An Epidemiologic Investigation of Snowboarding Injuries: Rates and Risk Factors

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ABSTRACT

This thesis study employed epidemiologic methods to investigate snowboarding injuries and, where appropriate, included alpine skiing injuries. There were two components: a descriptive component and an etiologic component. The injuries were described as proportions of the total number of respective sports injuries. Crude, specific and standardized injury rates were calculated. A variant of the case-control design was then used to identify potential risk factors for the more severe snowboarding injuries.

This project built upon previous studies and contributes to the growing body of knowledge regarding snowboarding injuries. The large sample size provided statistical power often lacking in other studies. This project investigated 2,501 snowboarding injuries experienced at 71 ski centres across the province of Quebec during the 1996/97 ski season.

The descriptions of snowboarding injuries in this project reinforce what has been published. However, the additional information provided by the participation data permits assessment of age and sex distributions in the injured sports enthusiasts. Previous descriptive studies suggest that snowboarding injuries most often involve young males. Chi-square tests were conducted between the injured snowboarders and injured alpine skiers and the respective sports participants. The results suggested that males were over-represented in snowboarding injuries and females were over-represented in alpine skiing injuries. The younger age groups (12-17 years and 18-24 years) were over-represented in the snowboarding injuries and older alpine skiers (over age 50) appeared to be at increased

risk for injury. The standardized injury rates, adjusted for the differing age and sex distributions in the two sports, suggested that the risk for snowboarding injury is 1.5-2.0 times that of the risk for alpine skiing injury.

In this study, the proportions of snowboarding injuries and body part affected were within the ranges of previous studies. Of the severe snowboarding injuries (those that would require medical attention), 69.2% were to the head and neck, 19.7% were to the torso, 8.5% were to the upper limbs and 2.6% were to the lower limbs. This suggests an increased number of injuries to the head and neck and torso and a lower number of injuries to the extremities in snowboarders who suffer more severe injuries. At 2.5, the upper:lower limb ratio for this study was also within the range calculated for previous studies.

Proportional Injury Ratios (PIRs) were calculated for the nature of injury and body part to further explore snowboarding injuries. The PIRs were adjusted for age and sex for each sport. Results reinforced the descriptive statistics that injured snowboarders are more likely to experience injuries to the upper limbs (2.06 times), specifically the wrist (7.06 times), compared with injured alpine skiers. However, there is a level of uncertainty regarding the interpretation of these differential risks.

Ability or skill level appears to be a key risk factor for severe snowboarding injuries. Those of lower ability levels are at twice the risk for severe snowboarding injury compared with those of higher ability levels. However, younger snowboarders may be at reduced risk for severe injury compared with older snowboarders and riding blue/difficult trails may pose a reduced risk for injury compared with the double diamond/most difficult trails. There may be an increased risk for injury on certain days.

Due to the exploratory nature of these analyses, the results warrant further investigation. Future studies should replicate these findings, in particular, those that have not been previously published. Furthermore, future work should include an uninjured comparison group of snowboarders. Appropriate designs could include case-control studies, case-crossover, cohort or nested case-control studies.

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1.0 BACKGROUND & RATIONALE

This study is an epidemiologic investigation of snowboarding injuries. Snowboarding as a sport and recreational activity has revitalized ski centres around the world. As with all sports, there is a risk for injury. This study examines those injuries and the potential risk factors for severe snowboarding injury.

There are two parts to this background section: the first provides a summary of injuries, sports participation and sports injuries in Canada. The second part states the rationale for this thesis project. It will be shown that injuries are a public health concern, sports participation poses an increased risk for injuries and the risk for injury is higher in some sports, for example, alpine skiing. It is believed that the recent increase in the popularity of snowboarding will contribute to the risk for sports injuries. Research in the area of snowboarding injuries is limited by the newness and rapid evolution of the sport.

1.1 The Study of Injuries

Prior to its study, the concept of injury needs to be defined operationally. A broad definition of injury will be introduced and approaches to injury prevention and control will be described.

Injury is commonly defined as damage to the body caused by energy transfer beyond the body's resilience or threshold.[1] The energy can be of five types: mechanical, thermal, electrical, chemical or from ionizing radiation. Injuries may also result from toxicity or deprivation. Examples of these are poisonings and suffocation respectively.

A pyramid is often used to characterize injuries, illustrating the inverse relationship between the frequency and severity of injuries. Figure 1 is an example of an injury pyramid. The severity of injury generally decreases as the frequency of injury increases. For every death due to injury in Canada, there are an estimated 21 hospitalizations and 320 emergency department visits which result from injury.[2] The availability and quality of data vary throughout the pyramid. Data commonly exist for the more severe and less frequent injuries (i.e. deaths and hospital admissions). However, if only these data are used to study injury, the public health impact of injuries is under-estimated because the less severe but more common injuries will be under-represented. These less severe injuries can result in time lost from work or school, short-term or long-term disability.

Figure 1 — An Injury Pyramid

The epidemiologic concepts of exposure and outcome can be applied to the study of injuries.[3] The approach to injury research that can be adopted is similar to that of infectious disease epidemiology.[4] Injuries are analyzed as predictable events involving factors of the host, the environment and the agent.[5] From an injury epidemiology perspective, the agent is the transfer of energy. Under this premise, most injuries are considered preventable or at least injury outcomes are modifiable. Haddon has developed a matrix or framework (Figure 2) to categorize the factors that contribute to injury.[6] It represents the chain of events involved in injury. The matrix incorporates three groups of factors (human, vehicle and environmental) over three phases of time (pre-injury, injury, and post-injury). The matrix was originally developed to study highway motor vehicle crashes. The vehicle factors pertained literally to the motor vehicle. However, the matrix is adaptable to other injurious situations. The vehicle factors then relate to safety devices, products or equipment used in an activity. The matrix as described by Robertson shows that

> "prior to injury, human, vehicle and environmental factors contribute to the increase or decrease in exposure to potentially damaging energy ... During the energy exchange, the susceptibility of the host's tissue to damage and the concentration of the energy on the host by vehicle and environmental characteristics are major factors in [injury] severity ... After the initial [energy] exchange, the condition of the host, the potential for more energy exposure, and the responses from the environment substantially affect survival and the time and extent of return to pre-injury functioning of those who survive." [1]

		Factors		
		Human	Vehicle	Environment
Phases	Pre-Injury			
	Injury			
	Post-Injury			

Figure 2 — Haddon's Matrix

Categorizing factors by phase reveals multiple potential points for intervention.[7] Interventions can be placed into one of three categories: education, engineering or enforcement.[7,8] Educational interventions aim to increase individuals' awareness, knowledge and skills about potentially injurious situations on the basis that this will influence behaviour change. Engineering interventions change the construction or manufacture of products or the environment. For example, seat belts, collapsable steering columns, crumple zones, airbags and divided highways are engineered interventions which affect the injury outcomes in motor vehicle crashes. Enforcement is the third intervention approach to reduce injuries. It can be the enforcement of safety policy/legislation directed at behaviours (e.g. wearing seat belts or helmets) or directed at engineering (e.g. product safety standards).

1.2 Injuries in Canada

Injuries account for a large portion of premature mortality; they are a major contributor to short-term and long-term disability and they constitute one of the largest components of direct health-care costs.[9] Injury is a major cause of mortality and morbidity among Canadians. In 1995, there were 13,337 deaths and 194,480 hospitalizations due to injury in Canada.[2] In that same year, unintentional injuries cost Canadians $8.7 billion in direct and indirect costs.[10] Unintentional injuries include those that result from falls, motor vehicle crashes, drowning, suffocation, poisoning, fires and railway and pedestrian injuries.

The impact of injuries is most pronounced in younger age groups. The proportion of deaths due to injuries increases throughout childhood and peaks at 74% of deaths for 15-19 year-olds.[11] Injuries remain the leading cause of death into adulthood where they account for 32% of all deaths in the 35-44 year age-group.[11] Nine percent of hospitalizations in children aged 1-4 years are the result of injuries.[12] This proportion increases through childhood and adolescence to the 15-19 year age-group. In the 15-19 year age-group, 22% of hospitalizations are due to injuries.[12] As with mortality due to injury, so too injury morbidity decreases after age 19 but remains a leading cause for admission to hospital.

Injuries, therefore, are a public health concern. They are a leading cause of morbidity and mortality from childhood into adulthood. Injuries constitute a large component of years of life lost due to premature death, as well as activity limitation, short-term and long-term disability.[10] The application of epidemiologic methods to study injuries aids in the design, implementation and evaluation of interventions which aim to prevent injuries and control their negative health and financial impacts.

1.3 Sports Participation & Sports Injuries in Canada

A large number of Canadians participate in individual and team sports both in a casual and organized fashion. Some of the most comprehensive national population-based estimates of sports participation are from the 1992 General Social Survey.[13] Almost half of all Canadians (45%) over the age of 15 reported that they regularly participate in sport.[14] Regular participation involved activity once per week or once per week during a sports season.

Participation in sports in Canada varies by age, province and sport. Generally, sports participation was greatest for younger Canadians: 76.8% of those aged 15-18 years, declining to 25.3% of those over age 55 years. The highest rates of sports participation were reported in the provinces of British Columbia, Quebec and Nova Scotia, respectively. The most popular sports reported were ice hockey, downhill skiing and swimming.

Alpine or downhill skiing has been a popular winter activity for decades while snowboarding is a comparatively young sport and has not been included in population surveys. The 1996 National Population Health Survey[15] asked Canadians about the physical activities they had participated in over the three months prior to the survey. Data were obtained for those who responded that they had gone alpine skiing in the three previous months. Due to the three-month time limit of the question, data were restricted to include only those respondents who were interviewed from December to June to cover the majority of the ski season. Of respondents over the age of 12 years, 7.0% or 367/10,000 Canadians had been alpine skiing within the previous three months. The age distribution of those who reported alpine skiing was similar for both sexes. Alpine skiing was most popular in those aged 12-17 years at approximately 1,000/10,000 in that age group (males 1,137/10,000 and females 982/10,000). Three-quarters (76.1%) of those who reported recently alpine skiing lived in the provinces of Ontario (31.8%), Quebec (25.7%) or British Columbia (18.6%).

In the past ten years there have been increasing numbers of snowboarders joining skiers on alpine slopes worldwide. In 1989, there were approximately 100,000 snowboarding participants[16] in the United States. That number grew to an estimated 1.8 million by 1994.[17] Confirming the sport's maturity, snowboarding became a full-medal event in the 1998 Olympic winter games and it is now part of the World Cup racing series. Snowboarders are projected to account for one-third of lift ticket sales by the year 2000.[18]

Inherent with sports participation is an increased risk for injury due to the increased energy exposure in these activities. From 1990 to 1992, sports and recreational activities were the cause of an annual average of 99 deaths and 14,000 hospitalizations for Canadians under the age of 20 years.[19] Drownings, off-road vehicles and bicycles were implicated in many of the sports/recreational injury deaths and hospitalizations.[19]

Alpine skiing is not only a popular sport but ranks as one of the top injury-producing activities.[20] The Alberta Sport and Recreation Injury Survey was a population-based telephone survey conducted in 1996. Investigators found that ice hockey, baseball, basketball, soccer, jogging/running, recreational cycling, volleyball, tackle football, alpine skiing and softball (in that order) were the top ten injury-producing sport/recreational activities based on self-reported participation and injury.[21] These rankings may not hold for all provinces and territories since sports such as alpine skiing depend on sufficient snow fall and the availability of terrain suitable for alpine ski slopes, both of which vary across the country.

1.4 Rationale for Thesis

There is increasing research activity in the areas of injury prevention and control. In this decade, journals and research centres have been established. The peer-reviewed journal, *Injury Prevention*, is now available as one of the *British Medical Journal* publications. Research centres have been established across the country. For example, Plan-It Safe! is a local centre for injury prevention and control located at the Children's Hospital of Eastern Ontario in Ottawa. World Health Organization international collaborating centres on injury prevention and control also exist. Many popular sports are leading injury-producing activities. Participation in these sports by various groups (e.g. age, sex, province) could mean increased risk for injury. Epidemiologic methods can and have been applied to the study of sports injuries.

Sports injury researchers have begun to investigate snowboarding injuries.[20] The popularity of snowboarding as a sport and recreational activity has grown and, as a result, is expected to contribute to sports and recreational injuries with an impact similar to that of alpine skiing because of the similarities between the sports.

Additional motivation for this thesis project came from different directions: a personal interest in the topic area, the recognition of an increasing number of participants snowboarding at centres that were built for and are used by other snow-sports enthusiasts, and the opportunity to contribute to a new but growing body of knowledge about snowboarding injuries.

This thesis project advances the current state of knowledge regarding snowboarding injuries. It builds upon previous studies and should fuel further study in the area. This thesis examines recent alpine skiing and snowboarding injuries with an emphasis on snowboarding injuries. It provides standardized injury rates for both sports permitting the direct comparison of risk. In addition, this study provides a preliminary exploration of risk factors for severe snowboarding injuries.

2.0 Review of the Literature on Snowboarding Injuries

This section provides a brief description of snowboarding, its history and the equipment. It is followed by a summary of the literature on snowboarding injuries. The English language literature in the Medline and Sport Discus electronic indices for all available years was searched using the key word "snowboard$" truncated to capture its use in various forms.

2.1 Evolution of the Sport

North America was first exposed to the concept of the snowboard during the 1960's.[34, 33,34] Sherwin Poppen created the "snurfer" which was marketed by the Brunswick Company and about one million were sold in that decade.[16] Snurfers were difficult to control because of their wooden construction and bottom fin.[16] The "winterstick" was patented in the 1970's by Dimitrije Milovich and was followed by the current snowboard concept of Jake Burton Carpenter and Tom Sims.[16] Today's snowboard is constructed like an alpine ski with steel edges and a plastic base on a fibreglass body.[16] There is no longer a bottom fin because the edges provide manoeuvrability.

There are snowboards specifically designed for freestyle, racing or "halfpipe" (a semi-circular snow construction where boarders ride from side to side).[22,23] Regardless of the type of board, the rider does not use poles and the stance is perpendicular to the axis of the board like riding a skateboard or surfboard. The angles of the feet (relative to the main axis of the board) and the distance between the feet vary with the type of board and activity.[46, 97] Boots can be hard or soft and most bindings do not release.[22,23] The non-releasable bindings facilitate turns and other manoeuvres that require a shift in weight as well as the flexion and extension of ankles, knees and hips.[24]

2.2 Epidemiology of Snowboarding Injuries

Studies of snowboarding injuries started appearing in the peer-reviewed literature in the late 1980's. Since that time, 10 case-series of specific injuries (Table 1), 21 descriptive injury series (summarized in Table 3) and 10 review articles (Table 2) have been published in the English language literature.

In this summary of the literature, the case-series studies are summarized to describe specific snowboarding injuries and a discussion of the other studies of snowboarding injuries follows. The results of the descriptive studies are varied but there is general agreement that the profile of snowboarding injuries is different from alpine skiing injuries. Due to the variability in the findings, the review articles present slightly different summaries of snowboarding injuries depending on which studies were used by the authors. The individual descriptive studies, rather than the reviews, are, therefore, included in this review of the literature.

