.“

What is noticeable is the fact that the `Changing snow conditions` were mentioned with the same frequency as `Aggressive snow conditions` and `Techniques of snow preparation` in the open question section. In the structured section, however, where they have been asked about the role of `Changing snow conditions` this frequency distribution between the three risk factors changed towards more statements about `Changing snow conditions`.

Another risk factor mentioned by some experts is a smooth `Snow surface`. It is expected that a more bumpy snow preparation would increase safety due to reduced ski-snow interaction and therefore the possibility of energy release without being transmitted to the body, as well as better speed control.

„Die Präparation von der Piste spielt eine wesentliche Rolle, da eine glatte griffige Oberfläche das 'ansaugen' des Skis begünstigt.“

„Bei unruhigen Pisten gibt es nach Fahrfehlern weniger grosse Auswirkungen.“

Only a very few experts are the opinion that `Snow in general` is not the key factor.

„Schneeverhältnisse werden nur dann zum Verletzungsproblem, wenn der Athlet unfähig ist sich anzupassen, mittels Technik, Fahrverhalten und Material. Ausserdem ist die Komponente Schnee nur bedingt steuerbar und somit nicht der Schlüssel zum Problem.“

Course

The most discussed topic within the basic category COURSE is `Jumps`. There is strong consensus among the experts what makes jumps dangerous. Risk factors are if racers have less preparation time or jumps have too high take off speeds, a steep ramp angle which

launches the athlete high, a landing in flat terrain or if jumps are situated in turns or in a difficult part of the course.

„Man muss genügend Zeit haben um sich auf Sprünge vorzubereiten.“

„Generell ist eine höhere Geschwindigkeit ein Faktor der Sprünge gefährlicher macht, da vor allem die Fehleranfälligkeit für Athleten steigt.“

„Sprünge sind problematisch wenn sie zu hoch gehen oder einen Kicker haben.“

„Weite Sprünge sind unproblematisch, wenn sie bei der Landung genügend Neigung haben.“

“Jumps with turns before the take-off are a problem as there is not enough preparation time.”

“Before and after jumps it needs to be easy.”

Another subcategory widely discussed is **‘Speed and course setting aspects’**. On one hand there is a strong consensus among the experts that speed in combination with small turn radii leads to high forces and is dangerous.

„Speed in Kombination mit engen Kurven ist gefährlicher, als eine etwas mehr auslaufende Kurve mit mehr Speed.“

„Durch die hohen Kurvengeschwindigkeiten sind die externen Kräfte sehr gross. Kommt es nun durch Verschneiden zu Rotationen im Kniegelenk kann der Körper kaum dagegenhalten.“

„Die Erhöhung der Kurvengeschwindigkeit stieg in den letzten Jahren überdimensional zur Kraftentwicklung der Athleten.“

“The turns are much faster than they were when the equipment would slide instead of carve.”

On the other hand there is about a fifty-fifty split whether speed can or should be controlled by course setting or not.

„Drehende Kurse senken das Risiko nicht, da die Kräfte höher werden. Temporeduktion durch drehende Kursetzung ist deshalb nicht sinnvoll.“

„Tempokontrolle muss über die Kursetzung passieren, kürzere Torabstände bei gleichbleibender horizontaler Distanz sind der Schlüssel.“

Some of the experts pointed out that speed can only be controlled by course setting if it forces the athlete to skid. As long as the turns can be carved due to a smooth course setting change, speed cannot be controlled through course setting.

„Das Entscheidende bei der Tempokontrolle durch die Kurssetzung ist, dass man nicht mehr auf Zug fahren kann.“

„Temporegulierung durch drehende Kursetzung ist sinnlos, solange der Athlet den engeren Radius immer noch geschnitten gefahren werden kann.“

„Taktische Aspekte sollten bei Kurssetzungen im Sinne der Tempokontrolle vermehrt forciert werden, sodass der Athlet sich wirklich überlegen muss wo er Speed rausnehmen soll und wo er voll durchziehen kann.“

As another disadvantage of speed control through **`Course setting in general`** is, according to the experts, the problem that turny course setting brings the athlete critically near and at a bad angle towards the nets.

„Die natürliche Streckenführung sollte nicht durch die Kursetzung zerstört werden. Durch eine zu drehende Kurssetzung kommt man zu nahe und in einem zu steilen Winkel in Richtung der Netze.“

Some of the experts see **`Speed in general`** as a risk factor. Only a minority do not see speed as a general problem.

„Der Faktor Geschwindigkeit ist ein grosses Problem, vor allem einen konstant hohe Geschwindigkeit, die die Sinne täuscht.“

„Stürze bei hoher Geschwindigkeit bringen öfters Verletzungen mit sich, als Stürze bei geringen Geschwindigkeiten.“

„Eine Temporeduktion von 20-30 km/h wäre sinnvoll und schadet der Attraktivität des Skisports nicht: ob man im Speed Bereich 120 oder 140 km/h fährt eigentlich kein Zuschauer.“

In terms of **`Race difficulty`**, some experts see a relation between race difficulty and injury risk, whereas more difficult courses seem to be less dangerous than easy courses. There are only a few contradictions among the experts.

„Die Schwierigkeit hat einen inversen Einfluss auf die Verletzungshäufigkeit. Leichte und mittelschwere ‚Bolzer-Läufe‘ bergen am meisten Gefahr; vor schwierigen Kursen hat man viel mehr Respekt und ist viel aufmerksamer.“

According to the experts, poor **`Visibility`** increases injury risk. Furthermore, the use of blue color lines as optical support is highly supported.

„Sicht beeinflusst die Sicherheit des Läufers wesentlich, da schlechte Sicht zu Passivität führt und sich dadurch die Wahrscheinlichkeit erhöht, Fahrfehler zu begehen oder zu stürzen.“

„Sicht ist ein wesentlicher Risikofaktor. Diese wird bei Entscheidungen immer mit berücksichtigt, insbesondere in Kombination mit schwierigen Pistenverhältnissen.“

“Blue colour lines are helping a lot to improve visibility on the course.”

„Die blaue Farbe wird meistens gut verwendet, es muss aber richtig nachgefärbt werden.“

Noticeable is the fact that experts did mention **`Visibility`** and **`Race difficulty`** as risk factors mainly in the structured section where they have been asked about the role of **`Visibility`** and **`Race difficulty`**. It is, therefore, questionable if **`Visibility`** and **`Race difficulty`** are often discussed as possible risk factors among the skiing community.

Concerning **`Discipline specific problems`**, **`Course in general`**, **`Course maintenance`**, **`Topography/terrain in general`**, **`Speed and topographic aspects`** there were only a few expert statements.

„Die Pistenarbeiter sind nicht gut genug geschult, und das ist speziell bei den Trainings ein Problem, denn da begehen die Athleten noch Fehler.“

„Werbepanzer haben kein Gelenk und stecken fest im Schnee. Diese sollten sicherer gemacht werden.“

„Wichtig ist, dass kein unnötiges Material auf den Strecken herumliegt. (Bsp. Ausgezogene Ski, Rucksäcke der Trainer, Schaufeln usw.)“

“I needs more small rolls/bumps or terrain to help to keep the speeds down instead of more turns.”

„Das Tempo muss durch unruhige Pisten reduziert werden. „Autobahnen“ sind hinsichtlich Verletzungen gefährlich.“

„Früher wurde aus technischen Gründen in der Abfahrt von Hand präpariert, was zu einer ruppigeren, welligeren, schwierigeren Piste führte. Dies schaut auf den ersten Blick zwar gefährlicher aus, aber führt zu Tempokontrolle und zu einer offeneren Körperhaltung um Stöße abzufedern. Heute ist alles glatt präpariert und der Läufer ist in einer kompakten Position. Wenn nun in einer solchen Position etwas passiert, hat dies katastrophale Auswirkungen.“

„Speziell im Riesenslalom wurden in der Vergangenheit zu hohe Geschwindigkeiten gefahren.“

„Von den Kursetzungen her ist der Super-G der gefährlichste Bewerb, eigentlich gefährlicher als Abfahrten weil es dort Trainings am Hang gibt.“

„In den Abfahrten sollten die Kurse weniger drehen.“

„In der Abfahrt sind die Kursetzungen gut. Speed und Radien sind o.k.“

„Minimum 2 training runs before a downhill needed.“

Equipment

In the basic category EQUIPMENT, a majority of the experts see the main problem in the characteristic of the **`System ski, plate, binding and boot`**. Therefore, the controllability, aggressiveness and directness of the equipment were the main discussion points.

„Das Material verzeiht fast keine Fehler mehr, wodurch es leicht zu stürzen kommen kann.“

„Solange der Athlet die Kontrolle über den Ski hat, macht der Ski was der Athlet will. Gerät der Athlet aus der Balance, wirken die Kräfte und der Ski entwickelt eine gewisse Eigendynamik.“

„Es kommt oft vor, dass wenn man den Druck auf den Aussenski in der Kurve verliert, der Innenski voll greift und man richtiggehend „herauskatapultiert“ wird.“

„Ist das Material einmal ausser Kontrolle entwickelt es eine gewisse Eigendynamik und der Athlet kommt nicht mehr von der Kante weg.“

„Wenn der Ski einmal auf der Kante ist, dann bleibt er drauf und zieht die Kurve fertig, auch wenn der Läufer aus der Balance gerät.“

„Das System Ski, Schuh, Bindung, Platte ist zu aggressiv und sollte mehr Fehler verzeihen.“

„Die Aggressivität des Materials hat sich kontinuierlich gesteigert, damit sind auch die Unfälle stetig gestiegen – Es hat aber nie eine sprunghafte Entwicklung gegeben.“

“When the ski don't slide there is a build up of energy is released into the body causing injury.”

„Beim System, Ski, Platte, Bindung, Schuh wird immer versucht die Kraftübertragung zu verbessern und noch etwas direkter zu machen. Dadurch lässt sich zwar die Performance verbessern, aber eventuell gehen diese Entwicklungen dann auf Kosten der Sicherheit.“

In terms of risk factors related to system ski, plate and binding the weight of the equipment, the homogeneity of the bending line and the edge angle were mentioned as driving factors for injuries.

„Gewichtsreduktion beim Material wäre ein grosser Fortschritt, da wenn diese Masse einmal in Schwung kommt, es zu einer unkontrollierten Eigendynamik des Materials kommen kann.“

„Die optimale Biegelinie des Skis ist ein grosses Problem.“

„Wenn man Verletzungen vermeiden will, muss der Ski Rutschphasen erlauben, indem man ihn in der Mitte steifer macht.“

„Die Konstruktion der heutigen Ski wurde dahin gehend optimiert, dass der Ski auf der ganzen Fläche eine Wirkung hat und es erlaubt Kurven ohne Rutschphase zu schneiden. Dies bedeutet aber auch dass der Ski beim Ski-Schnee Kontakt einen unweigerlichen Halt hat, von dem er nicht mehr weg zu bringen ist (er saugt).“

„Wenn man sicherer werden will muss man die Aufkantwinkel reduzieren das wäre ein ganz konkreter Ansatzpunkt.“

In the subcategory **`Ski`** construction the main discussed points were the ski side-cut and the ski width. Thereby, the majority of the experts are of the opinion that too much side cut and wide skis increases the injury risk.

„Die starke Taillierung ist ein grosses Problem und erhöht das Verletzungsrisiko.“

„Weniger Taillierung bedeutet weniger Kräfte und weniger „Gewalt“ bei den Stürzen.“

„Die breiteren Ski sind kontraproduktiv. Die Stabilität in der Kurve hat zugenommen und die Kurvengeschwindigkeiten sind höher geworden.“

“Wider skis will make it harder to get up on and off the edge.”

„Die breiteren Ski ermöglichen mehr Aufkantwinkel, da der Schuh nicht so leicht in den Schnee kommt. Dadurch kann man noch mehr ans Limit gehen, bevor der Ski ausbricht und den Gripp verliert.“

In this context, there is a strong consensus among the experts that recent equipment changes did not solve the problem or only partly solved it.

“Previous equipment changes did not change injury numbers or made them even worse, but cost a lot.”

„Vor vier Jahren wurde die Standhöhe verringert und der Ski wurde breiter gemacht. Es hat sich dadurch nichts geändert, da die Schräglage gleich bleibt und die gleichen Kurvengeschwindigkeiten und Fliehkräfte herrschen.“

„Die Läufer passen sich innerhalb kurzer Zeit immer wieder an Materialänderungen an und fahren nach kurzem Trainingsblock die gleichen Schwünge mit demselben Tempo wie vorher.“

Consequently some of the experts therefore call for more radical equipment changes.

„Man muss konsequent grosse Änderungen machen um etwas zu erreichen, es kann nicht um mm bei Standhöhen, Breiten und Taillierungen gehen.“

In terms of the **`Binding and plate`**, standing height, the release mechanism and setting of the binding were discussion points. The experts are mainly of the opinion that a high standing

height increases injury risk. Due to the fact that athletes rather risk an injury than lose a ski, as reported by the experts, the release mechanism of the binding must be improved in their opinion. Some of the experts, however, pointed out that the improvement of the release mechanism would be difficult and expensive.

