

Worcester Polytechnic Institute Digital WPI

Interactive Qualifying Projects (All Years)

Interactive Qualifying Projects

May 2013

Web Based Snow Sport Injury Reduction

Justin Bronson Lagassey
Worcester Polytechnic Institute

Matthew Gregory Butler
Worcester Polytechnic Institute

Michael Shamus Horgan
Worcester Polytechnic Institute

Nathan Edward Braun
Worcester Polytechnic Institute

Paul Francis O'Brien
Worcester Polytechnic Institute

Follow this and additional works at: <https://digitalcommons.wpi.edu/iqp-all>

Repository Citation

Lagassey, J. B., Butler, M. G., Horgan, M. S., Braun, N. E., & O'Brien, P. F. (2013). *Web Based Snow Sport Injury Reduction*. Retrieved from <https://digitalcommons.wpi.edu/iqp-all/1082>

This Unrestricted is brought to you for free and open access by the Interactive Qualifying Projects at Digital WPI. It has been accepted for inclusion in Interactive Qualifying Projects (All Years) by an authorized administrator of Digital WPI. For more information, please contact digitalwpi@wpi.edu.



Fall | 12

Web Based Snow-Sport Injury Reduction

Project Number: CAB 1211

Advisor:

Prof. Christopher A. Brown

By: Michael Horgan, Paul O'Brien, Nichole Holman, Justin Lagassey, Nathan Braun and Matt Butler

Table of Contents

Table of Contents.....	1
Table of Figures.....	3
Abstract.....	5
Background.....	6
0.1 Head Injuries.....	6
0.2 Upper Body.....	6
0.3 Lower Body.....	7
0.4 Inadvertent Release.....	8
1.1 Objectives.....	9
1.2 Rationale.....	9
1.2.1 Education.....	9
1.2.2 Inadvertent Release.....	9
1.2.3 Fitness.....	9
1.3 State Of the Art.....	10
1.3.1 Education.....	10
1.3.2 Inadvertent Release.....	10
1.3.3 Fitness.....	10
1.4 Approach.....	11
2 Methods.....	12
2.1 Online Education.....	12
2.1.1 Head Injuries.....	12
2.1.2 Upper Body Injuries.....	12
2.1.3 Lower Body Injuries.....	12
2.1.4 Inadvertent Release Reduction.....	12
2.1.5 Fitness.....	13
2.2 Inadvertent Release.....	13
2.2.1 Ski Camp Study.....	13
2.2.2 USCSA Ski races.....	13
2.2.3 Analysis.....	14
2.3 Fitness-Injury Methods.....	14

2.3.1 Outline.....	14
2.3.2 Fitness Testing Procedure	15
2.3.3 Injury Survey Procedure.....	18
3 Results	19
3.1 Survey Results	19
3.2 Inadvertent Release Results.....	21
3.3 Fitness-Injury Results	27
3.3.1 Fitness	27
3.3.2 Injuries.....	34
3.3.3 Fitness and Injury	36
4 Discussion.....	37
4.1 Survey Discussion.....	37
4.1.1 Total Responses	37
4.1.2 Head Survey	37
4.1.3 Knee Survey.....	38
4.1.4 Wrist Survey	39
4.1.5 Thumb Survey	39
4.2 Inadvertent Release Discussion	40
4.3 Fitness-Injury Discussion.....	42
4.3.1 Fitness	42
4.3.2 Injury survey.....	43
4.3.3 Fitness and Injury	44
5 Conclusion.....	45
5.1 Survey Conclusion	45
5.1.1 Total Responses	45
5.1.2 Head Survey	45
5.1.3 Knee Survey.....	46
5.1.4 Wrist Survey	46
5.1.5 Thumb Survey	46
5.2 Inadvertent Release Conclusion	46
5.3 Fitness-Injury Conclusion	47
6 References	48

7 Appendices.....	50
7.1 Survey Appendices.....	50
7.1.1 Survey Results.....	50
7.1.2 Survey Discussion Table.....	56
7.1.3 Survey Conclusion Table.....	58
7.1.4 Website.....	60
7.2 Inadvertent Release.....	61
7.3 Fitness and Injury Appendices.....	62
7.3.1 Fitness testing instructions and procedures.....	62
7.3.2 Injury Survey.....	65

Table of Figures

Figure 1: Number of responses to each survey.....	19
Figure 2: Select answers from injury surveys. Correct answers are highlighted.....	20
Figure 3: A frequency plot of ability on the horizontal axis and number of inadvertent releases on the vertical.....	21
Figure 4: Side-by-side comparison.....	23
Figure 5: Start of turn.....	24
Figure 6: Chatter, loss of balance.....	24
Figure 7: Flex on Outside Ski.....	24
Figure 8: Weight on Inside Ski.....	25
Figure 9: Outside ski regains contact with snow.....	25
Figure 10: Inadvertent Release.....	25
Figure 11: Skier without inadvertent release.....	26
Figure 12: Pressure on downhill ski.....	26
Figure 13: Little weight on inside ski.....	26
Figure 14: Male Overall fitness test scores. Each line represents a male subject and on the horizontal axis is the term in which testing occurred, except the red line labeled avg. The avg line is the average performance difference for each athlete.....	29
Figure 15: Female individuals overall score over time. Each line represents an athlete and the horizontal axis is the term during which testing was done. Overall score is the average of the normalized scores for each metric.....	30
Figure 16: Male hamstring to quadracep strength ratio over all five fitness tests.....	31
Figure 17: Female hamstring to quadracep strength ratio over all five fitness tests.....	31
Figure 18: The average of male athlete’s performance for each metric of the fitness test.....	32
Figure 19: The average female performance on each metric over the five fitness tests.....	32
Figure 20: The average performance for all the metrics that were tried more than once.....	33

Figure 21: The average difference between and athletes score and their average performance by metric of females. 33

Figure 22: A table summarizing every injury over the testing period. 34

Figure 23: Injuries by body area, the face and thumb injuries were a result of gate impacts during racing and the toe injuries were frostbite related. Knee injuries all occurred during falls, with three out of five occurring in gates training or racing. 34

Figure 24: Injuries by severity, although knee injuries accounted for just over half of the incidence, they accounted for 85% of the total injury severity points accumulated score. 35

Figure 25: Two tabulations of the survey points are compared against each other for accuracy in predicting the recovery period length for an injury. Days of recovery were plotted on the vertical axis and survey score plotted on the horizontal axis..... 35

Figure 26: Fitness scores are plotted on the horizontal axis and injury severity is plotted on the vertical axis. 36

Abstract

Skiing and snowboarding injuries have plagued riders of all ages and skill levels due to the dangerous nature of the sports. Injuries and deaths have driven people away from the sport and returning to the mountain. The website portion of this project aims to reduce these serious injuries through educating skiers and snowboarders over an Internet based platform.

The inadvertent release film study aims to observe inadvertent release in skiers in order to determine the mechanisms that cause it. Inadvertent release is a release of the ski binding under circumstances that would normally not warrant a release. An inadvertent release can be dangerous; as the skier often loses control after an inadvertent release occurs. The goal of identifying the mechanisms of inadvertent release is to inform manufactures of these mechanisms so they may design newer systems to reduce the occurrence of the phenomenon. The first step towards reaching this goal is alerting the ski community to the mechanisms of inadvertent release.

A major problem that has been identified by previous research on skiing injuries is that injuries occur more often at the end of the day when skiers are tired (Johnson, Ettlinger, & Shealy, 1989) (Julich, 2012). Our hypothesis for the fitness injury study in this project is that increased physical fitness reduces the risk of injury by reducing physical fatigue and improving skier response in potentially injurious situations. One of the goals was to develop a standard fitness test and benchmarks that alpine ski racing teams could easily administer. The objective of the fitness study is to determine if it is possible to determine the risk of injury in skiing from physical fitness tests. If so, it should be possible to take steps to reduce the risk of skiing injuries.

Background

The epidemiology of snow sports injuries has been well studied and there is a wide body of literature to draw information from. This section is provided to give the reader an idea about the most common injury types and specific research in the field related to our specific objectives. This is by no means an exhaustive or even comprehensive review; these are just a collection of findings and facts about the state of snow sports injury research.

0.1 Head Injuries

Head injuries account for about a fifth of skiing injuries and can be prevented or reduced in severity by the use of helmets (Sulheim, Holme, Ekeland, & Bahr, 2006). These injuries can have a severe effect on the casualty's quality of life including loss of mobility, memory, cognitive function, and death. The financial cost of the most severe head injuries is tremendous, with an average cost per case of a severe blunt trauma brain injury in the U.S. of \$59,274 in the first year following the injury (Siegel, Gens, Mamantov, Geisler, Goodarzi, & MacKenzie, 1991). In two analyses of head injuries sustained by skiers and riders not wearing helmets, an estimated 44%-60% of head injuries suffered could be reduced or prevented by the wearing of a helmet (Sulheim, Holme, Ekeland, & Bahr, 2006) (U.S. Consumer Product Safety Commission, 1999). Thus, head injuries represent a major preventable source of injuries and increasing the use of helmets in alpine skiing could reduce the number and severity of these injuries (Levy, Hawkes, Hemminger, & Knight, 2002).

Head injuries are typically caused by one of three types of impacts: the snow surface through a fall, a stationary object such as a tree or manmade device, or another skier or snowboarder. Levy et al found in their study that collisions with a stationary objects were the most frequent, accounting for nearly half of all head injuries and that this mechanism had the highest mortality rate at 7.6% (Levy, Hawkes, Hemminger, & Knight, 2002). While the vast majority of head injuries in skiing (90%) are relatively minor injuries such as cuts, abrasions, or minor bumps, the remaining 10% of injuries are a mix of injuries involving loss of consciousness, skull fractures, bleeding in or around the brain, and deep lacerations (Langran M. , 2012). These relatively rare but severe injuries are the leading cause of death in skiing (Ackery, 2007). Preventing the most serious and costly injuries in skiing should be addressed by encouraging more extensive use of helmets in the skiing population.

0.2 Upper Body

To date, there are two main ways to help prevent wrist injuries: proper training and protective gear (Langran M. , 2012).

Wearing protective gear can also prove to be helpful in the prevention of wrist injuries. One such item is Flexmeter, a brand of protective wrist gear created by a member of the International Society Ski Safety (ISSS), Dr. Marc Binet. The products made by Flexmeter range from standalone wrist guards to integrated glove/ guard systems. These are mainly used to prevent the hyperextension of the wrist

where the hand bends past its normal range of motion towards the top of the forearm (Flexmeter, 2013). Another well-known name in wrist gear is the Biomex Protection System, developed by Dr. Georg Ahlbaumer, another ISSS member. Their specialty is in the level range of protective gloves (Ahlbaumer, 2012).

The web is also a useful resource for the general public to learn about snow sports injuries. Dr. Mike Langran has been using his website at ski-injury.com as a means to educate the public. The website has pictures of the proper falling technique, which involves getting your arms out of the way when you fall. Dr. Langran's site in particular is a useful resource with many videos and images that illustrate the proper falling technique for both skiers and snowboarders (Langran M. , 2012). Dr. Langran also has a non-profit company, Stay Safe on Snow Ltd., to promote snow sport safety in Scotland through information leaflets and safety videos. During the 1999 to 2000 season, Dr. Langran conducted a study on injury risk factors at three different ski areas in Scotland. Currently, the only design that seems to reduce thumb injuries are smaller ski pole handles (Heim, 1999). Thumb stabilizers and wraps exist, but they have not been proven to reduce thumb injuries (Langran & Selvaraj, 2002).

Snowboarders are more at risk than skiers when it comes to wrist injuries (Heneved, 2002). This is because balancing on a snowboard is harder than balancing on skis (both feet are attached to a snowboard, thus making it harder to regain balance once it has been lost). When snowboarders start to fall, they cannot move their feet as easily or as precisely as skiers can. When snowboarders try to break their fall with their arms or hands, wrist injuries occur. This, however, does not mean that skiers do not hurt their wrists. Skiers do not injure their wrists as frequently as snowboarders. Since skiers who lose balance can move each ski independently of each other, they can regain their balance much better than snowboarders, making falling over less likely under the same conditions. Overall, the literature suggests that it should be possible to prevent some wrist injuries if all skiers and snowboarders are taught how to fall correctly and wear the proper type of wrist protection.

Upper body injuries also include thumb injuries; between 3% and 5% of all skiing injuries are thumb injuries (Heim, 1999). Since many thumb injuries go unreported, it could be the most common injury in alpine skiing. Of all snow sport participants, 10% of skiers and 1% of snowboarders have reported a thumb injury, suggesting that ski poles are the main cause of thumb injuries. Data from a 2010 study in France indicated that thumb injuries have decreased since the 1990's, as seen in the increasing mean days between injuries (MDBI) from 4,905 days in 1992 to 8,522 days in 2010 (Langran M. , 2012).

0.3 Lower Body

Knee injuries are understood to be the most prevalent of all skiing related injuries, due to the complexity of the joint and the forces acting on the joint, especially in an accident. Knee injuries account for 30-40% of ski injuries (Langran M. , 2012). An MCL or ACL reconstruction surgery can cost upwards of \$20,000 and includes a long and painful recovery process. Snowboarders experience far fewer knee injuries than skiers. Having both feet fixed to the board and parallel to each other limits the forces that can act on the knee.

With the introduction of safety bindings in 1950, alpine skiing saw a dramatic reduction in knee injuries. Most modern bindings have two release functions, a forward bending release, in which the heel piece releases if the skier falls forward over the tips of the ski, or a twisting toe release, in which the binding releases if a torque is exerted about the tibia (lower leg) axis. Both mechanisms of release are designed to limit torque transferred to the leg to a level that is deemed to be safe. There has been continuous improvement on the original design as well as other innovations to reduce leg injuries. Different bindings are offered for different ski styles, whether it is a park or a race course, or even the bunny slope (Brown, 2006).

