Fall 14

Web Based Snow-Sport Injury Reduction

Project Number: CAB 1414

Advisor:

Prof. Christopher A. Brown

By: Paul Buchanan, Joseph Giambarresi, Steven Hennessey, Stuart Sundseth, and Andrew Tanner

Table of Contents

Table of Figures:

Abstract:

Skiing and snowboarding has attributed to many injuries on the mountain. These injuries are due to different skill levels, age, trail design, terrain parks, inadvertent release, and equipment failure. Speed is the greatest factor of injury when on the mountain. Due to the texture of the snow and ice, it makes it difficult to stop as quickly as one may like. Many injuries and deaths have scared people from returning to the sport. The aim of this project is to evaluate the different areas on a mountain and see how much of a direct risk each area is.

It has been found that injuries are more likely to occur at the end of the day when skiers are tired. Some people on the mountain partake in consuming alcohol, energy drinks, and smoking marijuana on the slopes. Because they are not drinking as much water as they should, it often leads to riders becoming dehydrated and tired. The goal is to see how much substances people intake and how it affects the way that they ride and make decisions.

Mountains are hard to redesign, they are large and often have a lot of aggregate underneath that is hard to remove and dispose of. Therefore, trails often form themselves. The goal of identifying busy trails that cross each other and the skill level needed for one to enter a trail, terrain park, or glades is one that will help decrease injuries on the mountain. Inadvertent release is a release of the ski binding. Inadvertent release can be dangerous; as the skier often loses control after an inadvertent release occurs. Often people need to be educated on inadvertent release and what they can do to help prevent it.

Chapter 1: Head Injuries

1.1: Background:

Injuries to the head are the most frequent, as well as the most serious type of snow sport injury. Head injuries account for the majority of traumatic ski injuries with falls and collisions with stationary objects being the most common causes. Out of 196 adult injuries recorded over 10 years, 52% were injuries to the brain (McBeth, 2009). From this, we can conclude that the reduction of head injuries can significantly reduce serious injury and death in snow sports. In addition to this, the healthcare costs of patients with traumatic brain injury (TBI) are 5.75 times larger than the average injury (Rockhill et al, 2012). And, the effects of impairment due to TBI can last over 5 years with no substantial improvement (Millis et al, 2001). The potential damage caused by head injuries can be chronic, resulting in much larger healthcare costs. According to the National Electronic Injury Surveillance System of the U.S. Consumer Product Safety Commission 353,346 snow sport injuries were treated in 2009 and the total cost due to these injuries was over 9.28 billion (American Academy of Orthopaedic Surgeons, 2010).

1.2: Objective:

The objective of this study was to use a website and survey to determine the effects of helmet use on head injury prevention, to evaluate whether helmets contribute to reckless skiing/snowboarding, and to educate skiers and snowboarders on helmet use to reduce head injuries.

1.3: Rationale:

The use of a web-based survey will allow for ease of access to the survey, and the ability to analyze results immediately. Web-based surveys have been found to produce a significantly higher response rate at a substantially lesser cost than paper-based surveys (Greenlaw & Brown-Welty, 2009). The reduced cost is also important, as funding is limited for this study.

However, it has not been shown that education on safety can directly reduce injury, or that education on proper equipment use can reduce injury to due misuse or misfit. Education has only been shown to improve scores on subsequent evaluations, but failed to reduce injury rates compared to control groups (Cusimano, 2013).

1.4: State of the Art:

It is conclusive that head injuries are preventable, and that the use of helmets is a major factor in the reduction of both minor and severe injuries. The use of a helmet has been found to reduce the risk of head injury by up to 60% (Sulheim et al, 2010). In 1999, a report by the U.S. Consumer Product Safety Commission stated that 14% of all snow sport injuries were to the head, and that 44% of these injuries could be addressed by helmet use. More specifically, a study done in 2009 on snow sport injuries found that there was “a significantly lower incidence of loss of consciousness in helmet users who struck a fixed object” (Greve, 2009). Another study found that among hospitalized children who sustained a head injury while skiing or snowboarding, a significantly lower number of patients suffered a skull fracture if they were wearing helmets at the time of the injury (Rughani et al, 2011). It is clear that helmets are effective in reducing a large volume of injuries.

There is not sufficient research to conclude that helmet use influences risk taking in skiers and snowboarders. Risk taking in skiers and snowboarders has been linked to factors such as gender, age, and ability, but not to helmet use (Ruedl et al, 2010). A study done on 3,295 skiers and snowboarders failed to show that risk-taking was increased among helmet users (Hagel et al). In addition to this, injured skiers have shown the same level of risk taking tendencies as non-injured skiers (Bouter et al, 1988). Some indications exist that helmet use can affect injury rate in that previous research has shown that the average speed of skiers wearing a helmet was significantly faster than the speed of non-helmet users (Shealy, 2005).

Helmet use is becoming more and more common on the slopes, with numbers increasing over the past decade. In 2008, 16% of adults and 67% of children wore helmets while participating in snow sports and these numbers are expected to have risen since. (Cundy et al, 2010).

1.5: Methods:

A website, www.hurtskiing.com, was used as a platform for injury prevention education as well as to host links to the surveys. The website contained a survey page with links to all the project surveys. The head injuries survey was composed of six demographic questions and nine questions designed to collect data on the rider's helmet use, and risk taking tendencies. A complete list of the questions in all surveys can be found in the appendix. LimeSurvey online software was used to generate and host the surveys, and to organize and display the results. The data from these surveys was analyzed using Microsoft Excel along with the Stat Tools add-on to draw conclusions about how helmet use relates to risk taking. Surveys were advertised through email-lists and social media posts providing links to both the website and the surveys.

1.7: Results:

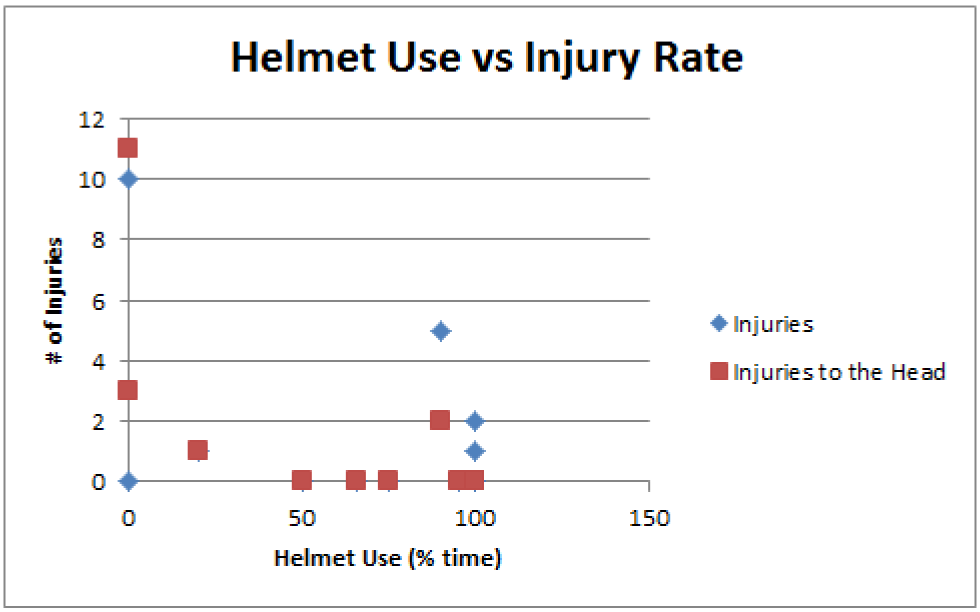


Figure 1: Helmet use vs. Injury Rate based on survey responses from skiers and snowboarders. Both Injuries to the head only (red) and all injuries (blue) are plotted.

Over half of respondents reported zero injuries to the head. All respondents who wear a helmet less than 50% of the time reported injuries to the head. Overall, injury rate decreased as helmet use increased.

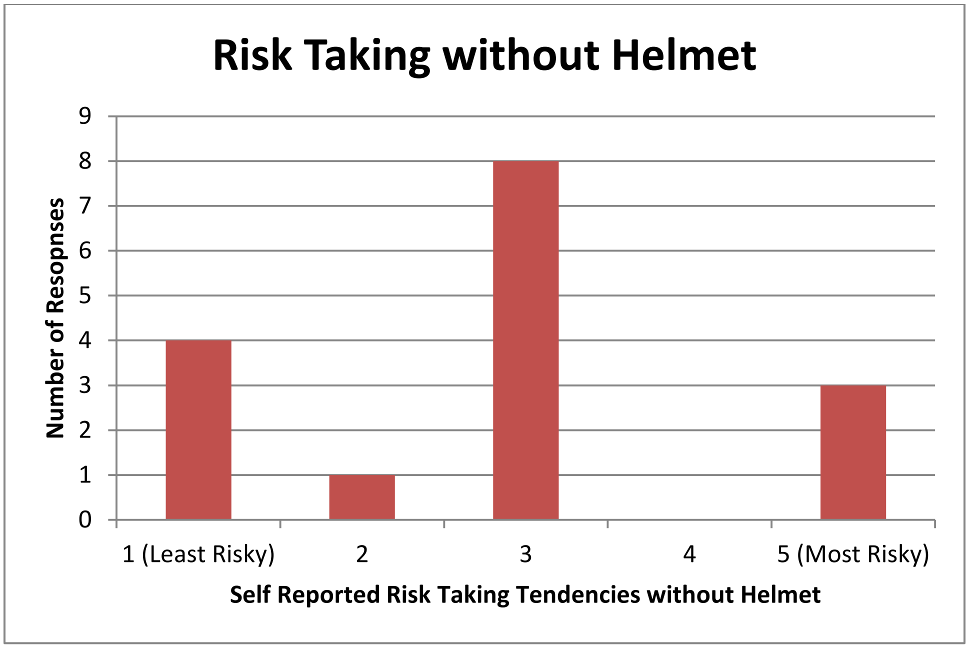


Figure 2: Responses when asked to self-rate risk taking without a helmet on a scale of 1-5

Most respondents reported medium risk taking, followed by least risky and then most risky. No respondents replied with a medium - most risky, and only one reported medium - least risky. This is most likely due to a psychological bias towards the extremes or the middle.

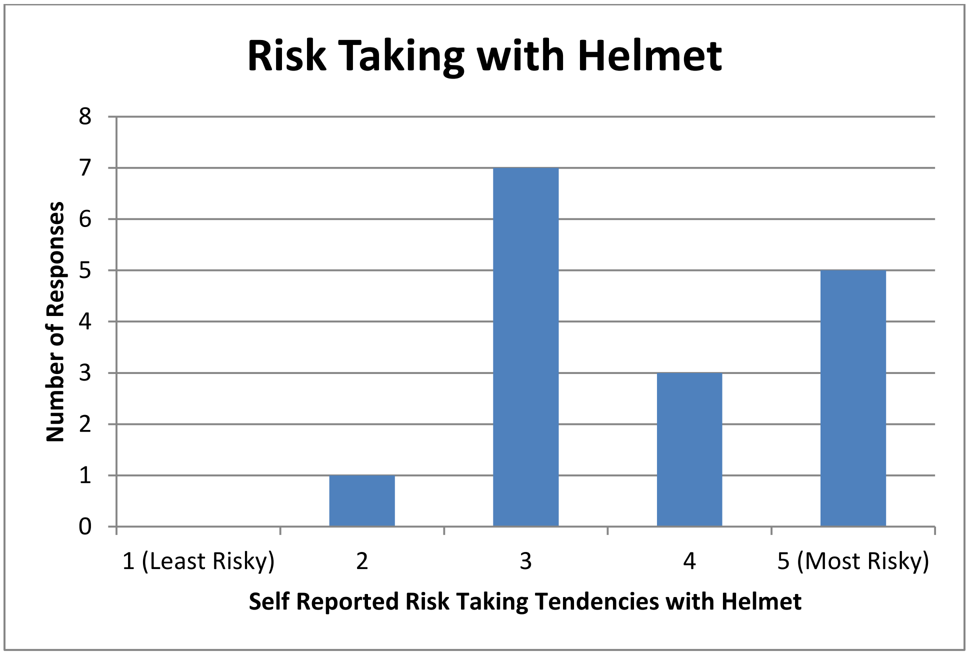


Figure 3: Responses when asked to self-rate risk taking with a helmet on a scale of 1-5

The chart is heavily skewed to the right, indicating that skier risk taking increases with helmet use. No respondents reported least risky actions while wearing a helmet. Once again, the extremes and the middle hold the highest values.

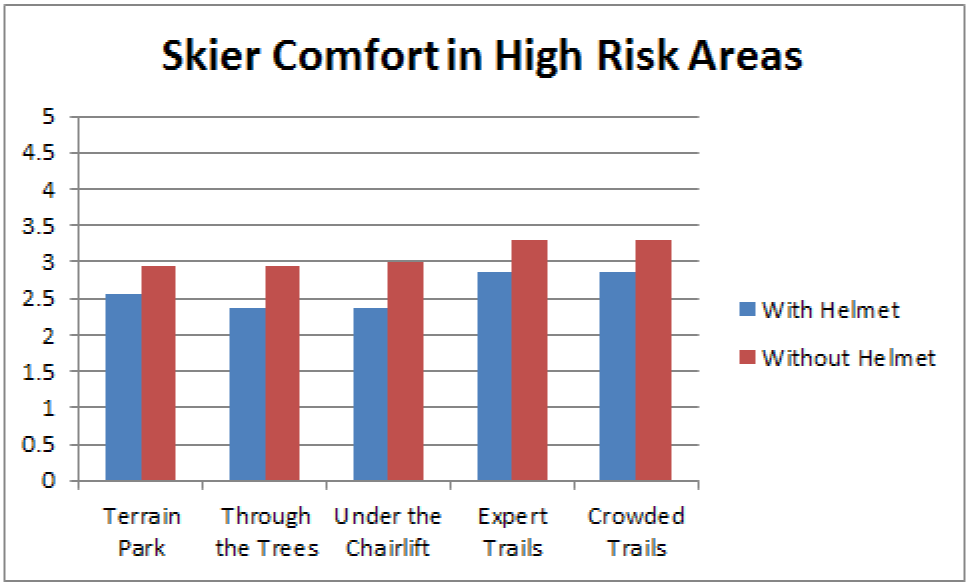


Figure 4: Skier Comfort in High Risk Areas. 0 = most comfortable, 5 = least comfortable

Respondents reported increased comfort while wearing a helmet in all high risk areas. The least comfort was experienced on expert and crowded trails, followed closely by the other three areas. The difference in comfort between helmet wearers and non-helmet wearers was constant across all high risk areas. All responses were centered around medium comfort as expected.

