THE GERMAN ALPINE CLUB (DAV) SKI TOURING STUDY: DO AVALANCHE AIRBAGS LEAD TO RISKIER CHOICES?

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ABSTRACT: Avalanche airbags have emerged as a significant advancement in avalanche safety, increasing survival rates by reducing burial depth during an avalanche. While they offer a potential reduction in mortality by up to 50%, as shown by Haegeli et al. (2014), their effectiveness depends on timely deployment and proper functionality. However, their use may also lead to riskier behavior, as individuals may feel safer and therefore take more risks, potentially offsetting the safety benefits of the airbag. This study, conducted by the DAV Safety Research Department during the winters of 2019/20 and 2021/22, investigated the knowledge, usage, and impact of avalanche airbags among 157 ski touring and freeride groups in the Austrian Alps. The study sought to understand whether airbag usage influences risk behavior, how well groups understand airbag functionality, and the socio-demographic predictors of airbag use.

Key findings include a significant difference in airbag usage between ski touring and freeride locations, with freeriders using airbags more frequently. However, both groups overestimated the probability of mortality with and without airbags. Interestingly, no correlation was found between airbag use and riskier tour decisions, nor did airbag knowledge predict tour risk potential or the number of danger spots. The study also found that gender and other equipment carried, such as helmets, predicted airbag use, while experience and self-assessed competence did not.

The results suggest that while airbags can increase survival chances in avalanches, they do not appear to significantly influence risk-taking behavior. The decision to use an airbag seems to be influenced by a range of factors beyond the perceived safety benefit. This research underscores the importance of comprehensive avalanche prevention strategies, emphasizing that the best approach to avalanche safety is to avoid being caught in an avalanche altogether, with airbags serving as a secondary safety measure.

KEYWORDS: Airbag use, Airbag knowledge, impact of airbag use, decision making, risk taking, backcountry skiing

1. INTRODUCTION

Avalanche safety has developed continuously over the last few decades thanks to improved technology and preventive measures. One advance is the use of avalanche airbags, which can increase the chances of survival for buried victims.

The basic idea of airbag backpacks is that in a flowing medium such as an avalanche, the larger bodies in terms of volume "migrate" to the surface. If persons affected increase their volume with the help of the airbag, there is a greater likelihood of less deep burials once the avalanche has stopped. Critical burials are therefore less frequent, which in turn results in fewer deaths from suffocation. As suffocation is the most common cause of mortality in complete burial (Procter et al., 2016), the widespread use of airbags has the potential to reduce the overall likelihood of mortality in avalanche events.

In practice, airbags must first be deployed in good time and then work to be effective. And while airbags can help to reduce the burial depth, they are not designed to protect against other dangers of an avalanche such as falling, impact, burial in terrain traps or certain types of avalanches such as ground or wet snow avalanches. Moreover, it could also be that airbags increase the subjective feeling of safety ("I'll try that slope - I've got an airbag"). In this case, the safety gain from the airbag would be lost or even overcompensated due to riskier individual behavior (known as risk compensation effect). Results of online studies designing such decision scenarios (e.g. Haegeli et al., 2019; Wolken et al., 2014) showed that there were no (e.g. Wolken et al., 2014) or only slight risk compensation effects under certain conditions (e.g. Haegeli et al., 2019). Nevertheless airbags should have an advantage under certain circumstances, but their use - like the rest of personal emergency equipment in the avalanche area - is accompanied by certain weaknesses.

Does the potential benefit of an airbag outweigh its weaknesses? If the worst comes to the worst, do I have a better chance of surviving in the terrain if I am wearing an airbag or does the airbag encourage me to take more risks? In this research, we report on how common airbags are among ski touring groups, whether airbag use depends on certain group characteristics, the knowledge groups do have about how airbags work and how effective they are, and whether wearing an airbag influences the willingness of groups to choose more demanding or riskier tours.

The decisive factor however is how effective an avalanche airbag is in practice: how much does my probability of survival increase if I am caught in an avalanche with or without an airbag?