The KNEE binding is an improvement on the contemporary binding design by integrating a laterally releasable heelpiece, allowing the binding to release when a force is applied underfoot (Howell, 2012). While conventional bindings have two modes of release; twisting toe and forward bending, the knee binding includes a third; lateral heel release. The binding manufacturer claims this is an important innovation because the traditional bindings require a torque to release and have no release mechanism for forces applied directly underfoot, forces that purportedly cause a large number of ACL tears. This design claims to greatly reduce ACL injuries by ensuring the loads in a phantom foot type fall release the binding instead of releasing the ligaments in the knee (Pure Lateral, 2013).

Ski MOJO is a type of knee brace designed to reduce the load on the knees while skiing. The company has reported great success in eliminating knee related injuries among their users, many of whom had already sustained knee injuries in the past (Kinetic Innovations Ltd., 2013).

0.4 Inadvertent Release

There exist many hardware problems that may cause an inadvertent release to occur, such as: the Flex Effect, the “Houdini effect”, and the “Jet effect” (VSR: FAQ for Skiers/Riders 2010). Hardware problems are issues with the ski equipment that cause an inadvertent release to occur.

Most of the hardware problems could easily be avoided by equipment maintenance at the beginning of every season. Software problems are much more common than hardware problems and are caused by the skier either from poor skiing technique or from inappropriate skiing technique. The “Bow Effect” and the “Superman Effect” are the two main software problems (VSR: FAQ for Skiers/Riders 2010). Tightening the release settings, as skiers tend to do, does not solve the inadvertent release problem and it may even make the bindings more dangerous.

1.1 Objectives

This project seeks to understand and influence risk factors that contribute to snow sports injuries. Three risk factors were identified for further research by this group; education and knowledge, physical fitness and inadvertent release. The education group focused on developing a web based strategy to test the knowledge of the general public and make educational resources available through a website. The fitness-injury tested the fitness of a group of athletes on the WPI Ski Team and measured the injuries that they experienced over two years to provide more evidence for the role of fitness in preventing or reducing injuries. Inadvertent release was studied by filming ski races and analyzing the observed events to determine patterns present in the data.

1.2 Rationale

According to the National Ski Area Association every year there are 135,000 (Troy Hawks, 2012) medically significant skiing or snowboard related incident and since the introduction of snowboarding the number of injuries has risen annually. Education is a major key in reducing these injuries. Therefore, in order to educate skiers on the mechanisms of injuries and reduce those risks on the mountain, it is crucial that we focus on the common causes of these mechanisms of injuries.

1.2.1 Education

Educating the public on injury mechanisms could be important because it could have the potential to give skiers and snowboarders a better understanding of how and why they are getting injured, so that they might avoid getting injured.

1.2.2 Inadvertent Release

A common issue regularly experienced by alpine skiers, especially racers, is an inadvertent release of either the toe or heelpiece of the binding. This can lead to loss of control and result in an injury of varying magnitudes, dependent on the conditions of the event. Capturing inadvertent releases on film allows for critical analysis of the scenario to determine the cause of the release. By utilizing training footage from the WPI Ski Team as well as races from the Thompson Division, we hope to capture inadvertent releases on multiple occasions.

1.2.3 Fitness

The hypothesis that increased physical fitness will reduce the risk of injury in skiers is important to test because if confirmed it would give skiers a proactive way to reduce their risk of injury. Previous research has shown that fatigue can increase reaction time and decrease magnitude of response, which is hypothesized to lead to increased risk of injury. The role of physical fitness in reducing fatigue has been established, thus the role of fitness in reducing injury would give the general public better strategies to reduce their risk of injury.

1.3 State Of the Art

1.3.1 Education

This project is a continuation of the 2011-2012 Snow Sport Injury IQP from WPI in which they used a website as a means of educating the ski population on various injury mechanisms. Dr. Mike Langran has been maintaining a website (ski-injury.com) which is devoted to ski injury prevention through public knowledge and awareness. Previous attempts at educating the skiing population on injuries have focused on the specific injuries; to our knowledge, no one else has tried to reduce injuries through a three pronged approach of fitness testing, inadvertent release, and education.

1.3.2 Inadvertent Release

Vermont Ski Safety's website has been collecting data for a video study of inadvertent release where they are asking for people to send them videos of instances of inadvertent release that have been captured. So far, they have not written any reports on their findings. Although many sources discuss inadvertent release and the mechanisms involved in its occurrence, a film-based observational study on inadvertent release has not been published.

1.3.3 Fitness

Ulli Julich conducted a review of fitness testing in alpine skiing (Julich, 2012). The study looked in the literature for papers relevant to several fitness parameters that may affect performance or injury risk in competitive alpine skiers including body composition (BMI, fat %), aerobic and anaerobic metabolic rates, muscle fiber composition, glycogen utilization, and strength. The fitness tests were reviewed in three sections: aerobic testing, anaerobic testing, and strength. Aerobic testing focused on athletes VO_2 max which measures oxygen uptake during exercise and reviewed some work related to on snow VO_2 max testing. The anaerobic testing procedures reviewed measured muscular endurance in a 60-second vertical jump test that measured power output during a one minute period of vertical jumping on a force plate. Strength testing, was based on measurement of maximum power output on an isokinetic dynamometer where the machine moves at a constant speed and athletes push against a foot bar. The study concluded that fitness testing can be used to assess the effectiveness of training routines, and rehabilitation programs, and a skier's readiness to return to on-snow training.

A ten year longitudinal study on Austrian ski racing youths examined the effect on physical fitness on injury rate and found that injury rates did correlate with certain fitness metrics, but not all metrics were predictive (Raschner, Platzer, Patterson, Werner, & Hildebrandt, 2011). The study group was a sample of 175 female and 195 male competitive junior alpine ski racers, aged 14-19, and they were fitness tested three times a year from 1996 to 2006. During this period, fifty-seven ACL injuries occurred and those injuries were shown to correlate significantly with four parameters: relative leg strength, ratio of leg extension/flexion, relative core strength, and reactive strength index.

1.4 Approach

The education group made use of surveys to determine to current knowledge of the general public before developing educational content. Current web strategies focus on either education or selling a product designed to reduce injury rates. Use of survey information from surveys of the general public to design targeted educational is a novel approach and will hopefully increase the impact of this research. Information gained in the fitness injury study and the inadvertent release study was also included on the website.

Inadvertent release has been the subject of some research, but the use of observational video at races to collect a sample to analyze is a new and innovative idea. This is was more successful in gathering video than the passive collection of film by the Vermont Ski Safety study.

The fitness injury study follows several other studies on the role of fitness in skiing injuries, but this is the first time a test has been developed that can be performed without specialized equipment for use in predicting injuries. This is an important change from previous tests because it allows the fitness test to develop benchmarks that athletes should aim for in their own physical training. This shift away from showing that a correlation exists to being able to use an easily accessible fitness test to determine risk is an important step towards empowering athletes to modify their own risk factors in injury prevention.

2 Methods

2.1 Online Education

In order to gather surveys results from willing participants it was necessary to develop a website. The website is a cost effective solution that allows a large volume of people to access the surveys and other educational information pertaining to injuries. Free software allows for the surveys to be collected in a central system and easily analyze the responses. The main focus of the website will be to promote people to take our surveys, while also reading about ski safety, inadvertent release, and fitness. For more information on the procedure of creating website, reference 7.1.4 Website.

2.1.1 Head Injuries

The purpose of the head injury webpage is to educate the skiing and snowboarding population on the types of head injuries that are likely to occur and also to promote helmet safety as a way to reduce head injuries while skiing or riding.

2.1.2 Upper Body Injuries

Upper body injuries consist of wrist injuries and thumb injuries. Using a webpage for upper body injuries will aim to inform the snowboarding population about wrist injuries and inform the skiing population about thumb injuries. Tips to prevent such injuries and current technology that is available to reduce the risk of upper body injuries will be covered in the webpage.

2.1.3 Lower Body Injuries

Lower body injuries consist of knee injuries, with the Medial Collateral Ligament (MCL) and the Anterior Cruciate Ligament (ACL) being the two most common knee injuries. The objective for the knee injury webpage will be a lesson on the anatomy of the knee and a lesson the physics of why knee injuries occur as a result of different forces acting on the knee. There will also be information on the webpage for readers to familiarize themselves with the Phantom Foot Mechanism. Following the technical information about the injuries will be a section on ways to avoid knee injuries while skiing.

2.1.4 Inadvertent Release Reduction

In order to educate people on the potential dangers of inadvertent release, an entire section of the website will be devoted to this danger to skiers. This section of the website will contain our findings from the data we have collected, surveys, questionnaires, and important information on how to avoid injury from inadvertent release.

The results that we gather from the WPI Ski Team and league races will be displayed on the website for everyone to see. From these results, people will be able to familiarize themselves with real life situations where inadvertent release may occur and how they may be prevented.

2.1.5 Fitness

In order to stress the importance of being in proper physical form before going skiing or snowboarding, a section of the website will be devoted to the education of this subject. The start of this section will display a user friendly fitness guide that will display information on why it is important maintain a high level of fitness as well as some easy exercises people can perform on their own.

Surveys and questionnaires will be available on the page for participants to provide insights to their personal experiences. WPI Ski Team's fitness testing will also be displayed in this section of the website. These results will show people how a person's physical fitness directly correlates to injury prevention.

2.2 Inadvertent Release

2.2.1 Ski Camp Study

The film study will take place this winter, primarily at Sunday River Ski Resort. Our primary study group will be voluntary members from the WPI Ski Team. As part of our training, many of our drills and practice runs in a racecourse are filmed for later review as a training tool. Our study will use this training exercise as an opportunity to capture binding releases and ideally, inadvertent releases, on film. We will inspect the bindings for wear, damage, or any other indications of a binding malfunction. We will collect data from these tests including DIN settings, binding manufacturer and model, boot manufacturer and model. We will also collect information on the conditions of the incident. This will include weather/lighting conditions, snow conditions, trail construction, time of day, whether the release occurred in a race course/during a drill, and any other information we deem useful.

2.2.2 USCSA Ski races

Our study will also incorporate footage from United States Collegiate Ski and Snowboard Association (USCSA) collegiate ski races. WPI races in the Thompson Division, which includes skiers of many different abilities from schools throughout the Northeast. Aside from changing course conditions, all athletes will be skiing the same line down a race course. Our study aims to film these races in order to observe inadvertent releases outside the WPI group. When a release occurs and is captured on film, the athlete will be asked to volunteer their equipment for testing, again using a Vermont Release Calibrator. Data will be collected from these tests in the same standard as was used for athletes from the WPI Ski Team, as well as data pertaining to conditions.

2.2.3 Analysis

Once data has been collected in conjunction with video footage of a release, we will determine whether the release was inadvertent or not. Once a release has been classified as inadvertent, we will use the data and video footage to determine the mechanics of the inadvertent release. The video software the team will be using this year is Dartfish. This software enables the user to slow down footage as slow as frame by frame, allowing us to observe the very instant that an inadvertent release occurs. Through observance of inadvertent releases collected throughout the study, we hope to pinpoint certain conditions and mechanics that are likely to cause inadvertent releases. We will use the results from this study as tools for skier education on the hurtskiing website.

2.3 Fitness-Injury Methods

The fitness testing study was conducted on the WPI Ski Team, a sample size of ten males and eight female athletes. This study included five testing periods, once per seven weeks during the academic year and spanned two ski seasons. The test was developed iteratively from a list of metrics that were self-developed and pulled from the literature. Injuries among this group of skiers will be observed for the duration of the study and will be quantified using an injury survey.

2.3.1 Outline

2.3 Fitness and Injury Study

2.3.1 Development of research questions (Suh, 1998) (Raschner, P, Patterson, Werner, & Hildebrandt, 2011)

2.3.2 Fitness Test (Julich, 2012)(Conn, 1998) (Holford, 1999)

2.3.2.1 Leg strength – Leg Press (Liebensteiner, Platzer, M, Hanser, & Raschner, 2012), Leg Extensions, Leg Curls, Wall Sit

2.3.2.2 Acceleration and Power – Vertical Jump (Patterson & Peterson, 2004), Shuttle run

2.3.2.3 Core – Plank, Crunch Test

2.3.2.4 Balance – Stork Test

2.3.2.6 Aerobic fitness – 400 m

2.3.3 Injury Survey (Florenes, Nordsletten, Heir, & Bahr, 2011) (Florenes, Bere, Nordsletten, Heir, & Bahr, 2009) (Hogg, 2003)

2.3.3.1 Injury severity

2.3.3.2 Environmental conditions (Sporri, Kroll, Amesberger, Blake, & Muller, 2012)

2.3.3.3 Skier fatigue (Schippinger, et al., 2009) (Subudhi, Davis, Kipp, & Askew, 2001)

2.3.3.4 Equipment

2.3.4 Data collection

2.3.4.1 Data collection timeline and decisions to modify timeline

2.3.4.2 Fitness test

2.3.4.3 Injury survey

2.3.5 Data analysis

2.3.5.1 Metrics applied to collected data

2.3.5.2 Graphical representation of fitness data

2.3.5.3 Comparisons to previously collected data

2.3.5.4 Statistical tests used on metrics, namely t-test and small sample size tests

2.3.2 Fitness Testing Procedure

Informed consent was to be collected from each athlete before testing begins in the form of an oral explanation to each athlete and a waiver was signed. WPI Ski Team members completed the fitness test on five different occasions between January 2012 and March 2013. The tests were completed in a one week period. Each athlete was required to have at least one spotter from WPI Ski Team. Spotters were familiarized with testing metrics and procedures beforehand. Each athlete was allowed to repeat or reattempt each test as many times as desired within the testing time frame. The test metrics were not completed in any specific order, and as many or as few could be completed in a given session of testing. Only the best score for each metric was counted. Medical waivers were granted to any ski team member that had a concern for their health from the attempting any of these metrics; however athletes were encouraged to complete the test to their utmost ability.