1.8: Discussion:

The number of injuries increases as helmet use decreases. Injuries to the head also decrease with increased helmet use. Outliers seen in Fig 1 are due to the majority of respondents reporting 100% helmet use. This result agrees with the hypothesis that helmet use would reduce head injuries.

50% of respondents reported an increase in risk taking when going from no-helmet to wearing a helmet, 38% no change, and 12% reported a decrease in risk taking while wearing a helmet. Overall, skiers felt more confident in taking risks while wearing a helmet than without. This indicates that wearing a helmet may increase the risks taken by a skier.

On average, respondents indicated less comfort skiing in high risk areas without a helmet than with a helmet. The most comfortable areas were in the terrain park and through the trees. The least comfortable areas were expert trails and crowded trails. This is most likely due to beginners being less confident skiing on expert trails and causing a false inflation in that response. Many people may also find crowded trails more uncomfortable because of the randomness and lack of control over the situation. In the terrain park and trees there are no obstacles that move so they would seem more comfortable.

75% of respondents have experienced a collision on the slopes in the past 5 years, and of these collisions, 17% occurred with no helmet. These results indicate that helmet use does not reduce collision rate. An increased number of responses would create more robust data to draw conclusions on this research question.

1.9: Conclusion:

- Helmet use decreases injury rate
- Risk taking increased with helmet use
- Helmet use increases comfort in high risk areas
- Helmet use does not reduce collision rate

.

Chapter 2: Terrain Park

2.1 Background:

Launch and landing angles are taken into consideration when designing jumps in a terrain park. When building half-pipes and jumps, a rover and shovels push the snow around to build a mound of snow. The snow needs to settle and harden before the builders can carve out the design for the terrain park apparatus. Just like inadvertent release, when the rider hit a divot they were more apt to fall, therefore, the divot needed to be removed, not have snow added to it. When comparing injuries in terrain parks to slopes separately among snowboarders and among skiers, there was higher likelihood for both snowboarding and skiing injuries in terrain parks to be a fracture or concussion, involving injury to the head, spine, and back, and required hospital transport compared to snowboarding and skiing injuries sustained on slopes (Brooks, 2010). Advanced skill implies faster speeds and attempts at higher, more difficult jumps. If amateur riders attempt jumps that are not in their ability level, more severe injuries may occur. The sport of snowboarding or skiing and terrain parks allow for extreme tricks and high risk-taking stunts.

In alpine winter sports, external risk factors such as snow and weather conditions, as well as slope characteristics (width, steepness, slope intersections, and snow parks) were considered when investigating potential risk factors. Therefore, ski patrol injury reports were used to compare factors associated with injuries occurred on slope intersections and in snow parks compared to on-slope injuries. In conclusion, injuries on slope intersections and in snow terrain parks differ in some factors from injuries sustained on ski slopes. (Reudl, 2013)

The problem with terrain parks is that the injury problems are related to types of activities and maneuvers performed in terrain parks. Future research could identify injury risk factors for each terrain park feature. Injury programs might target at-risk populations who use terrain parks and ski areas. Detailed examination of injury events in terrain parks could lead to design changes that decrease injury; for example, less difficult features for beginners, and marking the difficulty of terrain park features with the same ratings as traditional slopes. Also, if painted lines were marked out in the snow, riders could see how to approach the jump, almost like marked lines on a road.

On the mountain, terrain parks account for a greater amount of injuries. Injuries to the head, spine, sternum, and wrist are the most common type of injury within a terrain park. Therefore, these injuries account for the majority of traumatic ski injuries in a terrain park. It is important to study how terrain parks are built, because if they are not built correctly, more injuries will occur. Falls and collisions with stationary objects is the most common way for injury to occur. In Terrain Parks, injury is more likely to occur due to its nature of jumps and obstacles that are used: such as the rail, the box, and half-pipes.

Comparing ski and snowboarding injuries in terrain parks versus slopes at a ski area over two weeks, a total of 3953 (26.7%) injuries occurred in terrain parks, predominantly among young male snowboarders (Brooks, 2010). By understanding the dangers within a terrain park, users can more safely attempt stunts and enhance their skills.

Bettering the understanding of one's skills and limits can significantly decrease the amount of unnecessary injuries by allowing amateur riders to learn their abilities. Terrain parks are beginning to show a great interest among young riders who are looking to improve their skills. The teenage brain is more apt to make a decision without thinking of the repercussions. For example, they attempt stunts that are out of their skill level and, as a result, serious injury or death can occur.

2.2: Objective:

The objective of this study is to educate skiers and snowboarders on the effects of riding under the influence of alcohol and caffeine. Also, to educate skiers and snowboarders how to improve their skill in a terrain park.

2.3: Rationale:

Terrain parks on ski mountains amount for a large number of injuries on the mountain. Injuries to the head, spine, sternum and wrists are the most frequent type of injury inside a terrain park. These account for the majority of traumatic ski injuries in a terrain park. Falls and collisions with stationary objects are the most common way for injury to occur. It is important to study how terrain parks are built because if they are not built correctly, it may lead to serious injury. In Terrain Parks, injury is more likely to occur due to its nature of jumps and obstacles that are used: like the rail, the box, and half-pipes. Comparing ski and snowboarding injuries in terrain parks versus slopes at a ski area over two weeks, a total of 3953 (26.7%) injuries occurred in terrain parks, predominantly among young male snowboarders (Brooks, 2010). By understanding the dangers within a terrain park, users can more safely attempt stunts and enhance their skills.

Bettering the understanding of one's skills and limits in a terrain park can significantly decrease the amount of unnecessary injuries by teaching amateur riders their ability. Terrain parks are beginning to show a great interest among young riders who are looking to improve their riding ability. The teenage brain is more apt to make a decision without thinking of the repercussions. For example, if they attempt a stunt that is out of their skill level serious injury or death may occur. Therefore, how can riders safely learn to attempt these stunts?

2.4: State of the Art:

Both launch and landing angles need to be taken into consideration when designing jumps. When building half-pipes and jumps, a rover and shovels push the snow around to build a mound of snow. The snow then needs to settle and harden before the builders can carve out the design for the terrain park apparatus. Just like inadvertent release, when the rider hits a divot they are more apt to fall, therefore, the divot needs to be removed, not have snow added to it. When comparing injuries in terrain parks to slopes separately among snowboarders and among skiers, there was higher likelihood for both snowboarding and skiing injuries in terrain parks to be fracture or concussion, involving injury to head, spine, and back, and require hospital transport compared to snowboarding and skiing injuries sustained on slopes (Brooks, 2010). Advanced skill implies faster speeds and attempts at higher, more difficult jumps. If amateur riders attempt jumps that are not in their ability level, more severe injuries may occur. The sport of snowboarding or skiing and terrain park design allow for extreme tricks and high risk-taking stunts.

In alpine winter sports, external risk factors as snow and weather conditions as well as slope characteristics (width, steepness, slope intersections, and snow parks) should be considered when investigating potential risk factors. Therefore, ski patrol injury reports were used to compare factors associated with injuries occurred on slope intersections and in snow parks compared to on-slope injuries. In conclusion, injuries on slope intersections and in snow terrain parks differ in some factors from injuries sustained on ski slopes. (Reudl, 2013)

The problem with terrain parks is the injury problems that are related to types of activities and maneuvers performed in terrain parks. Future research could identify injury risk factors for each terrain park feature. Injury programs might target at-risk populations who use terrain parks and ski areas. Detailed examination of injury events in terrain parks could lead to design changes that decrease injury; for example, less difficult features for beginners, and marking the difficulty of terrain park features with the same ratings as traditional slopes.[1] Also, if painted lines were marked out in the snow, riders would see how to approach the jump, almost like marked lines on a road.

2.5: Approach:

This project will gather data through surveys questioning riders on their intake of substances. The survey will be distributed to as many people as possible. It will record information on substance intake on the mountain and risk taking. These surveys will solely be the view of the rider's mentality in different age groups when using riding on the mountain. This study will also use a website and survey to contribute to the understanding of riders on the way these substances affect the way you ride.

2.6: Methods:

A website was used to get information on the mindset of riders as they approach jumps and stunts within the terrain park. The surveys we used asked riders to relay the amount of confidence they had in attempting stunts. The purpose of this study was to educate riders on the common injuries that can occur when performing various stunts. At Mt. Stowe, the main jump, main rail, and main box were observed.

First, the height and width of the main jump was measured. Then, skiers and snowboarders were observed for an hour to see how the riders approached the jump. Then it was observed if the rider landed the jump, and if not, how the rider fell.

Second, the height and length of the main rail was measured. Skiers and snowboarders were observed for an hour to see how the riders approached the jump. It was observed if riders went the entire length of the rail or if they fell. If the rider fell, it was noted how they fell.

Third, the height, length, and width of the main box were measured. Skiers and snowboarders were observed for an hour to see how the riders approached the jump. It was observed if riders went

---

[1] "Effect of trail design and grooming on the incidence of injuries at alpine ski areas." *Bergstrøm KA, Ekeland A, Br J Sports Med. 2004 Jun; 38(3):264-8.*

the entire length of the box or if they fell. If the rider fell, it was noted how they fell.

A website and in-person survey was used to receive information on riders and their use of substances. Riders were asked if they use alcohol, caffeine, and marijuana while on the mountain. The purpose of this study was to help determine if these substances aided in the rider becoming more tired by the end of the day on the mountain.

2.7: Results:

Main Jump Observation

Figure 5: Mt. Stowe Jump. This jump is located in the middle of the Terrain Park. It is 12 feet high in the center and 11 feet wide. The two jumps on either side of the main jump are 8 feet high and 16 feet wide. This allows riders to choose what jump they are more comfortable with approaching the mountains main jump. There were a total of 9 different jumps a rider could choose from, each in varying heights and sizes where they could improve their skillset.

Total Riders	Wore Helmet	Height	Main/Side	Landed	Hesitated
37	31	12' or 8'	11/16	31	13

Figure 6: Mt. Stowe Jump Observations. Here it was observed how many riders decided to attempt the larger jump versus the two smaller jumps on either side. It was also observed if the rider slowed down to approach the jump and if they landed. Few experienced riders were able to jump of the ramp at a high speed and catch a lot of air. However, most people tended to approach the jump at a reasonable speed.

Main Rail Observation Results:

Figure 7: Mt. Stowe Rail. The main rail is located towards the top of the terrain park were the mountain becomes less steep. This allows riders to approach the rail at a comfortable speed, where they can attempt to grind the rail from beginning to end. This is one of three rails where riders are able to test their ability and stability on the varying rails of different skill level needed.

Total Riders	Wore Helmet	Height/Length	Went the Length of Rail	Fell (on hands)	Jumped off Early
29	29	3'/8'	17	3	8

Figure 8: Mt. Stowe Rail Observations. Here the height and length of the rail was measured. Due to its proximity to the ground, it is easy for riders to get on top of the rail. The length, however, made it difficult for riders to grind the full length of the rail if they did not have enough momentum or balance. Most riders did not approach the rail with great speed. From observing the riders, it was often that they only grinded the end of the rail after descending from the jump.

Main Box Observation Results:

Figure 9: Mt. Stowe Box. This box is a wooden structure with an 8-inch flat metal surface. This allows the rider to balance his or herself better due to the larger surface area. The height of the box is 4 feet tall and it is thirteen feet long. This is one of two boxes that are in the terrain park. The other box was much smaller in size and easier to attempt.

Total Riders	Wore Helmet	Height/Length/Width	Went the Length of Rail	Fell (on hands)	Jumped off Early
24	24	4'/13'/8"	14	1	9

Figured 10: Mt. Stowe Box Observations. Here, the height of the box made it difficult to get on top of. You had to jump off the ramp to get enough height to get on top of the box. From observing, many people did not have enough momentum to go the full length of the rail because they hesitated before they made the jump. However, those that were able to land the jump slid across the box with ease.

2.8: Discussion

Main Jump:

By observing 37 different riders approach the main jump in the terrain park, I found that people are more likely to go off the jump as compared to the other obstacles you may find in the terrain park. The jump is the most basic stunt, where mostly every rider landed their jump. It can be deduced that when people fall from a jump, the biggest injury sustained is in the legs and arms.

Main Rail:

In observing the 29 riders who attempted to grind and land the rail, I could see that people were a lot less confident as they approached it. There was a greater hesitation, where the rider would slow down before getting to it. In some cases there was not enough momentum for the rider to go the entire length of the rail before falling or jumping off. Those that fell off the rail fell forward where they put their hands out to brace the fall. This is the biggest common injury of the rail. The second most common injury being cracks or breaks in the sternum due to falling on the rail.

Main Box:

By observing the 24 riders who attempted to land on the box and ride it through were more confident than the rail. This is due to the width of the box aiding in a greater stability for the rider when attempting the box stunt. Those that fell off the box fell forward where they put their hands out to brace the fall. This is the biggest common injury of the box. The second most common injury being cracks or breaks in the sternum due to falling on the box.

The mountain can use signs and spray paint to indicate the sides of a jump and how difficult the jump/box/rail that the rider is trying to attempt to land may be. Although they are not liable for the injuries that occur on the mountain, these signs can help a rider be more aware of their skill level and the necessary skill level needed for the terrain park. Many injuries to the wrist and sternum accumulate from the terrain park due to riders trying to catch themselves or falling on the obstacle.

Advertisements like Red Bull have swayed heavily into the X Games where many young riders now drink the energy drink on the mountain. When this happens, there is a rise in adrenaline where the rider feels that they could attempt a harder stunt. The same can be said after a rider has a few alcoholic beverages. Inhibition is lost and the rider may attempt a more intricate stunt, often leading to injury.

Caffeine Survey:

Of the 11 survey responses that were received pertaining to caffeine intake on the mountain, it was determined that people were not more likely attempt higher risk-taking stunts on the mountain. The results determined that people thought that the sport is pretty risky as people are often attempting stunts at high speeds. They also understood that drinking caffeine leads to an increase in adrenaline, causing people to lose inhibition.