Several studies have been carried out to test the effectiveness of the avalanche airbag. One of the more recent and widely discussed studies was by Haegeli et al. (2014). They analyzed a large number of avalanche accidents and showed that the use of avalanche airbags significantly increases the survival rate. According to the authors, the use of avalanche airbags could reduce the mortality rate of buried victims by up to 50%.

Our study pursued the following questions regarding avalanche airbags:

- *What do ski touring and freeride groups know about the functioning and the effectiveness of avalanche airbags?*
- *Do airbags encourage riskier behavior?*

To answer these questions, during the winters of 2019/20 and 21/22, DAV Safety Research Department interviewed ski touring groups and freeriders at three locations in the Austrian Alps. A total of 157 groups with 465 people were surveyed, 112 groups with 345 people at two ski touring locations (Namlos in the Lechtal Alps and Kelchsau in the Kitzbuehel Alps), and 45 groups with 120 people at one freeride location (Hochfuegen in the Zillertal valley).

2. STUDY DESIGN AND METHOD

The study design (see Figure 1) consisted of the following sections: On the day of the survey, a pre-trained survey team interviewed the randomly arriving ski-touring and freeride groups at the respective parking lots at two times. First, upon arrival and before they started the tour (t1); second, when groups returned from tour (t2).

A complex terrain analysis determined the relevant terrain points for the relevant skiing and freeride routes in the locations. In the risk analysis, the current avalanche-relevant information was used to determine the current (on that day) hazardous spots. In addition, for each of these hazardous spots we had an expert assessment as to which behavioral measures were appropriate. From this the following objective measures of risk behavior can be derived: the number of hazardous spots and the risk potential of the planned and actual tours.

Interviews followed structured questionnaires, which were developed especially for the study. The two questionnaires (Q1 & Q2) contained both open exploratory questions, which were coded using a category system, as well as questions with a categorical response format and Likert scales. The questionnaire included the following question categories: socio-demographic information of the group, equipment, avalanche related education and ski touring or freeride experience, self reported willingness to take risk. In the present study, questions were asked about the assessment of mortality with and without an airbag as well as possible limitations of an airbag backpack.

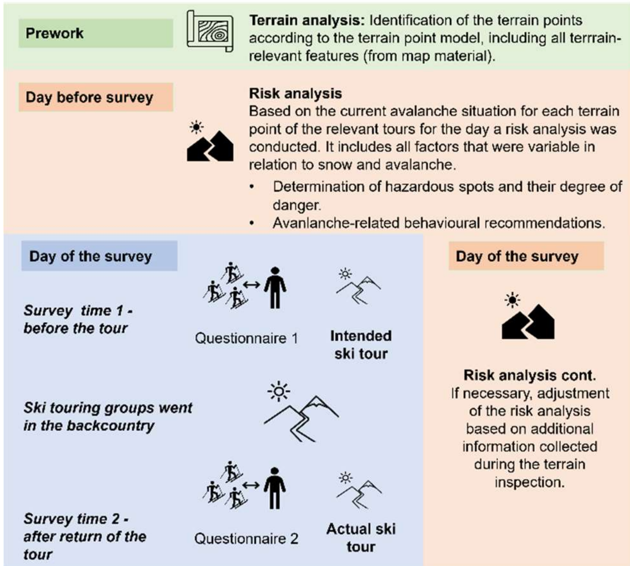

Figure 1: Study design of the 2019 to 2022 ski touring study.

A further main reference point was the well elaborated study by Haegeli and colleagues mentioned above (2014). They used data sources from Canada, France, Slovakia, Norway, Switzerland and the USA. Their study showed that the absolute mortality rate for avalanche victims without an avalanche airbag is 22%. For avalanche victims with avalanche airbags, the mortality rate is 14%. This takes into account that in 20% of cases the avalanche airbag did not open correctly (without this consideration, the study arrives at a mortality rate of 11%). Reasons for non-deployment include non-deployment by the user, maintenance errors, equipment faults and destruction of the avalanche airbag during the avalanche.