The test was designed iteratively based on several areas of fitness that were identified in the literature and observation during the testing phase. Those categories included absolute leg

strength, leg power, hamstring to quadracep ratio, core strength and endurance, cardiovascular capacity, and balance.

Leg Curls

This test was developed for the use in determining the athlete's ham: quad strength ratio. For this test use the WPI Recreation Center leg curl machine. Adjust seat position such that the knee is even with the hinge, the top leg restraint should be lowered as far as possible, exerting considerable pressure on the thigh, the lower calf should rest on curling mechanism with legs straightened. Set the initial load on the machine to a moderate level that the athlete is confident they can lift. Curl legs underneath the seat, until the spotter indicates the legs have completed 90° of flexion, then return to starting position. Increase the setting after each successful attempt such that 3-6 reps can be completed before failure. The athlete should increase the setting in small enough increments that the max limit is close to the maximum successful lift, but not so small that the number of repetitions required to reach failure limits the maximum due to exhaustion. Record the setting for the maximum successful attempt as the metric.

Leg Extensions

For this test use the WPI Rec Center leg extension machine. Adjust seat position such that the legs bend over edge of seat at 90°, the knee is aligned with the hinge of the machine, and the extension pad presses against the lower front tibia above the ankle. Set the initial load on the machine to a moderate level that the athlete is confident they can lift. Extend legs, keeping back of knees touching the edge of seat until the spotter indicates the knee has gone through a full 90° extension. Increase the setting after each successful attempt such that 3-6 reps can be completed before failure. The athlete should increase the setting in small enough increments that the max limit is close to the maximum successful lift, but not so small that the number of repetitions required to reach failure limits the maximum due to exhaustion. Record the setting for the maximum successful attempt as the metric.

Leg Press

Adjust the lower bar catches on the leg press machine so legs can bend to slightly more than 90°. Verify that the catches are functioning properly and that the athlete can bend their knees far enough to comfortably rest the sled on the lower bar catches. When lifting, disengage the upper bar catches and lower weight in a controlled flexion until the spotter indicates the legs have bent to 90°. The athlete must then extend the legs until they are fully straight, reengage the bar catches and set the sled on the upper catches for the lift to be counted. Load the sled at first with a moderate load that the athlete is confident they can lift. Load weight onto leg sled after each successful attempt such that 3-6 reps can be completed before failure. The athlete

should load weight in small enough increments that the max limit can be estimated from the maximum successful lift, but not so small that the number of repetitions required to reach failure limits the maximum due to exhaustion. Continue loading the sled until failure, when the athlete is unable to lift the weight of the sled and must abort the lift. It is important that once the athlete decides to abort the lift that they not fight the weight, but allow the weight to fall onto the lower bar catches. After failure the weight should be unloaded and the sled pushed back to the top bar catches with the help of a spotter. The best successful lift is used; the weight loaded on the sled plus the weight of the sled is recorded for the metric.

Vertical Jump

A piece of tape should be wrapped around the tip of the athlete's middle finger, sticky side out, such that the tape will slide off the finger when the athlete touches the wall. The top of the tape ring should be flush with the tip of the finger. Then the athlete then stands 6-12 inches away from the wall, leaps vertically as high as possible and touches the wall with the tape finger at the highest point of the jump. The athlete cannot step into the jump; feet must be solidly planted for several seconds before the jump. Touching the wall (except to place the tape) is also not permitted. After the jump the athlete stands against the wall and reaches up with the tape hand to maximum extension without stretching. Keep the feet flat on the ground and the toes, chest and face against the wall. The distance between the tip of the fingertip and the top of the tape ring in inches is recorded for the metric.

Stork Test

Remove shoes (socks optional) and place hands on hips. Stand on one leg and position the non-supporting foot against the inside knee of the supporting leg. The athlete raises the heel of the supporting foot and balances on the ball of the foot. The stopwatch is started as the heel is raised from the floor. If hands come off the hips, the athlete hops on the supporting foot, the non-supporting foot loses contact with the knee, or the heel of the supporting foot touches the floor, the test ends and the time is stopped. The time in seconds is recorded for the metric.

Crunch Test

The athlete lies on their back with shoulder blades touching the floor, knees bent at approximately right angles, feet flat on the floor, and hands resting on the thighs. A modified crunch technique is used where the athlete contracts the abdominal muscles and slides their hands up their thighs until the top of the palm touches the top of the knee. The athlete then returns to the start position with shoulder blades touching the floor to complete one repetition. Do not count repetitions where the shoulder blades fail to touch the floor or the top of the palm does not touch the top of the knee. A timer is set for one minute and the number of repetitions that the athlete can be complete successfully is recorded for the metric.

2.3.3 Injury Survey Procedure

An injury survey was conducted in tandem with the fitness testing. It consisted of asking athletes about the severity of their injury through six different questions, each of which addressed a unique aspect of the injury. Particularly, we asked about the effect that the injury had on the athletes' abilities to perform normal everyday tasks, as well as how long it took them to return to skiing.

3 Results

3.1 Survey Results

Complete results for each of the four injury surveys can be viewed in Appendix 7.1.1 Survey Results

Survey	Number of Responses
Head	116
Knee	65
Wrist	46
Thumb	30

Figure 1: Number of responses to each survey.

Head Injury Survey		
What is the most common type of head injury?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Concussion	114	98.28%
What is not the proper fit for a helmet?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Back of helmet should touch back of your neck	45	38.79%
When should you consider replacing a helmet?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
It doesn't fit correctly anymore	109	93.97%
The chinstrap no longer functions properly	102	87.93%
Which two qualities should influence your choice of which protective helmet to purchase?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Material satisfaction - how well the helmet will retain its physical appeal after a collision	23	19.83%
Weight management - whether the weight of the helmet causes unnecessary injury	56	48.28%

Knee Injury Survey		
What percentage of ski injuries are knee-related?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
30 - 35%	33	50.77%
What is the most common knee injury?		

<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
ACL Tear	45	69.23%
Which of the following conditions could cause a "Phantom foot"?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Foot falling out of boot	15	23.08%
Hips fall below knee, causing the uphill ski to be unweighted and all weight on the downhill ski.	39	60.00%
Upper body moves down the hill, while the downhill ski abruptly carves off to the side.	40	61.54%
What is the recommended technique when falling?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Draw your limbs closer to your body and do not attempt to stand up; skis preferably downhill from your body	53	81.54%
Which of the following devices have claimed to significantly reduce knee injuries?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
KNEE binding	47	72.31%
Wrist Injury Survey		
Which of the following is the proper way to fall in order to prevent wrist injuries?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
All of the above	26	56.52%
What are the positives of wearing wrist guards?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Reduce the risk of hand injuries	0	0.00%
Reduce the risk of forearm injuries	0	0.00%
Reduce the risk of wrist injuries	20	43.48%
All of the above	26	56.52%
What properties provide maximum protection in a wrist guard?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Extend up the length of the forearm	13	28.26%
Extend only a few inches up the forearm	25	54.35%
Thumb Injury Survey		
What are some causes of thumb injuries?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
All of the above	30	100.00%
Which group of participants are more likely to sustain a thumb injury?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Skiers	22	73.33%

Figure 2: Select answers from injury surveys. Correct answers are highlighted.

3.2 Inadvertent Release Results

3.2.1 Skier ability

The results of the film study showed a strong relationship between the ability of the skier and inadvertent release. During the analysis of the video, athletes were sorted into five different skill level classifications; low, mid/low, middle, mid/high, and high. An athlete classified as a high level skier would be one with a very refined racing form with years of experience, where a low level skier would be one with little to no racing experience. The total inadvertent releases experienced by each classification are as follows:

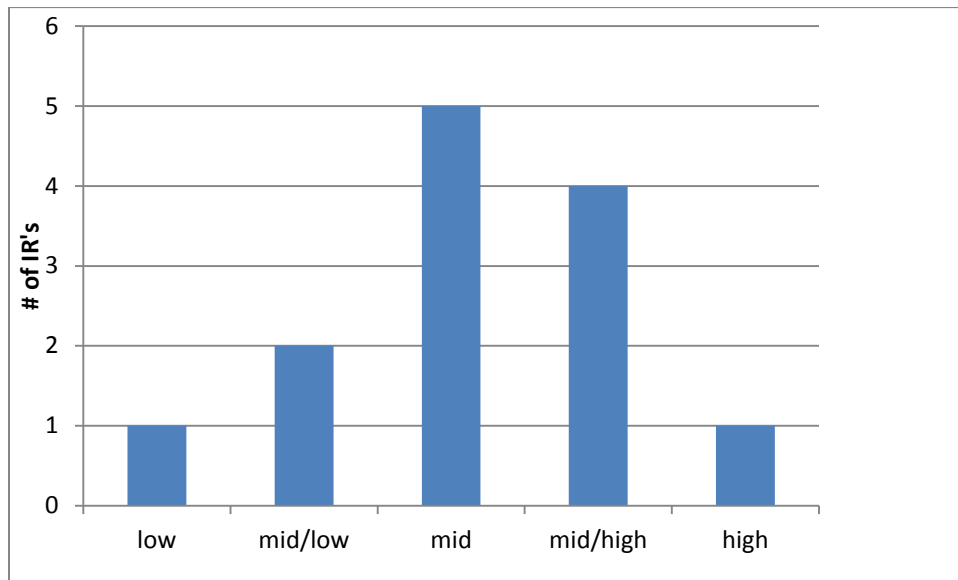


Figure 3: A frequency plot of ability on the horizontal axis and number of inadvertent releases on the vertical.

3.2.2 Filming location

The strategy of selecting filming locations yielded exceptional results; every inadvertent release reported was caught on film.

3.2.3 Terrain features

Upon careful analysis of the video, it was observed that inadvertent releases occurring at the Dartmouth race occurred over sections of the course that featured “chatter marks”; thin shallow ruts worn into ice running parallel to the arc of the turn. When the ski interacted with these marks in quick succession, it was subjected to a repetitive bouncing effect that would often flex the ski in an abnormal fashion.

The race at Cochran's featured a much more defined terrain feature; a large "hole". A hole is a very deep rut that develops after multiple athletes run through the same line in a course. Often forming in warmer conditions with softer racing surface, these holes can disrupt the skier quite dramatically if traversed incorrectly. The hole at Cochran's caused every inadvertent release and several falls as well. The hole increased in size over the course of the race, and the men running mid pack began to experience a high frequency of inadvertent release. The course crew did not attempt to modify the hole, although modification would have most definitely have prevented a large number of the inadvertent releases.

3.2.4 Technique

After close inspection of each video of an athlete experiencing an inadvertent release, it was noted that all athletes that experienced inadvertent releases exhibited common movements prior to the moment that the inadvertent release. When an athlete enters the turn, prior to the moment of release, they shift their weight distribution and place pressure onto their inside ski. Whether the skier places all of their pressure on to the inside ski or only half of their pressure; it is clear that by lifting pressure from the outside ski that it becomes more prone to release. This is supported by the fact that the outside ski was lost in every instance of inadvertent release. When compared with footage of athletes that did not experience inadvertent releases, it was determined that by placing as much pressure as possible onto the outside ski, the athlete experienced greater edge hold and retention of the ski would during interaction with a hazardous terrain feature.



Figure 4: Side-by-side comparison

The low level skiers had mixed techniques, but they experienced inadvertent releases very infrequently. The cause of this was determined to be the lower speeds and different lines they often took through the course. This cautious style of skiing lowered the frequency of inadvertent release. A breakdown of the technique frame by frame is shown below:



Figure 5: Start of turn

This frame shows the athlete entering the turn. Snow spray is visible off the inside ski, however it is not clear if the pressure is concentrated on the inside ski or not.



Figure 6: Chatter, loss of balance

In this frame the athlete has encountered chatter marks and has lost balance, indicated by the movement of the arms. The outside ski has encountered a terrain feature that has caused it to flex abnormally.



Figure 7: Flex on Outside Ski

At this point the athlete is in recovery mode. Both skis have lost contact with the snow and at this instant the athlete does not have control. Note the flex of the outside ski.



Figure 8: Weight on Inside Ski

The athlete has resumed contact with the racing surface. At this point the athlete will try to balance on the inside ski, as the outside ski is still undergoing shock from the initial impact with the chatter marks.



Figure 9: Outside ski regains contact with snow

The athlete has managed to get the outside ski to resume contact with the racing surface, however the majority of the pressure is still on the inside ski. The wave-flex pattern that has been affecting the ski has compromised the ability of the binding to retain the athlete's boot.

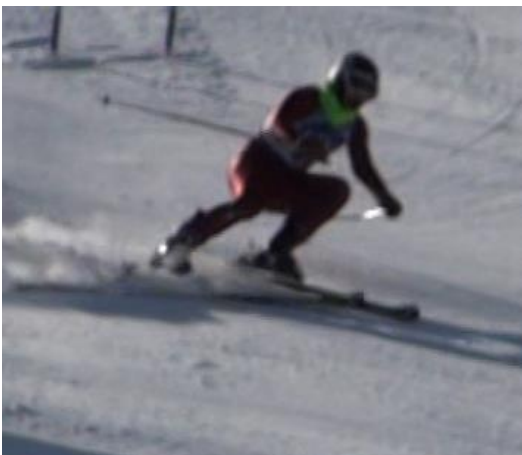


Figure 10: Inadvertent Release

The binding has inadvertently released. As the athlete is still balanced on the inside ski, he recovers and manages to stay on his feet, uninjured. However his race is over. This series of frames captures the contributing factors involved in this particular inadvertent release.



Figure 11: Skier without inadvertent release

This series of frames follows the athlete running immediately after the athlete above. He does not experience an inadvertent release. In this frame it is clear the athlete is placing the majority of pressure on the outside ski.