Alcohol Survey:

Of the 25 survey responses that were received pertaining to alcohol consumption on the mountain, it was determined that people were not more likely to drink on the mountain. However, it was interesting to see that people would be more likely to consume alcohol if the mountain offered a place for them to drink. The results determined that people thought that the sport is risky as people are often attempting stunts at high speeds.

Personal Survey:

By personally surveying 64 participants in what they consumed. It was interesting to find that young male and females were the ones who were consuming the most caffeine. This came from energy drinks such as Red Bull, Monster, and coffee. The Hockey Olympics were on and Canada was versing the United States. This attracted a larger group to the bar, where I observed that the male population consumed about 2-3 beers per person.

2.9: Conclusion:

- Riders who used substances were more tired at the end of the ski day compared to people who did not.
- Riders felt more comfortable approaching trails and stunts that were marked out by spray paint or signs.
- Most injury occurs in the wrist and sternum from riders falling onto the apparatus or trying to catch themselves.
-

Chapter 3: Inadvertent Release

3.1: Background:

Hardware problems are technical difficulties with ski equipment that cause inadvertent releases and exist in many forms such as the “Houdini Effect”, the “Jet Effect”, and the “Flex Effect” (VSR: FAQ for Skiers/Riders 2010). These problems have the potential for an inadvertent release to take place.

Software problems are skier based difficulties that occur from either inappropriate skiing technique or poor skiing technique. Two of the most common software problems are the “Superman Effect” and the “Bow Effect” (VSR: FAQ for Skiers/Riders 2010). An example of a software problem would be skiers tend to the idea of tightening the release settings as a way to potentially avoid inadvertent releases but actually may create the bindings into being more of a danger to the skier.

A ski binding will eject ones boot from the binding when a certain maximum load is met. This is so that if your ski got stuck in a way that it would rip and twist your legs the binding will release the skier. However sometimes the ejection will happen inadvertently without the skier falling or trying to release. Ski bindings can mistake non-injurious loads from injurious loads causing an inadvertent release unintentionally (Thompson 2011). In giant slalom, a common way to experience a inadvertent heel release is when the ski is pressed down in a trough well below a gate, with the skiers weight far forward and the weighted ski having decelerated, and having high heel release settings will not prevent this (Young 1989).

The majority of safety initiatives have involved developments in both release and retention performances of the ski binding and boot system. Most binding toe pieces perform well in tests that simulate combined weighted twisting falls. On the other hand, all heel piece designs perform poorly in combined weighted bending tests due to the fact that they only sense upward force of the boot heel and not the true bending moment of the leg. (Johnson 2001)

3.2: Objective:

The goal of this research is to demonstrate an effective approach to reducing the risk of inadvertent Release (IR) in alpine skiing.

3.3: Rationale:

The study will help provide a better understanding to the public on the seriousness of cleaning your ski bindings and boots. The consequences of not cleaning your equipment can increase your chances of inadvertent release. From a competitor's standpoint, an injury could result in withdrawal from the competition. For both competitive and non-competitive skier's, the potential risk of upper body injury because of high speed impacts with icy terrain or obstacles (including non-"breakaway" poles) is increased (Young L.R. 1989). If research can be provided to determine cleaning your ski bindings and boots reduces the risk of inadvertent releases, it can then be possible to better educate the public on the seriousness of cleaning your equipment.

3.4: State of the Art:

Though many references discuss the importance of cleaning ski bindings of ice, snow, or any foreign objects, an observational and equipment test involving packed ice in the bindings study has not been published.

3.5: Approach:

Analyzing the work previously done by others on inadvertent release we intend to further education on inadvertent release and help reduce the risk and occurrences of an inadvertent release. People believe inadvertent releases can be reduced by routine checks of equipment and making sure bindings/boots have no foreign objects stuck in them. On the other hand others say it is related to the skier's movements, weather that may be poor technique or inappropriate motion on skis. Analyzing both studies on inadvertent release through a series of methods we intend to reduce injury and occurrences of inadvertent releases.

3.6: Methods:

To demonstrate the dangers of having compacted ice or other foreign objects in one's ski bindings during alpine skiing, we must first collect and analyze results from the on-sight observations and ski binding foreign objects test. So that we can show everyone the importance of cleaning ones bindings and boots before clicking into their skis.

1. **Site Observations:**

   To achieve a proper understanding of how the average recreational skier prepares to put their ski boots into their ski bindings and ski we used a practical approach. The data was recorded using observation from a distance and recording how recreational skiers engage their ski boots to their bindings. Results were recorded on a chart as illustrated in figures eleven through thirteen. Data for the given day, weather conditions, and duration the observation charts were compiled. On three separate days of boot cleaning observations in three different weather conditions were observed for differences. Finally, with all the data from the three charts compiled into a graph to show the trends of recreational skier's techniques to clicking into their bindings. Below, figure fourteen illustrates a picture of the graph of cumulative data.

2. **Ski Binding Foreign Objects Test:**

Compacted ice, small rocks, or any other type of foreign object that could possibly be jammed or stuck in one's bindings, has potential to not allow for a full connection between the ski boots and ski bindings. By performing a self-release test on both skis, one can determine the binding setting with no foreign objects present that a skier could experience an inadvertent release from their bindings. Once there is a set standard of the lowest binding setting to self-release without having any foreign objects present, we proceeded to put compacted ice into the ski binding. Having the experimenter engage (if possible) into the ski binding. Once engaged, the binding setting was turned to the highest possible setting and the experimenter attempted to self-release. If the experimenter could not self-release at the highest setting, the setting would be lowered one unit at a time until the release occurred, all while recording, and observing the differences.

Two different techniques were used to pack the ice, both involving packing the heel and toe unit of the binding with ¼ inch of ice. Once the binding was put to the highest setting, each of the release experiments would be tested. The first technique was to demonstrate a heel self-release as shown in figures sixteen and twenty one. The other technique was to demonstrate a toe-release as shown in figures eighteen and twenty three. The cumulative data was collected and put into a spreadsheet for further observation.

3. **Inadvertent Release Survey**

An online and offline survey was developed to find a connection to the site observations and ski binding foreign objects test methods. The survey advertised both online through various social media websites, as well as given out personally to family and friends. Each question developed with critical thinking to achieve the most accurate results as possible. The survey and description of each question in the survey can be found in inadvertent release.

4. **Analysis**

Compiled data from all methods were analyzed for similarities. The Search was for connections between site observations and the ski binding foreign objects test to accurately show that leaving compacted foreign objects in one's bindings and engaging their ski boots will increase one's chance of an Inadvertent Release, with the survey responses verifying the connection between the other two methods. We had hoped from the survey responses that those who do not use a cleaning technique before engaging there ski boots to their ski bindings will have higher risk of experiencing an inadvertent release than those who take the time to clean their bindings of any foreign object.

3.7: Results:

Boot and Binding Cleaning Observations:

The results compiled from the site observations showed a strong favoring in not having any cleaning technique for recreational skiers. The observations were recorded in a table with four different techniques that would be recorded if occurred. The first is boot tapping. Boot tapping is simply when the skier taps his boots either on his other boot or ski to knock out any potential foreign object that may be preventing full connection between the boot and binding. The next is ski pole cleaning. Ski pole cleaning is more thorough in that the skier uses this tip of their pole to remove any foreign objects from both the bindings and boots. However, cleaning under one's ski boot with a pole is a difficult task to achieve. The third is simply no cleaning technique. Finally, there is another column were anything different from these techniques would be recorded and specify the technique used.

Cleaning Techniques	Wachusett Mountain 1/19/14 Duration: 2.0 Hours Snow/weather Conditions: Icy and very compacted snow on Trails. Average 30 degrees F
Tapping of Boots	9
Ski pole cleaning	5
No Cleaning Technique	37
Other (specify)	Hand cleaning (2)

Figure 11: Cleaning techniques Observation Trial 1

Cleaning Techniques	Mount Snow 2/1/14 Duration: 3.0 Hours Snow/weather Conditions: compacted snow with some ice on Trails. Average 35 degrees F
Tapping of Boots	23
Ski pole cleaning	7
No Cleaning Technique	61
Other (specify)	Hand cleaning (1) clapping skis (3)

Figure 12: Cleaning techniques Observation Trial 2

Cleaning Techniques	Mount Snow 2/2/14 Duration: 3.0 Hours Snow/weather Conditions: light fluffy snow (sticky), un-groomed trails. Average 28 degrees F
Tapping of Boots	33
Ski pole cleaning	17
No Cleaning Technique	58
Other (specify)	clapping skis (6) Hand Cleaning (2)

Figure 13: Cleaning techniques Observation Trail 3

Snow and Weather Conditions:

The conditions varied in each of the three observation trials. Each day the snow conditions were impacted differently due to the weather conditions effect on them. Different snow conditions means there is an increase or decrease in the chance of foreign objects sticking to your boots or bindings.

Compiled Results for all site observations:

The three site observation results were compiled into a graph to illustrate the overall average of ski binding and boot cleaning techniques. The collected data shown below shows that the majority of recreational skiers do not use any sort of ski boot or binding cleaning technique.

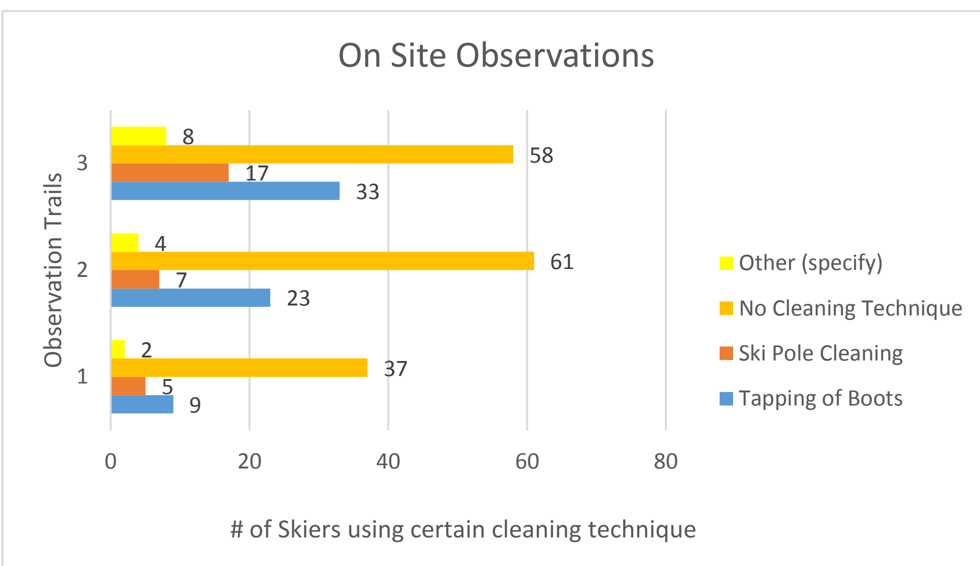


Figure 14: Observation Compiled Results

Ski Binding Foreign Objects Test;

The results from the ski binding foreign objects test were intriguing. In certain cases, the ski binding would experience an inadvertent release at a lower binding setting while being packed with ice (on average a ¼" of packed ice in the binding under the toe and heel units) then It would experience while it was free of foreign objects. In other cases, the packed ice made it almost nearly impossible to experience an inadvertent release without turning the settings down very low. In test one, the equipment used for the experiment was a Salomon binding. For test two, the equipment used for the experiment was a Tyrolia bindings.

Test 1 Ski Binding Foreign Objects Test:

Heel Release Test 1:

This experiment showed that having packed ice in one's bindings slightly increased your chances of an inadvertent release from the heel. The compacted ice made for a greater chance of the boot disengaging from the binding at a higher binding setting were as with no compacted ice present the boot would remained engaged with the binding. With no foreign objects present on the right ski the settings of the binding were set at 7 for the heel release.

Figure 15: (both heel and toe units of the ski binding are packed with roughly a ¼" of compacted ice.)

Figure 16: With the compacted ice shown in the figure above the skier experiences a self-release. The binding settings are 12 for the toe and 8 for the heel. (One setting higher than if no foreign objects were present).

Toe release Test 1

In the toe release experiment it was discovered that having ice compacted in your bindings slightly reduces one's chances of an inadvertent release from the toe by making it much more difficult to implement a load on the binding that would be strong enough to release the boot from the binding as opposed to having no foreign objects present in the boots or binding. With no foreign objects present on the right ski, the settings of the binding were set at 10 for the toe release.

Figure 17: (both heel and toe units of the ski binding are packed with roughly a ¼" of compacted ice.)

Figure 18: With the compacted ice shown in the figure above the skier experiences a self-release. The binding settings are 7 for the toe and 10 for the heel. (three settings higher than if no foreign objects were present).

Test 1 Chart

The data collected from test one was compiled into a chart to give a better understanding on what is happening in the experiment.

Test 1 Right Ski : Salomon bindings	
Trial 1 - No ice or foreign objects	
Setting at IR	
Heel Release	7
Toe Release	10
Trial 2 - Both Heel + Toe Packed 1/4" Ice	
Setting at IR	
Heel Release	8
Toe Release	7

Figure 19: Ski Binding Foreign Objects Test 1 – Salomon Bindings

Test 2 Ski Binding Foreign Objects Test:

The same exact experiment was performed as test one using compacted ice in ski bindings to determine if it will increase or decrease your chances of an inadvertent release.

Heel Release Test 2:

Using a different brand of binding, Tyrolia as opposed to test one with Salomon bindings, we determined that the same scenario occurs when packing the binding with roughly a ¼" of ice and performing a heel release equipment test. With no foreign objects present on the right ski the settings of the binding were set at 5 for the heel release.

Figure 20: Both heel and toe units of the ski binding are packed with roughly a ¼" of compacted ice.

Figure 21: With the compacted ice shown in the figure above the skier experiences a self-release. The binding setting was 6 for the heel. (one setting higher than if no foreign objects were present).

Toe release Test 2:

Using Tyrolia bindings for test two the results were the same as test one. Having compacted snow in the ski binding slightly decreases your chances of experience an inadvertent release from the toe. With no foreign objects present on the right ski, the settings of the binding were set at 3.2 for the toe release.

Figure 22: Both heel and toe units of the ski binding are packed with roughly a ¼" of compacted ice.

Figure 23: With the compacted ice shown in the figure above the skier experiences a self-release. The binding setting was 2.6 for the toe. (0.6 settings lower than if no foreign objects were present).