The absolute mortality reduction, known as the *airbag effect*, for avalanche victims is therefore 8% resp. 11% (Haegeli et al., 2014).

3. RESULTS

3.1 Characterization of surveyed groups

The group size varied from one (n = 13) up to 14 persons (n = 1). The most common group size was group of two (n = 80); 77.1 % of all groups were between 2 and 4. Of these, 56% of the sample consisted of gender-heterogeneous groups (n = 88), 40% consisted of men only (n = 63) and n = 6 (4%) were women-only groups. The average age of the groups was 39.82 years (SD = 11.52). Most of the ski tourers and freeride groups were out with friends/buddies (48%) or with family (35%). Over half of the groups (62%) were out in the skiing backcountry together regularly or very frequently. Therefore, it can be assumed that the group members knew each other very well. Most respondents (68%) were DAV members. On average, the people had traveled 139 (SD = 206.83) kilometers from home to the starting point of the ski or freeride tour and were out and about in this area monthly (41%) or less frequently (30%).

Proportion of airbag users in the group	Kelsau		Namlos		Hochfügen		Total	
	n	%	*n*	%	*n*	%	*n*	%
No airbag	25	40.3	22	44,0	13	28.9	60	38.2
Below 50%	11	17.7	6	12,0	3	6.7	20	12.7
Above 50%	11	17.7	11	22,0	2	4.4	24	15.3
All with airbag	15	24.2	11	22,0	27	60	53	33.8

Table 1: frequency distribution of airbag use in the groups by category and survey locations.

It should also be mentioned that 22% of those surveyed stated that they had no avalanche-related training. A practical avalanche transceiver course was stated for 36% of the groups, and 17% had training from an Alpine club. 10% of the groups stated official expert training (state-certified mountain guide or mountain rescue). The groups' ski touring or freeride experience averaged 15 years (SD = 9.93). B% y the time of the survey they had completed an average of 11 tours (SD = 10.87) in the current season.

The avalanche transceiver continues to be the standard emergency equipment: 94% of respondents carried it, closely followed by the probe (90%) and shovel with 91%. Looking at the group level, it is noticeable that 87% of the groups were fully equipped with the avalanche safety gear. A total of 189 people wore an airbag on tour. The number of airbag users in the groups ranged from 0 airbag users (in 38.2% of cases) to 7 users (in one case). A total of 123 ski tourers used an airbag, which is 35.65% of the total number of ski tourers encountered. See more results in Table 1.

3.2 Differences between airbag usage by survey location

There was a significant difference in airbag use between the locations, $F(2, 154) = 5.772$, $p = .004$, $\eta^2 = .070$ (medium effect). There was no difference between the two ski tour locations Namlos and Kelchsau. In contrast, the difference between ski touring locations and the freeride location Hochfuegen was significant.

3.1 Assumptions of the probability of mortality with/without airbag and safety gain of the whole sample and by location

Over all locations the groups assumed that 42.09 (SD = 22.70) out of 100 people affected by avalanches without an airbag would die as a result of the event, whereas only 24.24 (18.98) out of 100 with an airbag would die. This means that the probability of mortality was overestimated in both cases: Statistically, the probability of mortality without an airbag is 22%, with an airbag 14% (see above). The absolute mortality reduction known as the airbag effect in avalanche victims thus is 8% (Haegeli et al., 2014). The mortality reduction calculated by the assumptions of the groups amounts to 17.85% which is twice the real reduction.

An analysis of variance across the three locations showed that the ski tour groups in Namlos and the freeride groups in Hochfügen differed significantly in the probability of mortality without airbag, $t(90) = 2.447$, $p = .016$ and the mortality reduction, $t(90) = 2.394$, $p = .019$. However there is no systematic difference between the ski touring groups on one side and the freeride groups on the other. Table 2 shows the frequences and percentages of the mentioned limitations by the group. The most often mentioned limitation was the human error, for example not to be able to deploy the airbag.