Table 1 — Specific Injury Series

Case-Series Studies of Specific Snowboarding Injuries
Dalgren Gunnels M. Stranded on a mountain: A case of snowboarding injury in Oregon. J Emerg Nurs 1997; 23(6): 550-4.
Kirkpatrick DP, Hunter RE, Janes PC, Mastrangelo J & Nicholas RA. The snowboarders foot and ankle. Am J Sports Med 1998; 26(2): 271-7.
Kizer KW, MacQuarrie MB, Kuhn BJ & Scannell PD. Deep snow immersion deaths: A snowboarding danger. Phys and Sportsmed 1994; 22(12): 49-61.
Kocher MS, Dupré MM & Feagin JA Jr. Shoulder injuries from alpine skiing and snowboarding: aetiology, treatment and prevention. Sports Med 1998; 25(3): 201-11.
McCrory P & Bladin C. Fractures of the lateral process of the talus: A clinical review "snowboarder's ankle". Clin J Sports Med 1996; 6(2): 124-8.
Nicholas R, Hadley J, Paul C & Janes P. "Snowboarder's Fracture": Fracture of the lateral process of the talus. J Am Board Fam Pract 1994; 7(2): 130-3.
Spina N, Santamaria S, Basile G & Mancini AM. Complex wrist injuries in snowboarders. Journal of Sports Traumatology and Related Research 1997; 19(3): 119-27.
Vanmaele RG, Van Schil PE, Van den Brande F & Verbist AM. Case report: Hypothenar Snowboard Syndrome. Eur J Vasc Endovasc Surg 1998; 16: 82-4.
Williams JS Jr., Hang DW & Bach BR. Distal biceps rupture in a snowboarder. Phys and Sportsmed 1996; 24(12): 67-70.

Table 2 — Review Articles

Reviews of Snowboarding Injuries
Abu-Laban RB. Snowboarding safety and injuries: A review. Pulse, Sport Medicine Council of Alberta, Winter 1997: pp. 1, 4, 14.
Bladin C & McCrory P. Snowboarding injuries: An overview. Sports Med 1995; 19(5): 358-64.
Chissell HR, Feagin JA Jr., Warme WJ, Lambert KL, King P & Johnson L. Trends in ski and snowboard injuries. Sports Med 1996; 22(3): 141-5.
Elmqvist LG, Johnson RJ, Kaplan MJ & Renstrom PAFH. In: Fu FH & Stone DA, eds. Nordic and Alpine Skiing in Sports Injuries: Mechanisms, Prevention, Treatment. Baltimore: Williams & Wilkins, 1994: pp. 481-500.
Fujioka K & Janes P. Snowboarding injuries. Sports Medicine Digest 1989; 11(11): 1-2.
Humphreys D. Shredheads go mainstream? Snowboarding and alternative youth. Int Rev for the Sociology of Sport 1997; 32(2): 147-60.
Johnson RJ. Skiing and snowboarding injuries: When schussing is a pain. Postgrad Med 1990; 88(8): 36-8, 43-5, 49-51.
Pier J. The biomechanics of skiing injuries. Physical Med and Rehab 1997; 11(3): 587-610.
Robinson M. Hazards of alpine sport. Aust Fam Physician 1991; 20(7): 961-70.
Van Tilburg C. Surfing, windsurfing, snowboarding and skateboarding: Medical aspects of board sports. Phys and Sportsmed 1996; 24(11): 63-74.

Table 3 — Studies of Snowboarding Injuries[a] (refer to legend at end of table)

Authors	Pub Yr[b]	Country	# Ski Centres	Sample	# of Seasons	Data Source	Study Design[c]	Results[d]: Region (U/L)[e]	Results[d]: Body Parts	Results[d]: Nature of Injury[f]	Results[d]: Injury Rate[g]	Results[d]: Desc.[h]
Pino & Colville	1989	USA	not stated	267 SBers[i] 110 injs	1 1986-87	survey	survey	29% U 53% L 4% head 14% torso (0.55)	ankle knee shoulder	31% SS 26% FR 19% CNT 2% DSL	not stated	age, sex, falls, boot type, safety equip
Shealy & Sundman	1989	USA VT,CO,NH[j]	3	54 rpts 59 injs	1 1985-86	ski patrol	retro series	36% Ubody 59% Lbody (0.60)	ankle/foot wrist/hand knee	64% SS 14% FR 12% CNT 5% DSL	4.2 /1000 SBV	age, sex, ability, falls, boot type
McLennan & McLennan	1991	USA California	2	460 injs	since 1986	unclear	not stated	49% U 40% L 2% head 9% sp/thrx (1.23)	ankle forearm	55% SS 19% FR 16% CNT	1.7 /1000 SBV	age, sex, ability, lead, lessons, safety equip, falls, boot type
Abu-Laban	1991	Canada Alberta	3	115 SBers 132 injs	2 1988-90	clinic & qu're[k]	prospec series	12% U 49% L 2% head 15% torso (0.24)	ankle knee wrist	52% SS 26% FR 19% CNT 2% DSL	8-16 /1000 SBV	age, sex, ability, falls, boot type, lead
Ganong et al.	1992	USA California	10	415 SBers 424 injs	1 1989-90	8 clinics & qu're[k]	prospec series	44% U 43% L 4% head 8% torso (1.02)	wrist knee ankle	36% SS 44% FR 7% CNT 5% DSL (my calc)[l]	2/1000 SBV	age, sex, ability, trail dif, falls, boot type
Bladin et al.	1993	Australia	3	276 injs	4 1989-93	clinic	prospec series	29% U 52% L 11% head 6% tor/thl (0.56) (my calc)[l]	ankle/foot knee wrist/hand	53% SS 24% FR 12% CNT 4% DSL	4.2 /1000 SCV	ability, falls, boot type

Authors	Pub Yr [b]	Country	# Ski Centres	Sample	# of Seasons	Data Source	Study Design [c]	Results [d]				
								Region (U/L) [e]	Body Parts	Nature of Injury [f]	Injury Rate [g]	Desc. [h]
Shealy	1993	USA	15	1194 injs 255 ctrls	2 1988-90	ski patrol & control survey	retro series & case-control	33% U 44% L 10% head (my calc) [i] (0.75)	ankle wrist knee	44% SS 31% FR 6% CNT 4% DSL 9% LAC	3.03 /1000 SCV	sex, ability, trail dif, boot type, falls
Janes & Finken	1993	USA Colorado	7	847 SBers 937 injs	3 1989-91	clinic & qu're [k]	prospec series	42% U 45% L (0.93)	not stated	36% SS 42% FR 10% CNT 3% DSL	not stated	ability, boot type, lead
Callé & Evans (2 studies)	1995	USA Vermont	6	487 injs	2 1991-93	clinic & qu're [k]	retro series	48% U 34% L 17% hd/nk (1.41)	wrist knee ankle	60% soft tissue damage 5.5% CNC	not stated	age, sex, ability, afternoon, falls, lessons, equip type
		USA national		565 injs	since 1989	CPSC/ NEISS [m]		47% U 32% L 11% hd/nk (1.48)		57% soft tissue damage 1.7% CNC		
Warme et al.	1995	USA Wyoming	1	47 injs	1 1992-93	clinic	prospec series	17% soft tissue knee 21% ankle/foot	not stated	not stated	not stated	boot type
Prall et al.	1995	USA Colorado	Level I trauma ctr fed by 7 ski ctrs	37 severe injs	6 yrs 1987-94	clinic	prospec series	not stated	head spleen tib/fib	not stated	0.03 sev inj /1000 SBV	age, sex, afternoon, month
Lamont	1996	New Zealand	10	379 injs	2 1991-93	Mtn Safety Council	retro series	39% U 43% L 9% head 8% torso (0.91)	not stated	not stated	not stated	age, boot type
Cadman & Macnab	1996	Canada BC	1	2139 SK & SB injs	1 1991-92	ski patrol	retro series	authors do not present results by sport (i.e. skiing vs snowboarding injuries)				age, sex

Authors	Pub Yr [b]	Country	# Ski Centres	Sample	# of Seasons	Data Source	Study Design[c]	Results[d]				
								Region (U/L)[e]	Body Parts	Nature of Injury[f]	Injury Rate[g]	Desc.[h]
Chow et al.	1996	USA California	2	335 SBers 390 injs	1 1993-4	clinic & qu're[k]	prospec series	58% U 16% L 18% hd/fc 9% torso (3.74)	not stated	15% SS 43% FR 13% CNT 13% DSL (my calc)[i]	not stated	age, sex, ability, jumping, safety equip
Sutherland et al.	1996	Scotland	1	88 injs	1-2 1994 & 1995	ski patrol	retro series	48% U 27% L 14% hd/nk 10% tor/thi (1.78) (my calc)[i]	hand/forearm upper arm/shoulder knee	33% SS 29% FR 7% bruise 12% DSL 7% hd inj (my calc)[i]	0.3 /1000 SCV (my calc)[i]	age, sex, ability, falls, lead, boot type
Davidson & Laliotis	1996	USA California	2	931 injs	4 1989-93	ski patrol	retro series	40% U 38% L 10% hd/fc 9% torso (1.05)	not stated	27% FR 5% DSL 3% CNC	not stated	age, sex, ability, fall direction, boot type, lead, jumping
Shealy & Ettinger	1996	USA national	16	not stated	2 1988-90	ski patrol	prospec series	not stated	knee wrist ankle	more SS	3-4 /1000 SCV	sex, ability
Macnab & Cadman	1996	Canada BC	1	156 injs	1 1991-92	ski patrol	retro series	authors do not present results by sport (i.e. skiing vs snowboarding injuries)				safety equip
Shealy et al.	1997	USA western	2	3696 injs	7 1988-95	ski patrol	retro series	only present wrist, lower leg, knee & ankle	wrist	not stated	6.02 /1000 SCV may be SBV	boot type, falls
Pigozzi et al.	1997	Italy	not stated	106 injs	4-5 1989-94	ISF[n] survey	retro series	45% U 39% L 2% head 14% torso (1.17)	knee shoulder ankle	24% SS 30% FR 31% CNT 11% DSL	not stated	sex, ability, falls, boot type, lead, safety equip, lessons

Authors	Pub Yr [b]	Country	# Ski Centres	Sample	# of Seasons	Data Source	Study Design[c]	Results[d]				
								Region (U/L)[e]	Body Parts	Nature of Injury[f]	Injury Rate[g]	Desc.[h]
Sacco et al.	1998	USA Vermont	Level I trauma ctr fed by 2 ski ctrs	40 SBers	5 1990-95	clinic & qu're [k]	retro series	23% U 38% L (0.61)	not stated	FR most common inj	0.1 /1000 SBV	age, sex, falls,boot type

[a] some studies may have had objectives to address alpine skiing injuries; only the snowboarding injury data are presented
[b] year the study was published
[c] retro series = retrospective case series, prospec series = prospective case series
[d] results presented are the anatomic region, body parts and type of injury of highest proportions
[e] U = upper limbs, L = lower limbs, U/L = upper:lower limb ratio (my calculation), hd/fc = head & face, hd/nk = head & neck, sp/thrx = spine & thorax, tor/thl = torso & thigh
[f] CNC = concussion, CNT = contusion, DSL = dislocation, FR = fracture, hd inj = head injury, LAC = laceration, SS = strain or sprain
[g] SCV = ski centre visits, SBV = snowboarder visits
[h] 'Desc.' lists the risk factors proposed to contribute to snowboarding injury, equip = equipment, lead = leading limb (L or R), trail dif = trail difficulty, boots can be hard or soft
[i] SB = snowboard
[j] Vermont, Colorado, New Hampshire
[k] qu're = questionnaire
[l] my calc = my calculation because it was not presented
[m] Consumer Product Safety Commission & the National Electronic Injury Surveillance System
[n] Italian Snowsport Federation

2.2.1 Case-Series Studies of Specific Snowboarding Injuries

Snowboarders experience a range of injuries including (but not limited to) strains, sprains, fractures, lacerations, contusions, frostbite, hypothermia, concussions and dislocations of the upper extremities, lower extremities, head, neck and trunk. Certain injuries to the shoulder, arm, wrist and foot/ankle have been described. These specific injuries include: glenohumeral dislocation[25] (upper arm dislocation), clavicle fracture[25] (collar bone fracture), acromioclavicular separation[25] (collar bone joint separation), rotator cuff strain[25], proximal humerus fracture[25] (upper arm fracture), distal biceps sprain and rupture[26], fracture of the distal end of the radius[27] (fracture of the shorter forearm bone), carpal dislocation[27] (wrist dislocation), carpometacarpal dislocation[27] (dislocation of bones in the palm), Hypothenar Snowboard Syndrome[28](injury of the palm near the little finger), metatarsal fracture[29] (arch of the foot fracture), lateral/medial malleolus fracture[29] (fracture of the protuberances on the side of the ankle), fracture of the lateral process of the talus[29,30,31] (ankle bone fracture), deep snow immersion death[17, 32] and compartment syndrome[34] (nerve or tendon constricted in a space).

The body part injured usually depends on the body part which absorbs the impact of a fall.[16,41,42,44,45,47,49] Snowboard bindings do not release so it is often the upper body that is left to absorb the impact of falls. By reflex, many riders break their falls with outstretched arms. The diagnosis and treatment of snowboarding shoulder injuries is described by Kocher, Dupré and Feagin.[25] Diagnosis usually involves a neurovascular examination and x-rays. The injury is then reduced or iced followed by immobilization and rehabilitation.

Some fractures, high-grade injuries and older patients (i.e. over 40 years of age) may require surgical intervention. Williams, Hang and Bach[26] published a case report on a distal biceps rupture seen in a snowboarder. They included their previous experience with distal biceps injuries in snowboarders which had involved three sprains. At the time of rupture injury, there is intense pain, a popping sound and deformity that leads to swelling and tenderness. Non-operative treatment can result in loss of elbow flexion and supination strength. If these effects are undesirable then surgical treatment is warranted. Spina *et al.*[27] describe a series of 15 complex wrist injuries suffered by snowboarders over three ski seasons. The injuries, their etiology and management are discussed. The authors found that all of the injuries were caused by falling on the palm with the wrist in extension. They conclude that the wrist is at risk for injury and suggest that equipment and lessons might improve outcomes. Vanmaele *et al.*[28] report a case of ulnar artery aneurysm (Hypothenar Snowboard Syndrome). The report describes the diagnosis and management of the case. The authors believe that the in-line skating wrist guards that the snowboarder was using caused his injury.

Soft boots are preferred by many snowboarders to conduct aerial manoeuvres and other jumps.[43] A landing mishap can result in ankle, foot or knee injury. Fracture of the lateral process of the talus has come to be known as "Snowboarder's Ankle". Kirkpatrick *et al.*[29] describe the distribution of foot and ankle injuries in snowboarders. They implicate the lead foot and type of snowboarding activity in these injuries. Case reports suggest that "Snowboarder's Ankle" is easily misdiagnosed as a lateral ligament sprain and is most clearly visible in lateral radiographs or by computed tomography.[18,30,31] McCrory and Bladin[30] categorize the fracture into three sub-types and propose management accordingly. This injury is believed to result from a poor landing of aerial tricks or jumps in those wearing soft boots, which provide no ankle support.

Three snowboarder deaths, the result of deep snow immersion, have also been described.[32] In each case, the snowboarder was found vertically buried, head down and there was no evidence of a collision. The hazard in these situations was the non-releasable bindings. However, the snowboarders were all found in deep powder snow or tree wells outside of the groomed skiing trails. "Unpublished 1996 data from the Colorado Avalanche Information Center in Denver [indicate that] 12 snowboarders have died in avalanches since 1985; these included back country riders and those hiking out of bounds at mountain resorts."[33]

A case of compartment syndrome has been published describing the injuries suffered by a snowboarder who fell 75 feet. He too was riding off patrolled trails.[34]

2.2.2 Studies of Snowboarding Injuries

Twenty-one studies of snowboarding injuries have been published in the English language peer-reviewed literature: one snowboarder survey, one case-control study and 19 case-series studies. The methods and results are summarized in Table 3. Of the 19 case-series studies, nine used Ski Patrol injury data and the other ten used injury data collected at clinics close to the ski centres. The clinical injury data were often used in conjunction with questionnaires for supplemental information.

In this section, the methods of these studies are described and the results are introduced or reiterated. The limitations that apply to most of the studies are presented in Section 2.3 while those pertaining to a particular study will be discussed as its methods are presented.