„Die Standhöhe ist ein entscheidender Faktor, der reduziert werden muss. Heute herrschen ungesunde Hebelverhältnisse, die zu hohen Kräften führen, welche dann auf den Körper wirken.“

„Die Bindung ist ein Problemfeld. Fahrer riskieren eher eine Fehlfunktion der Bindung als ein Verlieren des Skis. Dies obwohl ein Sturz aufgrund einer aufgegangenen Bindung meist nicht so gefährlich ist, wie ein Sturz bei dem die Bindung nicht aufgeht.“

„Bindungen sind technologisch stehen geblieben. Der Auslösemechanismus funktioniert in Extremfällen nicht adäquat.“

„Die Leistung der Bindung ist nicht ausreichend. Verbesserungen in diesem Bereich sind aber schwierig und wären sehr teuer.“

Some experts do not see the release mechanism of the binding as the cause of an inadequate binding release. Some experts from the equipment companies see the cause mainly in the field of the boot, some experts from the trainer's group assume the cause in the field of the bending line.

„Wenn an den Schuhen herumgebastelt wird, dann verändern sich die Auslösewerte massiv; Das passiert öfters und ist daher ein Problem in Richtung von Fehl- und Nichtauslösungen und somit für Verletzungen.“

„Durch die starke Biegelinie der Ski unterhalb der Bindung funktioniert diese nicht mehr optimal, weil sich der Schuh in der Bindung verkeilt.“

Concerning **‘Nets and spill zones’** the majority of the experts are of the opinion that nets in general are at a good level, but that spill zones are often too small. According to the expert's statements the usage B-nets in front of A-nets is problematic.

„Sicherheitsnetze sind grundsätzlich auf einem guten Niveau, wobei die Situation vor allem auf Stufe Europacup und FIS-Rennen schlechter ist.“

„Oft werden die Pisten breiter gemacht und dann werden die Kurse auch wieder breiter gesetzt. Der Sturzraum bleibt jedoch gleich klein.“

„B-nets in front of A-nets sometimes takes too much room where athletes otherwise would be able to recover, they end up crashing into the B-net.“

„Bei B-Netzen vor A-Netzen läuft man Gefahr einzufädeln, hier wäre eine Plane am B-Netz nötig.“

„B-Netze vor A-Netze am Kurvenausgang sind oft ein Problem, wenn sie zu nahe an der Ideallinie stehen.“

‘Protectors and helmets’ are, according to the experts, already at a good level, but still can be improved in different directions. Some experts, however, pointed out that the limitation for protector improvement is the freedom of movement which should not be constrained.

„Beim Helm gibt es noch Verbesserungspotential: Dass Helme bei Stürzen verloren gehen, darf auf keinen Fall passieren.“

„Schnittfestes Material an wichtigen Stellen könnte in den Rennanzug integriert werden.“

„Der Rückenprotektor bringt zu wenig Schutz vor Brüchen und Verrenkungen. HWS ist nicht geschützt.“

„Mehr Protektoren sind nicht sinnvoll, da es die Bewegungsfreiheit der Athleten zu stark behindern würde.“

There is a fifty-fifty split among the skiing community experts whether speed can be controlled by **`Racing suits`** or not. On the other hand there is a strong consensus that racing suits should be optimized in terms of body temperature and resistance to cutting by the edge.

„Beim Rennanzug besteht Potential das Tempo zu reduzieren, es wäre ein sehr einfacher Weg den Speed herauszunehmen.“

„Änderungen des Rennanzuges bezüglich Luftdurchlässigkeit hätten nur minimalen Einfluss.“

„Der Rennanzug sollte dicker sein. Dies hat nur Vorteile: Der Anzug ist wärmer und der Läufer ist besser geschützt.“

A strong consensus among the experts is observed concerning the **`Gates`** are problematic. The majority are of the opinion that there is a danger of hooking due to high resistance of the panels. On the other hand, panel systems which release too quickly have risky side effect of having workers in the course to put them back again.

“The gates are a risk factor – the panels have too much resistance.”

„Die Torflaggen dürfen sich auch nicht zu leicht lösen, da sich dadurch die Gefahr von Pistenarbeitern, die die Flagge wieder befestigen und dadurch im Weg sind erhöht.“

In terms of the **`Boot`**, some experts see a problem in the extreme direct force transmission of today's boots.

„Das Problem beim Material ist der Schuh, da es praktisch kein Innenschuhdämpfungsmaterial mehr gibt. Dies ist als würde man ein Rennauto ohne Dämpfungssystem bauen.“

„Der Schuh hat sich enorm verändert in Richtung einer direkteren Kraftübertragung, dies wirkt sich speziell bei kalten Verhältnissen negativ auf die Unfallproblematik aus.“

„Die Schuhe sind zu steif, speziell bei kalten Temperaturen werden die Ski-Schuhe sehr direkt bezüglich Kraftübertragung.“

In terms of **`Equipment in general`**, only a few experts noted that equipment is not the key to solving the problem.

„Es gibt keine Auffälligkeiten in den letzten Jahren hinsichtlich Unfälle was das Material betrifft.“

Athlete

In the basic category ATHLETE the most discussed possible risk factors are in the field of **`Physical aspects`**, **`Fatigue`**, **`Skiing technique and tactic`**, and **`Psychological aspects`**.

In terms of **Physical aspects**, there is a strong consensus among the experts that a good fitness level is one of the most important factors for injury prevention. However, some experts mention the problem that the fitness level cannot be improved and that athletes today have reached their physical limitation. Furthermore, the younger athletes are not always sufficiently prepared entering the World Cup, because their fitness level is not developed as well as their skiing skills.

„Physical training is very important for the athletes to avoid injuries.“

„Körperlich schwache Athleten verletzen sich öfters.“

„Die Bedeutung der Fitness im Zusammenhang mit Verletzungsprävention hat in den vergangenen Jahren zugenommen.“

„Der Stand der physischen Vorbereitung verbessert sich stetig und war noch nie so gut wie jetzt.“

„Das Material entwickelt sich immer weiter, der Mensch bleibt gleich und irgendwann ist die Möglichkeit den Körper noch weiter auf zu trainieren am Limit.“

„Der Mensch steht bei der Leistungssteigerung durch Training früher an als die Materialentwicklung.“

„The younger athletes are also put through a lot of training at altitude when they are not physically prepared which puts them at risk for injury“

„A lot of younger athletes (women in particular) don't get enough time to work on their conditioning as they are selected younger and have pressure to move up in the ranks.“

According to the expert's statements, **Fatigue** seems to be main risk factor of basic category ATHLETE. Thereby, the overloaded schedule and the jetlag problem are the main points mentioned by the experts.

„Ermüdung ist ein zentrales Problem – Rennkalender, Reisestress und Jetlag.“

„Der straffe Terminkalender ist ein Problem. Besonders für Athleten die mehrere Disziplinen fahren.“

„Stress und Müdigkeit durch das viele/ lange Reisen ist problematisch und begünstigt Verletzungen.“

„Jetlag nach Übersee Reisen ist ein grosser Risikofaktor, der durch eine Anpassung im Terminkalender sehr einfach entschärft werden könnte.“

„Insgesamt weniger Rennen wären wünschenswert, der Terminkalender ist überfüllt. Weniger Rennen würden dem Sport nicht schaden, im Gegenteil würden mehr „Highlights“ die Attraktivität des Sports steigern.“

In terms of **Skiing techniques** some experts are of the opinion that a more stable technique means less injury. Although today's equipment allows for fast skiing with an improper technique, it does not allow for skiing safe.

„Athletes are generally not in a good stable body position when they get injured.“

„Viele Athleten haben keine ausreichend stabile Grundtechnik und sind anfällig auf Fahrfehler und somit Verletzungen, rückblickend verletzen sich jedoch nicht nur diese Läufer.“

„Manche Läufer sind mehr gefährdet als andere, dies hängt vor allem davon ab, wie riskant sie hinsichtlich des seitlichen Gleichgewichts unterwegs sind.“

„Mit dem jetzigen Material kann auch jemand mit einer schlechten Fitness und etwas unsauberer Technik die gleichen Kurven fahren wie jemand mit einer sehr guten Fitness und einer sehr sauberen Technik. Jedoch ist das Verletzungsrisiko für einen Athlet mit schlechterer Fitness und unsauberer Technik bedeutend höher.“

In terms of **`Skiing tactics`**, the majority of the experts are of the opinion that the right tactical decisions (=risk management) reduces injury risk and that experience allows better risk management.

„Die taktische Komponente – wie viel Risiko genommen wird – hat einen Einfluss auf Verletzungen.“

„Wenn der Athlet nicht sein Limit kennt, oder über seinem Limit fährt ist die Gefahr sehr gross, dass er stürzt. – Risikomanagement ist deshalb sehr wichtig.“

„Die Selbsteinschätzung der Athleten ist ein entscheidender Faktor bezüglich Verletzungsanfälligkeit, hier spielt auch die Erfahrung eine entscheidende Rolle.“

In terms of **`Psychological aspects`** problems in concentration and situations with increased pressure are the main points increasing injury risk for the experts.

„Die Konzentration bleibt besser aufrecht, wenn der Athlet gefordert ist und der Kurs nicht zu leicht ist.“

„Das Verletzungsrisiko steigt wenn Athleten unter Druck stehen.“

„Verletzungsanfälligkeit ist bei hoher Risikobereitschaft grösser, speziell bei jenen, die kurz vor dem Durchbruch sind.“

„Der Druck ist ein grosses Problem. Viele Läufer gehen volles Risiko obwohl sie es nicht drauf haben.“

„Problem beim Risikomanagement ist, dass aufgrund der enormen Leistungsdichte der Athleten viel Risiko genommen werden muss, um zu gewinnen.“

Another factor discussed among some experts is the **`Individual responsibility`** of the athletes. For them, influencing individual responsibility by increasing the difficulty of courses seems to be the main key to solve the injury problem.

„Wurzel des Verletzungs-Problems ist wohl die, an und für sich, "einfache" Pistenpräparation (= "Autobahn"). Die Rennläufer werden dadurch schon so erzogen, dass alles voll gefahren werden kann und es kein Risikomanagement mehr braucht.“

„Auf einfachen Strecken ist die Risikobereitschaft der Athleten grösser. Durch Entschärfen von Hindernissen werden Eigenverantwortung und Risikomanagement des Athleten unterdrückt.“

„Es besteht die Tendenz, dass die heutigen Athleten glauben man könne immer alles voll durchziehen. Dies darf nicht sein.“

„Es hat sich eine Generation entwickelt, die es gewohnt ist, dass alles perfekt ist, dass alles fahrbar ist und eigentlich nichts passieren kann.“

„Einerseits wollen wir perfekt sein in Sachen Sicherheit und entfernen jedes Hindernis, andererseits wird Eigenverantwortung der Athleten gefordert.“

„Wir brauchen Hindernisse, wir brauchen Probleme, wir brauchen unrhythmische Sachen. Auch im SL und RTL. Das ist der Schlüssel um das Risikomanagement zu schulen und dadurch die Sicherheit zu erhöhen.“

Some experts see problems in the subcategories `Authorization to participate in the race`, `Race preparation of the athlete`, `Pre-injury aspects`, `Aspects of body temperature`, `Crash behavior`, `Genetics and anthropometries` or `Adaptability`.

“Too many people are eligible to race in the world cup downhill and they are not well prepared physically, mentally, skiing skills ...”

„Im Nachwuchsbereich fehlt heute die Möglichkeit Speed-Erfahrung und Sprung-Erfahrung zu sammeln.“

„Für die Abfahrt sind gute Vorläufer entscheidend, um alles besser einschätzen zu können.“

„Sommertraining erfolgt vor allem auf Gletscher und Eis: Die Abstimmung des Materials ist somit zu extrem eingerichtet für aggressiven kalten Nordamerika-Schnee.“

„The possibilities for good downhill training on the glaciers are reduced because of limited space so it is harder to be well prepared for the first downhill races of the season.“

„Mit Vorverletzungen wird oft unverantwortlich und nicht vorsichtig genug umgegangen, da Vorverletzungen in Kombination mit einem weiteren Sturz zu schweren Verletzungen werden können.“

„Verletzungen werden oft nicht lange genug ausgeheilt wodurch die Gefahr sich wieder zu verletzen gross ist.“

„Verletzungen passieren oft bei tiefen Temperaturen.“

„Schlechtes Sturzverhalten kann zu Verletzungen beitragen.“

„Es gibt Athleten die ein sehr schlechtes Sturzverhalten haben. Mehr spezifisches Koordinationstraining als Verletzungsprävention könnte dieses Problem entschärfen.“

„Verletzungsanfälligkeit kann nicht durch Training beeinflusst werden, sondern ist genetisch bedingt. Manche Läufer verletzen sich bei einer bestimmten Situation, manche verletzen sich bei der genau gleichen Situation nicht.“

„Verletzungsanfälligkeit hat vor allem mit genetischer Prädisposition, Anthropometrie und Risikobereitschaft zu tun.“

„Unterschiedliche Pistenverhältnisse sind wichtig damit der Fahrer lernt bezüglich Technik und Material-Setup zu antizipieren, auch im Training. Werden immer gleiche Pistenverhältnisse bereit gestellt birgt dies deshalb auch ein grosses Gefahrenpotential, da die Variabilität und Anpassungsfähigkeit nicht geschult werden.“

Risk Factor Rating (RFR)

Overview

The risk factor ranking is described quantitatively in this evaluation section. The main goal of the RFR-analysis is to get overview about the key risk factors discussed among the skiing community and how the community ranks those key risk factors concerning their influence on injuries. For each basic category (RFR Analysis in Table3) and the corresponding subcategories (RFR Analysis in Table4-7) it was analyzed how often a risk factor was named and the mean ranking value. Note that a lower value means a higher loading risk factor. Those numbers are the base for defining if a risk factor is a key risk factor and how the priority of this key factor is. Therefore, key risk factors with high priority were coloured in **red** and key risk factors with lower priority were **orange** coloured.

