RISK TRENDS AT U.S. AND BRITISH COLUMBIA SKI AREAS: AN EVALUATION OF THE RISK OF SNOW IMMERSION VERSUS AVALANCHE BURIALS

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ABSTRACT: The risk trends for avalanche and snow accidents at U.S. and B.C. ski areas are changing. During the period from 1990/91 to 2005/06, there were four avalanche fatalities in bounds reflecting that that risk has been reduced significantly. Fifty-five fatal avalanche burials in the same time frame indicate that there is still a substantial risk associated with leaving the ski area boundary. What is not well documented is that during the same sixteen years, there has also been an increasing trend in the risk of asphyxiation in deep snow at ski areas. Fifty-one of these snow immersion events occurred during the study period. The classification for this type of fatality is Non-Avalanche Related Snow Immersion Death or NARSID.

This risk trend appears to be "under the radar' of many snow safety professionals. This study was designed to investigate these factors; the recognition of the risk, the key factors in the snow immersion phenomenon, and prevention strategies. Currently, the greatest single component of snow immersion risk is that it is substantially under-appreciated.

The investigation included analyzing avalanche and snow immersion statistical data and designing a database of all documented snow immersion accidents. Individual cases were further researched by personal communication with ski area personnel. A field experiment using human subjects was also conducted to test factors like the effect of body position, extrication techniques, and the impact of non-releasable snowboard bindings.

KEYWORDS: snow immersion, avalanche fatalities, NARSID, ski area, risk management

1. INTRODUCTION

Avalanche fatalities at North American ski areas have been well documented. Snow immersion deaths, on the other hand, are often seen as anomalous events or are misclassified under some other cause of death. From 1990/91 to 2005/06, there have been fifty-one NARSID cases reported. There have been fifty-five out of bounds avalanche fatalities during the same period. An important difference is that the NARSID risk is highest inside the operational boundaries of ski areas where personnel actively manage risk.

In earlier studies (Cadman, 1999) found that from 1993-1998, 25% of ski area fatalities in British Columbia were NARSIDs and (Hackett, 2000) found in the period from 1985-1995 the NARSID risk was ten times greater than the risk of an avalanche burial at a U.S. ski area.

This study shows that between 1990/91 and 2005/06, the risk of NARSID at U.S. ski areas has become fifteen times greater. That suggests that this risk trend is steadily increasing. Another important difference is that avalanche risk, both in bounds and out of bounds, is well understood and has been targeted with a robust public awareness and educational campaign.

The need to increase risk awareness among snow and avalanche professionals is clear. The goals of this research were to:

- Compare NARSID data to avalanche fatality data to determine risk trends.
- Develop information to explain these trends.
- Assemble a database of all reported NARSID cases in North America, obtaining detailed reports on specific cases wherever possible.
- Analyze the data for patterns.
- Conduct a field experiment to test these patterns and other physical factors in snow immersion.
- Use the information obtained to develop training and educational materials for use by snow and avalanche personnel to raise public awareness.

The preliminary findings include who, where, when, and how NARSIDs occur. Based on these findings are some thoughts about how to reduce the risks. These findings are based on data

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collected on sixty-five individual cases, experiment results, and accounts from snow immersion survivors.

The good news is that NARSID risk, like avalanche risk, can be managed using awareness, sound personal, and partner technique, and ski area risk management procedures.

2. STUDY SITE AND METHODOLOGY

2.1 *Avalanche statistics*

The geographic area of the study includes the ski areas of the western U.S. and British Columbia, Canada. The data range selected for statistical evaluation of risk trends included the sixteen ski seasons from 1990/91 to 2005/06. Avalanche fatalities, both in bounds and out of bounds, for these ski areas are well documented and accident and statistical data is readily available through the Westwide Avalanche Network. Specific U.S. ski area avalanche statistics were also obtained (Atkins, personal communication).

The ski area in bounds category was limited to cases that occurred while the ski area was operating and in areas designated as open. The ski area out of bounds category included ticketed customers that used lifts to access out of bounds terrain and cases that occurred in closed areas within the ski area boundary.