The first published study was a snowboarder survey by Pino and Colville.[16] They conducted personal interviews with snowboarders at snowboard racing events during the 1986/87 ski season. They described the distribution of 110 injuries using proportions and found that 90% of the snowboarding injuries were to males and the average age was 21 years. Over half (53%) the reported injuries were to the lower limbs; the most commonly reported injury was a strain/sprain and frequently injured body parts were the ankle, knee and shoulder. Based on the highest proportions and differences in proportions, the investigators suggested that snowboarding injuries were suffered by young males, that falls were one of the main mechanisms of injury, that those wearing hard boots or using boot inserts experienced fewer lower limb injuries and that few riders used protective equipment. The small sample size, the sampling method and their data collection methods potentially bias their results and prevent generalization of these findings. In the study, only 267 snowboarders reported on 110 injuries. Snowboarders were interviewed at racing events so were likely to be more experienced riders. The investigators report that 49% of respondents were of intermediate ability. Furthermore, there could be recall bias in remembering the circumstances and nature of their injuries.

A paper by McLennan and McLennan[40] indicates that the authors identified 460 snowboarding injuries in the five years prior to publication but offers no further details about their data collection and analyses. Nearly half the injuries (49%) were to the upper limbs. The most commonly reported injury was strain/sprain and the most common site of injury was the ankle or leading limb. Based on high proportions of injuries the investigators suggest injured snowboarders were young (average age of 19 years) males (90%); impact or falls were the main mechanisms of injury; those injured had limited instruction and experience; and fewer lower limb injuries occurred in those wearing hard boots.

The 18 other case-series studies, regardless of data source, were conducted using similar methods. Demographic information (e.g. age, sex, ability, previous instruction/lessons) was obtained from the injured individual. Details of the equipment used were often also collected. This may include details of both sporting and safety equipment. The sporting equipment can be owned or rented, snowboarding boots can be hard or soft and riders can have a left or right lead foot. Inserts for ankle support may be used with soft boots. Other safety equipment might be a helmet, knee/elbow pads or wrist protectors. Many of the studies collected some information on the circumstances of the injury. Circumstantial information may include difficulty of the trail, snow conditions, weather conditions and details of what went wrong (e.g. loss of control, collision, fall, equipment failure).

One of the first case-series studies was conducted by Shealy and Sundman.[39] They looked at demographic and nature of injury information provided by 54 Ski Patrol reports from three ski centres over one ski season. They found most injured snowboarders were young (average age of 19 years) males (91%). Over half (55%) those injured were beginners and over half (59%) the injuries were to the lower body. Frequently injured body parts were the ankle/foot, wrist/hand and knee and the most common injury was a strain/sprain. They suggest that stiffer (i.e. hard) boots may help reduce the risk of ankle injury and that instruction in falling might reduce upper limb injury since falls were the main mechanism of upper limb injury. They make comparisons with alpine skiing injuries and the data were from a previous study by one of the authors. Injured alpine skiers were older (average age 21 years) and fewer were male (60%), fewer were beginners (34%) and the same proportion of injuries (59%) were to the lower body. The knee was the most frequently injured body part and the most common injury was a strain/sprain. This study was based on a small sample size of 54 reports on 59 injuries so any differences observed could be due to chance. Their recommendations appear to be based upon expert opinion rather than on data on the circumstances or equipment used.

The first Canadian study appeared in 1991.[37] Clinical data on 132 snowboarding injuries treated at a hospital in Banff, Alberta were used. The clinical data were supplemented by a 23-item questionnaire which asked detailed demographic and circumstantial questions. Injured snowboarders were young (average age of 20 years) and 76% male. The majority (76%) were beginners either on a snowboard for the first time or it was their first year in the sport. Approximately half the injuries (49%) were to the lower limbs and the most common injuries were strains/sprains. Frequently injured body parts were the ankle, knee and wrist. Data were not available on boot type, lead limb or mechanism of injury but the author speculates that the type of boot was related to the type of leg injury sustained and that the higher proportion of injuries to the left side were due to the left lead used by many snowboarders. The author recommends lessons and hypothesizes that arm and coccyx injuries depend on which way the snowboarder falls.

Ganong, Heneveld, Beranek and Fry[41] questioned 415 snowboarders at eight emergency clinics over the 1989/90 ski season. The injured snowboarders were young (average age of 20 years), 74% male and many were in their first year of snowboarding (58%). They found approximately equal proportions of injuries to the upper and lower limbs; the most frequently injured body parts were the ankle and forearm. The most common injury was a fracture. The majority of injuries (87%) occurred on easy and intermediate trails and 74% were the result of falls. The investigators were able to compare three types of boots with the associated injuries and found a statistically significant difference in the frequency of both ankle and knee injuries (t-test $p<.01$). The injuries tended to occur farther up towards the knee as the rigidity of the boot increased. Based on their findings, the investigators recommend the use of wrist and ankle protectors.

Bladin, Giddings and Robinson[44] collected clinical and questionnaire injury data on 276 snowboarding injuries over four ski seasons in Australia. The questionnaire assessed demographic, equipment and circumstantial information. The injured snowboarders were young (average age of 21 years), 74% male and 58% were beginners. Over half the injuries were to the lower limbs and the most frequent injury was a strain/sprain. The most frequently injured body parts were the ankle, wrist and knee. Almost all (91%) lower limb injuries were to the leading leg and falling was the most common mechanism of injury. The site of injury varied by boot type and ability. Ankle injuries were more common in riders wearing soft boots ($p<.05$) and knee injuries ($p<.006$) and tibial fractures ($p<.01$) were seen in those wearing hard boots. Beginners suffered upper limb fractures ($p<.05$) and knee injuries ($p<.10$) while intermediate riders sustained more ankle injuries ($p<.001$). These differences in proportions were statistically significant by means of a chi-square test. The authors recommend lessons and that equipment, particularly rental equipment, be properly fit and adjusted.

Janes and Fincken[48] recruited 37 physicians who treat injuries from seven Colorado ski centres to collect clinical and questionnaire data from injured snowboarders. The questionnaire contained demographic and equipment questions. Data from 874 injured snowboarders were collected. The injured snowboarders were young (average age of 20 years), 77% male and 57% were beginners. There were approximately equal proportions of upper and lower limb injuries; fractures were the most frequent injury. The most common injury was a radius (forearm) fracture. The majority of lower limb injuries were sustained by the lead leg and occurred in those wearing soft boots.

There were two parts to the study by Callé and Evans.[49] The first part was a follow-up telephone interview of 487 injured snowboarders to collect circumstantial and equipment information. The injured snowboarders were identified from clinic records at six ski centres in Vermont. Injured snowboarders were young (average age of 19 years), 77% male and 42% were beginners. The second part of the study used data on 585 snowboarding injuries from the Consumer Product Safety Commission and the National Electronic Injury Surveillance System. These injured snowboarders were also young (average age of 18 years) and the majority were male (83%). Based on the results from both series, the majority of injuries were to the upper limbs and involved damage to soft tissue (e.g. strain/sprain) but the most frequently injured body parts were the ankle, wrist and knee in both series. The circumstances of the injuries were related to the time of day, the weather and falls. Over half the injuries occurred in the afternoon and on clear days with good visibility. Investigators suggest these conditions permit more daring manoeuvres.

Warme and colleagues investigated primarily alpine skiing injuries but included 47 snowboarding injuries in their study.[56] Their clinical data suggest 21% of snowboarding injuries were to the ankle and foot. They hypothesize that ankle and foot injuries may be due to the use of soft boots. The findings contribute little to the current state of knowledge because of the limited sample size.

Lamont[50] obtained two seasons of injury data from the New Zealand Mountain Safety Council. He used demographic information on 379 snowboarding and 5,677 alpine skiing injuries. Injured snowboarders were young (average age of 21 years) and 77% male compared with injured alpine skiers, for whom the average age was 25 years and approximately half (51%) were male. By simply comparing proportions, Lamont found slightly more lower limb than upper limb injuries in snowboarders and twice as many lower limb as upper limb injuries in alpine skiers. There were more head injuries in the injured alpine skiers and more ankle injuries in the injured snowboarders. No further analyses were presented and insufficient details were provided to perform post hoc calculations.

Chow, Corbett and Farstad collected clinical and questionnaire information throughout the 1993/94 ski season at an emergency department that serves two ski centres in California.[47] The questions were used to obtain demographic, equipment and circumstantial information from 355 injured snowboarders and 442 injured alpine skiers. The injured snowboarders were young (average age of 20 years), 62% male and 44% were beginners with less than one year of snowboarding experience. The injured alpine skiers were older (average age of 28 years), a lower proportion were male (62%) and only 22% had less than one year of skiing experience. Nineteen percent were snowboarding for the first time and 11% were skiing for the first time. Site and nature of injury were explored using chi-square tests. Compared with alpine skiers, the upper limbs were most frequent site of snowboarding injury ($p<.001$) and fractures were the most common injury. Compared with snowboarders, the lower limbs were the most frequent site of alpine skiing injury ($p<.001$) with approximately equal proportions of fractures and strains/sprains. They found that most of the injured snowboarders wore soft boots (86%) and that very few used protective equipment (14% knee pads, 3% elbow pads, 6% wrist protectors). Snowboarders using wrist protectors did not injure their wrists but rather their shoulder or radius ($p<.05$). Forty-one percent of the injuries resulted from attempts at aerial manoeuvres or jumps. Those injured while jumping were more likely than other injured snowboarders to injure their head, face, spine or abdomen ($p<.05$). Snow conditions were described as packed-powder or ice for 82.5% of injuries and the average time on the slopes before being injured was three hours.

Sutherland, Holmes and Myers reviewed 757 records of 1,233 injuries (one record can describe more than one injury) seen by the Ski Patrol over the 1994 and 1995 ski seasons at the largest ski centre in Scotland.[42] Members of the Scottish Ski Patrol are qualified emergency medical technicians. This publication is confusing as some of the analyses cover both ski seasons and others are only for one ski season. There were 88 snowboarding injuries over the two ski seasons. They found the proportion of injured snowboarders who were male dropped from 90% in 1994 to 72% in 1995 while the proportion of injured alpine skiers who were male remained at 52%. In 1995, 20 was the average age of injured snowboarders and 59% of them were beginners. For injured alpine skiers, the average age was 25 years and 49% were beginners. Investigators found upper limb injuries to be more common in snowboarders (χ^2 $p<.0001$) and knee injuries to be more common in alpine skiers (χ^2 $p<.01$).

Davidson and Laliotis used Ski Patrol injury data for four ski seasons at two ski centres in California.[51] The demographics were significantly different for injured snowboarders and injured alpine skiers. Snowboarders were younger (average age 21 versus 30 years), predominantly male (72% versus 48%) and beginners (49% versus 18%). The age, sex and ability differences between the two sports were statistically significant with a $p<.05$. Proportional data were compared using a z-test with Yates correction.

Skier/snowboarder error was the most reported cause of injury, snowboarders were injured more often jumping and skiers were injured more often in collisions. Snowboarders sustained approximately equal proportions of upper and lower limb injuries whereas alpine skiers sustained three times as many lower limb as upper limb injuries. Between the two sports, injured snowboarders had significantly more upper limb injuries ($p<.001$) and injured alpine skiers had significantly more lower limb injuries ($p<.001$). Of the upper limb injuries, snowboarders suffered significantly more arm, elbow and wrist injuries ($p<.001$) but alpine skiers suffered significantly more thumb injuries ($p<.002$). Of the lower limb injuries, alpine skiers suffered significantly more knee and leg injuries ($p<.001$) but snowboarders suffered significantly more ankle injuries ($p<.001$). Alpine skiers also experienced significantly more head and face injuries ($p<.005$) and snowboarders experienced significantly more clavicle (collar bone) injuries ($p<.001$). The site of injury was found to vary by ability in snowboarders. Beginners injured their wrist most often, intermediate riders injured their knees and ankles most often and advanced riders injured their shoulder most often. The knee was most frequently injured in alpine skiers of all ability levels. During one season of the study, additional equipment and circumstantial information was collected. Most of the injured snowboarders wore soft boots and rode with a left foot lead. The site of injury varied significantly with the direction of the fall. Lower limb injuries occurred in toe-side turns and upper limb injuries occurred in heel-side turns.

Shealy and Ettlinger investigated gender and ability differences in 23,011 snowboarding and alpine skiing injuries at various centres in the US.[43] The sample size is large but the authors do not state the proportion of snowboarding and alpine skiing injuries. The authors use injury rate ratios in their analyses which are literally ratios of injury rates where the injury rates were injury counts per 1,000 ski centre visits. The authors found that the injury rate ratios for males and females within each sport and between sports were not significantly different after adjusting for ability. These comparisons were investigated with a Student's t-test and were significant at the 5% level. They illustrated that the body part injured varied by sex and sport. Female snowboarders had double the wrist and knee injury rates of males whereas males had three times the head and face and twice the ankle injury rates of females. Female alpine skiers had a knee injury rate that was twice the male injury rate and males had twice the shoulder and face injury rate of females. They found the mechanism of injury varied by sex. Males were more likely to be hit by their equipment or impact with a surface and females were more likely to suffer twist or bending injuries. In both sports, the laceration and fracture rate was higher for males than for females and the strain/sprain rate was higher for females than for males.

Shealy, Ettlinger and Buomo investigated 15,323 alpine skiing and 3,696 snowboarding injuries over seven ski seasons at two ski centres on the western US coast.[46] Trend analyses were conducted using regression analysis and differences were explored using a t-test or using ratios of the injury rates. They claim that snowboarding participation increased from 4.2% to 36.7% of all ski centre visits (but do not state how this was established). The wrist was the most commonly injured body part among snowboarders and they suggested that snowboarders were 13 times more likely to suffer a wrist injury than alpine skiers based on the injury rate ratio. This elevated risk was evident throughout the seven ski seasons. Lower leg injuries were 50% higher among alpine skiers than snowboarders. The trend analysis found significant reduction in lower leg injuries in both sports over the seven ski seasons. Ankle injuries were over twice as likely among snowboarders than among alpine skiers. Risk of injury to these body parts varied by sex and sport. Females ($p<.01$) and snowboarders ($p<.01$) had a greater risk of wrist injury. Males ($p<.01$) and alpine skiers ($p<.01$) had a greater risk of lower leg injury. Females ($p<.01$) and alpine skiers had a greater risk of knee injury. Females ($p<.01$) and snowboarders ($p<.01$) had a greater risk of ankle injury. Investigators found that snowboarders were four times as likely to suffer a fracture.

Pigozzi, Santori, Di Salvo, Parisi and Di Luigi studied 106 snowboarding injuries in Italy over four or five ski seasons; the exact length of time is unclear.[52] Injuries were reported to the Italian Snow Sports Federation which is presumably the Italian equivalent of the Ski Patrol. They obtained demographic and some equipment information. The majority of injured snowboarders (86%) were male and they were older than in other case-series with an average age of 26 years. Nearly half (48%) the injured snowboarders were beginners. The study found slightly more upper than lower limb injuries. The most frequently injured body parts were the knee, shoulder and ankle. Fractures were the most common injury seen. Over half those injured (62%) were wearing hard boots and 63% rode with a left lead. The investigators state there was a statistical correlation between hard boots and knee injury, soft boots and ankle injury and soft boots and spinal injury. However, the statistical methods used were not described nor were sufficient data presented to replicate these results. Over half of those injured had taught themselves to snowboard (52%) and had injured themselves on trails of intermediate difficulty (60%).