RFR among Basic Categories (Table3)

Among the four basic categories (SNOW, COURSE, EQUIPMENT, and ATHLETE), SNOW was mentioned by 34 interviewees as key risk factors. The other three categories were mentioned more often (49, 46 and 44 times) as key risk factor. Interestingly, the SNOW was ranked with a higher priority than the others which is reflected by the lowest value (2.04). On the other hand, aspects of the COURSE were ranked with the lowest priority with a value of 2.49. ATHLETE (2.38) and EQUIPMENT (2.38) were from a priority point of view ranked between snow and course.

Snow (Table4)

Similar to the RFA analysis the subcategory **‘Changing snow conditions’** is the absolute highest loading category. This subcategory was mentioned 17 times and has one of the lowest mean ranking values among all key risk factors at 1.79 (also within the other basic categories). Therefore the changing snow conditions are a key risk factor with high priority. Yet, **‘Aggressive snow conditions’** (8) and **‘Techniques of snow preparation’** (9) were often mentioned, whereas due to the higher mean ranking values of 2.31 and 2.28, those two subcategories are key factors with lower priority. The other subcategories (‘Snow in general’, ‘Snow surface’) were due to no entries not defined as key risk factors.

Course (Table5)

Within the basic category COURSE, **'Speed and course setting'** was named 9 times as risk factors and the mean ranking value is 2. Hence this subcategory is defined as high priority key risk factor.

'Jumps' and **'Speed in general'** were both mentioned both 11 times as risk factor. With mean ranking values of 3.45 for jumps and 2.23 for speed, both are substantially higher than the ranking for speed and course setting. Therefore those two subcategories are defined as key risk factor with lower priority.

The results for jumps are rather interesting. The jumps are absolutely high loaded in RFA. But in risk factor rating (RFR) the mean rating value is with 3.45 one of the highest numbers within the key risk factors. This means that it is an important and very intensively discussed topic, but there are other key risk factors which are assigned to have a much higher influence on injury risk and therefore higher priority.

The other subcategories ('Course in general', 'Visibility', 'Course maintenance', 'Course / Race difficulty', 'Course setting in general', 'Topography / Terrain in general', 'Speed and topographic aspects', 'Discipline specific problems') were due to no or low numbers of entries not defined as key risk factors.

Equipment (Table6)

Within the basic category EQUIPMENT, there is only the subcategory **'System ski plate binding boot'** which was named 6 or more times as risk factor. Hence, this is the only key risk factor in the basic category equipment. This subcategory was mentioned 22 times (= **highest number of entries among all key risk factors**) and has a mean ranking value with 1.73 (= **the lowest mean ranking value among all key risk factors**). Therefore, the 'System ski plate binding boot' is a key risk factor with absolute high priority.

The other subcategories ('Equipment in general', 'Boot', 'Ski', 'Binding / Plate', 'Nets and spill zones', 'Protectors and helmets', 'Racing suit', 'Gates - panel and poles') were due to no or low numbers of entries not defined as key risk factors.

Athlete (Table7)

Many interviewees mentioned a combination of psychological, physical and skiing technique aspects as one risk factor. During the first part of the interview (RFA), where the subcategories are based on, always a differentiation between the different aspects

(psychological, physical, technique) was given. Hence we had to generate for the risk factor rating a new subcategory which is called **`Combination of psychological, physical and skiing technique aspects`**. This subcategory was mentioned 13 times as risk factor and has a mean ranking value of 1.81 which defines this subcategory as a high priority key risk factor. **`Physical aspects`** were mentioned 6 times with a mean ranking value of 1.92. Hence, this subcategory is also defined as a high priority key risk factor and is with regard to the content strong related to the first key risk factor (**`Combination of psychological, physical and skiing technique aspects`**).

`Fatigue` was mentioned 15 times as risk factor. With a mean ranking value of 2.83 this subcategory was defined as low priority key risk factor. Similar to the subcategory jumps within the basic category COURSE, the subcategory fatigue is absolutely high loaded in RFA. But in RFR the mean rating value is with 2.83 one of the highest numbers within the key risk factors. Note that a higher value means a lower loading risk factor. This means that it is an important and very intensively discussed topic but there are other key risk factors which are assigned to have a much higher priority.

Regimentation Suggestions (RS)

Overview

The main goal of the RS-analysis is to get an overview about short term suggestions which were given by interviewees. The total number of suggestions within the subcategory and three representative suggestions are served in Table4-7 for each subcategory. If the number of suggestions within a subcategory is six or more, the area is filled grey. Some of the suggestions did not fit into the existing categories, hence an additional category with four subcategories was built to present this suggestions too (Table8). Additionally all suggestions are served in unstructured mode in Table9. It is also important to understand that the suggestions were given by the interviewees and do not reflect the opinion by the University of Salzburg or the FIS.

Surprisingly the quality of the suggestions was rather moderate, compared to the quality of the rest of the interviews. Some interviewees argued that they cannot give concrete suggestions since more research has to be done. Other interviewees gave suggestions, but those suggestions were more generic phrases instead of a clear picture of rule changes. Another problem was that some of the regimentations sounded good on the first view, but lacked details or are not suitable into a regimentation text.

Snow (Table4)

Within the basic category SNOW only the `Changing snow condition` was mentioned often. However, the suggestions were on a very general level and hence no real regiment can be extracted.

Course (Table5)

Within the basic category COURSE, no subcategory was mentioned more often than five times. Hence, the (within some groups) discussed topic `General course setter` seems not to be a big topic among the different experts.

Equipment (Table6)

For the subcategory `System ski plate binding boot`, 6 more or less concrete regimentation suggestions were named. Interestingly, most of them were directed towards relatively radical changes. Within the system, another 7 suggestions were given for `Skis` and 6 were given for `Binding / Plate`.

The highest number of regimentation suggestions was served for the subcategory `Racing suit` (16). The focus of those regimentations was on three different goals: speed reductions, increase body temperature, reduce slip speed after a crash.

For the subcategory `Gates (panel and poles)` 6 suggestions were served, whereby some of them were just wishy-washy.

Athlete (Table7)

The highest amount on regimentation suggestions were served for the subcategory `Fatigue` (16). The suggestion went into two directions: On the one hand, a better organized schedule minimizes the influence of jet lag, and on the other hand the cancellation of a (more) discipline(s).

Furthermore, 7 suggestions were given in the area of `Authorization to participate races` whereas the suggestions within this category were relatively diverse.

Additional Suggestions - Not Fitting the Basic Categories – (Table8)

Four additional subcategories were built due to the fact that a couple of suggestions did not fit into existing categories. Two of those subcategories load relatively high since there were 7 suggestions given. The suggestions in the subcategory `Additional staff` were primarily given with respect to better preparation of the slopes. The suggestions within the subcategory `Evidence based decisions` go clear towards the call to research based rule changes.

Conclusion

Based on the results of the qualitative interview study, Injury Hot Spots can be determined in the in the four basic categories SNOW, COURSE, EQUIPMENT and ATHLETE. Therefore different Hot-Spot types can be classified:

High Loading Hot Spot's are risk factors that were quantified as high loading in the RFA- and RFR-analysis. This means they are risk factors which seem to have the highest influence on injury risk.

Low Loading Hot Spot's are risk factors that were quantified as low loading in the RFA- and/or RFR-analysis. This means they are risk factors which seem to have a lower, but still substantial, influence on injury risk.

Possible Hot Spot's due to **plausibility check** are risk factors that were not often mentioned, but were argued and seemed to be plausible from a theoretical point of view. That means they are risk factors that could have influence on injury risk from a subjective point of view.

Furthermore, each Hot Spot is discussed in the structure of **risk factor rating**, **problem** description, a **status of knowledge** and a section where **recommended strategies** are presented.

The focus of the further process of injury prevention should be on the highest loading key risk factors as they seem to have the most potential impact. This does not mean that lower loading risk factors do not have an influence on injury prevention. Hence they should not be neglected, if their impact can be reduced easily.

High loading Hot Spot

Risk Factor #1: `System ski, binding, plate, boot (=Equipment)`

Problem Description: The system of ski, binding, plate and boot is too direct in force transmission and too aggressive in the ski-snow interaction. As a result the equipment is not controllable if the athlete loses once the balance. Furthermore it is hard to get the ski off the edge. This tends to increase the force- and energy-transmission into the body because forces and energy cannot be released as when a ski can slide away and is able to skid. The homogeneity of the bending line, weight of the equipment, edge angle as well as some geometrical and stiffness parameters of the equipment are discussed as factors that influence injury rates. However, it is unclear, which are the main factors of the equipment unit increasing injury risk. On the other hand, it seems to be plausible that only radical equipment

changes can solve the problem due to the “Optimization cycle“ in which athletes and course setting are able to (be) adapt(ed) and compensate(d) on small changes. As a result the force- and energy-situations, as well as the ski snow interaction, will be the same as before the changes.

Status of Knowledge: Research needed to clarify the relationship and determining the efficiency of an equipment change.

Recommended Strategy: There is a great potential to reduce injury risk in the further development of the system unit ski, binding, plate, boot. Based on the knowledge of the RFA Database developed by the University of Salzburg and the know-how of the equipment companies, a common strategy for more radical long term equipment changes should be elaborated during a workshop in June 2010. Therefore, it is important that all equipment companies, FIS and the research partners have the common goal to find the solutions for the problem described above. Based on the elaborated strategies during the workshop, numerous prototypes should be developed by the equipment companies, which then will be evaluated in a scientific process during World Cup season 2010/11 at different World Cup races (“**Forerunner-Project**”) and under experimental conditions imitating a World Cup race situation (“**Experimental-Project**”). Thereafter new regimens for equipment are then possible due to an evidence based evaluation of the effects induced by the planned equipment changes.

Risk Factor #2: `Changing snow conditions`

Problem Description: Changing snow conditions within one run makes it very difficult for the athlete to adapt immediately and it is hard to set up and prepare the equipment for all different conditions. Partial injection is problematic because the equipment is set up and prepared for the iciest part. The ski is too aggressive and reacts too fast when going from an icy to an aggressive-grippy part.

Status of Knowledge: Relations clear.

Recommended Strategy: It is not possible to standardize and regiment snow conditions by quantitative rules due to the fact that weather conditions cannot be controlled by humans. Nevertheless, qualitative regimentations that allow for the same preparation technique from top to bottom, as far as it can be controlled by the organizers and FIS delegates seems to be reasonable. Therefore, a workshop with the aim of formulating the list of requirements concerning the snow preparation should be held. The RFA Database developed by the University of Salzburg could help in formulating the requests on the snow preparation with

regards to contents because it includes know ledge of different expert groups. Thereafter, the efficiency of the qualitative regimens can be controlled by measuring the snow conditions during next World Cup season (“**Monitoring Project**”).

Risk Factor #3: `Physical Aspects`

Problem Description: A superior fitness level is one of the most important factors for injury prevention. However, there are two main problems:

The fitness level of the top athletes today reaches the physical limitation and cannot be further improved to resist the outer forces getting higher and higher. Therefore necessarily the acting forces have to be reduced.

The younger athletes are not always sufficiently prepared entering the World Cup, because their fitness level is not developed as well as their skiing skills.

Status of Knowledge: Relations clear.

Recommended Strategy: The importance of a superior fitness level for injury prevention is clear. Nevertheless the problem is that athletes are not always sufficiently prepared cannot be solved by rules due to the fact that there are no significant physical, psychological and technical criteria available. Therefore, the responsibility for a sufficient fitness level must be directed by the national federations and coaches and may be achieved by appropriate awareness programs that influence individual responsibility of the athletes and by improved training programs.

Risk Factor #4: `Speed and course setting aspects`

Problem Description: In carved turns, speed in combination with small radii leads to high forces. The force- and energy-situations are not only related to the turn radius and speed, but also to the amount of skidding (skid angle of the skis). Therefore, it has to be distinguished between different situations. This means that as long as the turn can be carved, due to a smooth course setting change, speed control is not very effective, but higher forces are incurred. Therefore, speed control by a turny course setting is not the key risk reduction in every case. However, the relation between speed, course setting and energy is not well understood yet due to the fact that the skier never purely carves and that there is always a certain amount of skidding.

Status of Knowledge: Research needed for clarifying the relations.

Recommended Strategy: Due to the fact that it is not well understood yet how course setting is related to speed, force- and energy patterns, this risk factor is far away from the stage of

effective quantitative regimentation. Therefore, a 2-step process seems to be necessary: In the first step (short term), a qualitative guideline based on the experience of the coaches should be evaluated in the coaches working group. The RFA Database and the results of an experimental investigation already completed by the University of Salzburg may help formulate the requests on course setting. Thereafter, the efficiency of the qualitative regimens can be controlled by measuring all course settings over next World Cup season (**“Monitoring Project”**).