Limitations of airbag	Kelchsau n = 58, (%)	Namlos n = 44, (%)	Hochfügen n = 47, (%)	Total n = 149, (%)
Terrain traps	16 (28)	11 (25)	15 (32)	42 (28)
Fall	19 (33)	9 (20)	20 (43)	48 (32)
Post burial	19 (33)	10 (23)	7 (15)	36 (24)
Impact injury	29 (50)	11 (25)	14 (30)	54 (36)
Technical device failure	17 (29)	16 (36)	7 (15)	40 (27)
Human error	28 (48)	20 (45)	24 (51)	72 (48)
Others	22 (38)	19 (43)	23 (49)	64 (43)

Table 2: Frequencies and percentages of limitations of airbags by survey location. Different frequencies resulted from missing.

3.2 Assessment of the assumed probability of mortality with/without airbag and assumed safety gain by airbag use in the groups

We split the sample into four distinctions: no airbag in group; below 50%, above 50%, all group members carrying airbag. We examined the assumed risks of mortality with / without airbag and the safety gain.

Group differences for these three variables were tested with a Oneway-Anova. The following significance levels were obtained: no significance for assumed probability of mortality without airbag $F(3, 148) = 2.444$, $p = .067$; significant differences in assumed probability of mortality with airbag: $F(3, 148) = 3.554$, $p = .016$ $\eta^2 = .068$ (medium effect). The following categories were significant: less than 50% of the group wearing airbags compared to 50% and greater and all with airbags. The assumed absolute mortality reduction was not significant $F(3, 148) = .617$, $p = .605$. See the group estimations by usage of airbag in Figure 2.

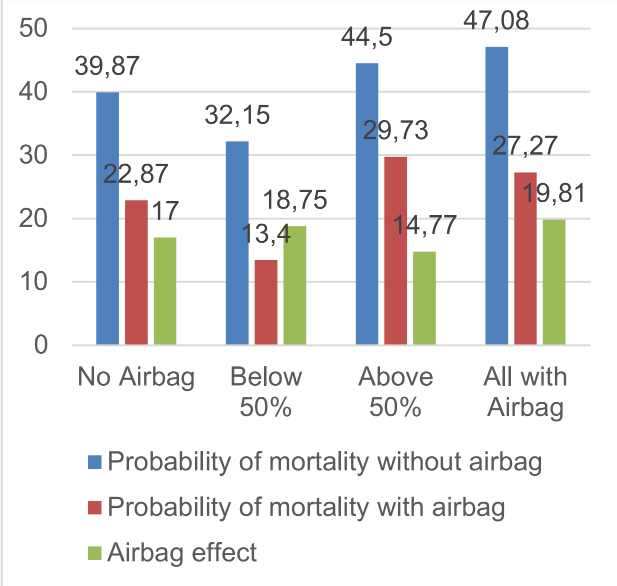

Figure 2: Estimates of probability of mortality without and with airbag and airbag effect depending on airbag use in the group with 4 categories.

To simplify matters, we then split the sample into two distinctions (see figure 3 on the opposite page): groups without airbags or with less than 50% participants with airbags and those with 50% or more participants with airbags.

Group differences for the variables were tested using a t-test (total values). The following significance levels were obtained: assumed probability of mortality without airbag differed significantly: $t(147) = 2.321$, $p = .022$, $d = .523$ (medium effect) as well as assumed probability of mortality with airbag: $t(147) = 2.545$, $p = .012$ $d = .343$ (small effect). There was no significant difference for the assumed absolute mortality reduction: $t(147) = .279$, $p = .780$.