Two of the case-series studies investigated severe snowboarding injuries.[38,55] Both studies were conducted at Level I trauma centres in the US. The studies had similar sample sizes (37[55] and 40[38]), time spans (5[38] and 6[55] years) and results. Severely injured snowboarders were younger (average age of 20 years[38,55]) than severely injured alpine skiers (average age of 27[55] ($p<.005$) and 29[38] ($p<.001$) years). Compared to severely injured alpine skiers, a larger proportion of severely injured snowboarders were male ($p<.005$[55]). The male:female ratio in snowboarders was 4.4:1 and for alpine skiers it was 2.6:1. Prall *et al.* found the average injury severity score (ISS) to be similar in both sports (8-9) but Sacco *et al.* found that injured snowboarders had a significantly lower average injury severity score, an average ISS of 11 compared with an average ISS of 22 for alpine skiers ($p<.03$). Sacco and colleagues found more lower limb injuries than upper limb injuries in the snowboarders. When compared with injured alpine skiers, snowboarders experienced more upper limb injuries ($p<.003$) and fewer lower limb injuries ($p<.001$). Prall and colleagues did not offer a comparable presentation of their results. The Sacco study was based solely on clinical information; therefore, they obtained no circumstantial or equipment information other than observing that no head injuries were seen in helmeted snowboarders or alpine skiers. The Prall study reports that falls were the most common mechanism of injury but they do not state their source for this circumstantial information. Findings were based on proportions and chi-square tests for difference.

Two other Canadian studies were found in the literature search. The case-series studies of Macnab and Cadman[35,36] identified snowboarding in their titles and text but they do not present sport-specific results. Consequently, the results from their studies are not detailed in this summary.

Shealy has conducted the only case-control study investigating snowboarding injuries.[45] The sample was acquired over two ski seasons (1988/89 and 1989/90). Cases (21,817 alpine skiing injuries and 1,194 snowboarding injuries) were obtained from Ski Patrol data and controls (2,318 alpine skiers and 255 snowboarders) were randomly selected and surveyed from the general skiing and snowboarding public. Details of the control selection were not presented although the investigator states that not all of the 15 participating ski centres provided control data. Demographic, equipment and circumstantial information was collected from cases and controls. Controls in both sports had a higher proportion of males, were taller, heavier and older than those who were injured. The chi-square and t-test statistics were not presented but stated to be significant at the 1% level. Comparisons of proportions (i.e. ratios) suggested that the injuries varied by sex. In snowboarding, males had twice the ankle injuries and three times the head and face injuries of females. Females had 50% more wrist injuries and twice the knee injuries of males. Findings suggested that ability was related to injury with increased risk for injury in those of lower abilities. Beginner snowboarders had seven times the risk for injury (Mantel-

Haenszel OR=7.31, 95% CI=5.69, 10.13) and beginner alpine skiers five times (Mantel-Haenszel OR=5.30, 95% CI=4.92, 6.02). Over half (57%) the injured snowboarders provided data on the type of boot worn. Using a chi-square test, there were no statistically significant differences between the injured snowboarders wearing soft and hard boots on any of the variables investigated. Reports indicated that snowboarders (cases and controls) fell 3-10 times as often than alpine skiers. There was no evidence that taking lessons reduced the risk for injury. This was presented based on a chi-square test of association. Sufficient detail was presented in the paper to calculate an odds ratio of 2.57 (95% CI=1.37, 4.83), or over twice the risk for snowboarding injury if lessons had been taken. Ratios of proportions were used to explore snowboarding injuries by trail difficulty. Shealy found that wrist injuries and knee injuries were more likely on easy trails (8 times and 3 times as likely, respectively). Lower leg and head/face injuries were 10 times and 50% as likely on the most difficult compared with the easy trails. This was a case-control study. Shealy used nearly 10 alpine skiing injuries per control and 5 snowboarding injuries per control because cases (i.e. injured alpine skier and snowboarders) are cheaper to obtain than uninjured controls. In summary, the study found that cases were of lower ability levels, that lessons did not reduce the risk for injury, that females were over-represented in the injured and that boot type was not associated with injury.

2.2.3 Snowboarding Injury Rates

Injury rates for sports are difficult to calculate due to the difficulty in quantifying and measuring exposure. An individual is at risk for sports injury only during sports participation. The ascertainment of denominator data is a recurrent problem in injury research.[1,7,60,62,66,70] It has become convention to use lift ticket sales as the basis for alpine skiing injury rates and to calculate the rates as an injury count per 1,000 ski centre visits. However, ticket sales do not distinguish between snowboarders and other snow-sport participants (e.g. alpine skiers, telemark skiers, monoskiers). Ticket sales do not include season pass holders, members of the Ski Patrol, staff or others who do not purchase lift tickets. Failure to distinguish between sports and using all lift ticket sales as a denominator results in an under-estimation of injury rates. Failure to capture all ski slope users results in an over-estimation of injury rates. This is not only problematic for the estimation of alpine skiing injury rates but an increase in the number of snowboarders will distort alpine skiing injury rates if lift ticket sales and a single denominator continue to be used.

Eleven studies presented snowboarding injury rates (Table 3 and Table 4). In six, the investigators estimated the number of snowboarder visits and used it as the injury rate denominator.[37,38,39,40,41,55] A count of snowboarder visits was obtained by applying industry estimates of the proportion of snowboarders on the slopes to the total number of ticket sales. The other five studies[42,43,44,45,46] based the rates on the total number of ski centre visits. Two of the studies focussed only on severe injuries and are excluded from this summary.

The injury rates, regardless of denominator, ranged widely, the lowest rate at 0.3/1,000 ski centre visits/season[42] and the highest at 16/1,000 snowboarder visits/season[37]. Snowboarding injury rates based on all ski centre visits under-estimate the risk for snowboarding injury however these rates which were based on all ski centre visits are dispersed between the extremes which include rates based on only snowboarder visits.

Table 4 — Snowboarding Injury Rates

Study	Year	Injury Rate
Sutherland et al.	1996	0.3/1000 SCV*
McLennan & McLennan	1991	1.7/1000 SBV
Ganong et al.	1992	2/1000 SBV
Shealy	1993	3.03/1000 SCV
Shealy & Ettlinger	1996	3-4 /1000 SCV
Bladin et al.	1993	4.2/1000 SCV
Shealy & Sundman	1989	4.2/1000 SBV
Shealy et al.	1997	6.02/1000 SCV (may be SBV)
Abu-Laban	1991	8-16/1000 SBV

* my calculation
SBV = snowboarder visits
SCV = ski centre visits

The range of snowboarding injury rates varied depending on the data source. Five of the studies used Ski Patrol injury data[39,42,43,45,46] and the rates range from 0.3[42] to 6.02[46] per 1,000 ski centre visits per season. The other three studies used clinical data[37,41,44] and the range in rates was wider, from 2[41] to 16[37] per 1,000 snowboarder visits per season. The two lowest rates were based on clinical injury data and are excluded from these ranges. These rates are expected to be lowest since the two studies were conducted in trauma centres which see fewer injuries but to which are referred the more severe alpine skiing and snowboarding injuries.

Overall, there was wide variability in the injury rates. The range extends from less than one to 16 injuries per 1,000 ski centre visits per season. The ranges are different depending on the denominator (all ski centre visits or only snowboarding visits) and they vary by data source. This could explain some of the variability.

2.2.4 The Site & Nature of Snowboarding Injuries

Injuries can be categorized by anatomic site and nature of injury. It is difficult to summarize the patterns of snowboarding injury by anatomic region since there were no uniform groupings used consistently in the studies that were reviewed. For example, some of the categorizations encountered were upper and lower extremities and upper and lower body. Rarely were the anatomic regions accompanied by clear delineations of the body parts included in each category.

For the purpose of this summary, four anatomic regions (upper limbs, lower limbs, head/neck and torso) were used. Results were grouped into these categories if not presented in this way and if sufficient information was provided to do so. These results are summarized in Table 3 and discussed here in more detail. Six of the studies[35,36,43,46,55,56] are not summarized because insufficient detail was provided to present results based on the four anatomic regions.

The majority of snowboarding injuries (over 70%) were to the upper and lower limbs. Injuries to the head and torso were also reported frequently. The range of the proportions of injuries to these anatomic regions was wide. The upper limbs accounted for 12%[37] to 58%[47] of the snowboarding injuries and a similar range was reported for the lower limbs at 16%[47] to 53%[16] of the injuries. Head injuries ranged from 2%[40] to 18%[47] of the snowboarding injuries and torso injuries accounted for 6%[44] to 15%[37] of the injuries studied. These figures are summarized in Table 3.

The distribution of injuries between the upper and lower limbs varied by study. This distribution was explored by calculating a ratio of the proportion of upper to lower limb injuries. A ratio was obtained for 15 of the studies. The upper:lower limb ratio was greater than one for seven of the studies and less than one for the other 8 (Table 5). Many of the ratios were close to one but two of the studies found two to four times more upper limb than lower limb injuries and three of the studies found two to four times more lower limb than upper limb injuries. The upper:lower limb ratio was 3.74 in the study by Chow *et al.*[47] and 1.78 in the study by Sutherland *et al.*[42] Each study used a different data source; one was based on Ski Patrol data[51] and the other on clinical data[47]. The upper:lower limb ratio was 0.24 in the study by Abu-Laban[37] and 0.56 in the study by Bladin *et al.*[44] and 0.55 in the survey by Pino and Colville[16]. The other two studies were based on clinical injury data.

Table 5 — Upper:Lower Limb Ratio

Study	Data Source	U:L Ratio
Pino & Colville[16]	**survey**	**0.55**
McLennan & McLennan[40]	not stated	1.23
Abu-Laban[37]	**clinic**	**0.24**
Ganong et al.[41]	clinic	1.02
Bladin et al.[44]	**clinic**	**0.56**
Janes & Fincken[48]	clinic	0.93
Callé & Evans[49]	clinic	1.11
	clinic	1.48
Chow et al.[47]	**clinic**	**3.74**
Sacco et al.[38]	clinic	0.61
Shealy & Sundman[39]	patrol	0.60
Shealy[45]	patrol	0.75
Lamont[50]	patrol	0.91
Sutherland et al.[42]	**patrol**	**1.78**
Davidson & Laliotis[51]	patrol	1.05
Pigozzi et al.[52]	patrol	1.17

Results in bold indicate an U:L ratio 2-4 times greater for one set of limbs (upper limbs if ratio >1 and lower limbs if ratio < 1)

This pattern remained even after the data source was taken into account. For example, of the seven studies with an upper:lower limb ratio greater than one, three used Ski Patrol data and three used clinical data. The body parts most frequently reported as injured in snowboarders were the ankle, knee, wrist and shoulder.

The nature of snowboarding injuries also varied across the studies. The summary presented here should be interpreted with caution, particularly the studies using injury data collected by the Ski Patrol. Members of the Canadian Ski Patrol are trained in first-aid. However, Ski Patrol training and experience is likely to differ both within and between countries.

In the 14 studies which categorized the nature of the snowboarding injuries, injuries commonly reported were fractures, strains and sprains, dislocations and contusions. Fractures accounted for 14%[39] to 44%[41] of the snowboarding injuries. The range of strains and sprains was wider at 15%[47] to 64%[39] of the injuries studied. Dislocations accounted for 2%[16] to 13%[47] and contusions were experienced 6%[45] to 31%[52] of the time. As previously mentioned, there is less confidence in the injury diagnoses of the Ski Patrol, however, the proportions of injuries varied regardless of the data source. The nature and severity of injury may influence the reporting of an injury, which, in combination with data source (Ski Patrol versus clinic) may explain some of the variation.

2.3 Limitations of Previous Studies

2.3.1 Lack of a Comparison Group & Interpretation of Proportions

The main limitation of the descriptive studies of snowboarding injuries is the lack of a comparison group.[53] In many studies, the discussion suggests factors which potentially increase the risk for injury (e.g. not taking lessons, soft versus hard boots, ability, trail difficulty). These suggestions are based on high proportions of those factors in the injured snowboarders. However, the distribution of those factors in the general snowboarding population is unknown and consequently they must remain suggestions that require further investigation.

There are additional issues to be considered when interpreting proportions. As mentioned, higher proportions may indicate increased risk for injury. However, the risk for injury or a particular injury can be similar for both sports while the proportions may be different. The factors highlighted in the descriptive case-series could be masking the relationship or suggesting an association that does not actually exist.[53] These situations are illustrated in Table 6. For each sample, the proportion of wrist injuries remains constant yet the actual risk for wrist injury varies depending on the overall risk for injury.

Table 6 — Examples of Relationships Between Proportions and Risk

Proportion and Risk (/10,000 SBV/season)	Male Snowboarders	Female Snowboarders
Proportion of Wrist Injuries (%)	30	60
Sample 1		
overall risk for injury	10	10
risk for wrist injury	3	6
Sample 2		
overall risk for injury	10	5
risk for wrist injury	3	3
Sample 3		
overall risk for injury	10	1.7
risk for wrist injury	3	1

2.3.2 Other Limitations

This summary must be viewed in light of the limitations of the studies upon which it is based: one convenience sample survey, one case-control study and 17 injury series. (Two other studies were excluded from this summary because they did not present sport-specific results.) However, the newness of the sport, geography, the inconsistent reporting of findings, the differing sources of data, the unclear methodologies, the lack of denominator data and the lack of comparison groups pose challenges in summarizing the literature and may explain the wide range of results.

A certain amount of variability in the findings is to be expected since snowboarding is a young sport which has experienced growth in popularity over the past ten years. This growth has spawned an evolution in the equipment, the participants, and, consequently, the injuries.

Geography can impact on the sports and resulting injuries because snow conditions vary both within and between countries. For example, Ontario and Quebec offer packed, groomed, granular conditions where the west coast offers fresh powder. The techniques for skiing and snowboarding change with the snow conditions and some sports participants are not prepared for the differences. The popularity of these winter sports varies by location. There are some areas where the slopes are very busy and others where there is less hill traffic.

The reporting of results is often unclear and/or details are omitted which are necessary to produce an accurate summary of the findings. Only four of the studies state the unit of analysis as the injury or the individual.[37,40,47,52] The unit of analysis can be deduced for six other studies[41,44,48,50,51,55] and is unclear for the remainder. Using the individual and their primary injury as the unit of analysis under-estimates the burden of snowboarding injuries but it simplifies and clarifies the analyses. Two of the publications[16,52] do not report the number of ski centres involved in their studies.

Sources of data for snowboarding injuries are limited in availability and quality. Using a single data source results in an under-estimation of injury.[1,54] The data sources vary throughout the literature. Nine of the published snowboarding injury studies use clinical data supplemented by questionnaire information provided by the patients[37,38,41,44,47,48,49,55,56], ten use Ski Patrol data [35,36,39,42,43,45,46,50-52], one surveys a convenience sample of snowboarders[16] and the data source is not stated for the remaining study[40]. The clinical data may be more accurate with respect to the diagnosis of injuries but, according to the injury pyramid (Section 1.1), far fewer injured snowboarders are seen by clinicians than by the Ski Patrol. The quality and quantity of data varies with each study. The Ski Patrol incident report forms and supplementary questionnaires for clinical cases are different in each study with respect to the type and amount of information they provide. In addition, the training received by members of the Ski Patrol varies both within and between countries.

Ascertainment of denominator data is a recurrent problem in injury research.[1,7,60,62,66,70] Estimates of the population at risk for alpine skiing injuries are routinely based upon lift ticket sales. However, lift ticket sales do not distinguish between the various groups of ski slope users and lift tickets are not required by other groups (e.g. Ski Patrol, season pass holders). Injury rates based on ski centre visits, therefore, are under-estimates or over-estimates of the injury rates. Most investigators who calculated snowboarder visits did so based on industry estimates not actual counts. Chow and colleagues conducted sample counts of snowboarders on chairlifts to determine the proportion of snowboarders and their estimates were comparable to industry estimates of 20%-25%.[47]

2.4 Summary of Findings

Although similar methodologies were employed in many of the studies, there are no consistent results describing snowboarding injuries. Case-series studies which focus on specific snowboarding injuries have highlighted injuries of particular concern in the sport. For example, "Snowboarder's Ankle" (fracture of the lateral process of the talus) has been identified as a sport-specific injury that can be easily misdiagnosed.