Figure 12: Pressure on downhill ski

In this frame the athlete has successfully avoided the trouble section of the turn. Maximum pressure is still concentrated on the downhill ski and the athlete is still in control. It should be noted that this athlete's ski does not undergo the same wave-like flex that the first athlete experiences.



Figure 13: Little weight on inside ski

In this frame, the athlete has encountered the same terrain that gave the first athlete trouble. The approach he takes to make it through the turn is quite different, however. The athlete has made a conscious move to focus all of the pressure into the downhill ski; it is clearly visible he has almost lifted the inside ski off the snow.

3.3 Fitness-Injury Results

The data was gathered from January 2012 to March 2013 over the course of two ski seasons by the fitness injury group. The fitness testing was hampered by low participation at times, but enough data was gathered that we can make conclusions regarding the efficacy of the test. Owing to the small sample size we were unable to collect statistically significant results correlating fitness and injury data, but we are able to produce good data relating to the fitness test and the injury survey.

3.3.1 Fitness

The fitness data examined three main areas; global averages, individual performance over time and the average performance on the metrics over time.

3.3.1.1 Global Data

The average of all the submitted scores for each metric was computed. Athlete metric scores were normalized against this data.

	Men				Ladies				P-value
	Count	Mean	St. Dev.	Coeff. of Variation	count	Mean	St. Dev.	Coeff. of Variation	
Leg Extension	26	239.3	51.1	0.21	18	183.0	38.7	0.21	0.306
Hamstring Curl	26	209.3	42.5	0.20	19	159.3	34.5	0.22	0.313
Ham:quad ratio	26	0.9	0.1	0.09	18	0.9	0.2	0.17	0.306
Leg Press	25	614.4	245.3	0.40	20	405.8	120	0.30	0.313
Vertical Jump	11	18.2	3.4	0.18	6	14.3	1.3	0.09	0.115
Stork Test	12	35.9	17.0	0.47	8	11.6	9.1	0.79	0.139
One Leg Right	7	59.3	43.8	0.74	3	104.0	102	0.98	0.064
One Leg Left	7	86.7	77.5	0.89	3	109.7	132	1.20	0.064
Plank	22	190.5	70.2	0.37	17	142.8	54.1	0.38	0.272
Crunch Test	11	52.1	9.4	0.18	8	50.5	17.0	0.34	0.132
Wall Sit	14	283.3	155.2	0.55	12	260.6	74.5	0.29	0.18

Shuttle	13	9.6	0.9	0.10	8	10.3	0.9	0.08	0.145
400 m	6	73.9	11.6	0.16	5	86.2	11.5	0.13	0.076
Bancroft	7	206.7	25.8	0.13					

Figure 14: Global results for males and females. For each sex the number of responses (count), arithmetic average (mean), standard deviation (St. Dev.) and coefficient of variation (Coeff. of Variation). The hypothesis that the males outperform females was tested and the P-value reported in the rightmost column. The men did not outperform the ladies significantly at any event, but none the less scored higher in every metric.

3.3.1.2 Individual Data over Time

Two primary metrics were examined to determine individual change over time, the overall score and the hamstring to quadracep strength ratio. Some ANOVA testing was done on the individual's distributions and the scores by test term. The null hypothesis in all cases was that the groups were not substantially different that a random draw from a normal distribution. An additional bright red line was added to each chart to show one interesting statistic related to group performance as a whole.

Overall Scores

The overall score for each athlete is calculated by taking the average the normalized metric scores in that test. Despite the fact that metrics included in each test were different scores remained relatively stable over time. An ANOVA test to determine if individuals were significantly different from the population was statistically significant with a remarkably low P-value of $1.47E-06$. The ANOVA test for the female scores were also able to reject the null hypothesis, albeit at a higher P-value of 0.0397.

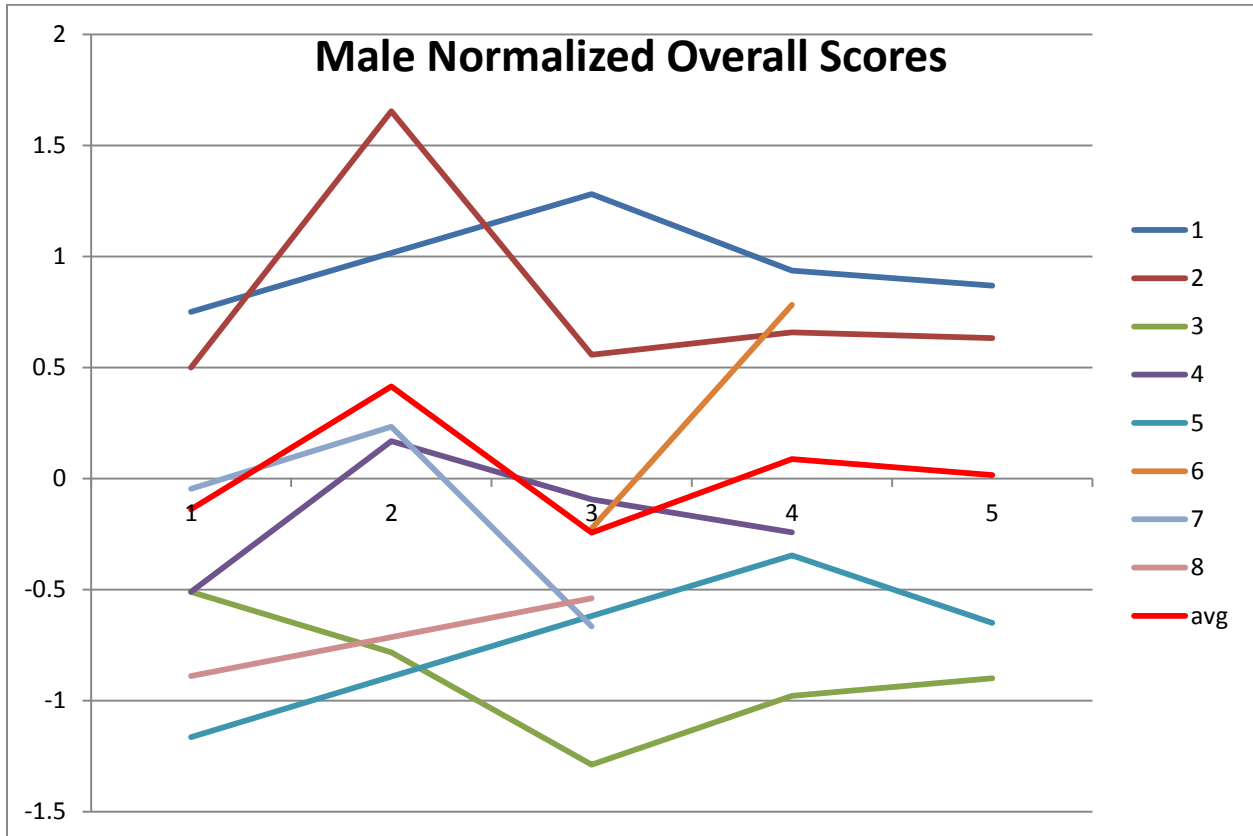


Figure 14: Male Overall fitness test scores. Each line represents a male subject and on the horizontal axis is the term in which testing occurred, except the red line labeled avg. The avg line is the average performance difference for each athlete.

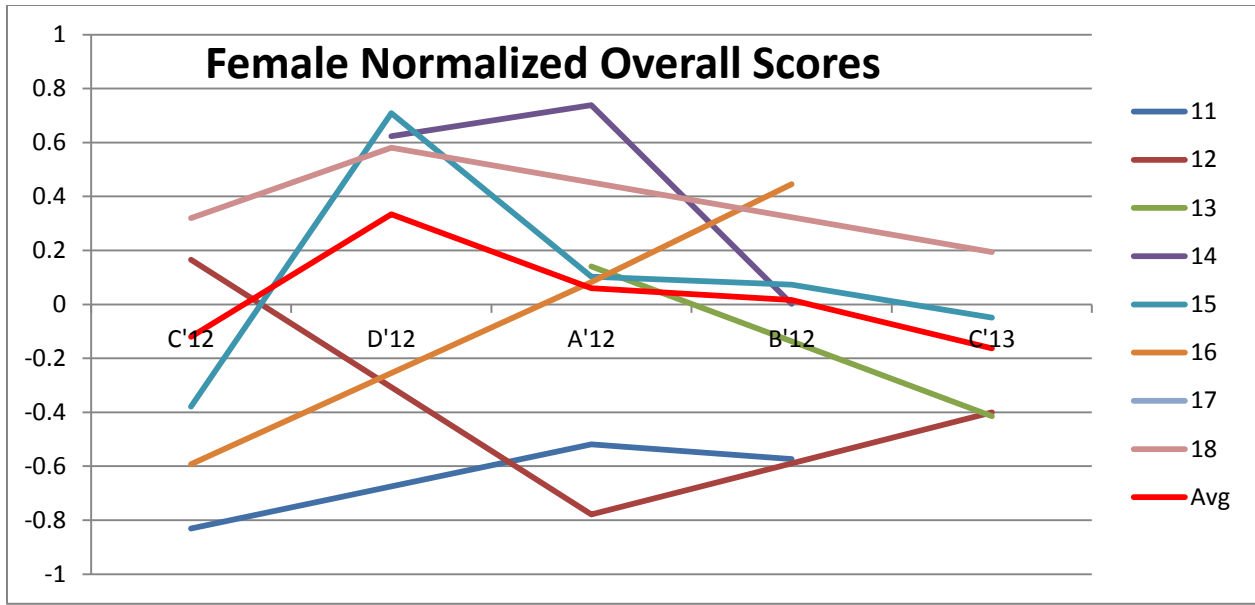


Figure 15: Female individuals overall score over time. Each line represents an athlete and the horizontal axis is the term during which testing was done. Overall score is the average of the normalized scores for each metric.

Hamstring to quadracep strength ratio

This metric measured in hamstring to quadracep ratio as a one rep maximum resistance score. This differs from the standard method of using an isokinetic dynamometer which was considered incompatible with the minimizing of specialized equipment.

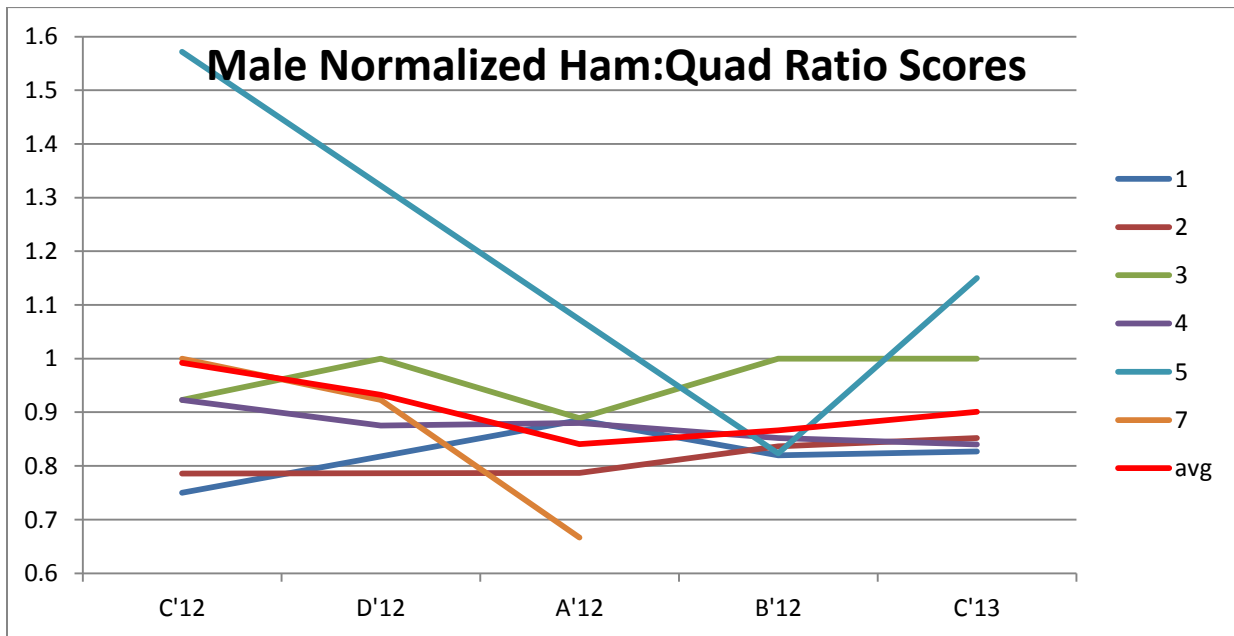


Figure 16: Male hamstring to quadracep strength ratio over all five fitness tests.

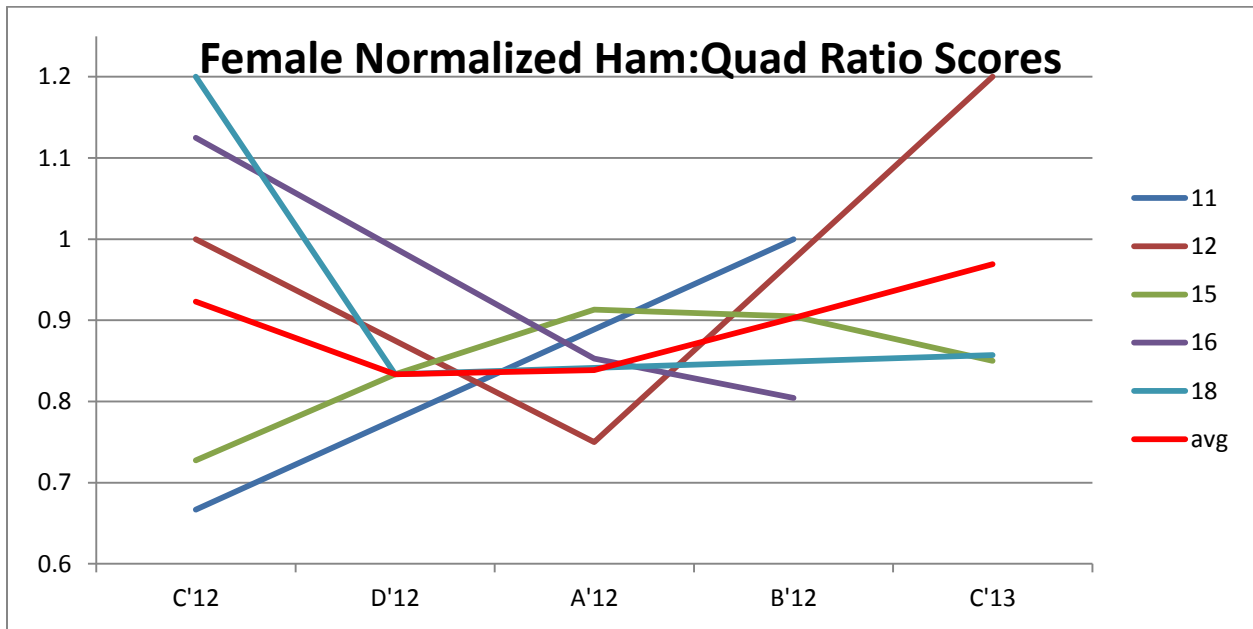


Figure 17: Female hamstring to quadracep strength ratio over all five fitness tests.