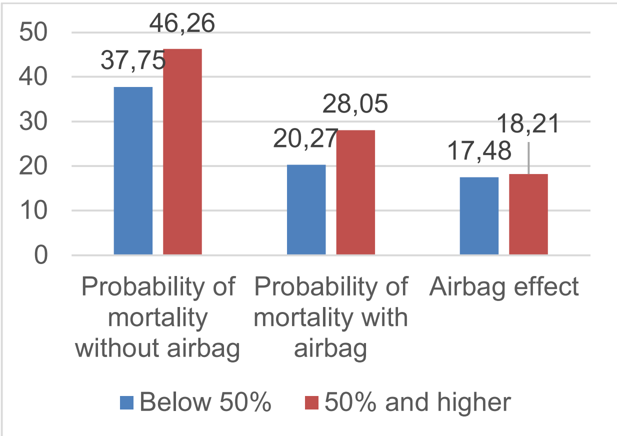

Figure 3: Estimates of probability of mortality without and with airbag and airbag effect depending on airbag use in the group (2 categories)

To sum up, when asked to estimate how many of 100 winter sports enthusiasts with and without airbags die in an avalanche accident, all respondents overestimated the probability of mortality. In groups with 50%

or more of the group members carrying an airbag, the probability of mortality was overestimated more than in groups without airbags or with an airbag rate of less than 50%. The reduction due to the airbag was estimated similarly in both groups, and was overestimated according to the absolute level. But even after the "reduction" by the airbag, the probability of mortality was still overestimated in both groups, even more so in the group with 50+% airbag users. Neither airbag users are lulled into a sense of security, nor do "non-airbag users" take the probability of mortality lightly.

Multiple regressions were calculated for the assumed mortality rate with and without airbags and the safety gain. The predictors in each analysis were: Airbag percentage in the group, avalanche danger level (ADL) and the interaction term airbag percentage*ADL. None of three regression models was significant (Model1: Mortality rate without airbag: F(3,123) = .1,808, p = .149; Model 2: Mortality rate with airbag F(3,123) = .2,219, p = .089 and Model 3: Safety gain: F(3,123) = .703, p = .552). Thus, airbag proportion within group and avalanche danger level had no effect on estimation of mortality rate without/with airbag or mortality reduction. Self-assessment of willingness to take risks and airbag use

The groups were asked to assess their own willingness to take risks on a 4 point Likert scale (1 = low; 4 = high risk tolerance). The mean value of the self assessed risk tolerance was $M = 2.09$ ($SD = .68$). Between this self-assessed risk tolerance and the use or non-use of airbags no significant correlations were found, $r_s = .075$, $p = .384$.

3.3 Avalanche danger level and airbag use

The Pearson correlation between airbag proportion in group and avalanche danger level was significant at $r = .182$, $p = .035$. The mean value of the danger level over all survey days was M = 2.40 (SD = .63), so to speak moderate to considerable.

3.4 Correlations between airbag use, risk potential of the tour and hazardous spots

Do groups with a higher proportion of airbag users undertake tours with more hazardous spots and a higher risk potential?

We investigated this question by means of a correlation between "number of hazardous spots of the intended tour", "number of hazardous spots of the passed tour" and "risk potential of intended tours according to the behavioral recommendations for the danger spots" "risk potential of passed tours according to the behavioral recommendations for the danger spots" on the one hand and "proportion of airbag users in the group" and "number of airbag users" on the other.

There were no significant correlations between the different variables for airbag use within the group and the risk potential of the tour, neither for the risk potential of the intended tour nor the risk potential of the passed tour.

Similarly, there were no significant correlations between the different variables for airbag use within the group and the danger spots, neither for the danger zones of the intended tour nor the danger points passed: These analyses brought the same results when carried out separately for the three individual locations.

There were no group differences (ANOVA) between the airbag use of groups (four categories: group without airbag, less than 50%, greater than 50% and all with airbag) and the risk potential of the intended tour as well as the conducted tour; $F(3, 133) = .435$, $p = .728$ (intended); $F(3, 101) = .708$, $p = .549$. Also, there were no significant differences for the hazardous spots for the intended tour, F(3, 130) = .580, p = .629, and hazardous spots for the actual tour F(3, 101) = .145, p = .063.

The group differences in airbag percentage were also calculated for the airbag group variable with 2 categories. No significant group differences were found in any of the results. Results are not reported further.