There is some consistency in the demographic findings but injury rates, the site of injury and the nature of injury vary throughout the literature. Injured snowboarders tend to be young with an average age of 20 years or less and the majority are male. A wide range of snowboarding injury rates have been calculated (Section 2.2.3). Body parts frequently injured are the wrist, ankle, knee and shoulder but the distribution of the injuries varies throughout the studies (Section 2.2.4). Frequent injuries include fractures, strains and sprains, dislocations and contusions but, as with the site of injury, the distribution of these injuries varies (Section 2.2.4).

One has more confidence in the descriptions of the nature of snowboarding injuries from those studies using clinical data because the injury has been diagnosed rather than assessed as a suspected injury by a member of the Ski Patrol. Although the injury diagnoses are more accurate, the results of these clinical studies (e.g. distributions of site and nature of injury) range as widely as those which used Ski Patrol data. Furthermore, clinical capture of snowboarding injuries is much more selective and, therefore, portrays a very biased view of all snowboarding injuries.

With the exception of the case-control study, all other studies of snowboarding injuries are descriptive case-series. It is difficult to summarize the literature due to the variability of results. The wide range of results may be explained by geography, methodology, the inconsistent reporting of findings, the differing sources of data, the lack of denominator data and the lack of comparison groups. The key limitation is the lack of information about the general snowboarding population. Risk factors are suggested based on high proportions in the injured snowboarders. However, the distribution of these factors among all snowboarders is relatively unknown. Without the comparative information, it is uncertain whether higher proportions in the injured are reflections of the underlying population or indications of increased risk.

3.0 Thesis Objectives

There were two objectives for the thesis:

① To profile current alpine skiing and snowboarding injuries by describing the characteristics of the injuries, the injured individuals and the circumstances surrounding the injuries.

② To identify risk factors for severe snowboarding injuries. Severe injuries are a concern for a variety of reasons: they can be life-threatening; they are a major cause of short- and long-term disability; and they result in increased utilization of health care services.[7,57]

4.0 METHODS

4.1 Overview

This thesis was a study of snowboarding injuries in the province of Quebec during the 1996/97 ski season. This study had two components: a descriptive component and an etiologic component. Both build upon earlier studies and advance the current state of knowledge regarding snowboarding injuries. Alpine skiers and skiing injuries were included because it is a natural comparison sport and alpine skiers constitute the majority of alpine slope users. The two sports use the same facilities and are frequently compared in the literature. The injury data used for the project were from the Quebec Sports Safety Board and were collected by members of the Ski Patrol. The census data were from Statistics Canada. The skiing/snowboarding participation data were provided by the Canadian Ski Council.

Descriptive analyses were conducted on a large retrospective case series of snowboarding and alpine skiing injuries. The injuries were described as proportions of the total number of the respective sports injuries. Specific and standardized injury rates were calculated. Differential risks for various injuries between the two sports were explored.

A variant of the case-control design was used to identify risk factors for more severe snowboarding injuries in the etiologic component. Cases (severe injuries) and controls (minor injuries) were identified. Potential risk factors were identified using logistic regression. The resulting model illustrates the multifactorial nature of injuries while controlling for the potential effects of other factors such as age and sex.

4.2 Injury Data

This thesis examined alpine skiing and snowboarding participation and associated injuries in the province of Quebec during the 1996/97 ski season. The injury data were provided by the Quebec Sports Safety Board. This provincial government agency was created in 1979 to support the *Act Respecting Safety in Sport*.[58] The Board conducts and facilitates research and assists in the establishment of regulations that pertain to safety in sports. Provincial legislation requires that ski centres share the prescribed Ski Patrol accident report forms (*Appendix A*) with the Quebec Sports Safety Board. Quebec ski centres have been supplying these injury data to the Quebec Sports Safety Board since the 1988/89 ski season. Injury data from the 1995/96 and the 1996/97 ski seasons were obtained. At that time, there were 92 ski centres in operation in Quebec and 71 (77%) forwarded their accident report forms to the Quebec Sports Safety Board. The 71 ski centres accounted for over 85% of 1996/97 ski centre visits in the province of Quebec (Personal communication, C. Goulet, Researcher, Quebec Sports Safety Board, 1999). For reasons of confidentiality, the identification of ski centres which were included and missing for the 1996/97 ski season data were not disclosed. Compliance is recognizably not 100% and is not actively enforced.

4.3 Derivation of an Injury Data Set for Analysis

Injury data received from the Quebec Sports Safety Board contained 20,466 records for the 1995/96 and 1996/97 ski seasons. The sample was narrowed to include 18,311 records where the activity was recorded as alpine skiing or snowboarding (Figure 3). The sample was then confined to a 17-week ski season from 01 December 1996 to 31 March 1997. The resulting data set contained 8,489 injury records: 5,708 alpine skiing injury records and 2,781 snowboarding injury records.

Figure 3 — Derivation of Data Set

The injury data set was further refined in an attempt to obtain more complete information and a single data set which could be used for all analyses. Records were deleted if they were missing values for either sex or age (82 records were missing sex and 76 records were missing age). The data set was then limited to cases over the age of 11 years since alpine skiing and snowboarding participation data are not available for children under age 12 years. There were 1,626 records excluded where age was less than 12 years. The resulting data set contained 4,226 alpine skiing and 2,501 snowboarding injury records.

Analyses were limited to data for the first site of injury and the nature of injury for that site. An individual can suffer multiple injuries and the accident report form provides space for information to be recorded for up to three injuries. However, only the primary injury was used because it would simplify analysis and interpretation of results since the unit of analysis would be the individual.

4.4 Skiing/Snowboarding Participation Data

Alpine skiing and snowboarding participation data were obtained from the Canadian Ski Council, an association of national ski organizations. Delegates from each member organization represent the industry and aim to increase participation in recreational snowboarding, alpine and cross-country skiing in Canada through marketing, promotion, education, research and advocacy.[59] Since the 1994/95 ski season, the Canadian Ski Council has conducted and contracted annual surveys and the results are used to develop regional and national market profiles.

Data provided by the Canadian Ski Council are proprietary data collected by the Print Management Bureau (a commercial survey company). The Print Management

Bureau conducts annual participation and market surveys although the results can only be purchased by the Canadian Ski Council and its members. However, the data are incorporated into the Canadian Ski Council's products and reports that were used for this thesis. The Print Management Bureau mails approximately 2,000 questionnaires across the country annually to obtain national participation estimates. Results are weighted by census population estimates.

The skiing/snowboarding participation data were used in the calculation of injury rates. Stratum-specific and standardized rates are described in sections 4.5.3 and 4.5.4.

4.5 Objective ① - Descriptions of Alpine Skiing & Snowboarding Injuries

4.5.1 Definition of Injury

Definitions and formulae presented throughout the thesis are summarized in *Appendix B*. The operational definition of injury is often dictated by the source of the data.[60] For the first objective, the definition of injury was provided by the Quebec provincial legislation concerning safety in alpine ski centres. In the legislation, an injury is defined as the result of an incident which occurred on a ski slope and for which a first-aider's assistance was required or provided.[61] In essence, an injury was defined as any injury event brought to the attention of and recorded by a member of the Ski Patrol.

4.5.2 Variables Used for Injury Descriptions

Snowboarding and alpine skiing injuries were described by detailing the persons who were injured, the equipment and the circumstances surrounding the injury. The injured individuals were described using factors of the host, vehicle and environment. Table 7 lists the variables/factors used to describe the injuries and the amount of missing information for each variable. Proportions were used to describe the injury distributions by each factor and for each sport.

Continuous variables and categories with small cell counts were collapsed. Age and hour of the injury event were recorded as continuous variables but were grouped and treated as categorical variables. Age was grouped into the seven categories used by the Canadian Ski Council (i.e. the skiing/snowboarding participation data): ages 12-17, ages 18-24, ages 25-34, ages 35-49, ages 50-64 and over age 65. Due to small frequencies in the three upper age groups, they were collapsed into one group for over age 35. The hour of the injury event was grouped into morning (0000h-1259h), afternoon (1300h-1759h) and evening (1800h-2359h). Possible activities were collapsed to three categories: competition/training, lessons and recreation. Equipment was collapsed to three categories: owned, rented or borrowed/demonstration.

Injured body parts were grouped into four anatomic regions: head and neck, torso, upper limbs and lower limbs. Table 8 lists the body parts included in each of these anatomic regions. These categories were created based on those used in previous studies.[41,51,52]

Table 7 — Factors of Alpine Skiing and Snowboarding Injuries

Factor Description	Missing (%)
Host Factors	
age (#)	0
sex (male, female)	0
body part injured (27 body parts, see Appendices A and C)	157 (2.3)
suspected injury (16 injuries, see Appendices A and C)	369 (5.5)
time out before injury event (<1 hr, 1-3 hrs, 3-5 hrs, 5-7 hrs, >7 hrs)	80 (1.2)
lessons (never, this yr, 1-2 yrs ago, 3-4 yrs ago, >5 yrs ago)	260 (3.9)
ability (self-rated as beginner, intermediate or advanced)	251 (3.7)
Vehicle Factors	
activity (competition, training, lesson, recreation)	472 (7.0)
equipment (own, rented, borrowed, demonstration)	133 (2.0)
bindings (toe-heel, plate, cable, pin, flexible snowboard, rigid snowboard)	169 (2.5)
Environmental Factors	
month (Dec, Jan, Feb, Mar)	0
day (part of date converted to day of the week - Sun, Mon, Tue, Wed, Thu, Fri, Sat)	0
time of day (hour of accident 0000h-2400h)	39 (0.6)
trail difficulty (green/easy, blue/difficult, diamond/very difficult, double diamond/extremely difficult)	1153 (17.1)
lighting (natural, artificial)	782 (11.6)
centre evacuation (toboggan, snowmobile, traction, skied, walked)	387 (5.8)
left ski centre (on own, with parent, with guardian, with instructor, with friend, by ambulance)	408 (6.1)

Table 8 — Anatomic Regions and Body Parts

Head & Neck	Torso	Upper Limbs	Lower Limbs
head	ribs	shoulder blade	thigh
face	thorax	shoulder	lower leg
eyes	cervical spine	upper arm	knee
nose	dorsal spine	forearm	ankle
mouth	lumbar spine	elbow	foot
neck	collar bone	wrist	
	abdomen	hand	
	hip-pelvis	thumb	

4.5.3 Calculation of Crude & Specific Injury Rates

An injury rate provides an indication of the injury occurrence in a defined population[7]: the key to a meaningful injury rate is the determination of an appropriate denominator that estimates exposure.[104] The rates for many health and disease events use the general population as a denominator. However, an individual is at risk for sports injury (i.e. exposed) only while engaged in the sport.

A variety of denominators have been used to create an estimate of risk for sports injury.[1] For instance, injury rates can be presented per person in a total population, per participant or per time unit of exposure.[62,63] The latter is the most difficult to obtain but is the most meaningful estimate of sports injury risk.[7,62,63,64,65,66,67]

A series of crude, sex-specific and age-specific alpine skiing and snowboarding injury rates were calculated. Three denominators were used in these calculations: the Quebec provincial population, the number of ski centre visits in Quebec for the 1996/97 ski season, and Quebec alpine skiers and snowboarders in 1996/97.

The time period of the study was the 17-week ski season from 01 December 1996 to 31 March 1997. The corresponding provincial population was obtained from the 1996 census.[68,69] Census data were grouped to reflect the Canadian Ski Council participation data: males over age 12; females over age 12; and for each sex, the age groups 12-17 years, 18-24 years, 25-34 years and over age 35.

A second set of injury rates were calculated based on the annual number of ski centre visits in Quebec for the 1996/97 ski season. Use of this denominator assumes that the sports exposure is similar amongst the groups of interest (i.e. alpine skiers and snowboarders).[1,67,70] In other words, the assumption is that the average number of hours spent on the slopes and the average vertical height covered during each visit is similar among all participants and remained constant throughout the 1996/97 ski season.[70] Length of time on the slopes and vertical height covered are proxies for exposures to hazards. The number of ski centre visits is not an ideal measure of sports exposure because it is based on lift ticket sales. Ticket sales do not account for season pass holders, members of the Ski Patrol, staff and others who do not purchase lift tickets. In the past, almost all lift tickets were purchased by alpine skiers. With increased snowboarding participation, ticket sales become a less accurate exposure estimate because the sales do not distinguish between alpine skiers, snowboarders and other alpine snow sports (e.g. monoskiing and telemark skiing). Despite these limitations, the number of ski centre visits was used as a denominator because it is conventionally used in the alpine skiing and snowboarding injury literature. The Canadian Ski Council reports that at least 20% of the ski centre visits are snowboarders. (Personal communication, H. Buckley, Research and Product Development Manager, 1998) This value was applied to the total number of ski centre visits in Quebec during the 1996/97 ski season to estimate the number of alpine skiing visits and the number of snowboarder visits.

A third set of injury rates, based on the number of Quebec alpine skiers and snowboarders, was calculated. Denominator data for these risk estimates were taken from the research reports provided by the Canadian Ski Council.[71] They report alpine skiing and snowboarding markets (i.e. participation) as counts and as proportions of the national population. It was assumed that the skiing/snowboarding participation rates for the province of Quebec were the same as those for Canada. The majority of Canadian alpine skiers and snowboarders are from Ontario and Quebec. These two provinces combined account for 60.5% of Canada's snowboarders and 61% of alpine skiers.[71] Furthermore, these two provinces account for 62.2% of the Canadian population.[68] Quebec alone accounts for 30.4% of the country's alpine skiers, 28.5% of the snowboarders and 24.7% of the Canadian population. The national participation proportions were applied to the Quebec census populations to obtain denominator counts of alpine skiers and snowboarders.

The following formula was used to calculate the crude, age-specific and sex-specific injury rates for alpine skiing and snowboarding. The rate calculations were made under a binomial assumption and were based on cumulative incidence.

Injury rate per 10,000 population per season calculated as:

$$\frac{\#injuries}{\#@risk} \times 10{,}000$$

Where the injury rate, injury count and population at risk are for a given sport, sex or age group

Confidence limits were calculated for the injury rates.[72]

95% Confidence Limits calculated as:

$$rate \pm (1.96 \times SE)$$

And Standard Error (SE) calculated as:

$$\sqrt{\frac{rate \times (1 - rate)}{pop'n@risk}}$$

Where

rate = injury rate calculated
pop'n@risk = denominator used for rate calculation

4.5.4 Direct Standardization of Injury Rates

Caution is warranted if the crude injury rates for alpine skiing and snowboarding are compared. The at-risk and injured alpine skiers and snowboarders differed in the distribution of both age and sex. The alpine skiing and snowboarding injury rates (based on the alpine skiers and snowboarders) were adjusted for age and sex separately. Injury rates adjusted simultaneously for both age and sex could not be calculated because the participation data broken down by age for each sex were not available. All rates were calculated with the aid of Quattro Pro[73] spreadsheet software.

The 1996/97 alpine skiing population was used as the standard. The age-specific and sex-specific injury rates were applied to the standard population to obtain an expected number of injuries in each age or sex stratum for each sport. A sex-adjusted or age-adjusted injury rate was obtained by summing the expected number of injuries across the two sex or four age strata and dividing that sum by the standard population counts summed across the same stratum. The resulting adjusted injury rates for each sport are more comparable since the rates are directly standardized using the same referent population.

4.5.5 Measures of Differential Risk

The nature of alpine skiing and snowboarding injuries was explored further through proportional injury ratios (PIRs). The PIRs were standardized to control for potential confounding by the differing age and sex distributions.[53] The outcomes of interest were the four anatomic regions, nature of the injuries (including severe snowboarding injuries) and the most commonly injured body parts in the two alpine sports (i.e. wrist and knee).

The PIRs were calculated in the manner of proportional mortality ratios (PMRs). The PIR formulae were adapted from those used to calculate proportional mortality ratios for cancers as documented by Boyle and Parkin.[74] A proportional mortality ratio (PMR) is the ratio of the proportion of deaths from a specified cause in the exposed group to the proportion of deaths from the specified cause in a comparison group.[53] Analogously, the

PIR is the ratio of the proportion of a specific injury in the injured snowboarders and the proportion of the same injury in the injured alpine skiers. The PIR is, therefore, conditional on the numbers in the comparison group (i.e. the injured alpine skiers). Alpine skiing injury proportions were used as the standard to estimate the expected number of snowboarding injuries.