Test 2 Chart

The data collected from test one was compiled into a chart to give a better understanding on what is happening in the experiment.

Test 1 Right Ski : Tyrolia Bindings	
Trial 1 - No ice or foreign objects	
Setting at IR	
Heel Release	5
Toe Release	3.2
Trial 2 - Both Heel + Toe Packed 1/4" Ice	
Setting at IR	

Heel Release	6
Toe Release	2.6

Test 2 Right Ski : Tyrolia Bindings	
Trial 1 - No ice or foreign objects	
Setting at IR	
Heel Release	5
Toe Release	3.2
Trial 2 - Both Heel + Toe Packed 1/4" Ice	
Heel Release	6
Toe Release	2.6

Figure 24: **Ski Binding Foreign Objects Test 2 – Tyrolia Bindings**

Survey Results:

Two questions from the survey gave correlation to the ski bindings foreign objects test.

Before clicking into your skis and you do decide a boot cleaning technique which option do you choose?

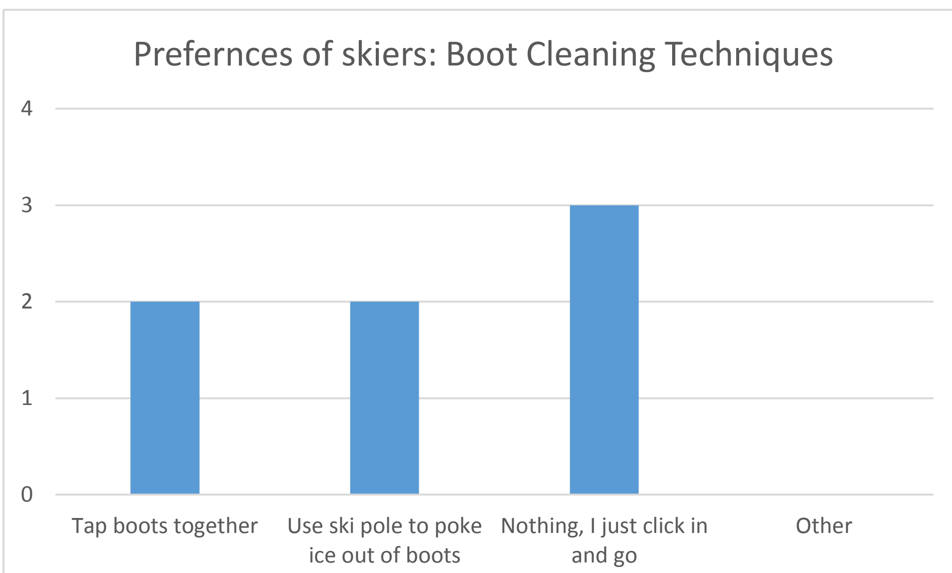


Figure 25: Preferences of Skiers – Boot Cleaning Techniques

Before clicking into your bindings, how often do you check the bindings making sure they are free of any foreign objects?

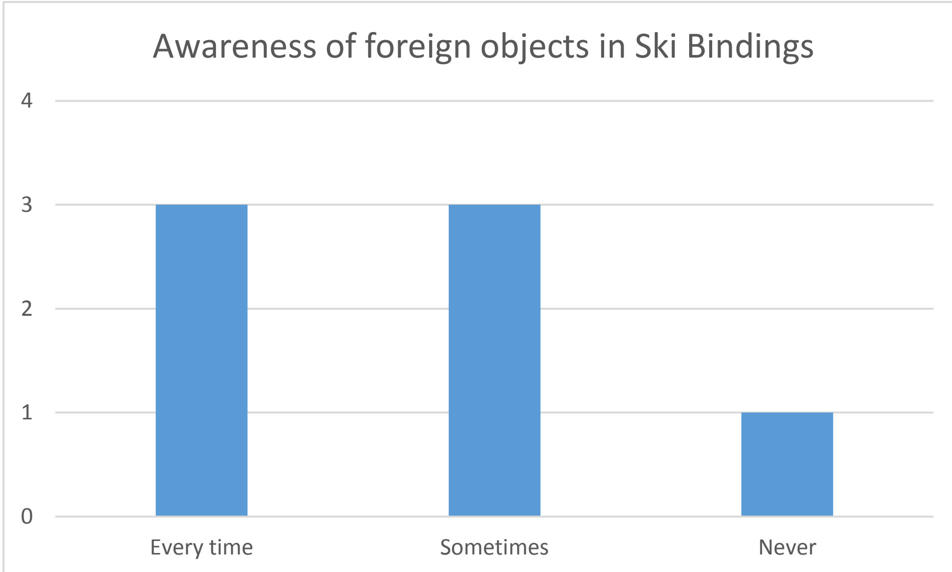


Figure 26: Awareness of foreign objects in ski bindings

3.8: Discussion:

Analysis of the compiled results from boot/binding cleaning observations and ski binding foreign objects test demonstrates the importance of using some sort of a cleaning technique for your ski boots and bindings before engaging them together. Out of the 264 recreational skiers that were observed for the boot and binding cleaning observations, 156 of them used no cleaning technique of any sort. Roughly 60% of the recreational skiers use no cleaning technique meaning they are not taking the time to use a cleaning technique or even thoroughly look at the binding to see if there are any foreign objects jammed in either the boot or binding. With this being determined, there is an increased chance of recreational skiers going up the mountain to ski not knowing they could potentially have a foreign object in between the boot and binding that is preventing a full proper connection. To most people, a ski binding is a basic system that once one hears the boot click into the binding their good to go, most skiers probably do not consider the fact that ice, rocks, or any kind of foreign object could be present and therefore the public needs to be educated on taking the steps to be aware their bindings are free of foreign objects.

Through the ski binding foreign objects test we finally were able to see what the effect of foreign objects in between your boots and bindings will have on the skier if they do not notice and continue to ski. The findings were that when foreign objects (i.e. compacted ice) are present in the boot and binding can increase or decrease your chances of an inadvertent release. When testing both Salomon bindings and Tyrolia bindings, we found that the same scenarios occurred with both bindings when showing a heel release and a toe release. During the tests, we first recorded the settings it would take for the experimenter to self-release from the binding with no foreign objects present attempting a heel release as well a toe release. After, we would pack compacted ice on to the binding under both the toe and heel units roughly getting a ¼" of ice present every time. We then would turn the settings up above the release point of no foreign objects and decrease the setting by small increments each time until a release occurred, then repeating the process for the other type of release.

The results we came to were that when attempting a heel release with compacted ice present the skier would eject from the binding at a higher setting then if no foreign objects were present. Using the Salomon bindings the heel release with no foreign objects was 7, when compacted ice was present the heel release occurred at 8. Using the Tyrolia bindings, the heel release with no foreign objects was 5, when compacted ice was present the heel release occurred at 6. This being said if a skier was to not notice the compacted ice or another foreign object of any kind, the skier would be at a slightly higher risk of experiencing a heel inadvertent release then others that use a cleaning technique or just have no foreign objects present. The toe release data had a very opposite result from the heel release data in that when compacted ice was present between the boot and binding the risk of experiencing an inadvertent release decreased. Using the Salomon bindings, the toe release with no foreign objects was 10, when compacted ice was present the heel release occurred at 7. Using the Tyrolia bindings the heel release with no foreign objects was 3.2, when compacted ice was present the heel release occurred at 2.6. This is not necessarily a good thing that the compacted ice prevents an inadvertent release especially in the toe unit. If a skier falls and a load big enough to release skier from the binding occurs with no foreign objects present the release will happen releasing the force that is being applied to the skier's knee in a torqueing motion. If a skier falls with compacted ice in the binding, the binding will not release the skier and therefore causing a large force on the skier's knee increasing the chances of an injury to the skier's leg such as ligament tears or broken bones.

Finally, in an attempt to show a stronger correlation between boot and binding cleaning observations and the ski binding foreign objects test results a survey was developed to see how many skiers experience inadvertent releases not using a cleaning technique. Unfortunately, with using social media, friends, and family members to get the survey out to the public the results that came back were not promising. The survey produced 38 total responders with only 7 responders being skiers and the other 31 responders being snowboarders. The survey method did not have enough responders to be sufficient data to correlate with the other methods. For those who did respond to the survey as skiers only two responders say they do not use a cleaning technique of any kind. This method was ineffective because I did not have enough respondents to the survey. After hours of observation, I determined that over 59% of recreational skiers do not use a cleaning technique. Survey responses were not an adequate measure of what is happening to skiers not using a cleaning technique.

3.9: Conclusion:

- **59% of recreational skiers use no cleaning technique when engaging there ski boots into their ski bindings.**
- **Skiers with foreign objects present in the heel unit of the binding increase our chances of experiencing an inadvertent release.**
- **Skiers with foreign objects present in the toe unit of the ski binding decrease your chances of experiencing an inadvertent release.**

Chapter 4: Trail Design

4.1: Background:

Ever since the first ski and resort areas opened in the 1910's and 20's, skiing and later on snowboarding, became an infectious hobby and profession. After Wildcat Mountain Ski area opened in 1933, an increasing amount of mountains began to sprout, and continued through the 30's. By the end of the decade, there were more than fifty open Ski Mountains. From that point forward, snow sports became an extensive market not only entailing passes and equipment, but also hotels, restaurants, bars and other attractions. This industry roughly averages $4 Billion in yearly revenue, which in part is put back into the operation to accomplish tasks like extending boarders, purchasing terrain features and installing injury prevention methods.

With all the excitement that comes with skiing and riding, there also comes an alarming amount of associated and assumed risk. Prior to 1978, The Assumption-of-Risk Doctrine gave Mountains the ability to deny recovery to any plaintiff's injured on their resort. This all changed when the court ruled in favor of James Sunday, a skier who incurred quadriplegia at Stratton Mountain. The judge felt that ski areas should no longer be able to eradicate charges based on the assumption-of-risk principles, and ruled Stratton 100% at fault. During the wait time before the appeal of this trial, the Sports Injury Statute was enacted. This essentially had a purpose: to reestablish the assumption-of-risk principles immunizing mountains from direct fault. The Statute reads:

> "Notwithstanding the provisions of [Vermont's comparative negligence statute], a person who takes part in any sport accepts as a matter of law the dangers that inhere therein insofar as they are obvious and necessary."

With the Statute in effect, Mountains are only obligated to prove that the conditions that cause an injury, were in fact, obvious and necessary ones. Defense attorneys made frequent use of the words "foreseeable" and "avoidable" as this would classify a condition or feature as obvious (Beersworth, 2012).

Even if a resort is not at all accountable for the behavior and risk that occurs on their mountain it should still be a main topic of interest to take measures to make the terrain a safer place. The more steps and measures mountain ops takes to mitigate severe conditions and obstacles, the more material they will have to go to bat with when legal conflict arises.

4.2: Objective:

The objective of this study is to investigate if certain trail features, or arrangement of trails, have an effect on the formation of sites with increased risk, if so, to warn skiers of these areas and propose possible solutions.

4.3: Rationale:

This is an important topic to study because injuries are sometimes avoidable if the skiers are well informed. The injury rate could be reduced by identifying dangerous areas on a slope or trail map and highlighting those areas to be looked out for. With reduced injury rate comes reduced costs, both legal and insurance/hospital.

4.4: State of the Art:

K. A. Bergstrom and A. Ekland used injury data collected over a 6 year span from December 1990 through the season of 96'. This injury data was courtesy of Hafjell and Voss Ski areas in Norway. The study was an attempt to define dangerous areas later deemed as "black spots". 1410 injuries were recorded collectively at these mountains. With each injury datum came a location pin point and this led to the visualization of concentrated injury sites. No other proof was needed to tell that there were conditions at these areas that added an extra element to injury. Each dangerous site was evaluated and the factors that created this increased risk were determined. The three sites at Hafjell identified were the cause of 40% of injuries in the entire Alpine area. The first site was where several trails met and then continued downhill. The mechanisms causing injury here were mainly collision and self-induced falls. The second site was a trail with a steep slope and the mechanism for injury was mainly self-induced falls with skiers sliding out of control down the advanced course. The third observed site involved travelling over a road tunnel. The bridge funneled the preceding trail down into a thinning hour glass shape. The compression before the bridge caused skiers that had built up speed from the last site to lose their balance and either fall forward or backward (Bergstrom, 2004).

D. Penniman wrote a paper examining the modern standard approaches used in trail configurations and maintenance. He also looked at the use of the "Safety Hierarchy" and how this determines precedence for which risks need to be mitigated and how a mountain can go about that. The hierarchy organized risk solutions into first, second and third priorities. First priority practices include re-shaping a trail such as; changing the slope gradient, building up a sharp corner, widening a trail or removing trees to increase visibility. Second priority practices include padding equipment like lift poles or snowmaking machines to minimize the risk of injury with collision of said equipment. Third Priority customs include stationing signs that warn riders of a slow zone, intersection or dangerous area (Penniman, 1999).

4.5: Approach:

This study gathered information through online survey, interviews of on mountain personnel, research and on-site video capture. The data is meant to find a relationship between trail features and injury rate.

4.6: Methods:

The first method used for obtaining data was an online survey (Appendix B). Questions were developed to record what types of trail features skiers felt were challenging and which were dangerous. It also aimed to investigate the percentage of collisions that happen at intersections. This is important as it helped to aim the efforts of the on-site video capture. This data alone is not enough to find a correlation between trail design and injury rate so it was time to turn to the slopes. Over 25 mountain resorts in New England were contacted by email to see if they were willing to cooperate with an injury-based research study. Most resorts respectfully declined, but two mountains; Mount Snow in West Dover, VT and Stowe Mountain, also in VT were happy to help and contribute to the study. The folks at Mount Snow were reluctant to give an interview but agreed to allow footage of the slopes while Stowe was fully cooperative. An interview was set up with the Risk Manager and sites were recorded at both mountains (Appendix C). Once the footage was captured it was analyzed to find occurrences like collisions, falls and near misses. Tables were constructed to display skier behavior. These numbers lead to percentages of each happening in an area and compared to the number of dangerous features that area had.

4.7: Results:

The features that have been determined by this study to add risk to a skier's potential for injury include: drop offs, knols, steep pitch, minimal visibility prior to intersection, side hills, abrupt turns, ice, change in width, mountain equipment, high intersecting angle (obtuse and 90^{o} angles), mixing skill levels, differing average speeds between intersecting trails, traverse roads and lack of warning signs. This was accomplished by using online survey results, the interview with Karen Wagner, and on site video capture.