3.3.1.3 Metrics and the Fitness Test Over Time

The fitness test has gone through several revisions and a table showing the average athlete performance for each metric over the course of the five fitness tests. Athlete performance on each metric was used to evaluate seasonal effects on fitness. Performance is defined as the difference between the athletes score on one metric and their average score on that metric.

	C'12	D'12	A'12	B'12	C'13
Leg Extension	-0.29122	0.378822	0.084546737	0.295454798	-0.6302
Hamstring Curl	-0.10873	0.57774	-0.07389237	0.06889475	-1.46253
Leg Press	-0.04603	0.601108	-0.51374565	0.233396555	1.279815
Vertical Jump				-0.12448825	1.630796
Stork Test				-0.17759125	1.510501
One Leg Right			0		
One Leg Left			0		

Plank	0.068049	-0.09337	0.224721433	-0.24608579	
Crunch Test				0.527914133	1.415103
Wall Sit		0.176778	0.108249806	-1.17983342	
Shuttle			-0.22138805	1.549716321	
400 m			0		
Bancroft			0		
Average	-0.09448	0.328216	-0.06525135	0.105264206	0.623914

Figure 18: The average of male athlete’s performance for each metric of the fitness test.

	C'12	D'12	A'12	B'12	C'13
Leg Extension	-0.187	0.16528	0.056241	0.360402	-0.20775
Hamstring Curl	-0.037	-0.10441	-0.15275	0.514308	-0.13631
Leg Press	-0.073	0.472321	-0.93082	0.3024	0.152064
Vertical Jump				0.187647	-0.37529
Stork Test				0.008209	-0.00821
One Leg Right					
One Leg Left					
Plank	-0.313	0.336311	0.143638	0.074322	
Crunch Test				-0.06619	0.066193
Wall Sit		0.597687	0.005596	-0.30724	
Shuttle			0.418145	-0.40715	
400 m					
Bancroft					
Average	-0.153	0.293438	-0.07666	0.074079	-0.08488

Figure 19: The average female performance on each metric over the five fitness tests.

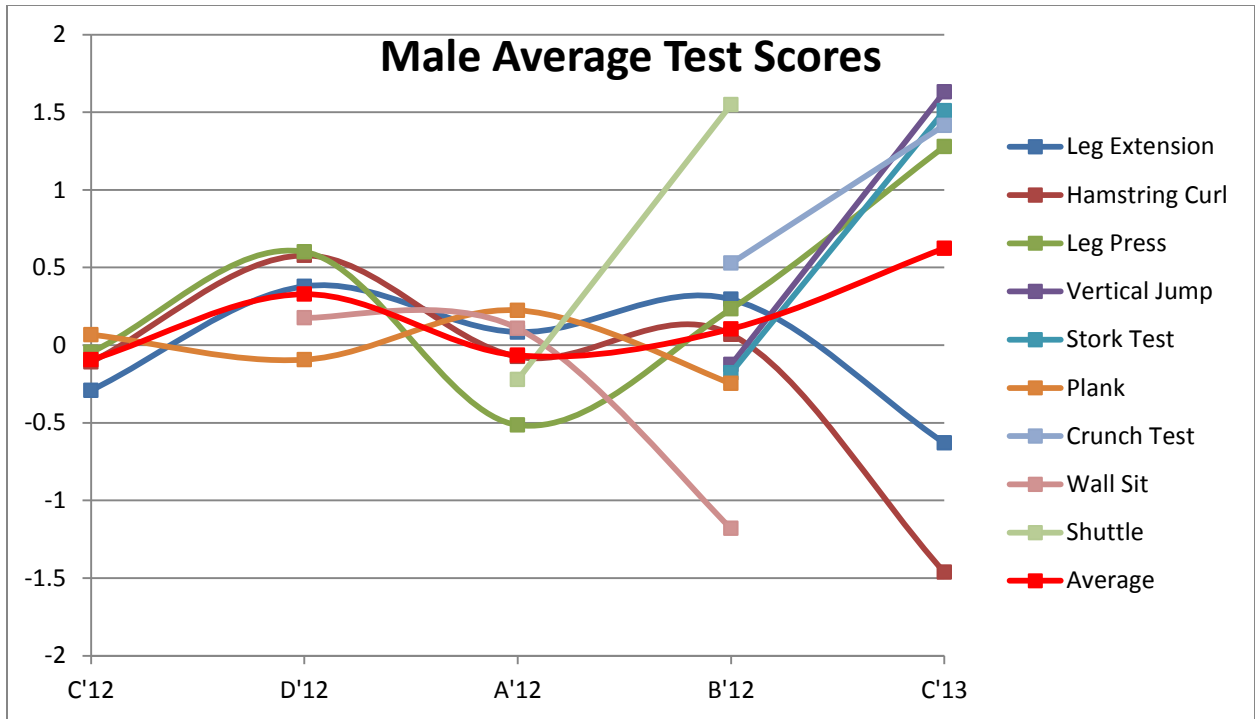


Figure 20: The average performance for all the metrics that were tried more than once.

An ANOVA test was completed to see if the term in which testing was completed had an effect on the data and it was not found to be significant (P-value of 0.21).

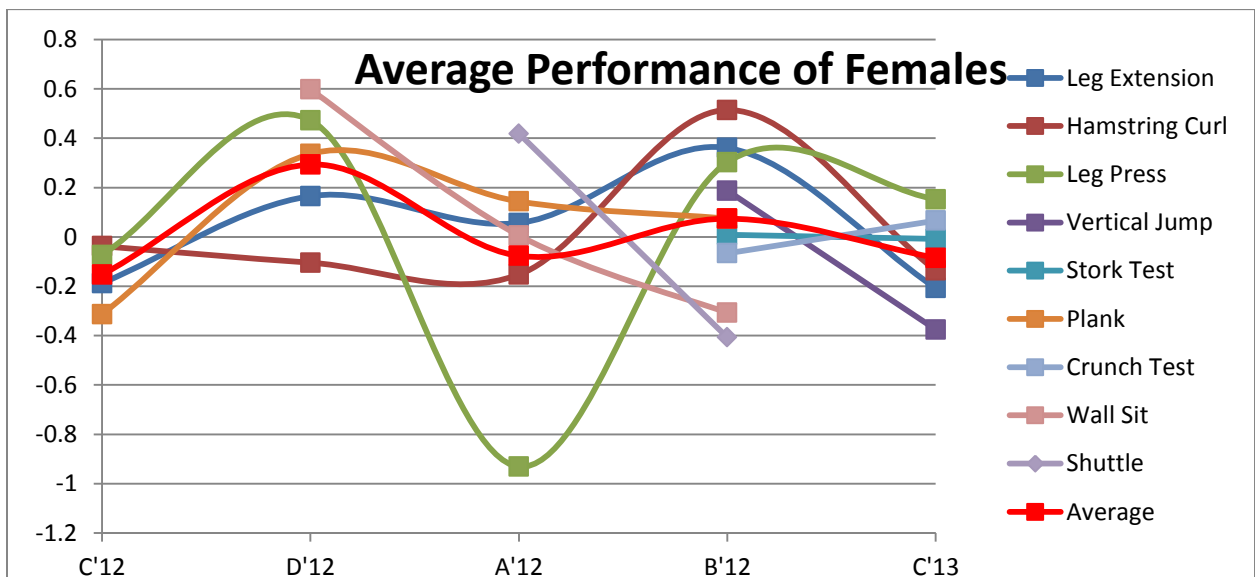


Figure 21: The average difference between and athletes score and their average performance by metric of females.

3.3.2 Injuries

The WPI Ski Team members were monitored for injuries and were interviewed

	12/29/11	1/2/13	12/14/12	12/20/12	2/13/12	12/28/12	1/10/13	1/12/13	3/8/12
	10	2	2	21	13	11	11	15	14
	Knee	Chin	Frostbite	Knee	Knee	Frostbite	Thumb	Knee	Knee
1.1	4	2	2	3	5	3	2	4	5
1.2	2	2	1	2	4	1	3	4	4
1.3	2	3	2	2	4	3	2	3	3
1.4	14	0.5	0.5	2	210	0.5	0.25	60	60
1.5	40	14	10	6	240	30	7	90	90
2.1	1	2	N/A	3	3	N/A	2	3	3
3.1	2	4	4	4	1	2	1	1	2
3.2	1.5	3	5	3	0	5	1.5	1.5	4
3.3	14	22	2	6	60	10	20	13	5
4.1	1	2	2	4	1	1	2	2	2
4.2	12	15	10z	14	12	9	11	9	10
4.3	12	15	10	14	12	9	11	9	10
4.4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure 22: A table summarizing every injury over the testing period.

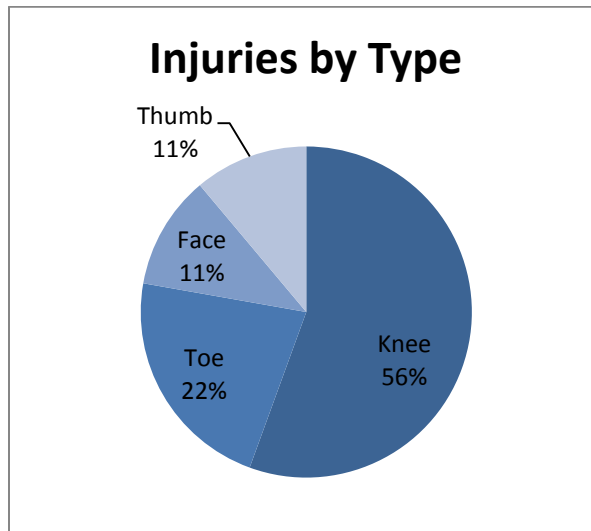


Figure 23: Injuries by body area, the face and thumb injuries were a result of gate impacts during racing and the toe injuries were frostbite related. Knee injuries all occurred during falls, with three out of five occurring in gates training or racing.

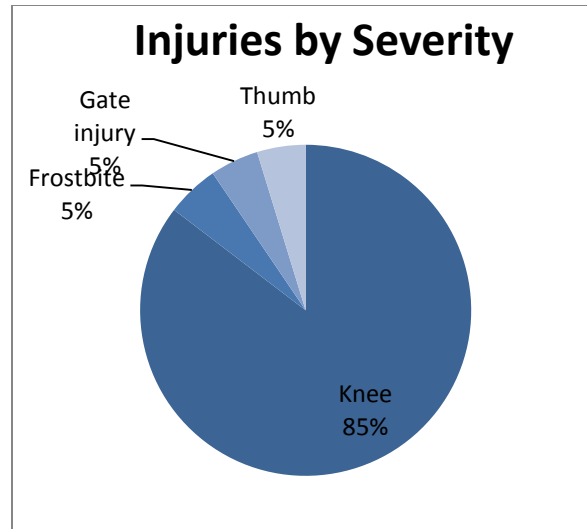


Figure 24: Injuries by severity, although knee injuries accounted for just over half of the incidence, they accounted for 85% of the total injury severity points accumulated score.

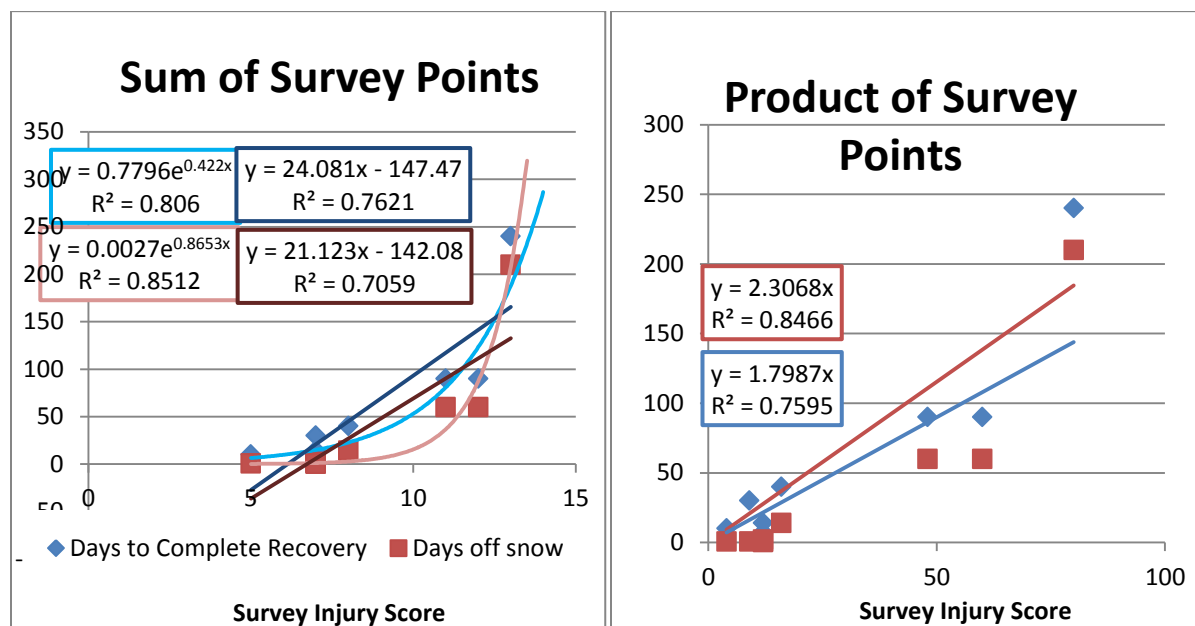


Figure 25: Two tabulations of the survey points are compared against each other for accuracy in predicting the recovery period length for an injury. Days of recovery were plotted on the vertical axis and survey score plotted on the horizontal axis.