It cannot be concluded from these results that increased airbag use leads to higher-risk tour decisions, nor conversely that it leads to lower-risk decisions. We think - and this is also the impression that we gained directly from the survey - that the decision for a particular tour depends on a bundle of factors and the question of whether an airbag is used or not is only one facet of many. Possible risk compensation through the airbag is absorbed by the other influencing factors - and can therefore not be found in our results.

3.5 Which variables and which socio-demographic characteristics predict airbag use?

Pearson and Spearman correlations were calculated first. For “airbag use” the relative frequency of airbag users in the group (number of airbag users/group size) was used.

Variable	***n***	**Correlations**
Number of group members	157	$r = -.186$, $p = .020$
Gender	157	$r_s = .182$, $p = .023$
Age	148	$r = .044$, $p = .598$
Level of avalanche related education	157	$r_s = .084$, $p = .297$
Group type	165	$r_s = .112$, $p = .165$
Ski touring / freeride experiences in years	157	$r = .099$, $p = .219$

Amount of Ski touring / freeride tours of the season	157	*r* = .128, *p* = .109
Self-assessment of willingness to take risk	137	*r* = .094, *p* = .272
Approach to location in kilometers	157	*r* = .055, *p* = ,492
Frequency in doing ski touring or freeriding in the backcountry within the same group	144	*r* = .121, *p* = .148
Avalanche transceiver in the group	157	r_s = .307, *p* < .001
Probe in the group	157	r_s = .213, *p* = .007
Shovel in the group	157	r_s = .264, *p* = .001
Standard emergency equipment	157	r_s = .219, *p* = .006
Emergency call device	157	r_s = .194, *p* = .015
Digital Map	157	r_s = .095, *p* = .467
Description of the tour	157	r_s = -.164, *p* = .040
First aid kit	157	r_s = .142, *p* = .076
Helmet	157	r_s = .329, *p* < .001

Table 3: Pearson and Spearman correlations of relative frequency of airbag users in the group and sociodemographic variables; different frequencies resulted from missing.

Furthermore, regressions were calculated with the variables showing significant bivariate correlations. The regression with the criterion relative frequency of airbag use in the group and the following predictors yielded a significant model: gender (dichotomous), number of group members, helmet, first aid, description of the tour, emergency call device and standard emergency equipment (avalanche transceiver-probe-shovel) (*F*(7,149) = 6.138, *p* < .001) with a variance explanation of 22.4%. The following predictors were significant: gender (dichotomous): β = .181, *p* = 021; standard emergency equipment: β = .227, *p* = 006 and helmet: β = .268, *p* < .001.

In addition, two regressions with the same variables were calculated separately for ski touring groups and freeride groups. The regression for the ski touring groups was significant (F(8,103) = 4.067, *p* < .001) with a variance explanation of 24%. However, only the two predictors gender, β = -.248, *p* = .012, and helmet, β = .283, *p* = .002, were significant. The regression for the freeriding groups was also significant, F(8,36) = 3.748, *p* = .003, with a variance explanation of 45.4%. However, only one predictor, namely the standard emergency equipment, was significant: β = -.518, *p* = .002.

In any case, it is interesting that intuitively obvious variables such as experience, touring frequency, self-assessed competence in assessing avalanche dangers or risk tolerance did not predict airbag use.

4. INTERPRETATION

There were no correlations between the indicators of risk behavior and the use or non-use of airbags. There were also no significant correlations when the data were analyzed separately by survey location. The only significant correlation was an increase in airbag use with a higher danger level. In our opinion, this indicates that the groups adapt their behavior and equipment to different conditions. If a popular tour with tracked slopes is undertaken at avalanche danger level 1, the question arises as to what the safety benefit of an airbag should be and how sensible it is to bring it. With ADL 2 or 3 in less tracked terrain, a safety benefit of an airbag is more likely.