Mount Snow Results

Figure 27

This figure shows the 3 different sites that were chosen for investigation and where they are on the mountain.

Figure 28 Site 1

Here is a zoomed view of site 1.

Figure 29 Site 1 up Trail

The areas highlighted are determined factors that add risk to a site.

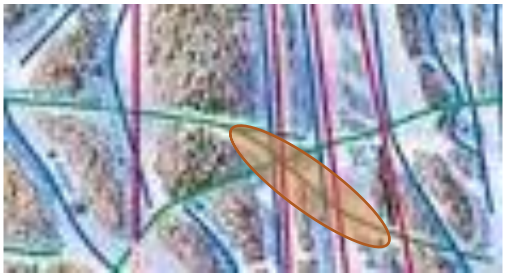
Figure 30 Site 1 Intersection

Figure 31: Site 1 Results

Direct Route	Hesitation (clean)	Near Miss	Collision	Fall
112	43	16	1	6

Site 1 exhibited a joining of two trails that rode parallel to each other. At the intersection, the outside trail sloped downward into an abrupt turn. This created a side hill that could carry skiers into the woods (figure 29 highlighted in orange). With one of the falls observed, a skier spun out of control trying to turn on top of the side hill and nearly careened into the woods. There is a slow sign but it is not positioned to be visible to the traffic of the outside trail before it makes its abrupt turn into the intersection (figure 30). Skiers that hesitated while navigating the site increased the time they could be seen by the traffic on the opposing trail. 4 of the falls occurred where the side hill and abrupt turn are located. The conditions that resulted from the following features led to a site of increased risk: side hill, low visibility (figure 29 highlighted in yellow), abrupt turn, lack of warning signs, light ice and a knol. The accidence chance was 3.93%, the hesitation chance was 24.02% and the near miss chance was 8.84%.

Figure 32 Site 2



Here is a zoomed view of site 2.

Figure 33: Site 2 View

Figure 34: Site 2 Results

Direct Route	Partial Route	Hesitation (clean)	Near Miss	Collision w/o Fall	Fall
46	85	9	16	1	1

Site 2 was a traversing trail that crosses over at least 5 downhill trails. It is sculpted to avoid a fall line that points down the hill to make for easier riding, but in doing this, a knol is created in all of the trails it intersects. This is shown in the highlighted area of figure 33. It has some visibility between trails but brings skiers of divergent ability together. The features that led this to be a site of interest were: traverse road, minimal visibility, lack of warning signs and the traversing trail creating knols in all intersecting trails. The Partial Route column (figure 34) indicates skiers that were only on the traversing trail for a short period before they exited and were safe about doing so. The accidence chance was 1.26%, the hesitation chance was 5.66% and the near miss chance was 10.06%.

Figure 35: Site 3

Here is a zoomed view of site 3.

Figure 36: Site 3 View

A skier who spun out of control after colliding with another skier lies on the trail as he/she is attended to.

Figure 37: Site 3 Results

Skiers on Outermost trail	Mergers	Hesitations	Near Miss	Collisions	Falls
22	52	38	10	1	2

Site 3 was a boundary trail on the main face that incorporated the traffic from up to 5 trails as it made its way downhill. It exhibited very low visibility before intersections and at times the intersecting angle was almost perpendicular. Also the outmost trail was relatively flat compared to the much steeper intersecting trails. This creates an environment of many mixings speeds which increases the variable distance between skiers. Another factor that added to the unpredictability was the reoccurring widening and narrowing of the trail that compressed and decompressed the traffic. The features exhibited here were: minimal visibility, high intersecting angle, different average speeds of intersecting trails, drop offs and change in width. The accidence chance was 4.11%, the hesitation chance was 52.05% and the near miss chance was 13.7%.

Stowe Results

Figure 38 Areas of Interest

Areas marked are those that were chosen for investigation.

Figure 39: Site 4

Here is a zoomed view of site 4.

Figure 40 Site 4 View

The orange lines indicate traffic flows through the intersection.

Figure 41 Site 4 Results

Entered Park	Direct Route	Hesitation (clean)	Near Miss	Collision	Fall
12	25	4	7	0	1

Site 4 was a trail intersection in between two terrain parks. It was a merger of 3 trails that then spilt back into 3 trails. The intermingling of beginner-intermediate skiers on the blue trails and the very advanced skiers navigating to the next terrain park was cause for an extra amount of risk. Skiers traveling to the terrain park navigated around other skiers in a fast and reckless manner. Mixing divergent ability skiers was the only feature exhibited here. The accidence chance was 2.7%, the hesitation chance was 10.81% and the near miss chance was 18.92%.

Figure 42: Stowe Site 5

Here is a zoomed view of site 5.

Figure 43 Site 5 View

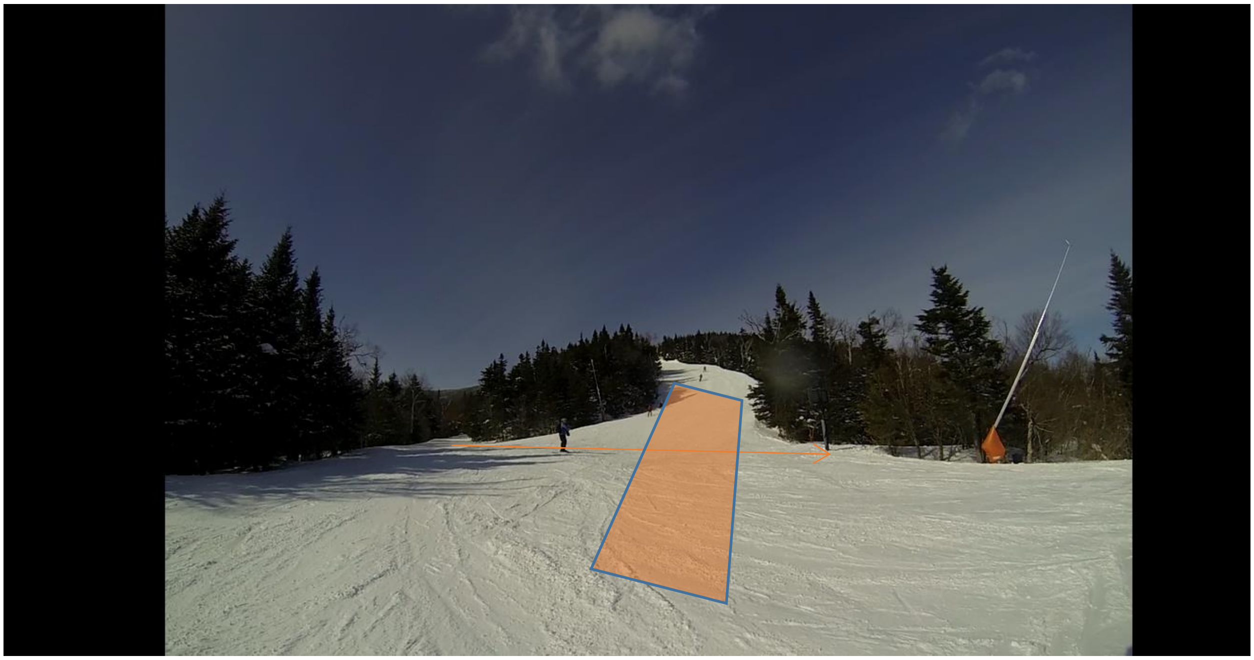


Figure 43 displays crossing traffic flows, the plane is to indicate a higher flow than the line.

Figure 44: Site 5 Results

Direct Route	Hesitation (clean)	Near Miss	Collision	Fall
40	17	10	0	2

Site 5 was an intersection between two trails of significantly differing nature. The left trail is a long outstretched pleasure ride through the woods called Toll Road. It is a slow, easy riding trail and marked green for that exact reason. It cuts directly across a sharp downhill portion of a trail called Sunrise. This angle and significantly slower speed of crossing traffic suggests an increased risk however the visibility of this intersection is very high. The risk adding features at this site were: steep pitch, high intersecting angle and differing average speeds. The chance of accidence was 2.9%, the hesitation chance was 24.64% and the near miss chance was 14.49%.

Figure 45: Site 6

Here is a zoomed view of site 6.

Figure 46: Site 6 View Right

Orange lines indicate traffic patterns .

Figure 47: Site 6 Left view

Figure 48: Site 6 Results

Direct Route	Hesitation (clean)	Near Miss	Collision	Fall
23	0	1	0	0

Site 6 involved the intersection of 3 trails that became 2. There is not much visibility between trails but the intersection itself is a large area. This gives skiers time to adjust their path. Also all trails are travelling very similar directions as they converge. This small acute angle also gives skiers time to adjust but more importantly, less velocity towards each other. Negatively, the fall line leads right into the woods, so the features exhibited here are: side hill and minimal visibility. The accidence chance and hesitation chance were 0.0% and the near miss chance was 4.17%.

Figure 49: Site 7

Here is a zoomed view of Site 6

Figure 50: Site 7 View

Orange lines indicated traffic flows.

Figure 51: Site 7 Results

Direct Route	Hesitation (clean)	Near Miss	Collision	Fall
26	2	6	0	3

Site 7 is an intersection of 3 double black diamond trails. The slope is very steep relative to the rest of the mountain which makes it far easier to lose control. The trail to the right, visible in figure 10, crossing the other two trails at an almost perpendicular angle, is hidden to skiers as they rise over the knol. The intersecting trail does however give skiers a path to merge safely downhill if they wish to abandon their current trail. The risk adding features were: steep pitch, ice, low visibility, knol, and a high intersecting angle. The accidence chance was 8.11%, the hesitation chance was 5.41% and the near miss chance was 16.22%.

Figure 52: Summary Measures

Site #	Direct Route	Hesitation	Near Miss	Collision	Fall	Total Skiers	# of Features	Collisions + Falls	% chance of an accident	% Hesitation	% Near Miss
1	112	43	16	1	6	179	6	7	3.91%	24.02%	8.94%
2	46	9	16	1	1	159	4	2	1.26%	5.66%	10.06%
3	21	38	10	1	2	73	5	3	4.11%	52.05%	13.70%
4	25	4	7	0	1	37	1	1	2.70%	10.81%	18.92%
5	40	17	10	0	2	69	3	2	2.90%	24.64%	14.49%
6	23	0	1	0	0	24	2	0	0.00%	0.00%	4.17%
7	26	2	6	0	3	37	5	3	8.11%	5.41%	16.22%
AVG	41.86	16.14	9.43	0.43	2.14	82.57	3.71	2.57	3.28%	17.51%	12.36%

This table was constructed to display all the recorded data in one place. Each site can be compared to the others and against the average values. The 3 Percent columns are out of the total skiers travelling through each respective site ex. the % Hesitation column is the amount of skiers that hesitated while navigating a site over the total skiers that passed through it. These are all defined in the appendix as well.

Figure 53

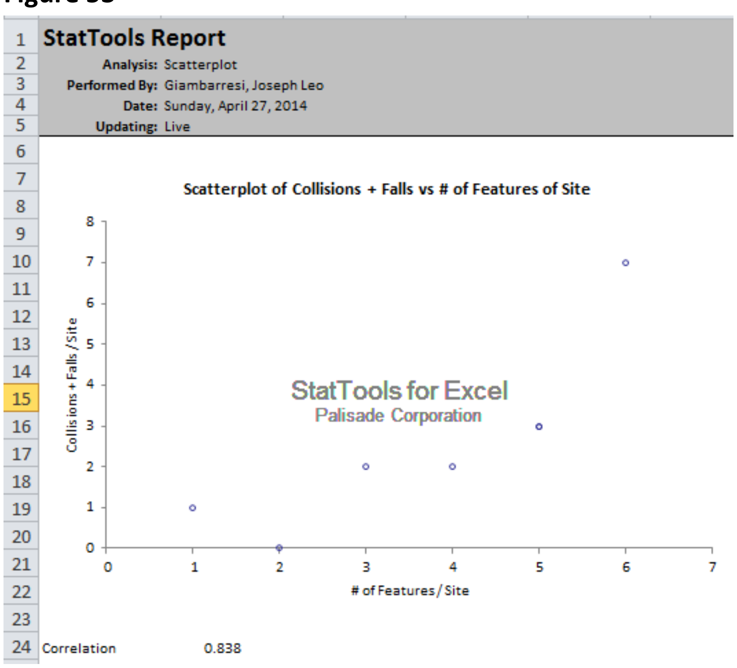


Figure 53 shows a chart plotting the number of accidents at a site against the number of dangerous features that trail harbors. The data yields a positive correlation of .838. This suggests that the more of these defined locations that are present, the more injuries occur and therefor, the more at risk skiers are.

4.8: Discussion:

From Site 1, it is gathered that the conditions and shape of the two trails formed an area of increased likelihood of falling, and therefor injury. The accidence chance is 3.91% which is greater than the average of all sites investigated. In order to decrease this, a first or third priority solution could be made. The first priority solution would be to use landscaping equipment to remove the side hill and or build up the outside corner of the abrupt turn. This would change the direction of the fall line so it would not be leading into the woods. A third priority solution would be to place signs farther up the trail as to warn riders of the upcoming turn and slow down.

In site 2, the data is not statistically significant. With only a 1.26% chance of accidence, skiers seem to regularly be able to safely navigate the site. This insignificance could be due to the 85 skiers who only travelled part way on the traversing trail and then continued downhill. This may have been a result of discomfort on the trail. With many other skiers passing in front and behind, it could be likely that a skier would feel unsafe.

Site 3 was the most evident of an area with increased risk. With traffic from five trails, joining onto one, skiers had the highest risk of an accident of 4.11%. Also the highest percent hesitation was noticed here at 52.05%. The features that had the largest effect here were the change in width and the intersecting angles. These would both take land reshaping equipment to widen the outermost trail and increase the intersecting angles. This would lower the percent of accidents and near miss at 13.7%.

There was only one feature of added risk at site 4 and it was mixing divergent ability skiers. This feature was clearly responsible for the high amount of near misses. Skiers that were in between terrain parks weaved through less skilled skiers trying to figure out where they wanted to head next. This could be solved by sectioning off terrain areas from all other trails. This would keep skiers of more advanced ability separate from less skilled skiers that take wider turns and travel slower.