3.3.3 Fitness and Injury

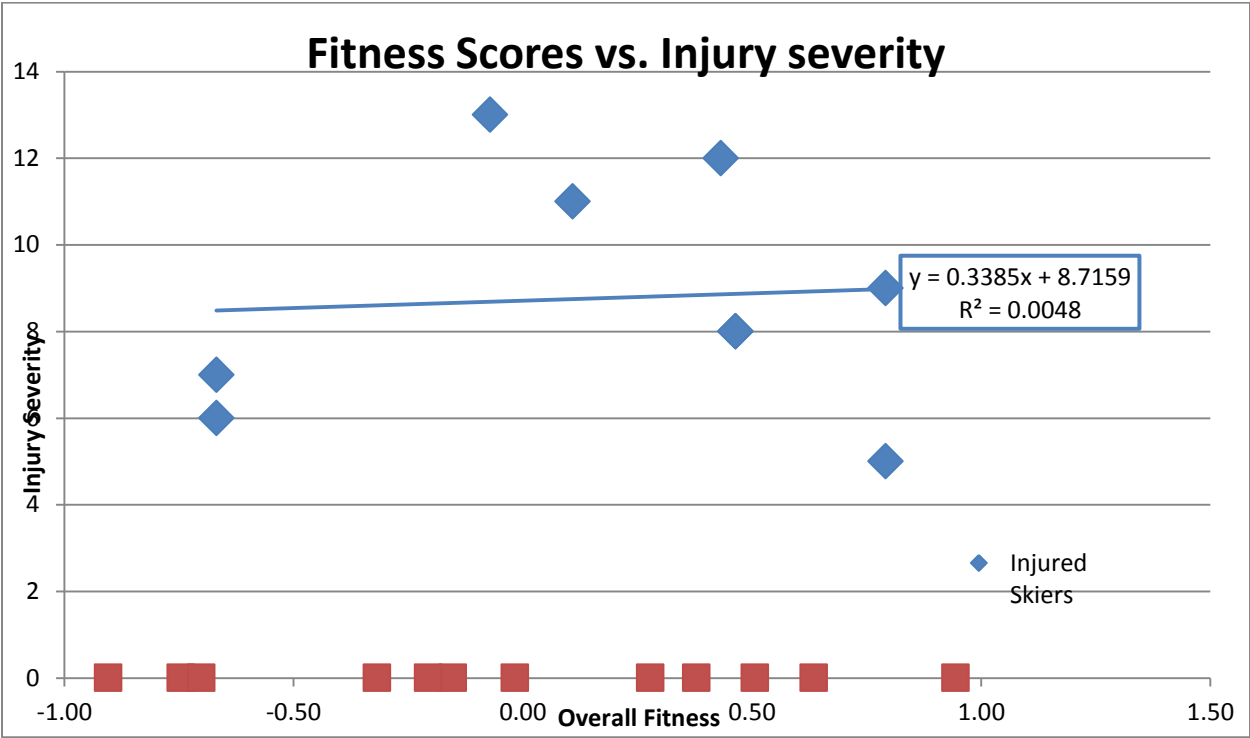


Figure 26: Fitness scores are plotted on the horizontal axis and injury severity is plotted on the vertical axis.

4 Discussion

4.1 Survey Discussion

There is potential for better education to reduce snow sport injuries, however, as a result of not enough responses to the post-season survey, we were unable to draw any conclusions as to whether education reduces injuries.

4.1.1 Total Responses

The total number of responses for each survey shows the level of concern people have for each injury type. A table displaying this data can be seen in Appendix 7.1.1 Survey Results.

4.1.1.1 Head Survey

In the total responses concerning snow sport injuries, there was a high response for the head which means that people are most concerned about head injuries. Since people are most concerned about head safety there should continue to be education on head injury prevention.

4.1.1.2 Knee and Wrist Surveys

There was a moderate response count for knee and wrist surveys. This shows that people are somewhat concerned about knee and wrist injuries, though not as concerned as they are about head injuries. Since people are still concerned about knee and wrist injuries, there should continue to be education about these types of injuries.

4.1.1.3 Thumb Survey

For the thumb survey, there was a low response. The low response shows that people are not as concerned about thumb injuries as they are for head, knee, or wrist injuries. Since people are not as concerned about thumb injuries, they are not as informed and thus should receive more thumb injury education.

4.1.2 Head Survey

Out of all four surveys that were available, the head injury survey received the most responses. A table displaying the data regarding the information obtained from the head survey can be seen in Appendix 7.1.3 Survey Conclusion Table.

4.1.2.1 Types of Head Injuries

Virtually all respondents for the head survey were knowledgeable on the most common type of head injury that exists. This shows that people are concerned about head safety so they learn about it. That being said, it might be beneficial for people to be educated on the second and third most common type of head injury. Overall though, people do not need more education on the most common type of head injury.

4.1.2.2 When to Replace a Helmet

As with the type of head injury, virtually all respondents for the head survey were knowledgeable on when a ski helmet should be replaced. This further shows that people are concerned about head safety so, in order to prevent head injuries, they learn about helmet safety. From this data, it is clear that people do not need more education on when to replace a helmet, but it cannot hurt to remind people of the information.

4.1.2.3 Protective Helmet Qualities

Virtually all of the respondents were knowledgeable on the protective qualities of a helmet. As previously stated, people are concerned about head safety so they make sure they know how to best protect their head. It would not be a bad idea to keep reminding people of the information.

4.1.2.4 Proper Helmet Fit

There was an even distribution of correct and incorrect responses for the question on the proper helmet fit. Only 39% of the respondents got the question correct. People may need more education on the proper fit for a helmet, or the wording of the question and the possible answers were confusing and unclear, which made people respond incorrectly. The latter is probably the case. If a re-test with a re-wording of the question shows that it was the wording that caused people to choose the incorrect answer, then no further education would be needed for proper helmet fit.

4.1.3 Knee Survey

A table displaying the data regarding the information obtained from the knee survey can be seen in Appendix 7.1.2 Survey Discussion Table.

4.1.3.1 Types of Knee Injuries

Of the people who responded to the knee survey, 69% got the question on the most common knee injury correct. The majority of people know the most common knee injury. Despite the fact that the majority of people know the most common type of knee injury, more education is

needed so that everyone is aware of knee injuries. It might also be beneficial for people to be educated on the second and third most common type of knee injury.

4.1.3.2 “Phantom Foot”

There was an even distribution of correct and incorrect responses for the Phantom Foot question in the knee injury survey. A fair amount of people may be unaware of what a “phantom foot” is, or they do not know what conditions cause a Phantom foot. From the results of this question, more education on “phantom foot” is suggested.

4.1.3.3 Risk of Knee Injuries

As with the Phantom Foot question, there was an even distribution of correct and incorrect responses for the question on which types of skiers have the highest risk for knee injuries. People may think that everyone is at an equal risk for knee injuries. More education is suggested on the correlation between skill level and risk of knee injuries based on the results for this question.

4.1.4 Wrist Survey

A table displaying the data regarding the information obtained from the wrist survey can be seen in **Error! Reference source not found.**

4.1.4.1 How to Fall Properly

There was an even distribution of correct and incorrect responses for the question on how to properly fall in order to reduce the risk of a wrist injury. Maybe people are answering how they fall, not how they should fall. Demonstrations on how to fall properly or a video explaining how to fall properly might be helpful in further education.

4.1.4.2 Wrist Guards

For the question regarding wrist guards, there was an even distribution of responses. Out of the people who answered the wrist survey, 54% answered incorrectly for the question about wrist guards. Many people are unaware of snowboarding wrist guards. There should be more awareness for wrist guards for snowboarding.

4.1.5 Thumb Survey

Out of all four surveys that were available, the thumb injury survey received the least amount of responses. A table displaying the data regarding the information obtained from the thumb survey can be seen in **Error! Reference source not found.** 7.1.2 Survey Discussion Table.

4.1.5.1 Causes of Thumb Injuries

All of the respondents were knowledgeable on the causes of thumb injuries. People know the causes of thumb injuries. This may be a display of common sense. As reinforcement, an educational video could be made to show skiers how to correctly put on a pair of ski poles.

4.2 Inadvertent Release Discussion

The analysis of the video obtained by the film study showed a strong correlation between skier ability and inadvertent releases. When reviewing the film, the ability of each athlete was noted. 11 out of 13 recorded inadvertent releases involved skiers classified as “mid-level” skiers, with one classified as “high-level” and one “low-level”. This proportion leads to the conclusion that skier level corresponds to susceptibility to inadvertent release. Although the athletes that experienced inadvertent release were experienced, and often finished in the upper middle end of the pack, they lacked refinement of “proper” ski racing technique. Especially in cases that inadvertent release was observed, the racers were skiing in a noticeably different form than the top racers in the division. Furthermore, it was observed that low level skiers; those with little race training and skiing at much lower speeds, did not sustain inadvertent release. The more conservative skiing style often put the athlete on a much different line than the higher level racers. Although they sustained falls and often were forced to hike a missed gate, these low level athletes were avoiding the terrain features that were causing their faster counterparts to experience inadvertent release. This would lead to the assumption that mid-level skiers are most susceptible to inadvertent release. However, upon further study, this may not be the case. Due to broad skill level of the Thompson Division of collegiate skiing, the skier group seemingly susceptible to inadvertent release may have been over represented in this race.

The method of predicting the locations most likely to cause inadvertent releases was successful. In every race that was filmed, every inadvertent release that occurred was caught on film. Although not every race filmed yielded inadvertent release, the prediction method worked exceptionally well for races in which inadvertent release did occur. In a future iteration of this study, it may be advantageous to film from multiple vantage points. The method of selecting a section to film was successful, however filming was always performed from the bottom of the pitch looking up the hill. In some instances the lighting caused the film quality to be drastically reduced. By setting up a camera at the top of the pitch looking down the hill to compliment the camera at the bottom of pitch, the film reviewer would have an additional perspective on the inadvertent release observed.

At the Cochran’s event, in every single observed inadvertent release incident, the heel piece of the binding was open. This observation is interesting because every inadvertent release observed at this race occurred at the same gate. This shows that the hole had a similar effect on

the equipment of each athlete who experienced an inadvertent release. Each of these athletes had four things in common: the location of the inadvertent release, skier ability, the downhill ski was lost, and the heel piece of the binding was open. The identical conditions of each observed inadvertent release leads one to believe that these conditions are present in most cases of inadvertent release. The hole itself should be subject to further discussion as well. This particular terrain feature caused every inadvertent release as well as several more falls. When a large terrain feature such as this causes an inadvertent release, it should be immediately inspected and adjusted by the course crew in order to reduce the risk of injury to athletes. Race directors should be trained to properly identify potentially problematic terrain features and use their authority to place a course hold until the terrain feature is fixed. This was an action that did not take place. Although a course crew was present, any attempt to modify the hole was neglected, even after such a high number of inadvertent releases occurred. Unfortunately, this study neglects to cite how many athletes did not fall victim to inadvertent release through the same gate. In a future iteration of this study start lists should be taken advantage of to allow for accurate statistical analysis.

Another observation made by this study is that some bindings could be more susceptible to inadvertent release than others. The majority of athletes experiencing inadvertent release were using either one of two manufacturers of bindings. However, this may be attributed to the majority of the athletes in the study using one of these types of bindings. In a future study modeled after this one, it could prove a valuable observation to record every athlete's equipment towards the beginning of the season to determine the frequency of certain manufacturers in the division being studied.

Due to this being the first iteration of this study, there were issues that arose that affected the original proposed structure of the study. Filming was directed by one individual on the WPI ski team and volunteers from the team performed the filming when the director had to race. This format for filming was inconsistent, as the director's instructions may not have been properly passed to later volunteers. In a future iteration of the study, the filming crew should consist of at least two individuals not competing in the event. Another proposition is to have a third member from the group to track down and personally interview each athlete that is suspected to have had an inadvertent release. This would improve the reliability of the data collected by this test and allow for additional athlete information to be collected that may factor into the mechanics of an inadvertent release.

4.3 Fitness-Injury Discussion

4.3.1 Fitness

The fitness test developed this year was an interesting combination of metrics and changed several times to reflect the challenges of certain metrics. These iterations produced a test that better measures athlete ability and fitness, although the challenge of small sample size and participant dropout rates made this difficult to quantify at times. Future studies should focus on expanding the sample size by both adding college ski teams and increasing participation rates within those teams.

One of the objectives of the test was to accurately measure the fitness of athletes with good repeatability. An ANOVA test of athlete score can determine repeatability if one assumes athletes maintain a smaller variation in their fitness levels than the variation present in the population being studied. In our testing we found that athletes tended to maintain their rank and average score for some metrics while other metrics were not repeatable. Metrics that could be found in the literature were favored for inclusion in the fitness test over novel metrics that we developed. Problems arose in each metric during testing and some metrics were discontinued or replaced in subsequent tests. A review of the pros and cons for each metric is therefore an important part of this study.