In the second step, further investigations on speed changes, force-and energy- situations within different course settings should be done under experimental conditions which imitate World Cup races (**“Experimental-Project”**). Thereafter, improved quantitative regimens should be possible.

Risk Factor #5: `Fatigue`

Problem Description: Fatigue seems to be one of the main risk factors for injuries. Thereby, the overloaded schedule and jetlag problems are the main causes of fatigue.

Status of Knowledge: Relations clear.

Recommended Strategy: All suggestions that reduce the number of races within a season and enable longer recovery times after long flights with jetlag problems should be considered and discussed. From the point of injury prevention, possible changes in the schedule that reduce fatigue of the athletes seem to be wise.

Low Loading Hot Spot

Risk Factor #6: `Speed in general`

Problem Description: Higher speed means more energy has to be dissipated during a crash. Therefore, speed in general is an energetic injury potential. There is no problem as long no crash occurs, but speed is still an important risk factor during a crash. This can be also objected injury statistics where the injury frequency is directly linked to the mean speed of a discipline.

Status of Knowledge: Relations clear.

Recommended Strategy: All suggestions that have a substantial potential to reduce speed in general and that are realistic in implementation should be considered and discussed. Nevertheless, possible side effects of the suggestions and their potential for speed control have to be clear before the stage of regimentation can be reached. (Example Racing Suit: If

racing suits have a substantial potential for speed control, and how this can be achieved in a fair way for all athletes, it is not yet clear → Need for research to clarify the aerodynamical aspects for speed control)

Risk Factor #7: `Techniques of snow preparation`

Problem Description: Hard and compact prepared slopes seem to be the most fair and safe snow conditions. The use of water (Injection, Water-Hose) for snow preparation leads to less direct force transmission and can be seen as a golden standard for snow preparation in World Cup. Nevertheless, water preparation has to be handled carefully, especially on the women's side. Too slippery of snow conditions can be counterproductive in terms of safety. Furthermore, it seems that the same technique of snow preparation may lead to different results depending on the influence of weather which limits the standardisation of the snow conditions.

Status of Knowledge: Relations clear.

Recommended Strategy: see changing snow conditions.

Risk Factor #8: `Aggressive snow conditions`

Problem Description: Cold temperatures, low humidity and artificial snow seem to be the driving factors for aggressive snow conditions. These snow conditions lead to a more direct force transmission at the ski-snow interaction and there is less room for error. The use of water for snow preparation generally reduces the aggressiveness of the snow.

Status of Knowledge: Relations clear.

Recommended Strategy: see changing snow conditions.

Risk Factor #9: `Jumps`

Problem Description: Jumps are dangerous if the athlete has a short preparation time, too high of take off speed, the jumps have a steep ramp angle which launches the athlete high into the air, a landing in flat terrain, or if jumps are situated in turns or in a difficult part of the course. The building of a safe jump that considers all these risk factors is not always easy. A model checking the jump dimensions for the given parameters could help make right decisions together with experience.

Status of Knowledge: Relations clear. Theoretical model could probably support decisions.

Recommended Strategy: The large discrepancy between RFA and RFR analysis shows that jumps are an important and a very intensively discussed topic, but that there are other key

risk factors which are assigned to have a much higher priority. Nevertheless, it seems to be a risk factor where solution strategies can be found quickly due to the fact that there is a very strong consensus among the experts as to what are dangerous jumps. On the other hand, the practical realization of these strategies on site is not always easy. Maybe theoretical modelling could make the decision-process easier.

Risk Factor #10: `Skiing Techniques and Tactics`

Problem Description: Today's equipment allows for skiing fast with an improper technique. An improper technique increases injury risk. Therefore, a stable technical basis is a very important requirement for injury prevention. Right tactical decisions (= a good risk management) reduces injury risk tremendously. It seems that experience allows better risk management. If every difficulty in training and race is eliminated due to safety reason, athletes are not able to train their risk management.

Status of Knowledge: Relations clear.

Recommended Strategy: The importance of a stable technique and right tactical decisions for injury prevention is clear. The problem cannot be solved by rules. Therefore, the responsibility for proper technical basis and a good tactical level must be laid by the national federations and coaches and may be achieved by specific programs that train technical and tactical skills under variable or complicated conditions.

Risk Factor #11: `Psychological Aspects`

Problem Description: Problems in concentration and situations with increased pressure increase injury risk.

Status of Knowledge: Relations clear.

Recommended Strategy: The importance of concentration and pressure for handling injury prevention is clear. Nevertheless, the problem cannot be solved by rules. The responsibility for a sufficient psychological support must be laid by the national federations and coaches and may be achieved by specific training programs focused on cognitive and mental skills.

Possible Hot Spot due to Plausibility Check

Snow

Possible Risk Factor: `Snow Surface`

Problem Description: A very smooth snow surface may lead to a strong ski-snow interaction over the whole length of the ski so that energy cannot be released without being transmitted to the body. However, the ski-snow interaction is not yet well understood in terms of vibrations and chattering. Furthermore, the bumpiness of the snow surface seems to be related to speed control, the athlete's concentration, and individual responsibility.

Status of Knowledge: Research needed for clarifying the relations.

Course

Possible Risk Factor: `Course setting in general`

Problem Description: A turny course setting brings the athlete critically near and at a bad angle towards the nets.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Race difficulty`

Problem Description: The level of difficulty may be related to concentration, risk management, and individual responsibility of the athlete. It can be often argued that there are fewer injuries on more difficult courses than on easy courses. The level of difficulty could, therefore, be a main key to influence the risk management and individual responsibility of the athlete.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Visibility`

Problem Description: Bad visibility increases injury risk. Due to fact that weather cannot be controlled and that ski racing is an outdoor sport, visibility cannot be improved. The only prevention that can be enacted is to improve the athlete's and organizer's handling of a bad visibility periods.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Discipline Specific Problems`

Problem Description: SL: Too many people and too close to the course / GS: Tendency of too high speeds / SG: No Training before the race that does not allow for estimating speed and course difficulty / DH: More than one training run needed to prepare the inexperienced athletes for the race

Status of Knowledge: Relations clear.

Equipment

Possible Risk Factor: `Ski`

Problem Description: Ski side-cut and ski width are the primary influencing factors in the injury risk. Other discussed factors are ski stiffness and weight.

Status of Knowledge: Research needed to clarify the relationship and determining the efficiency of an equipment change.

Possible Risk Factor: `Binding/Plate`

Problem Description: In terms of binding and plate, the standing height and the release mechanism of the binding are the main points. Higher standing height seems to be more dangerous due to longer lever arms. Furthermore, a reduced standing height would not allow for high edge angles that are directly linked to higher forces. However, the risk of a “boot-out” does not seem to be a big problem in terms of injury. Bindings do not adequately release in all situations. Causes could be the release mechanism itself, which has to be improved, the reduced release performance due to the boot sole, or the ski bending.

Status of Knowledge: Research needed to clarify the relationships. Development of improved binding systems needed.

Possible Risk Factor: `Nets and Spill Zone`

Problem Description: B-nets in front of A-nets have the danger of hooking in a situation where the athletes would be able to otherwise recover.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Protectors and helmets`

Problem Description: Protectors and helmets are already at a good level. Nevertheless, there is a need for optimization in different directions. Helmet: Losing or breaking open of the

helmet during a crash is problematic. Protectors: More protection without influencing the freedom of movement of the athlete. Furthermore, athletes should be allowed all important protectors needed.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Racing Suit`

Problem Description: In the context of safety, racing suits should be improved concerning the aspects of protecting body temperature and resistance to cutting by the ski edge. If racing suits have a substantial potential for speed control, and how this can be achieved in a fair way for all athletes, it is not yet clear.

Status of Knowledge: Relationships clear in terms of temperature control and resistance to cutting by the ski edge. Need for research in clarifying the aerodynamical aspect for speed control.

Possible Risk Factor: `Gates (Panels and Poles)`

Problem Description: Panels have too high of breakaway resistance and induce a certain risk of hooking. On the other hand, panel systems should not release too quickly, because this has the effect of having workers in the course to put the panels back on the poles again.

Status of Knowledge: Relations clear. Development of improved panel or gate systems needed.

Possible Risk Factor: `Boot`

Problem Description: Today's boots allow for a high direct force transmission due to stiffness and temperature-sensitive plastic and very little damping material in the liner.

Status of Knowledge: Relations clear.

Athlete

Possible Risk Factor: `Individual Responsibility`

Problem Description: Developing individual responsibility by increasing difficulty instead of decreasing it due to safety aspects seems to be another key to solve the injury problem. If every obstacle and difficulty is removed in the name of safety the individual responsibility of the athlete can be developed. Young athletes have to learn where they have to slow down and where not to. This aspect should at least be considered in training.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Aspects of Body Temperature`

Problem Description: Cold temperatures are a huge problem for body temperature. Muscles that are too cold have a significant decrease in force generation and joints and ligaments are exposed to increased injury risk. Therefore, all actions that could increase body temperature are, from a physiological point of view, absolutely necessary.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Pre-Injury Aspects`

Problem Description: Micro lesions of former crashes or overload in combination with a further crash can lead to serious injuries. This problem is often neglected in the skiing community. Furthermore, too short of rehabilitation time after a serious injury is a problem because a ligament is still weakened after one year from the injury date even though muscles are able to recover quickly following an injury.

Status of Knowledge: Relations clear.

Possible Risk Factor: `Authorization to Participate the Race`

Problem Description: Athletes that are not well prepared (mentally, physically, technically and tactically) for the world cup have a higher injury risk. The main problem seems to be on the speed disciplines and jumps due to lacking training possibilities.

Status of Knowledge: Relations clear.

Proposal and Outlook

The focus of the further process of injury prevention should be on the highest loading key risk factors as they seem to have the most potential impact. This does not mean that lower loading risk factors do not have an influence on injury prevention. Hence they should not be neglected, if their impact can be reduced easily.

Based on the results of the qualitative analysis, the following main injury hot spots were determined and ranked according to their potential to injury prevention:

Risk Factor #1: System ski, binding, plate, boot (=Equipment)

Risk Factor #2: Changing snow condition

Risk Factor #3: Physical aspects

Risk Factor #4: Speed and course setting aspects

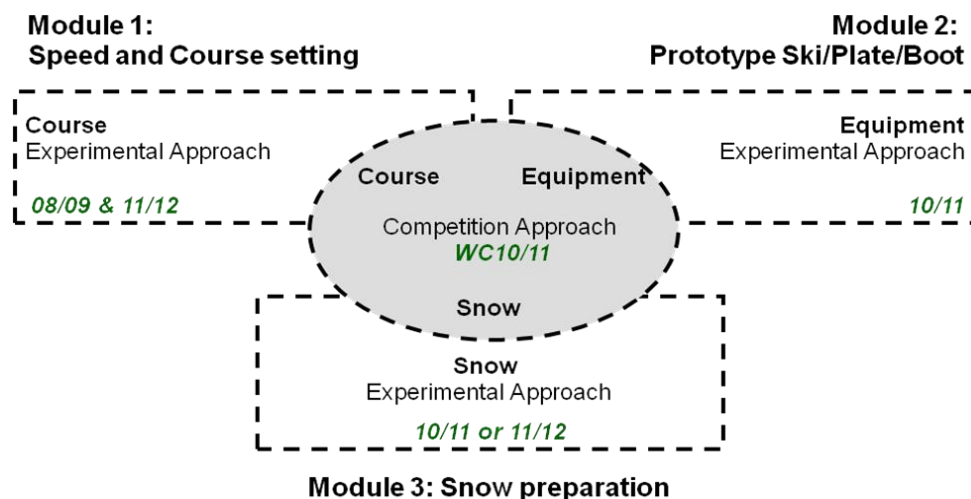
Risk Factor #5: Fatigue

The relationships between the risk factors “physical aspects” and “fatigue” seem to be clear and ready for prevention interventions. Therefore it is recommended to investigate priory:

- **Speed and course setting aspects** (Module 1)
- **New prototypes of Equipment** (Module 2)
- **Snow Preparation** (Module 3)

For these risk factors the University of Salzburg recommends a specific short-term process (see “Recommended Strategy” in the chapter “Conclusion”) in order to bridge and prepare the scientific long-term process.

In a scientific process that has to investigate a multifactor problem in the field under non-laboratory conditions, one has to balance the usage of time-intensive and highly sophisticated methods to clarify open questions in detail on one hand, and to gather information about how short term interventions may influence the non-experimental reality on the other hand.



To account for this general problem, the set up of the current project should contain two parts in each module, respectively:

Experimental Approach:

“Experimental Project”: Under an experimental setting similar to the World Cup, the effect of various interventions will be studied with highly sophisticated biomechanical methods (→ Module 2 / 3 / 1: What is the influence of different ski prototypes (2010/11), snow conditions (2011/12) or course settings (2008/09, 2011/12) on speed and on occurring forces and energy situations ?).

Competition Approach:

“Monitoring-Project”: During a complete World Cup season (2010/11), information of various racing situations will be collected (→ Module 1 / 3: What is the variety of snow conditions within a race and how is the course setting?).