2.2 NARSID database

NARSID events are not well reported and the data was much harder to come by. The NARSID data set currently contains sixty-five cases from the early 70's to the present. This number is certain to be understated. With the exception of heli-ski operations, almost all of the reported cases have occurred at ski areas or just out of bounds.

The sample used in the study was limited to the period from 1990/91 to 2005/06 and contains fifty-one cases. The selection criterion for inclusion in the NARSID dataset is any snow immersion death as a result of asphyxia except avalanche burial. Cause of death attributed to avalanches, trauma, or hypothermia, are excluded from the data set. For example, if the subject in a tree well immersion accident suffered fatal head and neck trauma as a result of hitting the tree, the case would be excluded.

Much of the initial NARSID data came in collaboration with Dr. Jasper Shealy, during the course of defending a lawsuit against Niedecker, U.S. Inc., a Swiss snowboard manufacturer. Data on British Columbia accidents (Cadman, 1999) and (Bezzola personal communication) was also provided. The database was further developed through the investigation of individual cases. Ski area and heli-ski operations personnel, and in some cases even the victims partners, provided more detailed information on the circumstances of snow immersion accidents.

The data was then analyzed for common factors, patterns, and statistical trends. The information was used to design a simple field experiment to test those factors.

2.3 *Field snow immersion experiment*

The snow immersion experiment was conducted on March 19, 2006 at the Crystal Mountain ski area in Washington State. The test site chosen was a tree well area next to small fir trees with submerged low lying branches, typical of accident locations found in the data. At the time of the experiment the actual tree well hazard was low and the snow was well consolidated. Excavation of the snow in the tree well was required.

All test personnel were briefed on the safety procedures including that any test subject could request immediate removal at anytime by holding their legs (above the surface) straight for a two second count. A mandatory removal occurred after the maximum allowable immersion time of two minutes was reached. A rope from the subject to the surface was in place to facilitate extrication of subject. A pulmonary physician with advanced life support equipment was on site and examined all test subjects after extrication.

The principal goal of the experiment was to place the test subjects in a tree well in a manner that replicates the conditions and circumstances of documented NARSID cases and then measure the subjects' abilities to maintain an airway and successfully extricate themselves.

The test subjects included five alpine skiers and five snowboarders with non-releasable bindings. Their ages ranged from 23 to 58 and all had a fairly high level of fitness. All were members of the volunteer ski patrol.

The experiment's parameters were designed to place the test subjects in varying degrees of an inverted body position with their heads submerged and then bury them to various depths. The test subjects were buried to a depth of 1-1.5 meters with snow that had been artificially disturbed by shoveling. An average snow density of 16% was

recorded during the experiment, although the snow in actual immersion accidents is generally found at lower densities. Data recorded include information on the test subject and ski or snowboard equipment, snow and weather parameters, depth from snow surface to subject's head, and total time of immersion.

The key observations, however, focused on the effect of the inverted body position and the ability of the test subject to:

- establish and or maintain an air pocket
- release ski or snowboard bindings
- extricate themselves from the tree well

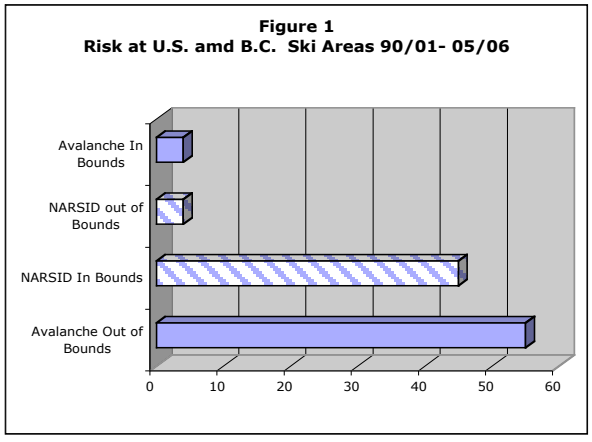
Other useful information about the subject's experience was noted including the time of useful activity before immobilization or panic occurred.