Individual Overall Score

Hamstring to Quadracep Strength Ratio

The hamstring to quadracep ratio was measured using an isotonic cable type leg extension and hamstring curl machine. This differs from the standard method of using an isokinetic dynamometer, however the cost and accessibility of these machines was considered incompatible with the goal of the fitness test to be accessible to the widest possible audience. Thus the more common cable type machines were used and our analysis showed that they were

Metrics and the Fitness Test Over Time

Performance is more robust against sampling bias when compared to a simple average of the metric scores for each test because different athletes are present in the data for different tests, and essentially looking at the average metric score depends more on who took the test than how athlete's fitness changes over time. The men displayed an expected large divergence in performance in the last two tests. This is especially interesting because it is not just the newer metrics that varied; the oldest metrics showed quite a bit of divergence from the expected

value as well. This trend was not present in the female data so it is possible that it was just an artifact in the data

Leg Extension

The leg extension is one of three tests that require gym equipment. This was included in the first iteration of the test to measure quadriceps strength in athletes. This was done so that the quadracep to hamstring strength ratio could be found. This test had the advantage of being easily standardized because the machine restricted movement to the one dimension and defining what constituted a lift was well recognized and was repeatable in the population. The test was not very adaptable or generalizable to other teams because each machine has a different weight profile and had different systems of reporting resistance. The test on which the machine was changed over the summer between D'12 and A'12 due to the opening of the new gym facilities at WPI.

Hamstring Curl

The hamstring curl is another original metric and also requires a dedicated isotonic gym machine. The hamstring is the agonist pair to the quadracep in flexion of the knee so the quad/hamstring ratio is supposed to prevent injury when the muscles are balanced. The same points from the leg extension apply here with respect to the ease of standardization in procedure but problems with consistency of equipment.

Leg Press

The leg press was found to have good repeatability and was even found to have a negative correlation with injury severity. One issue with the test is that it required specialized gym equipment; however the leg press machine is widely available at most gyms and is fairly standardized.

Vertical Jump

Included in the last two repetitions of the test, one issue with the vertical jump was marking the stand height before the jump. The accuracy of this measurement was a limiting factor for this test and should have an improved method developed for future testing. The coefficient of variation was fairly low for both males and females.

4.3.2 Injury survey

An objective of this project was the development of an injury survey to measure the severity of an injury and determine contributing factors in the injury. The survey we created based on

athlete perceived injury levels on a 0-5 scale correlated well with existing metrics for injury severity.

There were a total of nine injuries observed over two seasons. Observed injuries were mostly knee related (56%) followed by frostbite (22%) and there was one injury of both chin and thumb (11%). The knee injuries were the most severe injury, accounting for 85% of the accumulated injury severity points with an average severity four times greater than an average non-knee injury.

The sum of the three injury severity questions (left) were tabulated for a score 0-15. This could best be fitted by an exponential curve. The product of the survey points (right) was found to fit the data almost as well with a simple one parameter linear fit.

4.3.3 Fitness and Injury

There was a slight positive correlation between fitness and injury. This is most likely because of the very small sample size and the number of injuries seen. In coming years as more data becomes available, the correlation should become apparent.

5 Conclusion

5.1 Survey Conclusion

The original objective, to see if education can reduce skiing and snowboarding injuries, was unable to be measured due to lack of post-season survey responses. There was a high response rate for the pre-season survey for which there were a total of 257 responses. While no conclusions can be made whether education can reduce snow sport injuries, conclusions can be made about what topics people knew more about and what topics we suggest people have more education about. Conclusions can also be made, based on the number of responses for each survey, on which injury type people thought was more important to be educated about.

5.1.1 Total Responses

The total number of responses for each survey shows the level of concern people have for each injury type. A table displaying this data can be seen in **Error! Reference source not found.** 7.1.3 Survey Conclusion Table. People are most concerned about head information and least concerned about thumb information.

5.1.2 Head Survey

Out of all four surveys that were available, the head injury survey received the highest amount of responses. A table displaying the data regarding the information concluded from the head survey can be seen in Appendix 7.1.3 Survey Conclusion Table.

5.1.2.1 Types of Head Injuries

People know about the most common type of head injury.

5.1.2.2 When to Replace a Helmet

People know when to replace their helmet.

5.1.2.3 Protective Helmet Qualities

People know about the important qualities of a helmet.

5.1.2.4 Proper Helmet Fit

People may not know about proper helmet fit, but no conclusion can be made due to confusing wording of the question.

5.1.3 Knee Survey

A table displaying the data regarding the information concluded from the knee survey can be seen in **Error! Reference source not found.** 7.1.3 Survey Conclusion Table.

5.1.3.1 Types of Knee Injuries

The majority of people know about the most common knee injury. Some people do not know about the types of knee injuries.

5.1.3.2 “Phantom Foot”

The majority of people do not know about “phantom foot”.

5.1.3.3 Risk of Knee Injuries

Half of the survey respondents do know the types of skiers who have the highest risk for knee injuries.

5.1.4 Wrist Survey

A table displaying the data regarding the information concluded from the wrist survey can be seen in Appendix 7.1.3 Survey Conclusion Table.

5.1.4.1 How to Fall Properly

Half of the survey respondents do not know how to fall correctly.

5.1.4.2 Wrist Guards

People do not know about wrist guards.

5.1.5 Thumb Survey

Out of all four surveys that were available, the thumb injury survey received the least amount of responses. A table displaying the data regarding the information obtained from the thumb survey can be seen in Appendix 7.1.3 Survey Conclusion Table.

5.1.5.1 Causes of Thumb Injuries. People know the causes of thumb injuries.

5.2 Inadvertent Release Conclusion

5.2.1

Skiers that are more susceptible to inadvertent release are mid/high to mid/low level skiers.

5.2.2

It is possible to predict the most likely location of an inadvertent release on the hill.

5.2.3

Some Inadvertent releases are caused in part by terrain features, specifically holes and chatter, which can be prevented through proper course maintenance.

5.2.4

Some Inadvertent releases are caused in part by skiing technique.

5.2.5

A more intensive study is necessary to draw more precise conclusions regarding the mechanisms of inadvertent release.

5.3 Fitness-Injury Conclusion

5.3.1

The one leg balance test and the wall sit were best correlated with overall fitness, but other metrics were not predictive of overall score.

Individuals overall scores differed from the overall distribution by a significant amount and showed good repeatability.

5.3.2

The survey questions aimed at determining injury severity were good predictors of how long the injury recovery period was.

5.3.3

There was no good correlation between fitness and injuries, although this is primarily because not enough injuries were captured by the study to see the effect of fitness on injury.

6 References

- Pure Lateral*. (2013). Retrieved February 6, 2013, from KneeBinding: <http://kneebinding.com/KB-Product-PureLateral.aspx>
- Ackery, A. H. (2007). An international review of head and spinal cord injuries in alpine skiing and snowboarding. *Injury Prevention*, 13(6), 368-375.
- Ahlbaumer, G. (2012). *Biomex Protection Systems*. Retrieved January 1, 2013, from Snowboard: www.biomex-protection.com/snowboard/snowboard_gloves.html
- Brown, C. A. (2006). *Axiomatic Design and the Evolution of Conventional Alpine Ski Bindings*. Retrieved March 8, 2013, from Axiomatic Design: <http://www.axiomaticdesign.org/docs/AxiomaticDesignandSkiBindings.pdf>
- Flexmeter. (2013). *Flexmeter Snowboard Wrist Guards*. Retrieved May 1, 2013, from Snowboard Protection Shop: <http://www.wrist-guard.com/#>
- Heim, D. (1999). The skier's thumb. *Acta Orthopaedica Belgica*, 65(4), 440-446.
- Heneved, E. (2002). Skiing and Snowboarding Injuries in the Year 2000. *Wilderness Medical Letter*, 19(2).
- Howell, R. (2012, July 16). (J. Lagassey, & B. Merrill, Interviewers)
- Julich, U. (2012). *Fitness Testing Assingment: Alpine Skiing*. Bently, AU: Curtin University School of Physiotherapy.
- Kinetic Innovations Ltd. (2013). *Ski~Mojo*. Retrieved April 17, 2013, from Power Assisted Skiing: <http://www.skiallday.co.uk/sm/>
- Langran, M. (2012). Retrieved May 2, 2013, from Ski-Injury: www.ski-injury.com
- Langran, M., & Selvaraj, S. (2002). Snow Sports Injuries in Scotland: a Case-Control Study. *British Journal of Sports Medicine*, 135-140.
- Levy, A., Hawkes, A., Hemminger, L., & Knight, S. (2002). An analysis of head injuries among skiers and snowboarders. *The Journal of Trauma*, 695-704.
- Raschner, C., Platzer, H., Patterson, C., Werner, I., & Hildebrandt, C. (2011). The relationship between ACL injuries and physical fitness in junior austrian alpine ski racers – a 10 year longitudinal study. *British Journal of Sports Medicine*, 310-311.
- Siegel, J. H., Gens, D. R., Mamantov, T., Geisler, F. H., Goodarzi, S., & MacKenzie, E. J. (1991). Effect of associated injuries and blood volume replacement on death, rehabilitation needs, and disability in blunt traumatic brain injury. *Critical Care Medicine*, 19(10), 1252-1265.

Sulheim, S. M., Holme, I. P., Ekeland, A. M., & Bahr, R. M. (2006). Helmet use and risk of head injuries in alpine skiers and snowboarders. *Journal of the American Medical Association*, 29(8), 919-924.

Troy Hawks. (2012, October 1). *NSAA Fact Sheet*. Retrieved December 4, 2012, from nsaa.org:
<https://www.nsaa.org/media/68045/NSAA-Facts-About-Skiing-Snowboarding-Safety-10-1-12.pdf>

U.S. Consumer Product Safety Commission. (1999). *Skiing helmets an evaluation of the potential to reduce head injury*. Washington D.C.: United States Government.

7 Appendices

The appendixes from the three studies are included below

7.1 Survey Appendixes

7.1.1 Survey Results

Head Injury Survey		
Number of records in this query: 116		
Total records in survey: 116		
Q1. What is the most common type of head injury?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Internal bleeding	2	1.72%
Concussion	114	98.28%
Traumatic brain injury	0	0.00%
Skull fracture	0	0.00%
Q2. What is not the proper fit for a helmet?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Snug but not tight	28	24.14%
No gap between top of goggles and helmet	14	12.07%
Back of helmet should touch back of your neck	45	38.79%
No gaps between head and helmet lining	29	25.00%
Q3. When should you consider replacing a helmet?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
It is a few years old	56	48.28%

It doesn't fit correctly anymore	109	93.97%
After a mild impact (collision or short fall)	45	38.79%
After a significant impact (hard collision or severe fall)	103	88.79%
The chinstrap no longer functions properly	102	87.93%
Q4. Which two qualities should influence your choice of which protective helmet to purchase?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Material satisfaction - how well the helmet will retain its physical appeal after a collision	23	19.83%
Impact management - how well the helmet protects the wearer in collisions with large objects	114	98.28%
Retention system strength - whether the chinstraps are strong enough to hold onto the helmet during a collision	82	70.69%
Weight management - whether the weight of the helmet causes unnecessary injury	56	48.28%

Knee Injury Survey		
Number of records in this query: 65		
Total records in survey: 65		
What percentage of ski injuries are knee-related?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
5 - 15%	2	3.08%

20 - 25%	18	27.69%
30 - 35%	33	50.77%
70 - 80%	15	23.08%
What is the most common knee injury?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
ACL Tear	45	69.23%
MCL Tear	5	7.69%
PCL Tear	0	0.00%
Torn cartilage	15	23.08%
Which of the following conditions could cause a "Phantom foot"?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Foot falling out of boot	15	23.08%
Hips fall below knee, causing the uphill ski to be unweighted and all weight on the downhill ski.	39	60.00%
Upper body moves down the hill, while the downhill ski abruptly carves off to the side.	40	61.54%
What is the recommended technique when falling?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Lean back and regain control using the tails of the skis	17	26.15%
Sit on the tails of the skis, have tips of skis point back downhill	8	12.31%
Draw your limbs closer to your body and do not attempt to	53	81.54%

stand up; skis preferably downhill from your body		
Which types of skiers are at the highest risk for knee injuries?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Beginners (first week on snow)	29	44.62%
Intermediate	23	35.38%
Advanced	23	35.38%
Racers	39	60.00%
Freestylers	44	67.69%
Which of the following devices have claimed to significantly reduce knee injuries?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
KNEE binding	47	72.31%
Ski Mojo	19	29.23%
LEKI Trigger S	18	27.69%
Poc Spine Ergo	9	13.85%

Wrist Injury Survey		
Number of records in this query: 46		
Total records in survey: 46		
Q1. Which of the following is the proper way to fall in order to prevent wrist injuries?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Keep hands in a fist	1	2.17%

In a forward fall; land on forearms, not hands	6	13.04%
In a forward fall; land on knees	2	4.35%
In a backwards fall; fall on bottom, not hands	7	15.22%
Tuck arms into chest	4	8.70%
All of the above	26	56.52%

Q2. What are the positives of wearing wrist guards?

<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Reduce the risk of hand injuries	0	0.00%
Reduce the risk of forearm injuries	0	0.00%
Reduce the risk of wrist injuries	20	43.48%
All of the above	26	56.52%

Q3. What properties provide maximum protection in a wrist guard?

<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Have rigid inserts	25	54.35%
Have protection along the back of the wrist	32	69.57%
Extend up the length of the forearm	13	28.26%
Extend only a few inches up the forearm	25	54.35%
Have some degree of flexibility	35	76.09%

Q4. What type of snowboarders are more likely to sustain a wrist injury?