Overall, the data from our field study gave no indication that the use of airbags has an influence on the willingness to take risks or on practiced risk-taking behavior. When planning tours and assessing individual slopes, numerous factors contribute to the decision-making process; the question of bringing an airbag or not obviously only plays a subordinate role. However, this does not mean that the use of an airbag does not contribute to riskier behavior in individual cases - but according to our data, this should be the exception and not the rule.

5. CONCLUSION

Avalanche airbags are now widely used not only for freeriding, but also for classic ski touring - albeit to a lesser extent. The users we surveyed are aware that airbags do have limitations and do not guarantee safety. But for the most part, they systematically overestimate the safety benefits of airbags and the general likelihood to die in an avalanche without an airbag. Fortunately, not every avalanche with a critical burial ends fatally (note: the probability of mortality without an airbag is 22%)!

In our opinion, more information should be provided about when the use of an airbag can be a useful addition to avalanche emergency equipment and in which situations less so. On an individual level, the recommendation is - as so often - to reflect critically on one's own behavior and to become aware of the situations in which the airbag influences one's own risk behavior. As most non-inflated airbags in avalanche accidents are due to user error (e.g. cartridge not inserted correctly; not deployed), it is essential to check that the airbag is functional before each use.

The deployment of the airbag should be regularly practiced mentally and motorically on tour (e.g. grasping the deployment handle in different situations). Every now and then it makes sense to actually trigger the airbag. For most of us, suddenly finding ourselves in the middle of an avalanche is an event completely out of the ordinary - perhaps even beyond our imagination. In a sudden event, our perception is most likely overwhelmed, and we first have to understand what is happening to us and around us before we can make a decision and deploy the airbag. The better we prepare ourselves, the more likely we are to succeed. Electronic airbag systems offer a favorable learning environment due to the possibility of multiple deployments with one battery charge. For deployment training, it may make sense to borrow or rent such an airbag for a weekend. But even with mechanical systems, it is possible to practice deploying the handle without inflation (in the "unfocused" state). Some people will be surprised that, depending on the model, you must pull relatively hard on the deployment handle.

In the course of our work, we were able to show that well-equipped and gender-homogeneous groups generally are more likely to wear an airbag. We can only speculate about the reasons for the latter. However, contrary to expectations, obvious variables such as experience, tour frequency, self-assessed competence in assessing avalanche dangers or willingness to take risks do not predict airbag use. Similarly, contrary to popular opinion in mountain sports circles and the media, as well as results in older studies on risk compensation in other areas (e.g. Hedlund 2000), we were unable to find any evidence that the use of airbags has a negative effect on risk behavior to the effect that the undeniable safety benefit of airbags is reversed. More recent experimental studies find at best weak evidence of risk compensation. The use of an airbag can therefore, under certain conditions, further increase the probability of survival in the event of critical burials, which is not zero even without an airbag, and does not tend to reduce this further by increasing the user's willingness or behavior to take risks.

However, the airbag is only one component in the avalanche safety kit. The most effective strategy for experiencing many healthy tours in unsecured ski areas in the long term is to avoid getting caught in an avalanche in the first place. The premise in training must therefore be to invest even more in avalanche prevention - and not "just" to practice avalanche emergencies. Good tour planning, route selection adapted to your own risk level and fact-based decision-making in the terrain are the far more decisive building blocks here. The correct understanding of the danger description in the avalanche conditions report (in particular the avalanche problem!), standard measures and generally applicable rules of thumb can also be taught at a lower level without having to resort to more complex strategies such as reduction methods.

Should an avalanche accident occur despite all precautionary measures, an airbag can be an effective addition to the obligatory emergency equipment and group emergency equipment (first aid kit, bivouac sack, cell phone). It remains to be seen whether the expected further spread of avalanche airbags will lead to a new dip in the average number of avalanche mortality per winter (after the invention of avalanche transceivers and again after the introduction of 3-antenna devices at the turn of the millennium), or whether applications for automated risk assessment such as *Skitourenguru* or hazard information maps will play a greater role in the reduction of avalanche mortality, which will hopefully continue in the future.

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