The process followed is best described using an example calculation of the PIR for a specific injury — head and neck injuries. The same process was followed for the other outcomes describing the nature of snowboarding injuries (e.g. the other three anatomic regions, the nature of the injuries and the most frequently injured body parts).

Proportional Injury Ratio (PIR) calculated as:

$$\frac{a}{\sum_{males}^{females}\left[\sum_{age1}^{age4}\left(\frac{b}{c}\times d\right)\right]}$$

Where PIR is for SB head and neck injuries
SB = snowboarding
SK= alpine skiing
age1 = first age group 12-17 years
age4 = fourth age group 35+ years
a = # SB head and neck injuries observed
b = # SK head and neck injuries for an age and sex group
c = # SK injuries for the sex and age group
d = # SB injuries for the sex and age group

Confidence limits were calculated for the PIRs. It has been recommended that the statistical significance of observed differences be evaluated using the confidence intervals.[74] The 95% confidence limits were calculated using the following formulae using the previous example of the PIR for snowboarding head and neck injuries.

95% Confidence Interval calculated as:

$$e^{\ln PIR \pm (1.96 \times SE)}$$

Standard Error (SE) calculated as:

$$\frac{\sqrt{\sum_{males}^{females}\left[\sum_{age1}^{age4}\frac{e(d-e)}{d}\right]}}{a}$$

Where
- age1 = first age group 12-17 years
- age4 = fourth age group 35+ years
- e = # SB head and neck injuries observed for an age and sex group
- d = # SB injuries observed in the age and sex group
- a = # SB head and neck injuries observed

4.6 Objective ② - Risk Factors for Severe Snowboarding Injuries

The second objective of the thesis was to identify potential risk factors for severe snowboarding injuries. This was addressed in the etiologic component using a modified case-control study design. A variant of the case-control design, the case-case design, was used. This design has been used to study cancer etiology with other cancer sites as the referent group (i.e. controls).[75,76,77,78] This approach is used when denominator data are not available.[76,79] The underlying assumption of this approach is that the risk for the cancer being used as the referent group is not related to the exposures of interest.[76]

The case-case design was considered appropriate to explore the risk factors for severe snowboarding injuries. Given that a snowboarder has suffered an injury, the investigation of severe injuries was based on the assumption that there are risk factors that contribute to the severity of injury. A similar approach has been used in other studies of injuries.[80,81,82] The etiology of severe snowboarding injuries was explored by identifying the injuries in the data set which clinicians considered "severe" and using the remaining "not severe" injuries as the comparison group.

Multivariate analyses were used in order to address the multifactorial nature of injuries.[66,67,83] The potential risk factors for severe snowboarding injuries were identified using multiple logistic regression methods[84,85] with SPSS statistical software.[86]

4.6.1 Outcome Variable - Severe Snowboarding Injuries

Severe injuries are a concern for many reasons: they can be life-threatening; they are a major cause of short- and long-term disability; and they result in increased utilization of health care services (ambulatory and rehabilitation).[7,57] Severe injuries are, therefore, a public health concern. Robertson stresses the importance of severity when investigating injuries.[1] He explains that the energy sources, vehicles, vectors, and other circumstances are often not the same for severe as for less severe injuries.[1]

There are a variety of injury severity scores in use, for example, the Trauma Score[87], the Injury Severity Score (ISS)[88] and the Abbreviated Injury Score (AIS)[89]. These severity scores are used for triage, to plan for health care services and for a variety of research purposes including the evaluation of the effectiveness of treatment.[1] They provide a way to estimate the probability of death and disability or impairment among survivors.[1] The use of these severity scores, however, requires clinical examination and diagnostic evaluation.[90] Using their training in first-aid, members of the Ski Patrol identify and record the injured body part(s) and the suspected injury. A conventional severity score could not be applied to the data as they are not clinical data. Instead a severity classification had to be derived from the available Ski Patrol injury data.

Clinicians were consulted to categorize the Ski Patrol data into severe and not severe injuries using the information on nature of injury and injured body part. A convenience sample of emergency department clinicians provided the severity classification scheme. At a presentation to the Emergency Medical Rounds at the Children's Hospital of Eastern Ontario in Ottawa (09 September 1998), clinicians in attendance were asked which of the suspected injuries they would consider severe. A severe injury was defined as one that would require medical attention. The two variables (injured body part and nature of injury) were presented on a grid with one variable on each axis. Each combination of injury and body part was considered and if decided to be severe, was marked as such. Coding options for the two variables and the grid used to record severe injuries are included in *Appendix C*.

There was general agreement amongst the ten clinicians who participated. The results of the exercise are presented in Table 9. Fractures (simple and compound), internal injuries and dislocations were classed as severe injury types. Injuries to the head, thorax and spine were the main body parts identified as severely injured.

The injuries identified as severe by a majority (i.e. at least 50%) of the participating clinicians were coded as "severe" snowboarding injuries in the injury data set. All other injuries were coded as "not severe". The severity definition was similar to the severity classification used in a study of alpine skiing and snowboarding injuries by O'Neill and

McGlone.[91] They classified injuries as emergent and non-emergent. Emergent injuries were those which required immediate medical intervention (e.g. fractures, dislocations, lost teeth and concussions greater than grade 3 where there was lost consciousness).

Table 9 — Severe Injuries Based on Clinical Opinions

Nature of Injury	Site of Injury
compound fracture	head
	arm, forearm, elbow, wrist, hand, thumb
	cervical, dorsal, lumbar spine
	shoulder blade, collar bone, thorax, ribs, hip-pelvis
	thigh, knee, lower leg, ankle, foot
simple fracture	head
	cervical, dorsal, lumbar spine
	hip-pelvis
any fracture	neck
dislocation	cervical, dorsal, lumbar spine
	hip-pelvis
	elbow
	knee
internal injury	abdomen, thorax
	head
any heart problem	
any cerebrovascular accident	
concussion	head
burn	face, head, nose, mouth
cut	eye

4.6.2 Potential Risk Factors

Potential risk factors selected for study were based on the literature and information available in the data set. Those suggested in previous studies include: age, sex, level of experience, fatigue and lessons/previous instruction.[18,40,42,44,45,47,49,51,92,93] Self-rated ability was used as a measure of experience and length of time on the slopes before the injury event was used as a measure of fatigue. Other potential risk factors taken from the data set were chosen based on a combination of biologic plausibility and objectivity of measurement: month, day and hour of the injury event, activity (competition/training, lessons or recreation), type of equipment (rented, owned, or borrowed/demonstration), the posted trail difficulty and lighting (natural or artificial). The remaining variables in the data set were excluded either because they were based heavily on the opinion of the data recorder and, therefore, had the potential to be unreliable, or because the variable was not applicable to the research question. These unused variables and the reasons for their exclusion are listed in Table 10. It was decided not to use safety equipment and lighting as potential risk factors because data were missing in a large number of records (96.6% and 11.6% respectively). In summary, the 11 variables considered as potential risk factors for severe snowboarding injury were: age, sex, ability, length of time on the slopes, month, day of the week, hour of the injury event, activity, equipment, lessons and trail difficulty.

Table 10 — Variables Not Included in the Analyses

Description/Variable	Reason for Exclusion
minute (#)	no added value in analyzing the minute of the injury event
freestyle (ballet, aerials, mogul)	applies only to alpine skiers
snowboard (half-pipe, park, trail)	uncertainty regarding the number of ski centres that have these activity centres
days skied that season (1st, 2-10, 11-20, 20+)	not mentioned in previous studies, may be related to ability but utility questionable
description of injury event (lift, snow conditions, speed, hit tree, hit pylon/snow-maker, hit fence, hit machinery, hit skier, poor visibility, error, off slope, maladjusted bindings)	categories not mutually exclusive, too subjective, overlapped with other variables in the data set
snow conditions (<6" dry powder, deep powder, wet snow, hard-packed groomed, ice, corn/crud, crusty, groomed)	potential to be interpreted differently by various members of the Ski Patrol, too subjective
lighting (good, average, fair)	potential to be interpreted differently by various members of the Ski Patrol, too subjective
weather (clear, sunny, snowing, rain, fog, windy, blowing snow, freezing rain, cloudy)	categories not mutually exclusive, too subjective
temperature (<20°C, 10→20°C, 0→9°C, -1→-10, -11→-20, below -20)	potential to be interpreted differently by various members of the Ski Patrol, too subjective
binding type (toe, heel, plate, cable, pin, flexible snowboard, rigid snowboard, snowboard)	snowboard categories were not mutually exclusive
binding release (right, left, both, no release, pre-release, not applicable, snowboard)	snowboard bindings do not release, categories not mutually exclusive
safety equipment (helmet, other)	data missing for most records
state (unconscious, conscious)	data missing for most records
symptoms (pain, deformation, hemorrhage, limited motion/feeling)	too subjective, additional information questionable

4.6.3 Building the Risk Factor Model

A model was built using the 11 potential risk factors as candidates. Stepwise logistic regression is recommended when an outcome is fairly new and the risk factors and associations may not be known nor understood.[84,85] This describes the current state of knowledge with respect to snowboarding injury so stepwise logistic regression was used to build the model.

Backward elimination stepwise regression was used starting with all 11 potential risk factors in the model. SPSS statistical software[86] was used to generate the model. Alpha levels were set to determine the importance of variables in the model. The p-value for entry into the model was set at 10% since the default of 5% can be too stringent[84] and the p-value for removal was set at 15%. The p-value for removal must be greater than the p-value for entry so the same risk factor is not removed and entered on successive steps.[84] The SPSS software conducts a likelihood ratio test of the model containing the variable and the model without the variable based on the predetermined p-values. The automatic steps include checks to determine the continued importance of variables remaining in the model.

All potential risk factors were in a categorical format. The reference category varied depending on the risk factor but was chosen so that the reference category was not the level of interest. The coding of all of the design variables is listed in *Appendix D*.

4.6.4 Exploration of Interaction

Four potential interactions were also explored: sex and age, sex and ability, sex and trail difficulty and ability and trail difficulty. Interaction occurs when the association between the potential risk factor and the outcome varies by levels of a second factor.[53] All of the descriptive studies, including the studies of severe snowboarding injuries, found that the majority of those injured were male and were young. The risk for severe snowboarding injuries may be greater among those sex and age groups (sex*age). The works of Shealy[43,45] suggest that females are at greater risk for snowboarding injuries because more females are beginners. Furthermore, studies suggest that there are sex-specific risks for some sports injuries, particularly knee injuries (sex*ability).[94] This thinking was extended and consideration given to differing levels of risk for each sex on trails of various difficulties (sex*trail difficulty) and differing levels of risk for each level of ability on trails of various difficulties (ability*trail difficulty). Those of higher abilities will be riding more difficult trails, attempting more advanced manoeuvres such as jumps and suffering more severe injuries. Chow and colleagues[47] found that jumpers were more likely to have head, face, spinal and abdominal injuries. Each interaction was assessed separately by means of a likelihood ratio test.

4.6.5 Assessing the Fit of the Model

Once the model was built, the fit was assessed. The Hosmer-Lemeshow test was used to determine how well the model fit the data. SPSS grouped the data based on percentiles of the estimated probabilities. The test statistic provided was a Pearson chi-square statistic calculated from the observed and expected frequencies in each percentile. A small test statistic that is not statistically significant suggests that the model is a good fit for the data.

5.0 RESULTS

5.1 Descriptions of Alpine Skiing & Snowboarding Injuries

Tables 11, 12 and 13 contain descriptions of alpine skiing (n = 4,226) and snowboarding (n = 2,501) injuries by host, vehicle and environmental factors. These are presented as proportions of all the respective sports injuries and represent injuries to alpine skiers and snowboarders over age 11 years during the 1996/97 ski season in the province of Quebec.

There are a number of high proportions which suggest the potential for increased risk for injury. More than 60% of snowboarding injuries were suffered by youth aged 12-17 years compared with 40% of alpine skiing injuries for the same age group (χ^2=911.5, $p<.001$). Over twice as many males were injured snowboarding as females where 20% fewer males than females were injured while alpine skiing (χ^2=494.8, $p<.001$).

The majority of severe snowboarding injuries (69.2%) were to the head and neck region (Table 11). Approximately half the snowboarding injuries (48.6% of all snowboarding injuries and 52.9% of "not severe" snowboarding injuries) were to the upper limbs and nearly half the snowboarding upper limb injuries were to the wrist (23.7% and 26.2% respectively). The most common snowboarding injuries were wrist sprains (14.1%) and wrist fractures (10.0%) followed by knee sprains (6.4%), concussions (6.1%) and ankle sprains (5.6%).

Table 11 — Alpine Skiing and Snowboarding Injuries, Host Factors, Over Age 11, 1996/97 Ski Season, Quebec

Host Factor	Snowboarding Injuries n	% *	Snowboarding Not Severe n	% *	Snowboarding Severe n	% *	Alpine Skiing Injuries n	% *
Total Injuries	2501	100.0	2267	100.0	234	100.0	4226	100.0
Age								
age 12-17	1686	67.4	1544	68.1	142	60.7	1701	40.3
age 18-24	555	22.2	494	21.8	61	26.1	633	15.0
age 25-34	160	6.4	141	6.2	19	8.1	525	12.4
age 35+	100	4.0	88	3.9	12	5.1	1367	32.3
Sex								
males	1797	71.9	1636	72.2	161	68.8	1855	43.9
females	704	28.1	631	27.8	73	31.2	2371	56.1
Anatomic Region								
head & neck	441	18.0	279	12.6	162	69.2	690	16.8
head	258	10.5	111	5.0	147	62.8	343	8.3
face	70	2.9	70	3.2	0	0	127	3.1
eye	21	0.9	11	0.5	10	4.3	51	1.2
nose	43	1.8	43	1.9	0	0	85	2.1
mouth	29	1.2	29	1.3	0	0	48	1.2
neck	20	0.8	15	0.7	5	2.1	36	0.9
torso	337	13.7	291	13.1	46	19.7	445	10.8
ribs	36	1.5	36	1.6	0	0	57	1.4
thorax	13	0.5	8	0.4	5	2.1	24	0.6
cervical spine	8	0.3	6	0.3	2	0.9	18	0.4
dorsal spine	40	1.6	35	1.6	5	2.1	50	1.2
lumbar spine	63	2.6	54	2.4	9	3.8	94	2.3
collar bone	109	4.4	108	4.9	1	0.4	96	2.3
abdomen	16	0.7	6	0.3	10	4.3	19	0.5
hip-pelvis	52	2.1	38	1.7	14	6.0	87	2.1
upper limbs	1192	48.6	1172	52.9	20	8.5	873	21.2
shoulder blade	15	0.6	15	0.7	0	0	28	0.7
shoulder	202	8.2	202	9.1	0	0	315	7.6
upper arm	63	2.6	63	2.8	0	0	44	1.1
forearm	146	6.0	144	6.5	2	0.9	34	0.8
elbow	77	3.1	59	2.7	18	7.7	34	0.8
wrist	581	23.7	581	26.2	0	0	104	2.5
hand	58	2.4	58	2.6	0	0	62	1.5
thumb	50	2.0	50	2.3	0	0	252	6.1
lower limbs	481	19.6	475	21.4	6	2.6	2111	51.3
thigh	33	1.3	33	1.5	0	0	118	2.9
lower leg	57	2.3	56	2.5	1	0.4	275	6.7
knee	200	8.2	195	8.8	5	2.1	1469	35.7
ankle	168	6.9	168	7.6	0	0	230	5.6
foot	23	0.9	23	1.0	0	0	19	0.5