<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
---------------	--------------	-------------------

Low experience; first week on snow	24	52.17%
Moderate experience; hit the slopes every now and then	17	36.96%
High experience; regular snowboarder	5	10.87%

Thumb Injury Survey		
Number of records in this query: 30		
Total records in survey: 30		
Q1. What are some causes of thumb injuries?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Falling down with pole strap around thumb	0	0.00%
Not using ski poles correctly	0	0.00%
Trying to brace impact with ground while ski poles are still engaged	0	0.00%
All of the above	30	100.00%
Q2. Which group of participants are more likely to sustain a thumb injury?		
<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Skiers	22	73.33%
Snowboarders	2	6.67%
Both	4	13.33%
Neither	0	0.00%
Don't know	2	6.67%
Q3. What is the recommended way to reduce the likelihood of a thumb injury?		

<i>Answer</i>	<i>Count</i>	<i>Percentage</i>
Putting hands over and through pole straps	8	26.67%
Putting hands under and through pole straps	15	50.00%
Don't use ski poles	7	23.33%

7.1.2 Survey Discussion Table

Survey Type	Topic	Result	Discussion	More education?
Total responses	Injury concern.	High response for head.	People are most concerned about head injuries.	Since people are most concerned about head safety there should continue to be education on head injury prevention.
	Injury concern.	Moderate response count for knee and wrist surveys.	People are semi concerned about knee and wrist injuries, though not as concerned as they are about head injuries.	Since people are still concerned about knee and wrist injuries, there should still be education about these types of injuries.
	Injury concern.	Low response for the thumb survey.	People are not as concerned about thumb injuries.	Since people are not as concerned about thumb injuries, they are not as informed and thus should receive more thumb injury education.
Head	Type of head injury.	Virtually all were	People are concerned about head safety so	It might be beneficial for people to be

		knowledgeable.	they learn about it.	educated on the second and third most common type of head injury.
	When to replace a helmet.	Virtually all were knowledgeable.	People are concerned about head safety so they learn about helmet safety.	No, but it cannot hurt to remind people of the information.
	Protective helmet qualities.	Virtually all were knowledgeable.	People are concerned about head safety so they make sure they know how to best protect their head.	No, but it cannot hurt to remind people of the information.
	Proper helmet fit.	Even distribution of responses. 39% got it right.	People may need more education on the proper fit for a helmet or the wording of the question and the answers was confusing and unclear which made people respond incorrectly. The latter is probably the case.	If a re-test with a re-wording of the question shows that it was the wording that caused people to choose the incorrect answer, then no further education would be needed.
Knee	Most common knee injury.	69% got it right.	Majority know the most common knee injury.	More education so that everyone is aware of knee injuries. It might also be beneficial for people to be educated on the second and third most common type of knee injury.
	“Phantom foot”	Even distribution of	A fair amount of people maybe are unaware of	More education on “phantom foot” is

		responses.	what a “phantom foot” is or they do not know what conditions cause a Phantom foot.	needed.
	Types of skiers having the highest risk for knee injuries.	Even distribution of responses.	People think everyone is at equal risk for knee injuries.	More education is needed on the correlation between skill level and risk of knee injuries.
Wrist	How to fall properly.	Even distribution of responses.	Maybe people are answering how they fall, not how they should fall.	Demonstration or video might be helpful in further education.
	Wrist guards	Even distribution of responses. 54% answered incorrectly.	Many people are unaware of snowboarding wrist guards.	There should be more awareness for wrist guards for snowboarding.
Thumb	Causes of thumb injuries.	All were knowledgeable.	People know the causes of thumb injuries. This may be a display of common sense.	As reinforcement, an educational video could be made to show skiers how to correctly put on a pair of ski poles.

7.1.3 Survey Conclusion Table

Survey Type	Topic	Knowledge gage	More education needed?	Conclusion
Total	Concern	-116 head responses	Yes	People are most concerned

responses		-65 knee responses -46 wrist responses -30 thumb responses		about head information and least concerned about thumb information.
Head	Type of head injury.	Virtually all were knowledgeable.	No	People do not need more education on the most common type of head injury.
	When to replace a helmet.	Virtually all were knowledgeable.	No	People do not need more education on when to replace their helmet.
	Protective helmet qualities.	Virtually all were knowledgeable.	No	People do not need more education on important helmet qualities.
	Proper helmet fit.	Even distribution of responses. 39% got it right.	Maybe	No conclusion due to confusing wording of the question.
Knee	Most common knee injury.	69% got it right.	Some	People do not need a much more education on the most common knee injury.
	“Phantom foot”	Even distribution of responses.	Yes	People need more education on “phantom foot”
	Types of skiers having the highest risk for knee injuries.	Even distribution of responses.	Yes	People need more education on the types of skiers who have the highest risk for knee injuries.
Wrist	How to fall	Even distribution of	Yes	People need to be taught how

	properly.	responses.		to fall correctly.
	Wrist guards	Even distribution of responses. 54% answered incorrectly.	Yes	People need to be taught about wrist guards.
Thumb	Causes of thumb injuries.	All were knowledgeable.	No	People know the causes of thumb injuries.

7.1.4 Website

Website development rationale

In order to obtain our objective of reducing the amount of ski and snowboard injuries we will use a website, hurtskiing.com, to reach out and educate these snow sport participants. The website will be broken down into five different sections: Fitness, Inadvertent Release, Head Injuries, Upper Body Injuries, and Lower Body Injuries.

We will be using a basic layout for the webpage starting with an eye-catching homepage welcoming visitors, with links to different webpages devoted to the education of each major section. Images will be present in order to have more aesthetically pleasing webpages. The majority of the information within the pages will be bullet-point format to create the appearance of less reading so that the reader will be less likely to give up reading as a result of too much text.

The webpages will also feature surveys and questionnaires available for the website visitors to complete, so that we can observe the knowledge base of the respondents. Within the surveys, if the participant answers an injury knowledge question wrong, the participant will have the option to be redirected to an informational page specifically related to the question that was answered incorrectly. We will also have explanations next to each question asked in order to increase transparency with the user. This allows the survey participants a chance to educate themselves and understand how the questions affect them.

The specific informational pages will include images and the text will be in bullet-point format to encourage the surveyor to read the entirety of the page. These bulleted points will create a “safety guide” that will be eye catching and filled with easy to remember safety tips. Each of the different sections “safety guides” will then be compiled to create one single ski safety informational guide.

7.2 Inadvertent Release

A table of all observed inadvertent releases

Ski lost	Skier Level	Terrain feature	technique	bib #/gender	mountain	ir?
downhill	mid	hole	inside ski	15f	cochrans	y
downhill	mid	hole	even	16f	cochrans	y
downhill	mid/high	hole	downhill	18f	cochrans	n
downhill	mid	hole	even	10f	cochrans	y
downhill	mid/high	hole	even	71m	cochrans	y
downhill	mid	hole	even	82m	cochrans	y
downhill	mid/high	hole	downhill+lean	23m	cochrans	y
downhill	mid/low	hole	inside ski	7m	cochrans	y
downhill	high	hole	downhill	28m	cochrans	y
downhill	mid/high	chatter	inside ski	m	dartmouth	y
downhill	mid/low	chatter	even	f	dartmouth	y
downhill	mid/high	chatter	even	m	dartmouth	y
downhill	low	chatter	inside ski	m	dartmouth	y
downhill	mid	chatter	even	f	dartmouth	y

7.3 Fitness and Injury Appendices

7.3.1 Fitness testing instructions and procedures

WPI Ski Team Fitness Test Metrics - guidelines and instructions as issued to testing personnel and subjects [=] unit of measurement

Leg Extensions

- Sit down in seat with back flat against the seat
- Adjust seat position and place legs in proper position (legs bent over edge of seat, lower front tibia pressed against extension mechanism)
- Extend legs, keeping back of knees touching the edge of seat (which helps isolate the quad muscle)
- Go for 1RM (1 repetition maximum weight)

Hamstring Curls

- Sit down in seat with back flat against the seat
- Adjust seat position and place legs in proper position (back of knee touching edge of seat, lower calf/Achilles tendon on curling mechanism)
- Curl legs underneath the seat, until their position is directly beneath you, then return to starting position in a slow and controlled manner
- Measure the score by 1RM (1 repetition maximum weight)

Leg Press

- Adjust the bar catches on the leg press machine so legs can bend to slightly more than 90°
- Load weight onto leg sled such that 3-6 reps can be completed before exhaustion
- When lifting, disengage bar catches and lower weight in a controlled flexion and then a controlled extension

Vertical Jump

- Subject stands next to a wall and reaches up with the hand closest to the wall

- Keeping the feet flat on the ground, the point of the fingertips is marked or recorded
- Then the athlete then stands away from the wall, and leaps vertically as high as possible using both arms and legs to assist in projecting the body upwards
- Counter movements are not allowed
- Attempt to touch the wall at the highest point of the jump
- The best of three attempts is recorded
- The difference in distance between the standing reach height and the jump height is the score

Stork Test

- Remove shoes and place hands on hips
- Position the non-supporting foot against the inside knee of the supporting leg
- Subject raises the heel to balance on the ball of the foot. The stopwatch is started as the heel is raised from the floor
- If hands come off the hips, the supporting foot swivels or moves in any direction, the non-supporting foot loses contact with the knee, or the heel of the supporting foot touches the floor, the time stops
- Go for the longest time (measured in seconds)

One Leg Test

- Subject should stand on one leg, foot flat and eyes closed
- No hopping or shifting is allowed but the athlete can move the upper body as much as needed
- Both legs should be tested

Plank –

- Lay face down on a hard surface
- Get in normal pushup position (propped up by toes and arms)

- Lower yourself onto your elbows and straighten your back
- Hold for as long as possible (measured in seconds)

Crunch Test

- Lie on a carpeted or cushioned floor with your knees bent at approximately right angles
- Place feet flat on the ground and have hands resting on your thighs
- Squeeze stomach muscles, push your back flat and raise high enough for your hands to slide along your thighs to touch the tops of your knees, count only reps where the top of the palm touch the top (highest point relative to the ground in the crunch position) of the knee.
- Return to the starting position, complete as many as possible

Wall Sit

- Subject has back facing a wall Bending knees and leaning backwards causes the subject to suspend his or herself from the ground, with the back as the only point of contact with the wall
- Legs must be at ≥ 90 degrees to be considered a wall sit
- Go for longest time (measured in seconds)

Shuttle Run

- Place two shuttles, such as a 6" gate section, 30 ft from the start/finish line and one foot apart
- The tester counts down 3-2-1-go and the runner runs to the shuttle, grabs it and runs back, touching the start/finish and releasing the shuttle, then sprinting back to the next shuttle and then sprinting through the finish

400 meter

- The 400 meter sprint follows the same race rules for track and field
- The timer counts down 3-2-1-go and the subject(s) run around a standard 400 meter track as fast as possible.

Bancroft

- The Bancroft run is a road track in Worcester that starts at the corner of Russel St and Institute Rd and finishes at Bancroft tower, the timer is at the finish and starts the clock via a telephone call to the runners at the start.

7.3.2 Injury Survey

What level on a 0-5 scale did the injury affect the athlete's ability to participate in normal skiing training, and racing activities?

1 - Minimal effect, perhaps slight pain or slight discomfort while training, no significant effect on performance.

3 - Substantial effect, must take time off from gate training and/or limited to cautious skiing.

5 - Maximum effect, physically unable to ski or participate in any training activity.

What level on a 0-5 scale did the injury affect the casualty's ability to perform basic daily tasks?

1 - Minimal effect, perhaps slight pain or slight discomfort while using the injured appendage.

3 - Substantial effect, limited use of injured appendage and assistance required for some tasks.

5 - Maximum effect, physically unable to perform basic tasks, maximum assistance required.

What level on a 0-5 scale of care or attention to the injury was required to resolve injury?

1 - Minimal level, basic self-applied treatment minimal effort required for care.

3 - Substantial level, examples include; several days of rest, constant icing, significant bandaging.

5 - Maximum level, multiple day hospitalization and/or intensive care

How many days of recovery were taken before the athlete was ready to return to skiing?

How many days of recovery were needed before the injury was fully recovered?

Please identify the mechanism of injury below

Collision with other skier/rider
Collision with stationary object
ACL phantom foot mechanism
ACL BIAD type injury
Toe non-release tibia fracture
Inadvertent release associated
Skiers thumb
Racing equipment related (gate impacts)
Jump related falling injury
Other (explain)

Environmental Conditions

2.1 What level on a 0-5 scale was the estimated grade (steepness) of the trail where the injury occurred?

- 1 - Minimal slope, skating or poling required move but some slope does exist
- 3 - Average slope, typically blue square difficulty.
- 5 - Maximum slope, very steep, typically double black diamonds.

2.2 What item from the following list best describes snow conditions at the time of the injury?

Ice
Hard packed snow
Fresh loose snow
Granular
Crud

Wet water saturated
Other

2.3 What, if any, unique environmental risk factors were associated with the injury?

Flat light
Fog that reduces visibility
Uncontrolled skier crossing
Other (explain)

Skier Fatigue

3.1 What level on a 0-5 scale did the athlete perform a series of stretches and/or warm-up?

- 1 - Minimum warm-up, no dedicated stretches, skiing only.
- 3 - Substantial warm-up stretches completed at regular intervals throughout the day.
- 5 - Maximum warm-up, athlete stretches every skiing run and warms up before training runs.

3.2 How many hours of skiing did the causality complete that day before the injury occurred?

3.3 How many consecutive days of skiing did the casualty complete before the injury?

Equipment Used

4.1 What level on a 0-5 scale was wear or damage was present in the boot and binding?

- 1 - Minimal damage, slight wear or superficial damage
- 3 - Substantial damage, some wear on boot sole edges rounded, bindings may be under lubed.
- 5 - Maximum damage, boots severely worn, bindings unable to retain boots or never release.

4.2 What was the release indicator (DIN) setting on the toe piece of the binding?

4.3 What was the release indicator (DIN) setting of the heel piece of the binding?

4.4 Were the release indicator settings the same on both skis? Note any differences.