3. RESULTS AND DISSCUSSION

3.1 *Statistical comparison of the risk trends in avalanche and snow immersion*

The data range selected for statistical evaluation of risk trends was from 1990/91 to 2005/06. Based on the selection criterion noted in 2.1 the total number of reported avalanche cases is three in bounds and forty-five out of bounds cases in the U.S. and one in bounds and ten out of bounds cases in B.C. During the same period there have been forty-five NARSID cases reported, though as mentioned earlier, that number is almost certainly low. This is illustrated in figure 1.

Figure 1
Risk at U.S. amd B.C. Ski Areas 90/01- 05/06



The key findings in the risk analysis are:

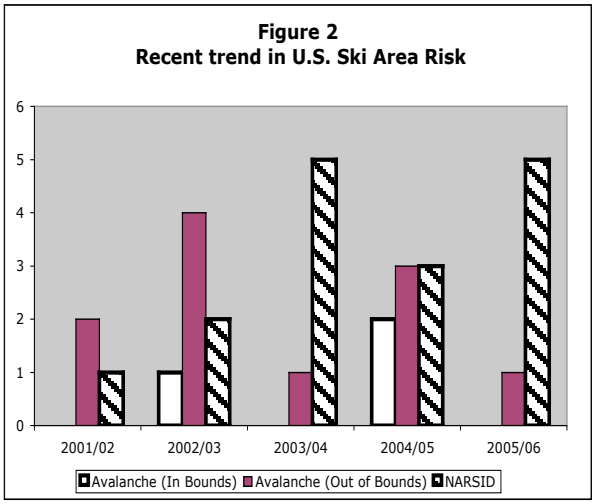
- The risk to in bounds skiers has been reduced to an incredibly small number.

This is a testimonial to the success of modern ski area avalanche control programs, This, of course, comes with the caveat that the skiers must respect posted closures and do not ski at the area before it opens for business.

- The trend in the number of out of bounds avalanche cases continues to stay at a fairly constant rate and accounted for 12% of the total U.S. and 9% of all Canadian avalanche fatalities.

There is a clear trend that more ski area customers are skiing on Alpine Touring (AT) gear and using the lifts to access backcountry terrain. Since the actual number of out of bounds users is unknown it can only be assumed that this flat trend actually represents a per capita decrease in the risk. This would be another testimonial to the excellent avalanche awareness and boundary management programs at ski areas.

Figure 2
Recent trend in U.S. Ski Area Risk

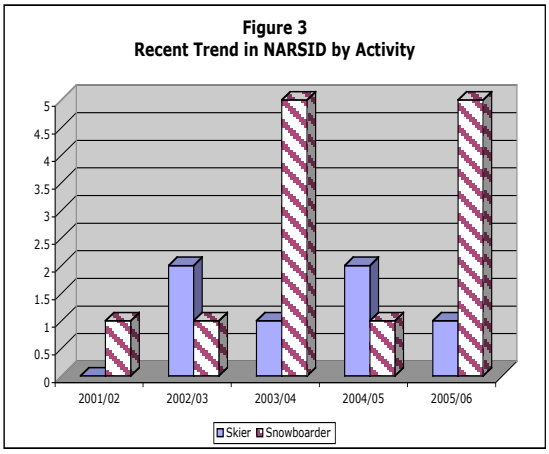


- The risk trend in the U.S. for NARSID correlates well with the risk of out of bounds avalanche fatalities until the last five years.

At that point the number of NARSID cases in the U.S. outpaced the out of bounds avalanche cases by approximately 50% (figure 2). It can only be speculated that there is an increased interest in exploring untracked powder within the ski area boundaries.

It should be noted that NARSID events correlate well with large precipitation events and high avalanche danger. These two factors may keep skiers and snowboarders in area as conditions are good and out of bounds travel is difficult or dangerous.

- Snowboarders are increasingly putting themselves at risk.



Skiers involved in NARSIDs outnumbered snowboarders by a 2:1 ratio in the period from 1990 –2000. In the last six years that risk trend has completely reversed. Currently snowboarders are twice as likely to become snow immersion victims at ski areas.