“Forerunner-Project”: During a complete World Cup season (2010/11), forerunners are testing equipment prototypes in different courses and snow conditions (→ Module 2: what is the influence of different ski prototypes on the skiing performance?).

For each module, both parts will be linked afterwards to get an overall picture.

Tables

1	Introduction	Accidents resulting in serious injuries have been increasingly discussed throughout the ski racing community. What are your feelings about the situation in general? Is there a problem?	RFA Open	RFA Structured
2	General	Considering accidents in alpine ski racing involving serious injuries, from your experience and perspective can you see or do you notice any distinct features or noticeable problems?		
	Detailed	In addition to the points you have mentioned, others also see problems in the area of... (Equipment, Course Setting, Snow and Athlete – only asking about those areas not already mentioned) (Table 2). Considering this area and accidents in alpine ski racing involving serious injury, from your experience and perspective can you see or do you notice any distinct features or noticeable problems?		
	Specific	If we return again to the area of... (Equipment, Course Setting, Snow and Athlete)... often the points... (asking about specific aspects of each area listed in Table 2 and only asking about those specific areas not already mentioned)... are mentioned. Considering this area and accidents in alpine ski racing involving serious injury, from your experience and perspective can you see or do you notice any distinct features or noticeable problems?		
3	Ratings	We have been talking about a variety of aspects relating to accidents with serious injuries. If you look think about your previous statements, what do you consider the key risk factors and how would you rank them?	RFR	
4	Suggestions	Assuming changes to the regulations will take place at the annual spring FIS meeting, if you could decide which short term and realistically implementable rule changes would you choose to make ski racing safer?		

Table1: Layout and questions for the interview process: Part 1 is the introduction; part 2 moves from general to specific questions about accidents in ski racing involving serious injury; part 3 identifies and ranks key risk factors; part 4 explores suggestions for rule changes.

Equipment	Trajectory/ Course
<ol style="list-style-type: none"> 1. Ski, binding, plate, boot construction and setup 2. Binding release 3. Gates and flags 4. Racing suits, helmets and protectors 5. Safety nets and spill zones 	<ol style="list-style-type: none"> 1. Topography, slope inclination 2. Course setting 3. Speed 4. Turn radius 5. Level of difficulty 6. Visibility 7. Jumps
Snow	Athlete
<ol style="list-style-type: none"> 1. Snow condition and preparation 2. Snow driving characteristics 3. Changing snow conditions 4. Changes due to racers 	<ol style="list-style-type: none"> 1. Physical aspects 2. Psychological aspects 3. Tactics 4. Technique

Table2. Checklist used for the detailed and specific questioning in part 2 (Table1). The category titles (equipment, snow, trajectory/course and athlete) were used in the detailed question and the numbered topics were addressed in the specific questioning.

	RFA	RFR
SNOW	98/37 247/38	2.04 34
COURSE	149/34 409/38	2.49 49
EQUIPMENT	138/34 472/37	2.38 46
ATHLETE	129/35 378/38	2.22 44

Table3: Overall RFA and RFR Analysis of the four Basic Categories

SNOW		RFA	RFR	Regimentation Suggestions
Snow in general	3/2 4/3			2 The injection bar should not always be used as the solution - more races should be raced on non-injected snow kompakte Schneepisten, dadurch automatisch fehlerverzeihenderes Material verwendet, wie Ende der 90er
Aggressive Snow conditions	31/18 46/23	2.31 8		1 Make all the slopes icy (doesn't have to be injected) and avoid any aggressive snow
Changing snow conditions	33/18 106/36	1.79 17		9 Piste gleichmäßig präparieren bezüglich vereisen Gleichmäßigkeit der Piste im Reglement formulieren absolutes NO-GO: kalter Kunstschnee + einzelne Tore vereisen
Techniques of snow preparation	26/14 82/33	2.28 9		1 Präparierung: bei Damen technische Disziplinen entweder mit oder ohne Wasserpräparation, SG/DH ohne Wasser
Snow surface	5/5 9/6			1 More care has to be taken for locking into snow surfaces and things like this

Table4: Overview results SNOW

COURSE		RFA	RFR	Regimentation Suggestions
Course in general	1/1 3/1			
Visibility	3/2 45/28	2.00 3		
Course maintenance	3/2 7/6			1 Some of the warm-up hills do not have enough safety protection on them and are very dangerous for crashes
Course / Race difficulty	6/4 28/19	2.00 1		
Jumps	53/19 128/34	3.45 11		4 Sprünge reglementieren (wie Absprung gebaut sein muss) Sprünge - klare Kante + farbliche Markierung keine Zielsprünge mit flacher Landung
Speed in general	13/10 24/17	2.23 11		
Course setting in general	20/14 48/23	2.90 5		5 SL+GS Torabstände kürzen (GS max. 23m), Kurvengeschwindigkeiten (RS) runter (wie heuer gegen Ende der Saison) + übergeordnete Kurssetter (2-3) von FIS Einwirkung auf Kurssetzung (SL/RS/SG); mehr aus Falllinie, FIS - Beauftragte setzen Kurs (wie in Abfahrt)
Topography / Terrain in general	0/0 11/11			
Speed and course setting aspects	31/21 70/33	2.00 9		
Speed and topographic aspects	4/2 16/9	C10 2.60 5		
Discipline specific problems	15/12 29/18	1.50 4		1 Damenbereich: Superkombi bestehend aus SG+SL, weil oft Kombi-Läuferinnen am Start die mit Abfahrt überfordert sind

Table5: Overview results COURSE

EQUIPMENT		RFA	RFR	Regimentation Suggestions
Equipment in general	16/12 32/20			
System ski plate binding boot (=Equipment)	56/25 95/33	1.73 22		6 Radikale Materialänderungen: Ski versteifen, Standhöhe runter - macht großen Unterschied Ski länger machen in allen Disziplinen + Standhöhe runter (durch Expertenteam festgelegt) Platte weggeben, ohne beweglichen Teil bei Bindung -> Ski kann sich unter Bindung nicht durchbiegen -> Rutschphase
Boot	8/4 27/17	2.75 2		1 zertifizierter Schuh (Flex, Härte)
Ski	17/13 41/24	3.13 4		7 Ski länger + eventuell wieder schmaler Skigewicht deutlich reduzieren (heute ca 10kg, sollte 30% leichter werden) Ski wieder schmaler und 10cm länger machen (SL/RS)
Binding / Plate	14/9 54/28	3.00 5		6 Platte weg, Ski runter => geringerer Aufkantwinkel möglich Standhöhe runter (keine konkrete Angabe, jedoch ganz zentraler Punkt!) Schuhe: Sohlen normieren - Duroplast anstelle von Thermoplast, dadurch Funktion Bindungsauslösung wieder genau
Nets and spill zones	11/7 63/30	2.88 4		1 Sicherheitsverantwortlichen (für Pistenabsicherung) anstellen, der sich vor Ort nur mit dieser Materie auseinandersetzt
Protectors and helmets	3/3 55/31	4.50 1		1 Schützer erlauben
Racing suit	2/2 34/26	2.67 3		16 Anzüge: Material, das langsamer ist (-10% Speed) Rennanzüge: langsamer machen durch höhere Luftdurchlässigkeit (Abfahrt minus 5km/h); Anzüge - Arbeitsgruppe einsetzen: Rutschen bei Sturz reduzieren, 3-5% weniger Speed
Gates (panel and poles)	11/7 71/34	2.90 5		6 New gate manufacturer for Super-G gates/ panels Tearaway panels on every gate in downhill Expertenteam einsetzen, das bis zum Sommer Resultate liefert -> neue Flaggen schon im Training eingesetzt werde können

Table6: Overview results EQUIPMENT

ATHLETE		RFA	RFR	Regimentation Suggestions
Combination of Psychological, Physical and Skiing Techniques Aspects	- -	1.81 13		
Psychological aspect	17/13 51/26	2.00 1		
Physical aspects	25/20 55/29	1.92 6		Athleten Bedeutung physischer Verfassung verdeutlichen ¹
Skiing techniques an tactics	25/13 73/31	1.83 3		
Fatigue	24/13 64/33	2.83 15		Rennkalender - Kontinentalzeitverschiebung beachten (pro 1h Zeitverschiebung mind 1/2 Ruhetag nach Ankunft Eine Disziplin streichen (SG oder Superkombi) - Entlastung der Athleten Terminplanung: Rennstress entschleunigen - vor allem Transatlantik z.B. 1 Woche Pause danach ¹⁷
Authorization to participate races	3/3 22/12			Grundqualifikation der Rennläufer über Punktelimits, Attest über funktionelle Belastbarkeit nach Knie-Verletzung Leistungstests ob Athlet fit genug z.B. Spiroergometrie (unpräzise ausgeführt) Hire professional forerunner to follow the world cup ⁷
Race preparation of the Athlete	5/5 9/8	1.75 2		
Pre-injury aspects	6/6 20/15	1.00 1		
Aspects of body temperature	3/3 18/17			
Crash behaviour	1/1 5/5			
Genetics and Anthropometrie	0/0 6/6			
Adaptability	1/1 2/2			
Individual Responsibility	19/3 33/12	2.67 3		

Table7: Overview results ATHLETE

ADDITIONAL		Suggestions
Rules and Rules making Process	IWO: einzelne Punkte (z.B. Höhenmeter) nicht so genau definieren, mehr Freiheiten für vor-Ort-Entscheidungen (z.B. bei Wind)	3
	Änderung der Diskussionsstrukturen der FIS -> zu viele einzelne Subkomitees, Infos gehen verloren -> zentralere Arbeitsgruppe Experten-Sicherheits&Materialkomitee bei FIS anstelle des derzeitigen "Alibi-Komitees"	7
Additional Staff at Races	Crew (5-6 Leute) für Pistenpräparation (professionellere Vorbereitung)	
	professionelles Pistenvorbereitungspersonal + Farbmarkierungen (nicht näher erklärt) je 2 Pistenpräparationsteams für Männer und Frauen für alle Rennen	3
Race Organization	Rennerverschiebung max. 1,5-2h, sonst Absage	
	There should be more races like the team event in Garmish as it was a good show with very little risk. maximal 45 Athleten (nicht konkreter formuliert - Vermutung; pro Disziplin)	7
Evidence based Decisions	Veränderungen erst auf absolut fundierter Basis, keine Schnellschüsse!!	
	Just don't jump the gun on decisions for changes without the enough knowledge Ski width should only be changed if the research says there are more injuries one way or another	

Table8: Additional Suggestions (not fitting the Basic Categories)

Athleten Bedeutung physischer Verfassung verdeutlichen
Kombi und SG streichen, nur 8 Rennen pro Disziplin (insg. 24 Rennen)
Better organized schedule: stay in North America for longer, then move to Scandinavia then stay in a certain part of Europe, etc. instead of bouncing around so much
There needs to be a proper time gap after travel
Change the schedule: more rest and/ or less travel
Rennkalender - Kontinentalzeitverschiebung beachten (pro 1h Zeitverschiebung mindestens 1/2 Ruhetag nach Ankunft)
Superkombi/SG streichen, nur 10 Rennen pro Disziplin (SL/GS/DH), Saison von 1.Nov. bis 15 März - regelmäßiger Rhythmus in Disziplinen
Sölden 1 Woche nach hinten, Levi streichen
Superkombi weg, nur noch 1 Speed-Disziplin (evtl. Herren/Damen unterschiedlich)
Terminplanung: Rennstress entschärfen - vor allem Transatlantik z.B. 1 Woche Pause danach
Get rid of the super combined
Keine Superkombi mehr
Rennkalender/Planung: nach Transatlantik am darauffolgenden Wochenende keine Speed-Bewerbe
Terminkalender: Wenn Bewerb nicht am geplanten Tag durchgeführt werden kann wird er ersatzlos gestrichen, nicht um 1-2 Tage nach hinten geschoben.
Eine Disziplin streichen (SG oder Superkombi) - Entlastung der Athleten
Reiserouten bei Kalenderplanung berücksichtigen
Leistungstests ob Athlet fit genug z.B. Spiroergometrie (Punkt sehr unpräzise)
Grundqualifikation der Rennläufer über Punktelimits, Attest über funktionelle Belastbarkeit nach Knie-Verletzung
Abfahrts-Qualifikations-Kriterien nach oben schrauben (unter 40 FIS Punkte)
Mehr Training und verpflichtend 1 Nonstop Trainingslauf von Jugend bis Europacup bei Speed-Disziplinen
Trainingslauf in SG, mind. 2 Trainingsläufe in Abfahrt
Hire professional forerunner to follow the world cup
Damenbereich: Superkombi bestehend aus SG+SL, weil oft Kombi-Läuferinnen am Start die mit Abfahrt überfordert sind, bzw. Abfahrten deswegen oft entschärft werden müssen
Sprünge reglementieren (wie Absprung gebaut sein muss)
Sprünge - klare Kante + farbliche Markierung
SL+GS Torabstände kürzen (GS max. 23m)