The high hesitation chance of 24.64% of site 5 tells us that skiers are recognizing the crossover traffic and using speed checks to avoid them. However, 14.49% near miss tells us that sometimes they did not recognize it early enough. To make skiers aware of crossover traffic, signs should be installed at the top of the steep pitch on Sunrise and just before the intersection.

The data from sites 6 and 7 were not statistically significant. The sample size was less than half the average for both. The falls witnessed were a result of end-of-day conditions.

The very strong positive correlation in Table 9 infers that the amount of trail features has a large effect of the amount of injuries occurring. These features cause concentrated areas of accidents and should be mitigated through various customs and practices. Practices include reshaping trails, padding objects and most importantly, educating skiers on what to watch out for and when to reduce speed. This will minimize their chances of incurring an injury.

4.9: Conclusion:

Drop offs, knolls, steep pitch, minimal visibility prior to intersection, side hills, abrupt turns, ice, change in width, mountain equipment, high intersecting angle, mixing skill levels, differing average speeds between intersecting trails, traverse roads and lack of warning signs are all features that add risk to skiing. The more of these features that are present, the higher the chance a concentrated injury area is of forming.

Chapter 5: Equipment Test

5.1: Background:

This research will provide useful knowledge about how to reduce the risk of injury when skiing. This research shows that if a self-test is performed to check if a skier can release from their bindings, they can reduce their risk of injury. This information has been uploaded to the group developed website, hurtskiing.com, so that anyone can access this website and educate themselves.

A study was done had 25 male and female skiers, ranging from the age of 11-63, try to pop out of their bindings with an inward twist of the foot and leg. Each person used the same boot and binding, but the tightness setting was adjusted for each person according to their height, weight, skiing skill, age, and boot sole length. The tests concluded with 19 of the skiers being able to release the binding (Werner, Willis, 2003). A similar study was done, where an informational video was shown to an “intervention group” versus a control group to see if the video would help reduce injury. Part of the video introduced a binding test that the skiers can do to check the binding settings, “the binding test was performed by 86% in the intervention group and by only 59% in the control group. Adjustment of the bindings was done by 22% in the intervention group vs 14% in the control group. In the intervention group 16% of all skiers were injured vs 23% in the control group, yielding a reduction in injury risk of 30%” (Jorgensen, et al. 1999). To help prevent knee injuries, boots have the ability to release from the bindings so that an extensive amount of torque is not applied to the knee and doesn’t cause any damage to the leg. “As long as the bindings can perform properly, self-release illuminates a gross impediment to release, if a gross impediment exists, and self-release minimizes grossly over-tightened release for racers (Howell, 2013).” If bindings perform properly and can release from the boot, then the skier can reduce their risk of injury.

These similar studies show that the self-test is a useful tool to make a skier safer when skiing. We want to take these studies, along with the data we will receive through our study, and make a more comprehensive education page for hurtskiing.com.

5.2: Objective:

The purpose of this research was to determine if the majority of skiers are aware of the ski binding release self-test.

5.3: Rationale

This study provided extra knowledge about the amount of people that can release their boots from their bindings. We gathered enough research to show that people can, can't, or have never tried to release their boots from their bindings, and now we can educate skiers with a few tips on how to stay safer by testing their bindings.

5.4: State of the Art:

A study was done had 25 male and female skiers, ranging from the age of 11-63, try to release their boot from their bindings with an inward twist of the foot and leg. Each person used the same boot and binding, but the tightness setting was adjusted for each person according to their height, weight, skiing skill, age, and boot sole length. The tests concluded with 19 of the skiers being able to release the binding (Werner, Willis, 2003). A similar study was done, where an informational video was shown to an "intervention group" versus a control group to see if the video would help reduce injury. Part of the video introduced a binding test that the skiers can do to check the binding settings, "the binding test was performed by 86% in the intervention group and by only 59% in the control group. Adjustment of the bindings was done by 22% in the intervention group vs 14% in the control group. In the intervention group 16% of all skiers were injured vs 23% in the control group, yielding a reduction in injury risk of 30%" (Jorgensen, etal. 1999). To help prevent injuries, boots have the ability to release from the bindings. "As long as the bindings can perform properly, self-release illuminates a gross impediment to release, if a gross impediment exists, and self-release minimizes grossly over-tightened release for racers (Howell, 2013)." If bindings perform properly and can release from the boot, then the skier can reduce their risk of injury.

5.5: Methods:

After learning about the self-test, it was decided that we can use this to try and teach people to help practice safer skiing. There were two options to go about this task of teaching people: to do an in person study with people on a ski mountain, and have them attempt the self-test, or develop a survey that will help us determine how many people actually know about the self-test and what it is for. We decided to make the survey because this would allow us to identify how many people know about the self-test, and if they can perform it for its intended use.

After extensive searching around the internet, we couldn't find any kind of video displaying the correct way to perform the self-test. We were able to find pictures showing the movements with arrows, but those pictures were from the late 90's, so we decided to make our own video performing the self-test. We borrowed a video camera from the school, set up the proper script that we wanted people to learn from, and gave instructions for performing the self-test. The self-test was properly performed with close up views of the inward twist to release, outward twist to release, and the forward pull to release.

This self-test video was uploaded to YouTube so that anyone can view it, and the video was also placed in our survey so that people taking the survey can fully understand what we meant by the self-test.

We developed the survey using lime survey, and then uploaded the survey to our website where we have a section for surveys. The questions in our survey all serve a purpose to answer a question that we wanted answered. After critical thinking and reviewing the questions, we decided that it was finalized and ready to be taken. Once we uploaded the survey, we needed to get people to take the survey to we can get results, so we started emailing groups around campus asking them to take our survey. For example, we emailed the ski team and fraternity houses, an email alias that would show to a large group of students to help us produce survey results.

5.6: Results and Discussion:

After analyzing the data from our survey, we found that the majority of people have never attempted the binding self-test.

Fig. 1: Have you ever attempted the self-test?

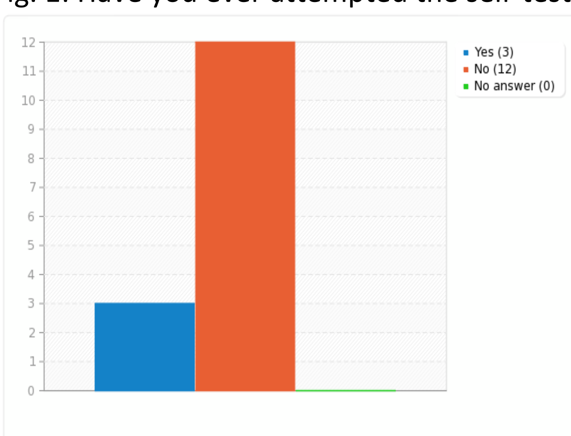
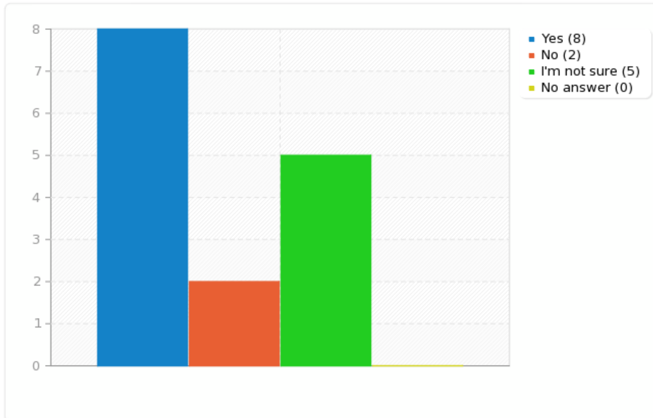
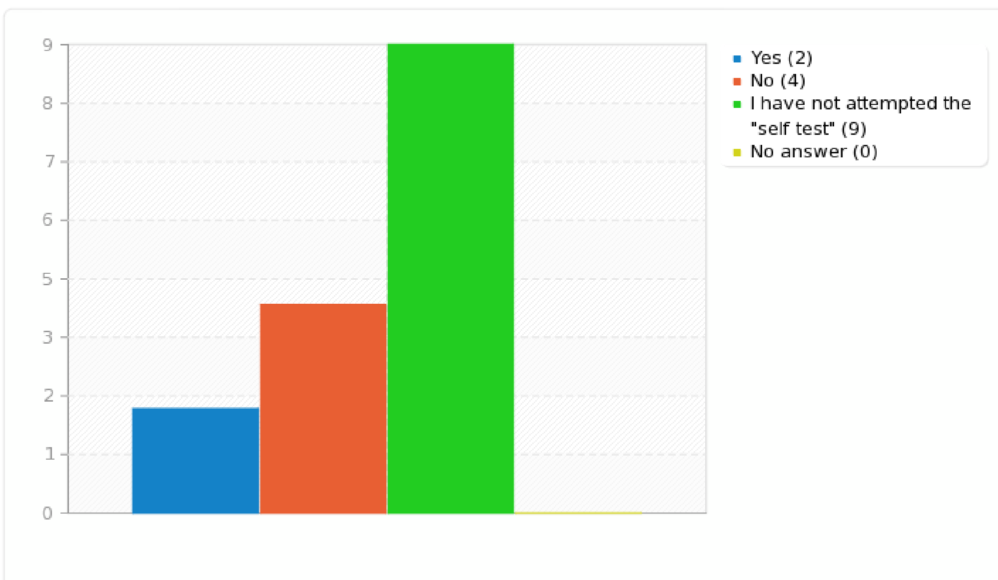


Fig. 2: Do you know if your binding tightness is set correctly?



80 percent of the survey participants, according to Figure 1, had never attempted a self-test to release their boots from their bindings, and figure 2 shows that one third of the people are unsure if their bindings are set to the correct settings.

Fig. 3: Can you release from your bindings using the self-test?



Again, we can see here in figure 3, that most of the participants have never attempted the self-test. Four people answered "no" to the question in figure 3, meaning that their bindings are most likely a little tight on their boots. If the skiers' bindings are too tight, then they can have a greater risk of injury when skiing.

What we can learn from this data is that most people don't know what the binding self-test is, so this would be a great area in ski safety to educate people on. The binding self-test will be a great information section to place on our website that people can read about to help skiers potentially prevent future skiing injuries. The information on the self-test will also teach people how to check their binding settings, because if the people who were unsure about their binding settings in the survey data had performed the self-test, they would have been able to determine if their bindings were set correctly or not. The fact that 80 percent of the people who took the survey didn't even know what the self-test was, means that we can assume there are plenty of other skiers who don't know what it is. If more skiers were educated about the self-test, then more skiers can decrease their chance of getting injured when skiing.

Our results prove that the binding self-test can be a great educational lesson for any skier. These results can be uploaded to our website so that people can educate themselves on how to reduce their risk of injury. The proposed methods proved to be an effective way of gathering and analyzing the desired data. The questions were well because we were able to answer all of our questions through the results. With that, we can now give survey tested data on our website to provide more evidence that the binding self-test is not a well-known tool to help skiers reduce their risk of injury.

Although we received good data from this survey, the survey results could have improved if we had more participants. We reached out to several different clubs and organizations by emailing them the link to the survey and requesting that they participate in our survey and help the study. We didn't receive too many participants by doing this, so maybe we should have reached out to people in a different way. This could have been our biggest source of error, it would have been great to see 50 or even 100 people to take the survey, but we can still manage good statistics with the data we have.

5.7: Conclusion: We have come to the conclusion that the binding self-test is not known by the majority of skiers. The self-test is an easy way to see if a skier can release their boots from their bindings, and reduce their risk of injury when skiing.

References

American Academy of Orthopaedic Surgeons. Position Statement 1152. December, 2000. Revised June 2005 and September 2010.

"An Important Caveat with Modern Bindings." *The Self Test for Alpine Skiers*. N.p., 2000. Web. 06 Oct. 2013.

Beersworth, Andrew. "Putting Risk Back on the Downhill Edge: The Case for Meaningfullimitations on Ski Area Liability." Vermont Bar Journal2012. Print.

Bergstrom, K, and A Ekeland. "Effect of Trail Design and Grooming on the Incidence of Injuries at Alpine Ski Locations." PubMed (2004). Print.

Benoit, Lamontagne, Greaves, Liti, and Cerulli. "Effect of Alpine Ski Boot Cuff Release." *National Center for Biotechnology Information*. U.S. National Library of Medicine, 13 Dec. 2005. Web. 14 Oct. 2013. <http://www.ncbi.nlm.nih.gov/pubmed/16440506>.

Bouter, L.M. Knipschild, P.G. Feij, J.A. Volovics, A. “Sensation seeking and injury risk in downhill skiing.” Personality and Individual Differences. Vol. 9, No.3. 1988.

Cundy, T.P. Systermans, B.J. Cundy, W.J. Cundy, P.J. Briggs, N.E. Robinson, J.B. “Helmets for snow sports in Australia: prevalence, predictors, recent trends and attitudes of use.” Injury Prevention, Vol. 16. 2010.

Dufour, D., et al. "“Alpine Trail Safety: An Interactive Qualifying Project Report” ". Worcester Polytechnic Institute2000 Print.

“Evaluation of skiing and snowboarding injuries sustained in terrain parks versus traditional slopes” M Alison Brooks, Michael D Evans, and Frederick P Rivara. April, 2010. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3069711/

“Factors associated with injuries occurred on slope intersections and in snow parks compared to on-slope injuries.” Ruedl G, Kopp M, Sommersacher R, Woldrich T, Burtscher M. January, 2013 http://www.ncbi.nlm.nih.gov/pubmed/23040506

Greve, M.W. Young, D.J. Goss, A.L. and Degutis, L.C. “Skiing and Snowboarding Head Injuries in 2 Areas of the United States.” Wilderness & Environmental Medicine, Sept. 2009.

Hagel, B.I. Pless, B. Goulet, C. Platt, R. Robitaille, Y. “The effect of helmet use on injury severity and crash circumstances in skiers and snowboarders.” Accident and Analysis Prevention, Vol. 37. 2005.

http://www.sciencedirect.com/science/article/pii/S0002961009000609

http://www.sciencedirect.com/science/article/pii/S1080603209701267

“Injuries among Skiers and Snowboarders in Quebec” Brent E. Hagel, Claude Goulet, Robert W. Platt and I. Barry Pless. May, 2004

Johnson, Robert J. "Skiing Trauma and Safety: Fourteenth Volume." 2001 Print.