Furthermore, during the period from 1990/91 to 2005/06, NARSIDs represented 5% of the total alpine skier fatalities and 15% of the total snowboarder fatalities. There is an opportunity for education here.

3.2 ***Analysis of the NARSID data***

The most useful information has come from the compilation and analysis of the database. It currently stands at sixty-one cases. Previously un-documented cases, or cases that were not initially identified as NARSIDs, are being continually added to the database.

This data was used to create a profile of the environmental characteristics and human behavior present during these events. This information can then be used to develop prevention strategies. The preliminary findings are used to address the following questions:

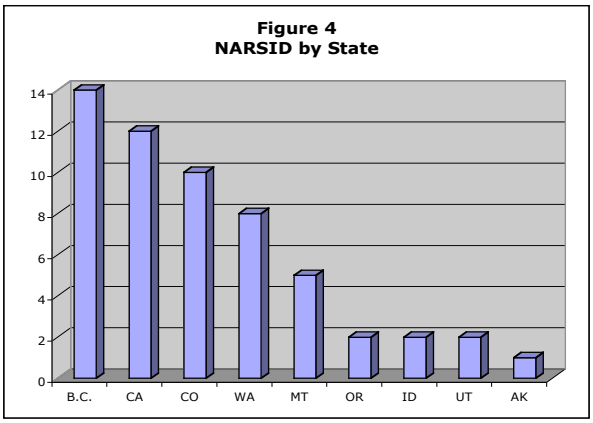
- What are the typical characteristics of a snow immersion event?

The classic profile would happen in January, in British Columbia or California, during or just after a fall of powder snow. The victim is a twenty-three year old male, advanced snowboarder, riding in bounds, in an area of moderately steep terrain. He is riding with a partner but they are not staying close. He falls into a tree well inverted, knocking a significant amount of snow off of the low-lying branches, and in on top of himself. He struggles but ends up working his body deeper into the tree well. He becomes immobilized as the snow around him densifies.

He cannot extricate himself. His partner waits at the lift then retraces their route and finds the snowboard sticking out of the tree well. He removes his partner, either alone or with help, but his friend has been immersed between thirty to ninety minutes and it is too late.

- Who is at risk?

Any skier or snowboarder that leaves the groomed ski runs during deep powder conditions is vulnerable. During the study period there were twenty-four alpine skiers, eighteen snowboarders, and three unknowns. But, as with many activities that involve risk, young adult males make up the bulk of the accident statistics. The average ages in the sample were twenty-three for snowboarders and thirty-two for the alpine skiers. Amazingly there have been only two females in the database.



- Where are these events happening?

Most NARSIDs have occurred in the western U.S. and Canada (figure 4). A steep, thick coniferous forest, combined with deep powder, is the prime environment (figure 5). Tree wells have been involved in most of the documented cases but deep snow immersions also occur in open terrain. The thick branches of a fir tree support the snow and form air pockets around its trunk. The low-lying branches at the surface also hide this airy well at its base. A victim passes through more easily with the downward bending branches then trying to come out against them. Additionally, a substantial load of snow from those branches can accompany them into the well. The lesson here is to grab the branches to help prevent inverting.

- When are these events happening?

January and December account for 40% of the accidents when the snowpack is generally weak and the base of tree wells have not had a chance to consolidate (figure 5).

Big precipitation events are usually associated with NARSIDs. It is not uncommon for immersion and avalanche accidents to occur locally within days of each other. However, anytime the snow structure in the upper part of the snowpack is weak to a depth of a meter or more there will be the potential.

- What can skiers and snowboarders do to reduce their risk?

The most important step is raising the level of awareness. Ski area personnel must be informed of the correct safety message to deliver to the customers. The customers can then be educated with the help of web site content, brochures, signage, and safety talks.
The important prevention steps include how to avoid the risk, how to ski or ride defensively during snow immersion conditions, and effective strategies for skiing with partners, and what to do if they do go down. Emphasizing the skill of keeping partners in continuous visual contact is of paramount importance.