Table8a: Overall list of suggestions given by the interviewees - Part1

Kurvengeschwindigkeiten (RS) runter (wie heuer gegen Ende der Saison) + übergeordnete Kurssetzer (2-3) von FIS
Einwirkung auf Kurssetzung (SL/RS/SG); mehr aus Falllinie, FIS - Beauftragte setzen Kurs (wie in Abfahrt)
Torabstände im Schülerbereich: RS max. 25m, SL max. 10m + Höhenunterschiede geringer machen dadurch weniger Intensität
übergeordneter Kurssetzer, der bei sicherheitsbedenklicher Kurssetzung ´overrulen´ kann
eigene Damenrichtlinien für Ski + eigene Herrenrichtlinien (z.B. Länge) - noch zu unkonkret. Keine Herrenski im Damenbereich, da schwache Läuferinnen auch zu Herrenski greifen, diese jedoch nicht beherrschen
Radikale Materialänderungen: Ski versteifen, Standhöhe runter - macht großen Unterschied
Abfahrtsski schmaler, Platte weg
Platte weg in SG/DH, dafür Ski etwas breiter um auf-Schuh-wegrutschen entgegenzuwirken, Taillierung weiter rauf (RS~40m/SG~45/50m/DH~50/55m)
Platte weggeben, ohne beweglichen Teil bei Bindung -> Ski kann sich unter Bindung nicht durchbiegen, dadurch entsteht Rutschphase
Ski länger machen in allen Disziplinen + Standhöhe runter (durch Expertenteam festgelegt)
Schuhe: Sohlen normieren - Duroplast anstelle von Thermoplast, dadurch Funktion Bindungsauslösung wieder genau
zertifizierter Schuhe verwenden (Flex, Härte)
Skilängen nach oben (alle Disziplinen +5cm), Breite 3 bis 4mm mehr (DH+SG), Radius gleich,
Ski länger + eventuell wieder schmaler
Skibreite SL auf 60mm bzw. GS 63mm Untergrenze
Materialkontrollen bzgl. Radien etc. (werden jetzt zu wenig durchgeführt)
Skigewicht deutlich reduzieren (heute ca. 10kg, sollte 30% leichter werden)
Taillierung: größere Radien in allen Disziplinen
Ski wieder schmaler und 10cm länger machen (SL/RS)
Platte weg, Ski runter => geringerer Aufkantwinkel möglich
Standhöhe runter (keine konkrete Angabe, jedoch ganz zentraler Punkt!)
Standhöhe reduzieren (keine genaueren Angaben)
Bindungsauslösung nach innen/außen getrennt einstellbar + unterschiedliche Auslösecharakteristiken (innen Lastspitzenlöschung, außen linear), Auslösetoleranzen (in Bezug auf Z-Wert) von +-30% auf +-10% senken, TÜV Zertifizierung zur Kontrolle, darf bei Lastspitzen (Schlägen) nicht zu leicht aufgehen
Form- und Kraftschlüssige Verbindung zwischen Ski und Schuh (z.B. Platte auf Sohle schrauben, Verbindung darf sich nicht verformen)
jeglichen Schützer erlauben
Anzüge: Material, das langsamer ist (-10% Speed)

Table8b: Overall list of suggestions given by the interviewees – Part2

Rennanzüge ändern um Speed zu reduzieren
Anzug dicker und wärmer - normierter Stoff, kann individuell geschneidert werden.
Rennanzüge: langsamer machen durch höhere Luftdurchlässigkeit (Abfahrt minus 5km/h);
Rennanzüge (5% Speed-Reduktion) (Keine Info wodurch erreicht)
Anzüge - Arbeitsgruppe einsetzen: Rutschen bei Sturz reduzieren, 3-5% weniger Speed
Anzüge: weniger Speed (5-10% weniger)
Anzüge: realistisch ist 4% weniger; dickeres Material + Protektoren; kurzfristig können GS Anzüge in Speed Disziplinen eingesetzt werden, langfristig können Veränderungen genauer angegangen werden
Anzug, noch mehr Luftwiderstand und mehr Reibungswiderstand (5% Speed Verringerung + Reibungswiderstand)
Anzüge dicker und rauer machen, dadurch 10-15% weniger Speed. Im Nachwuchs z.B. 1 Anzug für alle Disziplinen
Anzüge, Oberflächenrauigkeit, Luftdurchlässigkeit, 5% Speed sollte möglich sein
Mindestluftdurchlässigkeit der Rennanzüge nach oben reglementieren, Know-how der Skispringer nutzen (keine konkreten Angaben zu Luftdurchlässigkeit), minus 5-10km/h soll erreicht werden
Einheitsanzug evtl. in Kombination mit Protektoren um Speed zu reduzieren + passive Sicherheit zu erhöhen (Schnittfeste Materialien)
Rennanzüge (Luftdurchlässigkeit), Speed um 2-4 km/h reduzieren (nicht näher konkretisiert)
Anzug dicker und luftdurchlässiger - Wärme, Dämpfung, Luftwiderstand als Resultat, 3-4 Sek. langsamer dadurch
New gate manufacturer for Super-G gates/ panels
Tearaway panels on every gate in downhill
As well as DH and SG, all GS gate panels should be tearaways
Flaggen - Expertenteam einsetzen, das bis zum Sommer Resultate liefert, damit diese Flaggen schon im Training eingesetzt werden können
Torflaggen mit mehr Sicherheit, die wieder schnell befestigt werden können (nicht näher erklärt)
The injection bar should not always be used as the solution - more races should be raced on non-injected snow
kompakte Schneepisten, dadurch wird automatisch fehlerverzeihenderes Material verwendet, wie Ende der 90er
Make all the slopes icy (doesn't have to be injected) and avoid any aggressive snow
SL Piste homogen (z.B. Wasserpräparierung überall oder nirgends)
Prepare the slope consistently from top to bottom
If injecting any pitches then must inject all pitches on the course
Pisten einheitlich präparieren

Table8c: Overall list of suggestions given by the interviewees – Part3

Gleichmäßigkeit der Piste im Reglement formulieren
Pistenhomogenität gewährleisten
keine partielles Vereisen - alles oder nichts
absolutes NO-GO: kalter Kunstschnee + einzelne Tore vereisen
bei Damen technische Disziplinen entweder mit oder ohne Wasserpräparation, SG/DH ohne Wasser,
IWO: einzelne Punkte (z.B. Mindest-Höhenmeter einer Disziplin) nicht so genau definieren, mehr offenlassen für vor-Ort-Entscheidungen (z.B. bei Wind kürzere Strecken)
Änderung der Art und Weise der Diskussionsstrukturen der FIS -> zu viele einzelne Subkomitees, zu viel Infos gehen dazwischen verloren - eher zentralere Arbeitsgruppe
Experten-Sicherheits-& Materialkomitee bei FIS anstelle des derzeitigen "Alibi-Komitees"
Bigger travelling FIS crew to manage races
Crew (5-6 Leute) für Pistenpräparation (professionellere Vorbereitung)
There needs to be more people from FIS travelling with the world cup, more people constantly watching and looking at the races.
professionelles Pistenvorbereitungspersonal + Farbmarkierungen (nicht näher erklärt)
je 2 Pistenpräparationsteams für Männer und Frauen für alle Rennen
Sicherheitsverantwortlichen (nur für Pistenabsicherung) anstellen, der sich vor Ort nur mit dieser Materie auseinandersetzt
Experte für Abtransport Kette von FIS für alle Rennen, Kette schon im Vorfeld überprüfen
Rennverschiebung max. 1,5-2h, sonst Absage
There should be more races like the team event in Garmisch as it was a good show with very little risk.
maximal 45 Athleten pro Disziplin um flexibel in der Renndurchführung zu sein (im Weltcup)
Veränderungen erst auf absolut fundierter Basis, keine Schnellschüsse!!!
Everyone needs to work together to make decisions for safety
Not for equipment as it is too late for equipment changes for next year
Just don't jump the gun on decisions for changes without the enough knowledge
keine konkreten Änderungen genannt, will keine "Schnellschüsse" bzgl. Materialänderung abgeben
Ski width should only be changed if the research says there are more injuries one way or another
Standing height should only be changed if the research says there are more injuries one way or another
Alle Beteiligten ins Boot holen (FIS, Industrie, Organisatoren,...) alle müssen Teil beitragen (Reglement, Material, Pistentopographie,...)
Gesamtsystem muss geändert werden, überall ein bisschen "schrauben" (Pistentopographie, Material, Präparation)

Table8d: Overall list of suggestions given by the interviewees – Part4

Figures



Figure1: The initial layout of statements (white strips of paper) separated into basic categories (large brown squares) and organized into subcategories (yellow squares) based on similarities. These were then entered into a computer database for ease of analysis.

The screenshot shows the FIS software interface. On the left, a tree view displays the hierarchy of statements. The right pane shows a table of statements with the following data:

ID	Code	Text	Timecode
156	02_05_28_23	Veränderte Schneebedingu...	00:25:46-7
157	02_05_38_32	Veränderte Schneebedingu...	00:38:40-7
158	02_02_15_22	Veränderte Schneebedingu...	00:18:10-3
159	02_06_06_21	Changing snow conditions w...	00:04:02-5
160	02_06_05_21	Constantly changing snow c...	00:03:06-7
161	03_05_07_21	Changing snow conditions w...	00:04:47-1
162	08_07_47_23	Veränderte Schneebedingu...	01:02:19-5
163	05_07_37_23	Constantly changing snow c...	00:15:32-2
164	02_05_21_23	Veränderte Schneebedingu...	00:20:38-1
165	03_09_21_23	Es sollten vom Start bis ins Z...	00:23:27-9
166	04_07_09_21	When on the aggressive eq...	00:04:22-4
167	02_07_07_22	Changing snow conditions b...	00:14:26-6
168	04_04_25_23	Changing snow conditions in...	00:23:06-5
169	04_07_08_21	The equipment has to be set...	00:03:38-5
170	04_07_07_21	A mix of injected and aggres...	00:02:30-6
171	03_04_11_01	Snow conditions need to be ...	00:05:57-6
172	02_03_15_23	Changing snow conditions in...	00:20:34-4
173	02_05_35_31	Veränderte Schneebedingu...	00:36:22-8
174	08_07_46_23	Ständig wechselnde Schne...	01:01:58-7
175	08_07_23_22	Ständig wechselnde Schne...	00:32:02-5
684	04_06_06_21	Das Problem sind wechseln...	00:07:30-9
730	04_02_13_21	Wechselnde Bedingungen i...	00:08:19-5

Figure2: Example for the database - In total 247 statements according *SNOW* were given. 106 out of them contained “*Changing snow conditions*” as topic, whereby again 69 included “*Changing snow conditions within a run*” as problem. 34 statements out of the 69 specified the problem as “*Changing snow conditions within a run: Adjustment of equipment setup is difficult*”.

- ☐ GENERAL STATEMENTS (217 / 37)
 - ☐ Injuries: Problem or part of the game (89 / 36)
 - ☐ Evident injury problem (47 / 28)
 - └ Injuries are a huge problem (15 / 14)
 - └ Increasing number of injuries in recent years (6 / 5)
 - └ Pattern of injuries have changed in recent years (16 / 11)
 - └ Knee injuries are the most common injuries (5 / 5)
 - └ Periodic accumulation of injury frequency and sensibility (5 / 4)
 - ☐ No evident injury problem (19 / 14)
 - └ No increasing number of injuries in recent years (10 / 7)
 - └ Injuries have recently been hyped (9 / 8)
 - ☐ Injuries are part of the game (23 / 16)
 - └ Risk is in the nature of ski racing (23 / 16)
 - ☐ Injuries: Image of ski racing (26 / 14)
 - ☐ Injuries have influence on the image (26 / 14)
 - └ Injuries have bad influence on image (16 / 8)
 - └ Show yes but without too much risk (10 / 8)
 - ☐ Injuries: Prevention in ski racing (66 / 28)
 - ☐ Radical Changes needed due to optimization loop (20 / 6)
 - └ Injury problem can only be solved by radical changes due to optimization loop (20 / 6)
 - ☐ Radical Changes are not possible due to decreasing of attractiveness (2 / 2)
 - └ Radical equipment changes to go back to skidded turns make no sense (2 / 2)
 - ☐ Injury problem is recognized, accepted and discussed (17 / 15)
 - └ No general pattern obvious (11 / 10)
 - └ Problems obvious, solutions difficult (6 / 5)
 - ☐ Injury problem is recognized but neglected (2 / 2)
 - └ Athletes are not sensible enough for injury prevention (1 / 1)
 - └ Injury problem is swept under the carpet (1 / 1)
 - ☐ Some prevention strategies are already realized (22 / 16)
 - └ Prevention interventions should not be rushed (9 / 7)
 - └ Prevention strategies are on a good level (13 / 11)
 - ☐ Groups of interest should be more involved in prevention (3 / 2)
 - └ (Former) Athletes should be more involved in decisions (3 / 2)
 - ☐ Group specific interests (34 / 17)
 - ☐ Group specific interests have influence on safety (28 / 15)
 - └ Maximizing performance is the main goal of the ski company's (7 / 5)
 - └ "TV Time" pressure versus safety aspects (4 / 4)
 - └ Disagreement between the involved groups make prevention difficult (17 / 9)
 - ☐ Conflict between performance and safety (6 / 5)
 - └ Seeking perfection instead of safety (2 / 2)
 - └ Double role of coaches: performance versus safety (4 / 3)
 - ☐ FIS competition rules (2 / 2)
 - ☐ Rules in general and its influence on safety (2 / 2)
 - └ Rule changes don't automatically solve the problem (2 / 2)