Host Factor	Snowboarding Injuries n	Snowboarding Injuries % *	Snowboarding Not Severe n	Snowboarding Not Severe % *	Snowboarding Severe n	Snowboarding Severe % *	Alpine Skiing Injuries n	Alpine Skiing Injuries % *
Nature of Injury								
sprain	918	38.7					2155	54.1
simple fracture	661	27.9					561	14.1
compound fracture	5	0.2					5	0.1
dislocation	161	6.8					197	4.9
ecchymosis	142	6.0					333	8.4
cut	146	6.2					292	7.3
scratch	64	2.7					97	2.4
frostbite	3	0.1			(see Table 16)		10	0.3
hypothermia	0	0.0					10	0.3
internal injury	51	2.2					51	1.3
concussion	156	6.6					164	4.1
dizziness	43	1.7					48	1.2
heart problem	0	0.0					7	0.2
cerebrov. accident	2	0.1					2	0.1
hyperventilation	1	0.0					2	0.1
other	18	0.8					53	1.3
Injury & Body Part								
head cut	47	2.0					80	2.0
face cut	–	–					55	1.4
face scratch	31	1.3					–	–
concussion	143	6.1					150	3.8
other head & neck	196	8.5					367	9.3
lumbar spine sprain	33	1.4					51	1.3
collar bone fracture	85	3.6					79	2.0
other torso	183	7.8					269	6.9
shoulder sprain	65	2.8					109	2.8
upper arm fracture	42	1.8					–	–
forearm fracture	97	4.1					–	–
wrist sprain	331	14.1					51	1.3
wrist fracture	234	10.0					–	–
thumb sprain	38	1.6					167	4.2
thumb fracture	–	–					59	1.5
other upper limbs	359	15.2					458	11.7
knee sprain	150	6.4					1322	33.6
lower leg sprain	–	–					63	1.6
lower leg fracture	–	–					105	2.7
ankle sprain	131	5.6					183	4.7
ankle fracture	30	1.3					–	–
other lower limbs	147	6.2					363	9.3
Hours on the Hill								
up to 1 hr	437	17.7	412	18.3	25	11.1	732	17.5
1-3 hrs	1061	42.9	961	42.8	100	44.2	1780	42.6
3-5 hrs	720	29.1	637	28.4	83	36.7	1235	29.6
5-7 hrs	222	9.0	206	9.2	16	7.1	399	9.6
more than 7 hrs	32	1.3	30	1.3	2	0.9	29	0.7
Ability								
beginner	994	41.4	903	41.4	91	41.4	1484	36.4
intermediate	1001	41.7	902	41.4	99	45.0	1758	43.1
advanced	404	16.8	374	17.2	30	13.6	835	20.5
Lessons								
never	1462	60.5	1414	58.1	156	62.7	1182	29.2
this yr	453	18.8	520	21.4	40	16.1	1089	26.9
1-2 yrs ago	349	14.5	359	14.8	35	14.1	602	14.9
3-4 yrs ago	93	3.9	88	3.6	11	4.4	309	7.6
over 5 yrs ago	58	2.4	51	2.1	7	2.8	870	21.5

* percent is based on cases with complete information and, therefore, excludes cases with missing data

The distribution of injuries by anatomic region is different for alpine skiing injuries (χ^2=770.2, p<.001). Approximately half (51.3%) the alpine skiing injuries were to the lower limbs and 69.6% of the lower limb injuries were to the knee. One-third (33.6%) of all alpine skiing injuries were knee sprains. Other common injuries were ankle sprains (4.7%) and thumb sprains (4.2%).

The distribution of injuries can be alternately described using the upper:lower limb ratio. The ratio was highest for severe snowboarding injuries (3.3) followed by a ratio of 2.5 for both the less severe snowboarding injuries and all snowboarding injuries combined. For alpine skiing injuries the upper:lower limb ratio was 0.4.

Compared with injured alpine skiers, nearly twice the proportion of injured snowboarders had no formal instruction in the sport (χ^2=824.3, p<.001). Approximately 60% of injured and severely injured snowboarders reported that they had never taken lessons while 29% of injured alpine skiers had not taken lessons (Table 11).

These proportions highlight potential differences between the various types of injuries studied. The proportions suggest that younger (age 12-17 years) snowboarders and alpine skiers, male snowboarders and female alpine skiers are more likely to be injured.

The age and sex of those injured are significantly different from the age and sex of all participants. The availability of skiing/snowboarding participation data from the Canadian Ski Council facilitated comparison of the age and sex distributions of those who were injured with the overall number who participate in the two sports (Tables 14 and 15). Chi-square tests were conducted and suggest that young participants aged 12-17 years are over-represented in snowboarding and alpine skiing injuries (snowboarding injuries $\chi^2=1,364.0$, $p<0.01$; severe snowboarding injuries $\chi^2=98.6$, $p<0.01$; alpine skiing injuries $\chi^2=1,032.1$, $p<0.01$).

Table 14 — Comparison of the Age Distributions of Injured and Uninjured Snowboarders and Alpine Skiers

Age Groups	Snowboarding Participation (%)	Snowboarding Injuries (%)	Severe Snowboarding Injuries (%)	Alpine Skiing Participation (%)	Alpine Skiing Injuries (%)
12-17	36.0	67.4	60.7	21.0	40.3
18-24	19.5	22.2	26.1	18.0	15.0
25-34	17.0	6.4	8.1	21.5	12.4
35-49	20.0	3.5	4.7	30.0	21.7
50+	7.5	0.5	0.4	9.5	10.6
χ^2 (df=4)		1364.0	98.6		1032.1
p		<0.01	<0.01		<0.01

Table 15 — Comparison of the Sex Distributions of Injured and Uninjured Snowboarders and Alpine Skiers

Sex	Snowboarding Participation (%)	Snowboarding Injuries (%)	Severe Snowboarding Injuries (%)	Alpine Skiing Participation (%)	Alpine Skiing Injuries (%)
males	58.6	71.9	68.8	52.5	43.9
females	41.4	28.1	31.2	47.5	56.1
χ^2 (df=1)		181.0	10.0		125.5
p		<0.01	<0.01		<0.01

The male:female ratios of the various injuries are also significantly different from the skiing/snowboarding participation proportions. Chi-square tests were conducted and suggest that males are over-represented in snowboarding injuries (χ^2=181.0, p<.001) and severe snowboarding injuries (χ^2=10.0, p<.01). Conversely, females are over-represented in alpine skiing injuries (χ^2=125.5, p<.001). Age and sex are the only factors which could be compared with participation data since the distributions of the other factors in the sports participants are unknown.

Over 87% of injured alpine skiers and snowboarders were on a recreational outing. Less than 10% of those injured were taking lessons at the time of injury and less than 2% were in training or competition (Table 12). The majority of those injured owned their own sporting equipment (72%-74% of injured snowboarders and 67% of injured alpine skiers).

Table 12 — Alpine Skiing and Snowboarding Injuries, Vehicle Factors, Over Age 11, 1996/97 Ski Season, Quebec

Vehicle Factor	Snowboarding Injuries		Snowboarding Not Severe		Snowboarding Severe		Alpine Skiing Injuries	
	n	% *	n	% *	n	% *	n	% *
Total Injuries	2501	100.0	2267	100.0	234	100.0	4226	100.0
Activity								
competition	25	1.1	23	1.1	2	0.9	79	2.0
training	21	0.9	20	1.0	1	0.5	79	2.0
lesson	89	4.0	87	4.3	2	0.9	350	8.7
recreation	2094	93.9	1888	93.6	206	97.6	3518	87.4
Equipment								
owned	1778	72.3	1613	72.2	165	73.7	2789	67.4
rented	521	21.2	481	21.5	40	17.9	1182	28.6
borrowed/demonstration	160	6.5	141	6.3	19	8.5	164	4.0

* percent is based on cases with complete information and, therefore, excludes cases with missing data

The environmental factors of month, day and hour all suggest that the popular times to be on the slopes are also when the injuries tend to occur (Table 13). January, February and March are the key months for skiing and snowboarding in Eastern Ontario and Quebec. The start and end of a given ski season depends on the weather but only rarely would a season not provide optimal conditions in these months. Over 80% of injuries occurred in these three months. Injuries tended to cluster on the weekends with 53%-60% of the injuries happening from Friday to Sunday. Nearly half (42%-45%) of those injured were injured in the afternoon hours between 1:00 p.m. and 6:00 p.m.

Severe snowboarding injuries were identified and defined as a combination of injury and body part (n=234). Table 16 lists the frequencies of the severe snowboarding injuries reported in the 1996/97 ski season in Quebec. Severe snowboarding injuries accounted for 9.4% of all snowboarding injuries. The majority of severe snowboarding injuries (61.1%) were concussions.

Table 13 — Alpine Skiing and Snowboarding Injuries, Environmental Factors, Over Age 11, 1996/97 Ski Season, Quebec

Environmental Factor	Snowboarding Injuries		Snowboarding Not Severe		Snowboarding Severe		Alpine Skiing Injuries	
	n	% *	n	% *	n	% *	n	% *
Total Injuries	2501	100.0	2267	100.0	234	100.0	4226	100.0
Month								
Dec	465	18.6	427	18.8	38	16.2	559	13.2
Jan	663	26.5	607	26.8	56	23.9	1013	24.0
Feb	684	27.3	615	27.1	69	29.5	1453	34.4
Mar	689	27.5	618	27.3	71	30.3	1201	28.4
Day								
Sun	438	17.5	462	18.4	39	14.7	704	16.7
Mon	239	9.6	227	9.0	29	10.9	392	9.3
Tue	240	9.6	233	9.3	28	10.6	395	9.3
Wed	238	9.5	233	9.3	29	10.9	476	11.3
Thu	327	13.1	314	12.5	37	14.0	499	11.8
Fri	427	17.1	431	17.1	51	19.2	730	17.3
Sat	592	23.7	616	24.5	52	19.6	1030	24.4
Hour of the Event								
0000h-1259h	878	35.4	801	35.6	77	33.3	1710	40.6
1300h-1759h	1040	42.0	937	41.7	103	44.6	1906	45.3
1800h-2359h	561	22.6	510	22.7	51	22.1	593	14.1
Trail Difficulty								
green	769	38.6	699	38.7	70	37.6	1059	29.6
blue	698	35.0	647	35.8	51	27.4	1393	38.9
diamond	391	19.6	344	19.0	47	25.3	924	25.8
double diamond	136	6.8	118	6.5	18	9.7	204	5.7
Transported by								
toboggan	763	32.5	659	31.0	104	47.3	2071	51.9
snowmobile	252	10.7	229	10.8	23	10.5	473	11.9
traction	1	0.0	0	0.0	1	0.5	3	0.1
self, skiing	147	6.3	132	6.2	15	6.8	494	12.4
self, walking	1050	44.7	982	46.1	68	30.9	849	21.3
other	136	5.8	127	5.9	9	4.1	101	2.5
Left Ski Centre								
on own	437	18.6	405	19.0	32	14.5	1094	27.6
with parent	715	30.4	679	31.9	36	16.3	730	18.4
with guardian	77	3.3	66	3.1	11	5.0	176	4.4
with instructor	169	7.2	154	7.2	15	6.8	348	8.8
with friend	591	25.1	539	25.3	52	23.5	969	24.4
by ambulance	239	10.2	170	8.0	69	31.2	350	8.8
other	122	5.2	117	5.4	6	2.7	301	7.6

* percent is based on cases with complete information and, therefore, excludes cases with missing data

Table 16 — Severe Snowboarding Injuries, Quebec, 1996/97 Ski Season

Severe Snowboarding Injury	n	%
compound fracture, collar bone	1	0.4
compound fracture, hip-pelvis	1	0.4
compound fracture, forearm	2	0.9
compound fracture, lower leg	1	0.4
simple fracture, cervical spine	1	0.4
simple fracture, dorsal spine	5	2.1
simple fracture, lumbar spine	9	3.8
simple fracture, hip-pelvis	9	3.8
dislocation, hip-pelvis	4	1.7
dislocation, elbow	18	7.7
dislocation, cervical spine	1	0.4
dislocation, knee	5	2.1
cerebrov. accident, head/neck	2	0.9
concussion, head	143	61.1
internal injury, head	1	0.4
simple fracture, head	2	0.9
any neck fracture (all simple)	4	1.7
internal injury, abdomen	10	4.3
internal injury, thorax	5	2.1
cut, eye	10	4.3
total	234	100.0

5.2 Injury Rates

Table 17 summarizes the crude, age-specific and sex-specific injury rates for alpine skiing and snowboarding in the province of Quebec for the 1996/97 ski season. There are differences in the overall risk for injury in the two sports. The injury rates increase as the denominator becomes more refined. For example, the snowboarding injury rate based on the Quebec population is 4.0/10,000/season, the rate based on the number of snowboarder visits is 21.3/10,000/season and the rate based on Quebec snowboarders is 99.5/10,000/season. The crude sports injury rates based on the number of ski centre visits and the Quebec skiers/snowboarders suggest that the risk for injury in snowboarding is significantly higher than the risk for injury in alpine skiing as illustrated by the large difference between the upper bound of the alpine skiing injury rate and the lower bound of the snowboarding injury rate.

The injury rates vary by age and sex in the two sports. These patterns can only be explored in the rates based on the Quebec provincial population and the rates based on the skiers/snowboarders. Snowboarders aged 12-17 years have the highest risk for injury at 1.6-3.4 times that of those aged 18-24 years and 5.0-21.0 times the risk for injury as those aged 25-34 years. Alpine skiers aged 12-17 years have over twice the risk for injury as those aged 18-24 years and 3.3-6.2 times the risk for injury as alpine skiers aged 25-34 years. The risk for alpine skiing injury generally decreases as age increases to age 34. However, the risk for injury increases in those over age 35 (based on the alpine skiers). Rates based on the

Quebec provincial population decline in both sports as age increases with the lowest injury rates in the oldest age group. The alpine skiing injury rates for males, regardless of denominator, are significantly lower than the alpine skiing injury rates for females. This pattern is reversed for snowboarding where the injury rates for males are significantly higher than the injury rates for females. Male snowboarders have approximately twice the risk for injury as female snowboarders where male alpine skiers have only 0.7-0.8 times the risk for injury as female alpine skiers. Issues related to denominator selection are discussed further in Section 6.1.4.

The alpine skiing and snowboarding injury rates based on the Quebec skiers/snowboarders were then adjusted to control for the effects of the differing age and sex distributions in the two sports (Tables 18 and 19). The alpine skiing injury rates remain unchanged after adjustment because the alpine skiing population was used as the standard population. The sex-adjusted snowboarding injury rate changed very little (99.5 → 96.2) suggesting that proportions of males and females in the two populations are similar. However, the age-adjusted snowboarding injury rate dropped from 99.5/10,000 snowboarders/season to 73.3/10,000 snowboarders/season. This suggests that the age structure of the two sports populations was different and that snowboarders were younger than alpine skiers. Overall, snowboarders had 1.5 to 2 times the risk for injury compared with alpine skiers.