Jorgensen, U., Tommy Fredensborg, Jorgen P. Haraszuk, and Karen-Lise Crone. "Reduction of Injuries in Downhill Skiing by Use of an Instructional Ski-video: A Prospective Randomised Intervention Study - Springer." *SpringerLink*. Knee Surgery, Sports Traumatology, Arthroscopy, 01 July 1998. Web. 04 Dec. 2013. <http://link.springer.com/article/10.1007/s001670050098>.

Langran, Mike. "Daily Testing of Ski Bindings." *Bobski.com*. N.p., n.d. Web. 30 Sept. 2013.

McBeth, P.B. Ball, C.G. Mulloy, R.H. and Kirkpatrick, A.W. “Alpine ski and snowboarding traumatic injuries: incidence, injury patterns, and risk factors for 10 years.” The American Journal of Surgery May 2009.

Millis, S.R. Rosenthal, M. Novack, T.A. Sherer, M. Nick, T.G. Kreutzer, J.S. High, W.M. Jr. Ricker, J.H. “Long-term neuropsychological outcome after traumatic brain injury.” The Journal of Head Trauma Rehabilitation, Vol.16, No. 4. 2001.

Penniman, D. "Customs and Practices at U.S. Ski Areas for Mitigating Common Hazards through Configurations and Maintenance." Skiing Trauma and Safety:. West Conshohocken, PA: American Society for Testing and Materials, 1999. Vol. Twelfth. Print.

Rockhill, C.R. Jaffe, K. Zhou, C. Fan, M.Y. Katon, W. Fann, J.R. "Health Care Costs Associated with Traumatic Brain Injury and Psychiatric Illness in Adults." Journal of Neurotrauma, Vol. 29, No. 6. 2012.

Ruedl, G. Pococco, E. Sommersacher, R. Gatterer, H. Kopp, M. Nachbauer, W. Burtscher, M. "Factors associated with self reported risk-taking behavior on ski slopes." British Journal of Sports Medicine, Vol. 44, pp. 204 -206. 2010.

Rughani, A. I. Lin, C.T. Ares, W.J. Cushing, D.A. Horgan, M.A. Tranmer, B.I. Jewell, R.P. Florman, J.E. "Helmet use and reduction in skull fractures in skiers and snowboarders admitted to the hospital." Journal of Neurosurgery: Pediatrics, Vol.7, No. 3. 2011.

Shealy, J.E. Johnson, R.J. and Mote, C.D. "Death in Downhill Skiing" Skiing Trauma and Safety Fifth International Symposium, American Society for Testing and Materials, Philadelphia, 1985.

Shealy, J.E. Johnson, R.J. and Ettlinger, C.F. "Do Helmets Reduce Fatalities or Merely Alter the Patterns of Death?" The Engineering of Sport, pp 163-167, 2006.

Shealy, J.E. Ettlinger, C.F. Johnson, R.J. "How Fast Do Winter Sports Participants Travel on Alpine Slopes." Journal of ASTM International, Vol. 2, No. 7, 2005.

Shealy, J.E. Johnson, R.J. and Ettlinger, C.F. "On Piste Fatalities in Recreational Snow Sports in the U.S." Journal of ASTM International, Vol.3, No. 5. 2006.

Sulheim, S. Holme, I. Ekeland, A. Bahr, R. "Helmet Use and Risk of Head Injuries in Alpine Skiers and Snowboarders." Journal of the American Medical Association, Vol. 295, No. 8. 2006.

Thompson, Mary K. "Proceedings of the 6th International Conference on Axiomatic Design." 2011 Print.

U.S. Consumer Product Safety Commission. "Skiing Helmets—An Evaluation of the Potential to Reduce Head Injury." 1999.

"VSR: FAQ for Skiers/Riders - Vermont Ski Safety" http://www.vermontskisafety.com/vsrfaq5.php 2010 Published.

Werner, S., and K. Willis. "Self-Release of Ski-Binding." *National Center for Biotechnology Information*. U.S. National Library of Medicine, n.d. Oct.23, 2002.

"Wilderness Medical Society." *Wilderness Medical Society*. N.p., Aug. 2000. <http://www.wms.org/news/snowboard.asp>.

Young, L.R. "Skiing Trauma and Safety: Seventh International Symposium, Issue 1022." Elevated Racer Binding Settings and Inadvertent Releases1989 Print.

https://www.nsaa.org

http://www.terrainparkconsulting.com/TPC/pages/about.html

http://xgames.espn.go.com/skiing/article/8623928/andreas-hatveit-gives-tips-building-backyard-terrain-park

Appendices:

Head Injuries Appendix

Helmet Survey

Justification

Q1: What percent of the time do you spend wearing a helmet while skiing or snowboarding?	Helmet use is becoming more and more common on the slopes, with numbers increasing over the past decade. In 2008, 16% of adults and 67% of children wore helmets while participating in snow sports and these numbers are expected to have risen since. (Cundy et al, 2010).
Q2: How many snow sport related injuries have you had in the past 5 years? (Note: An injury is defined as any incidence of injury that requires professional first aid attention i.e. ski patrol, medical office, ER, etc…)	Injuries to the head are the most frequent, as well as the most serious type of snow sport injury. Out of 196 adult injuries recorded over 10 years, 52% were injuries to the brain (McBeth, 2009).
Q3: How many of these injuries were to the head?	
Q4: Indicate the number of injuries you have had at each severity level: (__)Mild (__)Moderate (__)Severe	It is conclusive that head injuries are preventable, and that the use of helmets is a major factor in the reduction of both minor and severe injuries (Sulheim et al, 2010). Knowing the severity of the injury allows efforts to be directed at reducing more severe injuries as opposed to minor cuts, bruises etc..
Q5: Rate your risk taking tendencies while wearing a helmet. 1 being least risky, 10 being most risky: 1 2 3 4 5 6 7 8 9 10	There is not sufficient research to conclude that helmet use influences risk taking in skiers and snowboarders. Risk taking in skiers and snowboarders has been linked to factors such as gender, age, and ability, but not to helmet use (Ruedl et al, 2010).
Q6: How many snow sport collisions have you had on the slopes?	Collision rate is an indication of reckless skiing, and in the past the average speed of skiers wearing a helmet was significantly faster than the speed of non-helmet users (Shealy, 2005).

Helmet Use Survey		
Q1. What percent of the time do you spend wearing a helmet while skiing or		

snowboarding?		
Answer	*Count*	*Percentage*
0-50% of the time	4	4/16
51-100% of the time	12	12/16
Q2. How many snow sport related injuries have you had in the past 5 years? (Note: An injury is defined as any incidence of injury that requires professional first aid attention e.g. ski patrol, medical office, ER)		
Answer	*Count*	*Percentage*
None	11	11/16
1-2 injuries	3	3/16
3-5 injuries	1	1/16
More than 5 injuries	1	1/16
75% of respondents who wear a helmet over 50% of the time reported 0 injuries in the past 5 years. Only 1 head injury was reported from respondents who wear helmets. 66% of respondents who do not wear a helmet also reported at least one injury; 36% of these to the head. This indicates that helmets not only reduce the rate of head injuries, but also reduce a skier's overall injury rate.		
Q3. How many injuries were to the head?		
Answer	*Count*	*Percentage*
None	12	12/16
1	1	1/16
2	1	1/16
3	1	1/16
More than 3 injuries	1	1/16

Jump and Terrain Park Appendix

Caffeine Survey:

Caffeine Survey (completed)		

Number of records in this query: 11		
Total records in survey: 11		
Q1. If you drink caffeinated beverages when you ski/snowboard, how many drinks o you usually consume?		
Answer	*Count*	*Percentage*
I do not drink caffeinated beverages when I ski/snowboard	4	36.36%
1-2 drinks	7	63.64%
3-4 drinks	0	0.00%
5 or more drinks	0	0.00%
Q2. Do you drink energy drinks or other caffeinated drinks (such as coffee or soda) when you ski/snowboard?		
Answer	*Count*	*Percentage*
Yes	5	45.45%
No	6	54.55%
Q3. Did you know that an increase in adrenaline aids in higher risk-taking activity?		
Answer	*Count*	*Percentage*
Yes	9	81.82%
No	2	18.18%
Q4. How often do you attempt high risk-taking stunts such as jumps, rails, half pipes, and box rails when you are NOT drinking caffeinated beverages?		
Answer	*Count*	*Percentage*
Never	2	18.18%
Sometimes	6	54.55%
Often	2	18.18%
Always	1	9.09%

Q5. How often do you attempt high risk-taking stunts such as jumps, rails, half pipes, and box rails when you ARE drinking caffeinated beverages?		
Answer	*Count*	*Percentage*
Never	2	18.18%
Sometimes	5	45.45%
Often	2	18.18%
Always	2	18.18%
Q6. Do you consider skiing/snowboarding to be a high risk-taking activity?		
Answer	*Count*	*Percentage*
Very High	2	18.18%
High	4	36.36%
Average	5	45.45%
Low	0	0.00%

Alcohol Survey:

Alcohol Survey (completed)		
Number of records in this query: 25		
Total records in survey: 25		
Q1. If you drink alcohol when you ski/snowboard how many drinks do you usually consume?		
Answer	*Count*	*Percentage*
I do not consume alcohol when I ski/snowboard	14	56.00%
1-2 drinks	5	20.00%
2-3 drinks	2	8.00%
4 or more drinks	4	16.00%

Q2. If a ski resort were to serve alcohol, would you be more inclined to drink?		
Answer	*Count*	*Percentage*
Yes	12	48.00%
No	13	52.00%
Q3. Do you drink energy or caffeinated drinks (such as coffee or soda) while skiing or snowboarding?		
Answer	*Count*	*Percentage*
Yes	12	48.00%
No	13	52.00%
Q4. Did you know that an increase of adrenaline aids in higher risk-taking activity?		
Answer	*Count*	*Percentage*
Yes	16	64.00%
No	9	36.00%
Q5. How often do you attempt risk-taking tendencies such as jumps, rails, half pipes, and box rails when NOT under the influence?		
Answer	*Count*	*Percentage*
Never	5	20.00%
Sometimes	11	44.005
Often	7	28.00%
Always	2	8.00%
Q6. How often do you attempt risk-taking tendencies such as jumps, rails, half pipes, and box rails when you ARE consuming these substances?		
Answer	*Count*	*Percentage*
Never	14	56.00%
Sometimes	6	24.00%

Often	2	8.00%
Always	3	12.00%
Q7. Do you consider skiing/snowboarding to be a high risk-taking activity?		
Answer	*Count*	*Percentage*
Very High	2	8.00%
High	11	44.00%
Average	12	48.00%
Low	0	0.00%

In Person Alcohol/Caffeine Consumption Survey

Total Number of Participants	**Consumed Alcohol**	**Consumed an Energy Drink**	**Consumed Caffeine**	**Average Alcohol Consumption**
64	18	11	23	2-3 Beers

Inadvertent Release Appendix

When taking this survey approach it as if you are recreationally skiing and not competitively racing.

1. Before putting your boots on, how often do you check the bottom of the boot for any foreign objects such as; ice, rocks, etc.
    a. Every time
    b. Sometimes
    c. Never
2. Before clicking into your bindings, how often do you check the bindings making sure they are free of any foreign objects?
    a. Every time
    b. Sometimes
    c. Never
3. Before clicking into your skis and you do decide a boot cleaning technique which option do you choose?
    a. Tap boots together
    b. Use ski pole to poke ice out of boots

c. Nothing, I just click in and go
d. Other [___________________________]

4. If you answered C in the previous question do any of the following scenarios occur
   a. Notice later on that you were not fully inserted into your binding
   b. Have an Inadvertent release (your boot is ejected from the binding) on the mountain.
   c. Nothing, I never seem to have a problem just clicking in and going.
5. How many times in the duration of 1 ski season do you experience Inadvertent Releases?
   a. Never
   b. 1-2times
   c. 3-4 times
   d. 5 or more
6. During an Inadvertent Release on a turn which ski ejects from your bindings.
   1) The inner ski
   2) The outer ski
7. During an Inadvertent Release why do you suppose it occurred?
   1) Poor technique
   2) Equipment failure
   3) Inappropriate skiing

This survey was developed with intent to see how often people clean their ski boots and/or bindings before alpine skiing. Ice or other foreign objects such as rocks can build up under the springs of your bindings and only allow for partial connection between the bindings and boots, potentially increasing your risk of an inadvertent release. Having responses generated from the survey will allow us to get a better understanding on how knowledgeable the public is on boot and binding cleaning procedures to assure full connection between the boot and the binding.

The first question states *"Before putting your boots on, how often do you check the bottom of the boot for any foreign objects such as; ice, rocks, etc."* this question was placed first not only to give the respondents a general idea of what the survey will be about but also to get them thinking about how appropriately do they check to make sure there equipment is properly ready for use.

Before clicking into your bindings, how often do you check the bindings making sure they are free of any foreign objects? The same thought process went into the second question as the first but now with the hope for a deeper thought in the respondents mind as to what do they take into consideration more the cleaning of their bindings or the cleaning of their boots.

"Before clicking into your skis and you do decide a boot cleaning technique which option do you choose?" People that race alpine skis competitively usually have a whole process were they check both their boots and bindings to make sure they are clear of any ice and other foreign objects. On the other hand people that alpine ski recreationally do many different techniques to cleaning there boots and/ or

bindings and to my findings the majority of recreational skiers do not use any cleaning techniques when recreationally alpine skiing.

"If you answered C in the previous question do any of the following scenarios occur?"

a. *Notice later on that you were not fully inserted into your binding*
b. *Have an Inadvertent release (your boot is ejected from the binding) on the mountain.*
c. *Nothing, I never seem to have a problem just clicking in and going.*

This survey question was developed in hope to be correlated with onsite data taken that had findings of the majority of recreational skiers not using any cleaning technique. With that being the case I ask this question to the respondents to evaluate what scenarios occur from not cleaning your equipment.

"How many times in the duration of 1 ski season do you experience Inadvertent Releases?" Because I cannot follow every recreational skier that does not use a cleaning technique down the mountain and watch for an inadvertent release. I developed this survey to see if those who do not use cleaning techniques experience inadvertent releases more than others.

"During an Inadvertent Release on a turn which ski ejects from your bindings." The responses from this survey question could lead to more insight on witch ski is more prone to inadvertent release when carving on your skis down the mountain, especially if ice or other foreign objects are present in the bindings and/or boots.