Figure3: Structure of Categories – GENERAL STATEMENTS

- ☐ SNOW (247 / 38)
 - ☐ Snow in general (4 / 3)
 - ☐ Snow has influence on safety (0 / 0)
 - ☐ Snow is the key factor (0 / 0)
 - ☐ Snow has no influence on safety (4 / 3)
 - ☐ Snow is not the key factor (4 / 3)
 - ☐ Aggressive Snow conditions (46 / 23)
 - ☐ Aggressive snow in general is a problem (24 / 18)
 - ☐ Aggressive snow is dangerous (8 / 7)
 - ☐ Direct force transmission due to aggressive snow in combination with the equipment is dangerous (16 / 12)
 - ☐ Aggressive artificial snow is a problem (6 / 6)
 - ☐ Artificial snow: aggressive and no space for error (6 / 6)
 - ☐ Aggressive cold dry snow is a problem (15 / 11)
 - ☐ Cold dry snow is aggressive (15 / 11)
 - ☐ Aggressive snow conditions are not a problem (1 / 1)
 - ☐ Athlete should be able to adapt to aggressive snow conditions (1 / 1)
 - ☐ Changing snow conditions (106 / 36)
 - ☐ Changing snow conditions from run to run are a problem (21 / 13)
 - ☐ Different conditions between different races makes it hard to adapt (11 / 8)
 - ☐ Different conditions between inspection and race makes it hard to prepare (8 / 7)
 - ☐ Different conditions between training or warm up runs and races leads to unadequate race preparation (2 / 2)
 - ☐ Changing snow conditions from run to run are no problem (4 / 4)
 - ☐ Athlete should be able to adapt changing snow conditions from run to run (4 / 4)
 - ☐ Changing snow conditions within one run are a problem (69 / 30)
 - ☐ Changing snow conditions within a run: adjustment of equipment setup is difficult (34 / 25)
 - ☐ Consistent snow preparation within a run is desirable (35 / 17)
 - ☐ Changing snow conditions within one run are no problem (5 / 3)
 - ☐ Athlete should be able to adapt changing snow conditions within one run (5 / 3)
 - ☐ Changes due to bip number are a problem (1 / 1)
 - ☐ Relation between worsening of the slope during the race and injuries (1 / 1)
 - ☐ Changes due to bip number are no problem (6 / 6)
 - ☐ No relation between worsening of the slope during the race and injuries (6 / 6)
 - ☐ Techniques of snow preparation (82 / 33)
 - ☐ Snow preparation has an influence on safety (19 / 15)
 - ☐ Injected slopes lead to less direct force transmission (10 / 9)
 - ☐ Difficult to make a slope perfect (7 / 7)
 - ☐ Snow preparation has a great potential (2 / 2)
 - ☐ Snow penetration depth has an influence on safety (10 / 7)
 - ☐ Hard grippy snow is less dangerous than soft snow (5 / 4)
 - ☐ Hard slopes leads to more direct force transmission (3 / 3)
 - ☐ Hard slopes are dangerous if the athlete crashes and hits the slope surface (2 / 2)
 - ☐ Water prepared slopes are a problem (16 / 10)
 - ☐ Preparing slopes with water is problematic (13 / 10)
 - ☐ Bumpy and icy slopes are dangerous (1 / 1)
 - ☐ On water prepared slopes there is no room for errors (1 / 1)
 - ☐ Using a hose is better than injection (more consistent surface) (1 / 1)
 - ☐ Water prepared slopes as a golden standart (36 / 23)
 - ☐ It makes sense to use injection for all WC races (20 / 14)
 - ☐ It makes sense to prepare the slopes with water at all men's races (4 / 4)
 - ☐ It makes no sense to inject all slopes on the women's side (12 / 9)
 - ☐ Manipulation during the artificial snow production has an influence on safety (1 / 1)
 - ☐ Manipulating artificial snow production results in less aggressive snow, but also in less hard snow (1 / 1)
 - ☐ Snow surface (9 / 6)
 - ☐ Snow surface has influence on safety (9 / 6)
 - ☐ Smooth snow surface is more dangerous than a bumpy snow surface (8 / 5)
 - ☐ A more bumpy slope preparation does not increase safety (1 / 1)

Figure4: Structure of Categories – SNOW

- [-] COURSE (409 / 38)
 - [-] Course in general (3 / 1)
 - [-] Keeping courses up to date has an influence on safety (3 / 1)
 - [-] Adjustment of the course on actual situation has influence on safety (3 / 1)
 - [-] Visibility (45 / 28)
 - [-] Bad visibility has an influence on safety (45 / 28)
 - [-] Bad visibility increases injury risk (27 / 22)
 - [-] Optical support (colors / lighth) reduces injury risk (14 / 11)
 - [-] Inconsistent blue lines ar problematic (4 / 4)
 - [-] Course maintenance (7 / 6)
 - [-] Course maintenance has influence on safety (1 / 1)
 - [-] Course maintenance is reduced for higher bip numbers (1 / 1)
 - [-] People working on the slope have an influence on safety (4 / 3)
 - [-] Slip crews are a safety risk (4 / 3)
 - [-] Obstacles near the course have an influence on safety (2 / 2)
 - [-] Obstacles near the course are a problem (2 / 2)
 - [-] Course / Race difficulty (28 / 19)
 - [-] Level of difficulty has influence on safety (25 / 16)
 - [-] Easy course is more dangerous than a difficult course (9 / 9)
 - [-] Level of difficulty in WC is to high (4 / 4)
 - [-] Level of difficulty in WC is ok (7 / 3)
 - [-] Level of difficulty in WC is to low (2 / 2)
 - [-] Level of difficulty in EC and WC is too diverse (3 / 2)
 - [-] Level of difficult has no influence on safety (3 / 3)
 - [-] Level of difficulty is not linked to injury risk (3 / 3)
 - [-] Jumps (128 / 34)
 - [-] Jumps are an inherent part of ski racing (12 / 12)
 - [-] Jumps have to be part of downhill courses (12 / 12)
 - [-] Take off and landing of jumps have an influence on safety (49 / 24)
 - [-] Jumps in combination with turns are no problem (1 / 1)
 - [-] Jumps in combination with turns are dangerous (13 / 12)
 - [-] Before and after jumps the course should be easy (14 / 10)
 - [-] Landings in the steep are less dangerous than in the flat (21 / 15)
 - [-] How jumps are builded has an influence on safety (52 / 23)
 - [-] High take off speeds are problematic (7 / 7)
 - [-] Artificial jumps are often builded badly (15 / 12)
 - [-] Marked drop point of the jump increases safety (5 / 3)
 - [-] Jumps with a steep ramp angle which launch you high are a problem (22 / 16)
 - [-] Jump fixing only the optimal line is problematic (2 / 2)
 - [-] If jumps are builded right the jump distance is not a problem (1 / 1)
 - [-] Jumpraining has an influence on safety (8 / 5)
 - [-] More jumpraining would improve safety (8 / 5)
 - [-] Jumps are a gender specific problem (7 / 5)
 - [-] Jump-problem is a women's problem (6 / 5)
 - [-] Jump-problem is a fear problem (1 / 1)
 - [-] Speed in general (24 / 17)
 - [-] Speed in general has influence on safety (17 / 13)
 - [-] Speed is a general problem (17 / 13)
 - [-] Speed in general has no influence on safety (7 / 5)
 - [-] Speed in general is no problem (7 / 5)

Figure5a: Structure of Categories – COURSE

- ☐ Course setting in general (48 / 23)
 - ☐ Course setting has influence on safety (27 / 17)
 - └ Course setting is a risk factor (2 / 2)
 - └ A safe course setting must be adapted to terrain (3 / 3)
 - └ Course setting that brings the racers in difficulties (5 / 4)
 - └ Gates on rolls or blind gates after rolls are a problem (5 / 4)
 - └ Turny course setting brings the athlete critical towards the nets (8 / 6)
 - └ Turny course setting brings the athlete not critical towards the nets (1 / 1)
 - └ Difference between sid cut radius and gate distance is dangerous (3 / 3)
 - ☐ Course setting has no influence on safety (12 / 8)
 - └ Course setting is not the key problem (5 / 5)
 - └ Course setting adapts on equipment and is therefore not the source of the problem (7 / 3)
 - ☐ Rules on course setting and it's influence on safety (9 / 7)
 - └ FIS course setter would make sense (3 / 3)
 - └ FIS course setter would make no sense (2 / 2)
 - └ Course setting rules are ok (1 / 1)
 - └ Course setting rules are not sufficient (3 / 2)
- ☐ Topography / Terrain in general (11 / 11)
 - ☐ Topography has no influence on safety (5 / 5)
 - └ Topography has no influence on crash frequency (5 / 5)
 - ☐ Topography has influence on safety (6 / 6)
 - └ Flat and middle steep terrain is more dangerous than steep (3 / 3)
 - └ Compressions in combination with speed are dangerous (2 / 2)
 - └ Smooth terrain changes are more dangerous than sharp terrain changes (1 / 1)
- ☐ Speed and course setting aspects (70 / 33)
 - ☐ Speed in turns have influenc on safety (70 / 33)
 - └ Speed in combination with small radii is dangerous (17 / 13)
 - └ Speed in combination with small radii leads to high forces (11 / 9)
 - └ Speed in turns is higher today then in the past (4 / 4)
 - └ Speed control through turny course setting is problematic (13 / 13)
 - └ In carved turns speed can not be controlled through a turny course setting (9 / 9)
 - └ Speed can be controlled through course setting (16 / 13)
- ☐ Speed and topographic aspects (16 / 9)
 - ☐ Terrain and bumpy preperation has influence on safety (15 / 8)
 - └ Speed can be controled through rolls and bumps (6 / 3)
 - └ Speed can be controlled through icy and bumpy preperation (9 / 6)
 - ☐ Terrain and bumpy preperation has no influence on safety (1 / 1)
 - └ Speed can not be controled through rolls and bumps (0 / 0)
 - └ Speed can not be controlled through icy and bumpy preperation (1 / 1)
- ☐ Discipline specific problems (29 / 18)
 - ☐ Problems in SL / GS (4 / 4)
 - └ Space for falls in SL an GS too less (1 / 1)
 - └ Speed in GS is to high (3 / 3)
 - ☐ Problems in SG /DH (23 / 15)
 - └ Course setting in downhill is too turny (7 / 5)
 - └ Speed in downhill is too high (2 / 2)
 - └ Speed and radii in DH / SG are ok (6 / 5)
 - └ More than one training run needed in DH (2 / 2)
 - └ SG is dangerous (6 / 6)
 - ☐ Problems in Super Combined (2 / 2)
 - └ Suber combined makes no sense (2 / 2)

Figure5b: Structure of Categories – COURSE

- ☐ EQUIPMENT (472 / 37)
 - ☐ Equipment in general (32 / 20)
 - ☐ Equipment in general has no or limited influence on safety (7 / 6)
 - └─ Equipment is not the key solve the problem (7 / 6)
 - ☐ Equipment changes in recent years had almost no influence on safety (20 / 13)
 - └─ In future equipment changes have to be based on evidence based research (7 / 4)
 - └─ Recent equipment changes solved the problem not or only partly (10 / 9)
 - └─ Equipment changes only make sense in combination with slope preparation (3 / 3)
 - ☐ Equipment changes in recent years opened new fields of problems concerning injuries (5 / 4)
 - └─ Equipment allows extreme body positions (2 / 2)
 - └─ Recent equipment changes have shifted the problem instead of solving it (3 / 2)
 - ☐ System ski plate binding boot (=Equipment) (95 / 33)
 - ☐ Ski, plate, binding and boot has to be considered as one unit (10 / 9)
 - └─ Ski, plate, binding and boot has key influence on safety (6 / 6)
 - └─ Boot out is problematic in terms of injuries (1 / 1)
 - └─ Boot out is not problematic in terms of injuries (3 / 3)
 - ☐ Weight of equipment has influence on safety (6 / 6)
 - └─ If the equipment is heavy and the mass is accelerated it is getting dangerous (6 / 6)
 - ☐ Aggressiveness of equipment has influence on safety (10 / 10)
 - └─ Equipment is too aggressive (10 / 10)
 - ☐ The controlability of equipment has influence on safety (33 / 19)
 - └─ Equipment: there is no room for error (10 / 8)
 - └─ If equipment is once out of control, it is not possible to do corrections (17 / 10)
 - └─ Once the ski is carving it is very difficult to get rid off the edge (6 / 6)
 - ☐ Directness of the force transmission from equipment to athlete has influence on safety (8 / 7)
 - └─ Direct force transmission from equipment to athlete is dangerous (8 / 7)
 - ☐ Bendingline of the system ski, plate, binding has influence on safety (12 / 5)
 - └─ Homogenous bendingline is a driving factor for injuries (11 / 4)
 - └─ Bendingline influences speed control and therefore safety (1 / 1)
 - ☐ Edge angle has influence on safety (3 / 2)
 - └─ Edge angle is a driving factor (3 / 2)
 - ☐ Equipment setup and preparation has influence on safety (13 / 9)
 - └─ Situational setup adjustment has potential to reduce injuries (6 / 4)
 - └─ Situational setup adjustment has no or limited potential to reduce injuries (2 / 2)
 - └─ Preparation has potential to reduce injuries (3 / 2)
 - └─ Preparation has no potential to reduce injuries (2 / 2)
 - ☐ Boot (27 / 17)
 - ☐ Boot has influence on safety (21 / 12)
 - └─ Direct aggressive boots are a problem (21 / 12)
 - ☐ Boot has no influence on safety (6 / 6)
 - └─ Boots are not a key factor for the injury problem (6 / 6)