- What else can be done to reduce the risk of snow immersion accidents?

Ski areas can take additional steps after educating the staff and customers. It is important to monitor the level of snow immersion risk. Warning signage can then be used when the risk is high and removed as it abates. Responding to a missing person report with appropriate urgency includes sending initial searchers to the area while the witness and avalanche dogs are escorted to the site.

Figure 5. Site of a recent snow immersion accident and is typical of the NARSID environment.

3.3 *Analysis of the snow immersion experiment*

In general, there were no surprises and the results were in line with the statistical evidence discussed in 3.1 and 3.2. Extrication ranged from very difficult to impossible. The time window for the test subjects to manage useful activity like securing an airway, or maneuvering their arms and legs was very short. We also confirmed that releasable ski bindings do not guarantee a successful extrication as has been suggested for snowboarders.

Figure 6. Snow immersion experiment data

Test Subject	Head Depth	Allowed 90° Bending	Maintain Airway	Struggle Helpful	Release Binding	Able to Extricate	Immersion Time
Alpine Skier 1	130	No	Compromised by struggling	Worse	Yes	No	00:53
Alpine Skier 2	110	Yes	Yes	Helped	No	Yes	01:00
Alpine Skier 3	100	Yes	Yes	Helped	Yes	Yes	00:20
Alpine Skier 4	130	No	Compromised by struggling	Worse	No	No	00:49
Alpine Skier 5	150	No	Yes	Worse	No	No	01:20
Snowboarder 1	111	Yes	Yes	Helped	No	Yes	00:59
Snowboarder 2	141	No	Compromised by struggling	Worse	No	No	01:10
Snowboarder 3	110	No	Yes	Worse	No	No	01:20
Snowboarder 4	130	No	Yes	No effect	No	No	01:25
Snowboarder 5	122	No	Yes	No effect	No	No	01:34

The preliminary findings from the experiment data are:

- The ability of the test subjects to establish and or maintain an air pocket could be affected by their attempts to extricate.

As in any burial in the snow, survival time is extremely short. None of the test subjects made it to the mandatory removal time of two minutes. With the exception of the three that were able to get out on their own, all of the subjects requested early extrication (figure 7). This correlates well with the accident data. One NARSID study found that in a sample of twenty cases, six were unburied in less than thirty minutes and three in less than fifteen minutes (Hackett, 2000). To underscore this, we had a survivor of a recent tree well burial present during this experiment. She had stopped breathing before being recovered by her partner in less than ten minutes.

All of the test subjects initially had or made air pockets. They all were initially able to move their arms or legs in an attempt to extricate themselves. As shown in the table in figure 6, ten subjects found that struggling either did not help or made things worse. Three of the subjects compromised their air pockets as a result of struggling.

This confirms the accident data that it is difficult to impossible to escape without a competent partner's help. It also suggests that while an attempt to escape should be made it is more important to protect the air pocket and hope that a partner is coming to the rescue.

- The ability of the test subjects to extricate themselves from the tree well was dependant primarily on the degree of the inverted body position and the depth of burial.

This correlates well with the accident data. Out of the ten test subjects only two alpine skiers and one snowboarder were able to extricate themselves. In all three cases the subject's initial degree of inversion and depth of burial allowed their bodies to bend 90° at the waist as shown in figure 6. The subjects were then able to work their legs downhill escaping the inverted position and allowing them to extricate.

This emphasizes the need for a person falling into a tree well or deep snow to make an effort to stay out of, or minimize, the inverted position.

- The ability of the test subjects to release from their ski or snowboard bindings is difficult and may not be a significant factor in self-extrication.

Figure 7. Test subject during tree well experiment.

Only two of the alpine skiers were able to release at least one ski. However, only one of the alpine skiers was able to extricate himself. The other was not. None of the five snowboarders were able to release from their bindings, although one person was still able to extricate himself. It should be noted that these results also correlate well with a similar experiment done at Blackcomb, British Columbia where none of the subjects were able to extricate themselves including the alpine skiers that successfully released from their bindings (Cadman 1999).