"During an Inadvertent Release why do you suppose it occurred?" lastly this question was developed to see why the public believes inadvertent releases occur. This question may not be the most beneficial question in terms of my objective but may help in learning what to better educate the public on in the topic of inadvertent release.

Inadvertent Release Definitions

Houdini Effect: the heel piece of the skit binding begins to open and presents an inclined plane to the boot's heel ledge. Slight counter flex on the ski can increase the mechanical advantage of that inclined plane, which will drives the heel piece rearward allowing the boot heel to escape upward from the heel piece of the ski binding.

Jet Effect: the ski ejects from ones ski boot and shoots forward up into the air as one leaves the ground such as off a mogul or jump. The effect can occur with both bindings that offer upward release at the toe unit and with bindings that do not offer upward release at the toe unit at all.

Flex Effect: the inability of the toe and heel units of the binding to stay the set distance apart during rapid flexing and counter flexing of the ski witch then gives the ski boot room to escape from the binding.

Superman Effect: this effect is a software problem, created and controlled completely by the skier. This problem commonly occurs at low speeds and is due to a skiers thoughts that the hardware is the problem when in fact it is the skier making mistakes. Weather it is trying to torque the ski too hard in one direction, bad technique in unguarded moments, or trying to use strength to compensate during poor technique situations.

Bow Effect: the skier tries flexing the fore body of his skis in reaction to a rut or bump causing energy to be stored in the ski witch will shoot the skis backwards during an inadvertent release.

Inadvertent Release: a non-intentional release of ones ski boot(s) from the ski binding(s).

Trail Design Appendix

Appendix A

Definition of Terms/Glossary

Skiers : Any users of skis or a snowboard.

Trail Intersections: Points where two or more trails meet and continue down the mountain.

Knol: A large rolling bump perpendicular to a trail's direction.

Side Hills: A feature on a trail where gravity would no longer take a skier down the trail, that is to say that the fall line is not parallel with the direction of the trail.

Abrupt Turns: A feature that demands a skier to change direction severely

Separating divergent ability skiers: The effort to keep skiers of significant difference in skill apart from one another.

Surface Grooming: Using over snow vehicles to improve the surface conditions on trails.

Equipment: Any mountain owned/operated object that is on or near a trail that poses a threat to a skier (snowmaking, buildings, lift poles or warning equipment).

Fall Line: The direction a ball would roll down a hill.

Safety Hierarchy: A system formulated by the Journal of Safety Research in 1986 to assign precedence to the need of attending to certain dangerous aspects at a ski resort.

Traverse Road: A trail meant to take you across the mountain rather than down it, generally used to navigate to a desired lift or lodge.

Direct Route: The skier made no hesitation or speed check through the site, and was a safe distance from others.

Partial Route: A skier travelled only through a portion of the site.

Hesitation (clean): The skier speed checked or slowed down to find a safe route through the site.

Near Miss: Two skiers almost colliding and coming within arm's length, or about 3 feet) of each other.

Mergers: Skiers merging to a higher traffic trail, or one that contains the traffic of more trails.

Collision without fall: Two skiers' body parts or equipment bumped and did not cause a fall.

Collision: Two skiers colliding and falling.

Fall: A single, self-induced fall

Accidence Chance: The amount of collisions and falls over the total number of skiers to pass through the site.

Hesitation Chance: The amount of Hesitations over the total number of Skiers.

Near Miss Chance: The amount of near misses over the total number of skiers.

Appendix B

Online Survey

The objective of this interview was to find out which type of features common skiers and riders, both recreational and professional, find challenging and or dangerous.

1) What type of trail do you find most challenging?

This is a base question to note the participants' thoughts on challenging areas of a mountain without creating a bias from seeing the following questions in the survey.

2) What aspects do you find dangerous while skiing or riding? I.e. (sharp corners, drop offs, knolls, moguls)

This question switches from "challenging" to "dangerous" suggesting a possible correlation between the two and then giving a few example terms.

3) Have you ever collided with another skier?

This question sets up the answer for the next, which is used to determine how collisions occur and if intersections would be good sites to investigate.

4) Were you both on the same trail or was it at an intersection?
5) Do you feel more at risk, or fatigued after a trail has been bending in the same direction for an extended period of time?

This question attempted to define a long bending trail as an increased risk for snowboarders.

6) Do you feel safer on a finely groomed trail rather than one with little care taken of it?

This attempted to define an ungroomed trail as risky or dangerous.

7) How often would you say you have skied on a finely groomed trail?

This was aimed to observe skier preferences.

Survey Results

Question 1: What type of trail do you find most challenging?	
One with steep pitch	4
Moguls	7
Glades	7
Black Diamond	2
Double Black	3
Ice/loose granular	3
Ungroomed	5
Narrow	3
Terrain Park	2
One with beginners	1
Converges to a touhger one	1
Back Country	2
Question 2: What aspects do you find dangerous?	
Dropoffs	12
Moguls	10
Intersection	1
Trail width (narrowness)	2
Knols	1
Unskilled skiers	1
Other skiers	2
Ice	5
Objects In Trail	1
Abrupt Changes	1
Washboards	1
Blind Spots	3
Cut across trails	1
Sharp Corners	5
Question 3: Have you ever collided with another skier/snowboarder?	

Yes	18
No	14
Question 4: If you answered yes, where you both on the same trail or was it at an intersection?	
Intersection	5
Same Trail	11
Don't Know	1
Did not answer yes	14
Question 5: Do you feel more at risk or fatigued after turning in the same direction for an extended period of time?	
More Fatigued	13
More at Risk	1
Both Fatigued and at Risk	5
Neither	14
Question 6: Do you feel safer on a finely grromed trail rather than one with little care taken of it?	
Yes	24
No	8
Question 7: How often do you say you have skied/snowboarded on a finely groomed trail?	
Never	1
Someimes	10
Often	18
Always	2

Appendix C

Interview with Karen Wagner: Risk Manager at Stowe Mountain Resort

Do you have any marked slow or dangerous areas?

Not dangerous, we have slow areas certainly where we have slow banners up routinely, and those are typically up at intersections, places where people converge. So we have slow banners, we have some, recently we bought terrapads that say slow on them, that are bright orange that are in certain areas.

I noticed that you have the “Look” signs.

Yep, yep just to catch people’s attention. You know, one of the manufacturers of ski area sipplies sells them. So, I think we are probably not the only ones to use them. Somebody, and I don’t know who it is, I remember seeing them, has the look sign and they put like eyeballs in it, looking in the direction where the traffic is coming from which I thought was kind of cool. It’s just different to draw your attention.

How do you enforce those signs?

I wouldn’t say we enforce them as much as we, you know on a busy days we station patrollers and hosts and they rotate through at certain areas where we know there’s a lot of traffic and they you know, remind people through hand motions or speaking to people. An example would be down near the gondola and we go to different locations depending on the day. We can't be everywhere at once but I wouldn't say we enforce it because we can never enforce it but we do pull passes. We don't like to we would rather just educate people, people are usually pretty cool about understanding.

How do you implement punishment?
We are actually really lucky because we have an electronic ticketing system so if we can't physically get someone's pass but we know their name or we have a good description and can identify them we can shut their ticket off.

I feel like your ticket system contributes to the safety of the Mountain.
Yes we've certainly used it in that context a number of times.

Do you use padding or fences?
Yep. We have padding and fences.

How do you tell what to use where?
Well I mean, they're all awareness devices so you have to remember the pad is not meant to save you if you hit something it's more to say, "look there really is something here and this is a bigger surface area", something, we switched to orange pads we were going with yellow but now we're phasing over to orange. We still have some old gray ones out there before we can get them in different colors. So typically we look at what the level of the trail is, whether it's beginner, intermediate or advanced and whether, you know a hydrant or if it's in the fall line, if it's in the trail where we think someone's going to be skiing around the other side of it we will pad it. You know, we have a method to it.

Louise was speaking to me about another mountain that had pads on their poles but then removed them because that meant that they were recognizing them as a risk.
We put pads on our poles, both as an awareness device, but also because the ladder has really sharp edges so you know that's another impact that you prefer someone not to impact the sharp edges. A high speed collision nothing is going to save you.

How do you define a risk here as the risk manager?
Well skiing is inherently risky but you know we have so much that goes on here that has inherent risks so. You know you can get injured anywhere, you can fall and get injured in the middle of a broad wide gentle trail, just catch and edge so there may be an increased risk in certain areas like the terrain parks where you're going in the air or intersections as we've discussed just because there's cross traffic, sharp corners if you aren't looking or anticipating that there might be something around the corner it's kind of like driving. I think it's important to remember though, that, you're on a mountain, it's really the skiers' responsibility to be able to control themselves and to be aware of what's below them. We can't take that burden off anybody… It's all risky.

What are your biggest concerns?
A huge one is people like to ski and ride off piece, and we're fortunate in Vermont that we have a statute that explains to people that they are on their own but we still want to educate people so that they don't go where there's not enough snow, that they don't go late in the day because if they get lost,

it's much harder to find your way around when it's dark. You know don't go alone, those sort of things. We try to educate folks about that like on our trail maps and signs and so forth and that can be frustrating because people don't always make the best decisions. So that's one area of concern for sure, the off piece travel. People don't understand that when we have to go rescue them, when they are not on a trail it is much more involved, takes a lot of resources.

Do you fine people when that happens?

We have in the past, we haven't as of late. We may again. This season we haven't had a whole lot of snow other than artificially made snow. So it hasn't been an issue until recently we've had several lost people and so far it hasn't been too cumbersome; although we did have one that was, that we may fine them, or send them an invoice. We also are very fortunate here, because the Stowe Mountain Rescue group operates out of this town and they do a lot of back country work. They are a separate entity. There are other agencies around that do some work.

Do you deal with any grooming concerns?

If something is evident, for example if at the top of a rise, you know snow builds up from grooming and from skier usage and if you notice there starts to be a lip or too much of a rise then we will re groom it. That is pretty routine; we just watch that tuff day to day. Other long term grooming concerns, I can tell you one thing that we did with great success. We had an intersection where the downhill trail is one where people travelled rather quickly so we decided to leave it bumped up. That was a natural shape where it crosses over the downhill trail we left it mogulled in this one particular area, because that slows people down. Occasionally we will have to groom it and then we take measures to try to supplement the slowing people down. We have a meeting every day to discuss things like this.

Do you record where injuries occur?

Well we know where they occur just by virtue of the incident report, and we know anecdotally where more injuries are occurring but we really don't have those hotspots. We monitor to see if there's any one location or like really particularly and one feature in a terrain park that is not working out for any reason but again we hope it doesn't get to that point because we have the terrain park rangers watching people and talking to them. You know we try not to get to the point where there's a location where we have more accidents than in other places. I can't think of any one, looking at this map, right now.

So do you know have locations that you recognize as more dangerous?

Yeah, we do have a lot of twisty mogully trails but no there is definitely no, I would say there's no one spot.

Do you mitigate any locations?

Yeah, I mean that's just routine grooming, good grooming yes. We know that you know, you don't want to groom a beginner trail with a fall line going into the woods and that's just standard practice.

What is more important to you, preventing injuries, or preventing financial problems?

Oh preventing injuries of course I mean that's the whole game, if we can. I mean it's all education and telling people look ahead, know the code. That's why we have signs that's why we have bamboo and other awareness devices just so people can see where things are.

Bamboo?

The orange and black sticks with the orange disc on them. We use them to mark our snowmaking equipment.

I noticed a couple of them under the quad.

Oh yeah okay, there are some to mark low spots to keep people out of the spots where there's low clearance. We have a lot of snow right now. So yeah sometimes it's rocks sometimes it's a bare spot depending on the trail, if you can see it from above. Often, most of the bamboo that we use is to tell people that there is a set of snowmaking hydrants.

Do you recognize and high traffic areas other than where everyone convenes at the lifts?

Early in the season certainly its what's open because like all resorts we start, well unless you have this incredible fall, but we start with the snowmaking trails and what's open is high traffic because people don't have a lot of choices, that's really the only time we see it otherwise we have a pretty big resort and people spread out pretty well.

Do you find that you have more injuries at the park than anywhere else?

No, not necessarily. It does seem like we have a lot of wrist injuries and arm shoulder injuries because people break their falls.

Do you have acceptable risks?

The whole sport is a risk, I can't emphasize enough skiing is inherently risky and if you approach it smartly you minimize it. So there's a ton of acceptable risks.

Equipment Test Appendix

Our survey for the self-test binding release study, consisted of 6 questions that can help us verify what people know about the self-test.

The first question: Have you ever attempted a binding release using a "self-test"? This was asked first so that we can see how many people actually know what the self-test is. For people that didn't know we added a link to a YouTube video that we created, which clearly shows how the self-test is performed. Which we then followed up with the question, Can you release your boots from your bindings using the "self-test"? If yes, then we know that the skier's bindings are not too tight, and if no then the bindings are too tight and the skier can be at risk when skiing.

The third question is: Do you know if your bindings are set to the correct torque release value (DIN)? This was asked because we can see how many skiers definitely knows if their bindings are set correctly. If their bindings are not set correctly or unsure if they are, then the self-test can be used as an indicator as to whether or not they have the proper settings. We also recommended on our web page that if a skier cant release from their bindings, or if they are unsure if there binding settings are right, that they seek a professional to adjust their bindings properly.

The fourth and fifth questions are paired together: Have you ever experienced a lower leg injury from skiing? If you have ever experienced a lower leg injury from skiing, did your bindings release during the injury event? We wanted to ask these questions because if we do have some responses that show that they have had a lower leg injury and the bindings did not release, then we can assume that the bindings were too tight and therefore not set correctly. This is something that can potentially be avoided by performing the self-test before skiing. The self-test would help recognize that the bindings are too tight and would have to be adjusted to benefit the skier and help reduce the risk of injury.

The last question is: Have you ever experienced a pre-release of the bindings? This question provides us knowledge about the torque release value of the skiers' bindings, and we can assume that their bindings may be too loose if they have experienced a pre-release. The self-test can also be used to see if skier's bindings are too loose. If a skier releases from their bindings without any struggle, then the bindings are most likely not tight enough and should be adjusted. If a skier has never experienced a pre-release, then we can use the answers from the previous questions to determine if skiers' bindings are set correctly.