Figure6a: Structure of Categories – EQUIPMENT

- ☐ Ski (41 / 24)
 - ☐ Ski length has influence on safety (6 / 5)
 - └ Short ski's causes less control and are therefore dangerous (3 / 2)
 - └ Short ski's causes less control and therefore increases safety because more central skiing is required (1 / 1)
 - └ Longer ski's have longer lever arms and might be a problem (1 / 1)
 - └ Longer ski's means higher speed (1 / 1)
 - ☐ Ski sidecut has influence on safety (13 / 11)
 - └ Side cut is not the key to solve the problem (2 / 2)
 - └ Too much side cut is dangerous (9 / 8)
 - └ Less sidecut is an efficient way to reduce speed (1 / 1)
 - └ Less side cut can be a problem because it forces more angulation to make the same edge angle (1 / 1)
 - ☐ Ski with has an influence on safety (13 / 10)
 - └ Wide skis are safer (2 / 2)
 - └ Wide skis are dangerous (11 / 8)
 - └ Wider skis reduce the risk of "boot out" (0 / 0)
 - ☐ Torsional stiffness of the ski has an influence on safety (3 / 3)
 - └ Torsional stiffness is a driving factor (3 / 3)
 - ☐ Ski construction has influence on safety (3 / 2)
 - └ The combination of the construction parameters is the key to solve the problem (2 / 1)
 - └ To make rules about ski construction is difficult (1 / 1)
 - ☐ Friction coefficient of the base has influence on safety (1 / 1)
 - └ More friction on ski base means less speed (1 / 1)
 - ☐ Use of gender or discipline unspecific equipment has influence on safety (2 / 2)
 - └ The use of gender or discipline unspecific equipment decreases the problem (1 / 1)
 - └ The use of gender or discipline unspecific equipment increases the problem (1 / 1)
- ☐ Binding / Plate (54 / 28)
 - ☐ Setting of the binding has influence on safety (10 / 10)
 - └ Racers rather risk injury than lose a ski (10 / 10)
 - ☐ Release mechanism of the binding has influence on safety (32 / 18)
 - └ Release mechanism is on a good level (5 / 5)
 - └ Release mechanism must be improved (10 / 10)
 - └ Improvement of the release mechanism is difficult and expensive (3 / 3)
 - └ If the binding does not release during a crash the injury risk is increased (4 / 4)
 - └ Boot is responsible if the binding release not adequate (8 / 2)
 - └ Bending of the ski is responsible if the binding releas not adequate (2 / 2)
 - ☐ Differences between standing height toe and heel and point of binding assembling has influence on safety (1 / 1)
 - └ Toe-heel differences influences aggressivness and therefore safety (1 / 1)
 - ☐ Standing height has influence on safety (10 / 8)
 - └ High standing height increases injury risk (4 / 4)
 - └ High standing hight reduces the risk of "boo out" (1 / 1)
 - └ Low standing height can be a problem because it forces more angulation to make the same edge angle (3 / 3)
 - └ Standing height needs to be researched (2 / 2)
 - ☐ Damping system between plate and boot would have influence on safety (1 / 1)
 - └ Damping system would have potential to reduce injuries (0 / 0)
 - └ Damping system would have no potential to reduce injuries (0 / 0)
 - └ Damping system would increase injury problem (1 / 1)

Figure6b: Structure of Categories – EQUIPMENT

- ☐ Nets and spill zones (63 / 30)
 - ☐ A-nets have influence on safety (12 / 9)
 - └─ Level of A-nets is near the optimum (5 / 4)
 - └─ Level of A-nets is bad (7 / 6)
 - ☐ B-nets have influence on safety (5 / 4)
 - └─ Level of B-nets is near the optimum (1 / 1)
 - └─ B-nets are on a bad level (4 / 3)
 - ☐ B-nets in front of A-nets have influence on safety (17 / 15)
 - └─ B-net in front of A-net are dangerous (12 / 11)
 - └─ B-net in front of A-net are dangerous but there would be more risk without them (4 / 4)
 - └─ Usage of B-nets in front of A-nets depends on the situation (1 / 1)
 - ☐ Spill zones have influence on safety (13 / 8)
 - └─ Spill zones are better than net (3 / 3)
 - └─ Spill zones are in the majority of cases ok (1 / 1)
 - └─ Spill zones are often too small (specially traditional courses) (9 / 6)
 - ☐ Safety nets in general have influence on safety (13 / 12)
 - └─ Nets in general are on a good level (11 / 11)
 - └─ Nets in general are very important (2 / 2)
 - ☐ Perfect safety equipment in all situations is not realisable (3 / 3)
 - └─ Safety net concept that is suitable for all kind of crashes is not possible (1 / 1)
 - └─ On warm up hills the safety protection is bad (2 / 2)
- ☐ Protectors and helmets (55 / 31)
 - ☐ Protector and helmets have influence on safety (47 / 30)
 - └─ Protectors and helmets are important (5 / 4)
 - └─ Protectors and helmets are on a good level (23 / 20)
 - └─ Protectors and helmets can be improved (19 / 15)
 - ☐ Smart systems have influence on safety (3 / 3)
 - └─ Smart systems reduce injury problem (2 / 2)
 - └─ Smart systems increase injury problem (1 / 1)
 - └─ Smart systems shift injury problem (0 / 0)
 - ☐ Rules on protectors and helmets and their influence on safety (5 / 5)
 - └─ All protectors should be allowed, air drag aspects should have second priority (5 / 5)
- ☐ Racing suit (34 / 26)
 - ☐ Aerodynamics of the racing suits has influence on speed and therefore on safety (29 / 23)
 - └─ Racing suits have potential for speed control (13 / 11)
 - └─ Racing suits have no or limited potential for speed control (16 / 13)
 - ☐ Slippery surface of the racing suits influences the safety (5 / 5)
 - └─ Smooth surface of racing suits cause non-braked slipping (5 / 5)
- ☐ Gates (panel and poles) (71 / 34)
 - ☐ Panels have no influence on safety (4 / 4)
 - └─ Panels rarely causes injuries (4 / 4)
 - ☐ Panels have influence on safety (48 / 30)
 - └─ Panels have too high resistance (danger of hooking) (19 / 15)
 - └─ Panels should be a tear away panel (11 / 9)
 - └─ Panels have to release quickly but not always (18 / 14)
 - ☐ Poles have no influence on safety (5 / 5)
 - └─ Poles rarely causes injuries (5 / 5)
 - ☐ Poles have influence on safety (5 / 5)
 - └─ Poles can be a problem (5 / 5)
 - ☐ Type of gates has influence on safety (9 / 7)
 - └─ Redesign of gate construction desirable (1 / 1)
 - └─ Snowboard gates would be less dangerous (1 / 1)
 - └─ Outer gate are a unnecessary obstacle (2 / 1)
 - └─ Gate impacts are a problem (5 / 4)

Figure6c: Structure of Categories – EQUIPMENT

- ☐ ATHLETE (378 / 38)
 - ☐ Psychological aspect (51 / 26)
 - ☐ Psychological training and care has influence on safety (4 / 4)
 - └ FIS psychologist should be at every race destination (1 / 1)
 - └ To less mental training is problematic (3 / 3)
 - ☐ Concentration has influence on error rate and therefore on safety (9 / 9)
 - └ Problems in concentration increase the risk of injury (9 / 9)
 - ☐ Motivation has influence on risk management (2 / 1)
 - └ Overmotivation increases risk of injury (2 / 1)
 - ☐ Fear has influence on risk management (12 / 9)
 - └ Fear leads to risk reduction (less injury risk) (3 / 3)
 - └ Fear leads to higher risk due to passive skiing (9 / 6)
 - ☐ Pressure has influence on risk management (23 / 16)
 - └ Situations with increased pressure increases injury risk (23 / 16)
 - ☐ Psychological aspects have no influence on safety (1 / 1)
 - └ Unsufficient mental fitness level is not a risk factor (1 / 1)
 - ☐ Physical aspects (55 / 29)
 - ☐ Fitness level has influence on safety (40 / 26)
 - └ Fitness level in general (27 / 21)
 - └ Actual level of fitness is sufficient (11 / 7)
 - └ Actual level of fitness is not sufficient (2 / 2)
 - ☐ Quantity and quality of fitness training has influence on injuries (11 / 7)
 - └ Fitness level can not be improved (9 / 6)
 - └ Too specialized physical training is a problem (2 / 1)
 - ☐ Sickness has influence on safety (1 / 1)
 - └ Sickness increases injury risk (1 / 1)
 - ☐ Forces acting on the body have influence on safety (3 / 2)
 - └ Forces acting on the body are too high and must be reduced (3 / 2)
 - ☐ Skiing techniques an tactics (73 / 31)
 - ☐ Technique has influence on injury risk (27 / 18)
 - └ More stable technique means less injury risk (17 / 14)
 - └ Equipment allows unproper technique which leads to higher error rate (7 / 5)
 - └ Technique is adapted on equipment and snow (3 / 2)
 - ☐ Technique has no influence injury risk (5 / 5)
 - └ Technique is not directly linked to injury risk (5 / 5)
 - ☐ Tactics have influence on injury risk (40 / 22)
 - └ Right tactical decisions (= Risk management) reduce injury risk (26 / 18)
 - └ Experience allows better risk managment (14 / 11)
 - ☐ Tactics have no influence on injury risk (1 / 1)
 - └ Accident Proneness does not depend on tactics (1 / 1)
 - ☐ Fatigue (84 / 33)
 - ☐ Fatigue in general has influence on safety (4 / 4)
 - └ Fatigue in general increases injury risk (4 / 4)
 - ☐ Course has influence on fatigue and therefore on injury risk (13 / 6)
 - └ To long courses increases injury risk (9 / 5)
 - └ Turny course setting causes higher fatigue and therefore higher injury risk (2 / 1)
 - └ Bumpy slopes causes higher fatigue and therefore higher injury risk (1 / 1)
 - └ If the Athlete gets tired he takes less risk (1 / 1)
 - ☐ Course has no influence on fatigue and therefore on safety (1 / 1)
 - └ To long courses do not increase injury risk (1 / 1)
 - ☐ Schedule has influence on fatigue and therefore on injury risk (66 / 30)
 - └ Schedule how it is, is ok (3 / 3)
 - └ To many races for Allrounder (14 / 13)
 - └ Jetlag is a big problem (19 / 16)
 - └ Overloaded schedule is a big problem (30 / 21)

Figure7a: Structure of Categories – ATHLETE

- ☐ Authorization to participate races (22 / 12)
 - ☐ Level of difficulty should fit with the level of racers abilities (22 / 12)
 - └ Athletes that are not well prepared for the world cup have higher injury risk (17 / 10)
 - └ Level of forerunners is not good enough to test course on a compareable level (5 / 4)
- ☐ Race preperation of the Athlete (9 / 8)
 - ☐ Instantaneous race preperation has influenc on safety (2 / 2)
 - └ Instantaneous race preperation is a problem (2 / 2)
 - ☐ Pre season training has influence on safety (7 / 7)
 - └ Pre season training is a problem (7 / 7)
- ☐ Pre-injury aspects (20 / 15)
 - ☐ Micro traumas of former days have influence on safety (11 / 10)
 - └ Micro traumas of former days are a problem (11 / 10)
 - ☐ Time of comback has influence on safety (7 / 6)
 - └ To early time of comeback is a problem (7 / 6)
 - ☐ Pre-injuries have no influence on safety (2 / 1)
 - └ Pre-injuries do not increase risk of new injuries (2 / 1)
- ☐ Aspects of body temperature (18 / 17)
 - ☐ Body temperature has influence on safety (18 / 17)
 - └ To cold outside temperature and therefore body temperature is dangerous (6 / 6)
 - └ Thicker racing suits would increase body temperature and therefore safety (12 / 12)
- ☐ Crash behaviour (5 / 5)
 - ☐ Crash behaviour has influence on safety (5 / 5)
 - └ Bad crash behaviour increases injury risk (1 / 1)
 - └ Crash behaviour can be trained (3 / 3)
 - └ Crash behaviour cannot be trained (1 / 1)
- ☐ Genetics and Anthropometrie (6 / 6)
 - ☐ Genetics and Anthropometrie have influence on safety (6 / 6)
 - └ Accident Proneness depends on Genetic and Anthropometric predisposition (6 / 6)
- ☐ Adaptability (2 / 2)
 - ☐ Adaptability has influence on safety (2 / 2)
 - └ To be able to adapt adequate on the situation is very important (2 / 2)
- ☐ Individual Responsibility (33 / 12)
 - ☐ Individual Responsibility has influence on safety (33 / 12)
 - └ Individual Responsibility is very impotent concerning safety (9 / 6)
 - └ Steering individual resposibility by increasing difficulty is the main key to solve the problem (22 / 7)
 - └ Steering individual responsibility by increasing difficulty is problematic (2 / 2)

Figure7b: Structure of Categories – ATHLETE

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