The skiers in that experiment almost all successfully kicked off their first ski and those who got the second ski off tended to fall deeper into the hole and remained upside down (Cadman, personal communication).

It has been suggested that snowboarders may benefit from a releasable binding (Heneved, 2000). Currently, Meyer of Switzerland and Miller of Utah have manufactured releasable snowboard bindings since 1991. The market has not yet been enthusiastic about releasable snowboard bindings.

To date, there is simply no evidence in the accident data or the field experiments to support the assertion that they will help in NARSID prevention.

4. CONCLUSIONS

Over the last sixteen years, risk trends are changing at U.S. and B.C. ski areas. In bounds avalanche fatalities are virtually disappearing while the trend for out of bounds avalanche has remained relatively flat even though there is much more out of bounds traffic. This reflects diligent ski area risk management efforts in the form of avalanche control, boundary management policies, and robust public education. However,

also in the last sixteen years, there has been a trend in risk at U.S. and B.C. ski areas that has remained “under the radar”. This study was designed to investigate; the recognition of the risk, the key factors in the snow immersion phenomenon, and prevention strategies**. T**he preliminary findings are:

- The greatest single component of snow immersion risk is that it is substantially under-appreciated.

The risk of snow immersion accidents (NARSID) is on the increase and currently accounts for 15% of all ski area fatalities in the United States.
In B.C. during the period from 1993 to 1998 it accounted for 25% of all ski area in bounds fatalities (Cadman, 1999). In fact, the NARSID risk in the U.S. is currently fifteen times greater than the avalanche risk in bounds at a ski area.

- In the last 5 years, snowboarders appear to be increasingly placing themselves at risk.

It has been suggested that snowboarders have a greater risk of NARSID then alpine skiers because of their equipment (see issues of legal liability below). It is true that currently NARSIDs account for 15% of all snowboard fatalities as opposed to being only 5% of all skier fatalities. In the 2005-06 season alone, four out of the ten total snowboard fatalities (40%) at U.S. ski areas were NARSIDs. However, the data support that this is not due to equipment and releasable bindings do not appear to work as a NARSID prevention measure. It is the snowboarders that are exposing themselves to the risk of NARSID.

- It is important to recognize key factors in snow immersion accidents in order to design prevention strategies.

Certain key elements appear to be present in most NARSID cases. The vast majority of these accidents occur in tree wells. They almost always correspond with recent deep snowfalls. The inverted body position is a critical factor. Training to fight to stay out of it is a basic tenet of prevention. Most NARSID victims had partners that were out of visual contact. Training on good partner technique is essential.

- The good news is that NARSID risk, like avalanche risk, can be managed successfully.

This presents a great opportunity for the same ski area and snow professionals that have been so successful managing the risks associated with avalanche. This can be readily accomplished by providing the ski area customers with prevention strategies like those discussed in 3.2.
It should be noted that the heli-ski operations have been successfully managing this risk since the 70’s. Strict adherence to the “buddy system”, demonstration and prevention instructions to the clients, and sophisticated rescue gear have helped to reduce the snow immersion risk (R. Atkins, personal communication)
Currently there are educational materials like signage artwork and brochure and website content being developed by the Pacific Northwest Ski Areas Association as part of an ongoing public awareness campaign. These materials will be made available to ski areas and snow and avalanche professionals.

- Snow immersion risk management has had legal issues.

Although this was not discussed in the preceding study, it should be noted that there have also been issues of legal liability for both ski areas and snowboard manufacturers. to date there have been four wrongful death lawsuits in NARSID cases. Twice negligence was asserted against ski areas and twice against snowboard manufacturers. The manufacturers have had to defend against product liability claims associated with non-releasable bindings. It needs to be emphasized that the ski areas and ski and snowboard manufacturers have no “silver bullets” to prevent snow immersion accidents. The risk has to managed by the skiers and snowboarders themselves and we can help with education.

- More research needs to be done on snow immersion.

These findings are preliminary and many questions remain to be answered.
Anyone with information on these events, including surviving snow immersion, are encouraged to contact the author of this paper.

ACKNOWLEDGEMENTS

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