Table 17 — Crude and Specific Injury Rates Based on Three Different Denominators Over Age 11, Alpine Skiing and Snowboarding, Quebec, 1996/97 Ski Season

Group	Rates Based on Quebec Population		Rates Based on Skier & Snowboarder Visits [a]		Rates Based on Skier & Snowboarder Populations [b]	
	/10,000 /season	95% CI	/10,000 /season	95% CI	/10,000 /season	95% CI
Skiing	6.7	6.5, 6.9	9.0	8.7, 9.3	48.0	46.6, 49.5
males	6.0	5.8, 6.3			40.2	38.3, 42.0
females	7.4	7.1, 7.7			56.7	54.4, 59.1
age 12-17	29.3	27.9, 30.7			92.1	87.6, 96.5
age 18-24	9.8	9.0, 10.6			40.0	36.8, 43.1
age 25-34	4.7	4.3, 5.1			27.8	25.3, 30.2
age 35+	3.5	3.3, 3.7			39.3	37.2, 41.5
Snowboarding	4.0	3.8, 4.1	21.3	20.4, 22.1	99.5	95.5, 103.4
males	5.9	5.6, 6.1			122.0	116.3, 127.7
females	2.2	2.0, 2.4			67.6	62.6, 72.7
age 12-17	29.0	27.6, 30.5			186.3	177.3, 195.3
age 18-24	8.6	7.8, 9.3			113.2	103.7, 122.8
age 25-34	1.4	1.2, 1.7			37.4	31.5, 43.3
age 35+	0.3	0.2, 0.3			14.5	11.6, 17.4

[a] is the injury rate based on the number of skier or snowboarder visits in Quebec during the 1996/97 ski season
[b] is the injury rate based on the number of alpine skiers or snowboarders in Quebec during the 1996/97 ski season

Table 18 — Adjusted and Crude Alpine Skiing Injury Rates Over Age 11, 1996/97 Ski Season, Quebec

Adjusted for	Alpine Skiing Injury Rate /10,000 participants/season	Crude Alpine Skiing Injury Rate /10,000 participants/season
sex	48.0	48.0
age	48.0	

- 1996/97 alpine skiing population used as standard

Table 19 — Adjusted and Crude Snowboarding Injury Rates Over Age 11, 1996/97 Ski Season, Quebec

Adjusted for	Snowboarding Injury Rate /10,000 participants/season	Crude Snowboarding Injury Rate /10,000 participants/season
sex	96.2	99.5
age	73.3	

- 1996/97 alpine skiing population used as standard

5.3 Proportional Injury Ratios

Proportional injury ratios (PIRs) and their 95% confidence limits were calculated to explore the nature of snowboarding injuries. They were adjusted for age and sex and alpine skiing injuries were used as the reference group. The ratios are presented in Table 20.

The 95% confidence limits for most of the PIRs exclude the value of one although many are close. This suggests an increased or reduced likelihood of that particular injury in injured snowboarders compared with injured alpine skiers. The PIRs for upper and lower limb injuries reinforce the suggestion from the descriptive proportions that injured snowboarders are more likely, approximately twice as likely, to suffer an upper limb injury compared with injured alpine skiers. The PIR suggests that wrist injuries are about seven times as likely in injured snowboarders compared with injured alpine skiers. The converse is a very low PIR for lower limb injury suggesting increased likelihood, approximately two times, of lower limb injuries in injured alpine skiers. Specifically, the PIR suggests injured alpine skiers are three times as likely to suffer a knee injury compared with injured snowboarders.

The PIRs suggest the nature of injuries is different in the two sports. Injured snowboarders are more likely to experience simple fractures (PIR=1.66), dislocations (PIR=1.44), internal injuries (PIR=1.73), concussions (PIR=1.33) and severe injuries (PIR=1.34) compared with injured alpine skiers. Injured alpine skiers are more likely to experience strains/sprains (PIR=0.83), ecchymosis (PIR=0.67) and cuts/lacerations (PIR=0.60) compared with injured snowboarders.

The PIRs also suggest that specific injuries differ between the two sports. Injured snowboarders are more likely to suffer wrist sprains, nine times as likely as injured alpine skiers and six times as likely to fracture their wrist. Injured alpine skiers are four times as likely to experience knee sprains and three times as likely to suffer thumb sprains. Ankle sprains are equally likely in the injuries in both sports (PIR= 1.10, 95% CI=0.94, 1.30).

The PIRs are measures of differential risk between the injuries in the two sports. They are not direct measures of the risk for injury. Therefore, the PIRs must be interpreted with caution.

Table 20 — Proportional Injury Ratios (PIRs) for Snowboarding Injuries Relative to Alpine Skiing Injuries

Injury Description	PIR	95% CI
Anatomic Region & Body Part		
head and neck	0.84	0.77, 0.91
torso	1.19	1.08, 1.31
upper limbs	2.06	1.98, 2.15
lower limbs	0.45	0.42, 0.49
wrist	7.06	6.58, 7.57
knee	0.31	0.27, 0.35
Nature of Injury		
strain or sprain	0.83	0.79, 0.88
simple fracture	1.66	1.57, 1.79
compound fracture	1.21	0.50, 2.89
dislocation	1.44	1.24, 1.67
ecchymosis	0.67	0.57, 0.79
cut	0.60	0.51, 0.70
scratch	0.86	0.68, 1.10
internal injury	1.73	1.32, 2.27
concussion	1.33	1.15, 1.55
severe injury	1.34	1.21, 1.55
not severe injury	0.97	0.96, 0.99
Injury & Body Part		
thumb sprain	0.29	0.21, 0.39
knee sprain	0.26	0.23, 0.31
ankle sprain	1.10	0.94, 1.30
wrist sprain	8.78	7.95, 9.70
wrist fracture	6.27	5.55, 7.08

5.4 Risk Factors for Severe Snowboarding Injuries

Tables 11 to 16 include descriptive statistics about the severe snowboarding injuries. Severe snowboarding injuries were distributed similarly to less severe snowboarding injuries with respect to almost all of the host, vehicle and environmental factors with the exception of anatomic region. The majority of less severe snowboarding injuries were to the upper limbs (52.9%) compared with the majority of severe snowboarding injuries which were to the head and neck (69.2%). Table 16 lists the nature and body part of severe snowboarding injuries.

5.4.1 Main Effects Model

Backward elimination, likelihood ratio, stepwise logistic regression was conducted using SPSS statistical software[86] with the 11 potential risk factors of age, ability, sex, activity (competition/training, lessons, recreation), day of the week, month, hour of the injury event, type of equipment (owned, rented, borrowed/demonstration), length of time on the slopes, history of taking lessons and trail difficulty.

The resulting model contained seven risk factors: ability, activity, age, day of the week, length of time on the slopes, trail difficulty and sex. The statistical software uses only cases with complete information to build a model. Therefore, only 1,641 cases out of the sample of 2,501 snowboarding injuries were used. Once the seven risk factors were identified, the model was tested using only those seven risk factors. The number of cases used for the testing increased to 1,717.

The model is summarized in Table 21. The univariate odds ratio describes the relationship between that potential risk factor and severe snowboarding injury. The multivariate odds ratio also describes the relationship but adjusts for the effects of the other risk factors in the model. These findings suggest that snowboarders of lower ability levels are at increased risk for severe injury, approximately double (OR=2.3, 95% CI=1.2, 4.4 and OR=2.7, 95% CI=1.4, 5.0), relative to snowboarders of advanced ability. It also suggests that younger snowboarders may be at reduced risk for severe injury compared with older snowboarders (OR=0.4, 95% CI=0.2, 0.9), that on certain days of the week there is an increased risk for severe snowboarding injury (Wednesday OR=2.0, 95% CI=1.1, 3.9) and that riding blue/difficult trails poses a reduced risk for severe injury compared with double diamond/extremely difficult trails (OR=0.4, 95% CI=0.2, 0.7).

Table 21 — Risk Factors for Severe Snowboarding Injuries

Risk Factor		Univariate Odds Ratio	95% Confidence Limits	Multivariate Odds Ratio	95% Confidence Limits	n
Ability						
	advanced	reference	reference	reference	reference	274
	beginner	1.3	0.8,1.9	2.3	1.2, 4.4	746
	intermediate	1.4	0.9, 2.1	2.7	1.4, 5.0	697
Activity						
	train/compete	reference	reference	reference	reference	35
	lessons	0.3	0.1, 2.0	0.1	0.0, 1.6	71
	recreation	1.6	0.5, 5.1	1.0	0.2, 4.6	1611
Age Group						
	35+ years	reference	reference	reference	reference	79
	12-17 years	0.7	0.4, 1.3	0.4	0.2, 0.9	1140
	18-24 years	0.9	0.5, 1.8	0.5	0.2, 1.1	374
	25-34 years	1.0	0.5, 2.1	0.8	0.3, 2.0	124
Day of the Week						
	Sunday	reference	reference	reference	reference	309
	Monday	1.0	0.6, 1.6	1.8	0.9, 3.5	164
	Tuesday	1.5	0.9, 2.6	1.5	0.7, 3.0	161
	Wednesday	1.4	0.8, 2.3	2.0	1.1, 3.9	164
	Thursday	1.6	1.0, 2.7	1.5	0.8, 2.9	228
	Friday	1.4	0.9, 2.3	1.8	1.0, 3.1	299
	Saturday	1.3	0.9, 2.1	0.8	0.5, 1.5	392
Length of Time on the Slopes						
	7+ hours	reference	reference	reference	reference	21
	up to 1 hour	0.9	0.2, 4.0	0.4	0.1, 2.1	310
	1-3 hours	1.6	0.4, 6.6	0.8	0.2, 3.8	731
	3-5 hours	2.0	0.5, 8.3	1.2	0.3, 5.3	498
	5-7 hours	1.2	0.3, 5.3	0.8	0.2, 4.1	157
Trail Difficulty						
	double diamond-extremely difficult	reference	reference	reference	reference	117
	green-easy	0.7	0.4, 1.1	0.5	0.3, 1.0	675
	blue-difficult	0.5	0.3, 0.9	0.4	0.2, 0.7	594
	diamond-very difficult	0.9	0.5, 1.6	0.8	0.4, 1.5	331
Sex						
	female	reference	reference	reference	reference	493
	male	0.9	0.6, 1.1	0.7	0.5, 1.0	1224

5.4.2 Interactions

Four potential interactions were explored: sex and age, sex and ability, sex and trail difficulty and ability and trail difficulty. Each was assessed by means of a likelihood ratio test between the model which contained all seven main effects and the interaction term and the model containing only the main effects. The chi-square test statistic was not significant for any of the interactions (Table 22). Therefore, the final model contained only the seven main effects.

Table 22 — Likelihood Ratio Test Statistics for Assessment of Interaction

Interaction	Chi-square (df)	Significance
sex*age	2.2 (3)	0.5
sex*ability	4.0 (2)	0.1
sex*trail difficulty	3.1 (3)	0.4
ability*trail difficulty	0.2 (6)	1.0

5.4.3 Goodness-of-Fit

The Hosmer-Lemeshow Goodness-of-Fit test was conducted to assess the fit of the model to the data. The chi-square test statistic was small and was not significant (χ^2=8.1, p=0.4), thereby suggesting that the model was a good fit for the data.

6.0 DISCUSSION

The objectives of this thesis were to describe snowboarding and alpine skiing injuries and then to explore and identify potential risk factors for the more severe snowboarding injuries. These objectives were met by obtaining injury data that had been collected by the members of the Quebec Ski Patrol, by conducting descriptive analyses and by using logistic regression in a variant of the case-control study design. This project advances the current state of knowledge regarding snowboarding injuries. It builds upon previous work and should fuel further study in the area of snowboarding and other sports injury research.

The descriptions of snowboarding and alpine skiing injuries formulated in this thesis reinforce what has been previously published. The overall sport-specific injury rates based on the number of snowboarder visits and the descriptive statistics (i.e. distributions of host, vehicle and environmental factors) are comparable to other studies. Additional analyses in this study include standardized injury rates, measures of differential risk between alpine skiing and snowboarding injuries (i.e. the proportional injury ratios) and the identification of risk factors for more severe snowboarding injuries.

This section relates the present findings to those of previous studies, where applicable. It details and discusses the limitations of the study and provides recommendations for future work in the areas of snowboarding injury research and intervention.

6.1 Descriptive Findings

6.1.1 Age & Sex

Previous descriptive studies suggested that snowboarding injuries most often involved young males. These conclusions were based on consistently high proportions of young males in the injured samples that were studied.[16,18,23,39,40-43,47,48-52,56] However, previous studies did not all have information on the demographic structure of the underlying snowboarding population. The availability of skiing/snowboarding participation data for this study facilitated comparisons of the age and sex of injured snowboarders and alpine skiers with uninjured sports participants. Injuries varied by age and sex in each sport. Compared with older sports participants, those aged 12-17 years were significantly more likely to be injured while snowboarding, to suffer a severe snowboarding injury and to be injured while alpine skiing. Males were significantly more likely than females to be injured while snowboarding and were significantly more likely to suffer severe snowboarding injuries. Females were significantly more likely to be injured while alpine skiing. The statistical comparisons reinforce the suggestion that injured snowboarders are generally young and male. Participation data were not available by age within sex groups so the differential risk of young male snowboarders could not be explored.

These findings are contrary to those of Shealy.[43,45] In his studies he found females to be over-represented in injured snowboarders and attributed this difference to their lower ability levels. Neither his results nor his methods (i.e. case-control study) have been replicated in further study. Data regarding ability within sex groups were not available for the uninjured snowboarding population in this thesis study.

Some work suggests that women are more susceptible to knee injuries in sports. Arendt and Dick[94] found significantly higher rates of anterior cruciate ligament injury in women compared with men in the sports of soccer and basketball. They suggest that both intrinsic (e.g. limb alignment, notch dimension, ligament size) and extrinsic factors (e.g. movement, strength, skill level) contribute to this risk. A similar situation may exist for alpine skiing injuries and may explain why females were found to be more likely to suffer injury in this sport.

6.1.2 Site & Nature of Injury

The site and nature of injury varied for each sport. Approximately half of all snowboarding injuries were to the upper limbs and half of all alpine skiing injuries were to the lower limbs. The remainder were distributed throughout the other three anatomic regions. The most common snowboarding injuries were wrist injuries (wrist sprains and simple wrist fractures). The most common alpine skiing injuries were knee sprains. These patterns were reflected in the high upper:lower limb ratio for snowboarding (2.5) and severe snowboarding injuries (3.3) and by the low upper:lower limb ratio for alpine skiing injuries (0.4).

Severe snowboarding injuries accounted for approximately one in ten of all snowboarding injuries with concussions accounting for over two-thirds of the severe snowboarding injuries. The anatomic distribution of severe snowboarding injuries reflects that found previously. Prall *et al.* found that severely injured snowboarders (i.e. injuries referred to a Level I trauma centre) suffered the majority of injuries to the head and neck (69%), with 20% to the torso, 8% to the upper limbs and 3% to the lower limbs.[55] In the Prall study, 54% of patients had closed head injuries and 32% had abdominal injuries. Despite limitations with the severity classification and a different definition of severe injury, the anatomic distribution of severe injuries in this thesis study reflects that of the Prall study.

The distributions of injuries by the four anatomic regions in this study were within the ranges reported in previous studies. The range for head and neck injuries found previously was 2%[37,40] to 18%[47], for torso injuries it was 6%[44] to 15%[37], for upper limb injuries it was 12%[37] to 58%[47] and for lower limbs it was 10%[47] to 53%[16]. The findings in this study were at the high end of the ranges for three of the four anatomic regions. The proportion of lower limb snowboarding injuries was towards the lower end of the range. This result is also reflected in the high upper:lower limb ratio. When the existing literature is limited to the more recent studies, nearly all of those published since 1995 report that approximately half of all snowboarding injuries affect the upper limbs as in this thesis study.[42,47,49,51,52]

There are a number of potential explanations for the variability of previous findings. The wide variety of results could be due to chance because of small sample sizes. Evolution in the sport of snowboarding has created differences in equipment, technique, participants and injuries over time. Geography can influence the sports and the resulting injuries since snow conditions vary by location. Equipment and/or techniques for groomed, granular conditions can be different than those for fresh powder. The training received by members of the Ski Patrol varies both within and between countries. The data collection tools (e.g. Ski Patrol reporting forms and supplementary clinic questionnaires) are different for each study.

6.1.3 Other Factors

There were other descriptive findings in this study that suggest differential risks for snowboarding injury. The majority of injured snowboarders (and alpine skiers) were on a recreational outing and owned their sporting equipment. Over half the injuries in both sports happened on the weekends and nearly half of all injuries occurred in the afternoon. A small proportion of snowboarders and alpine skiers were injured while training or in competition. However, this does not imply that these activities do not pose a risk for injury. Risk remains uncertain because the proportion of snowboarders and alpine skiers who compete is unknown. Although no comparison group or data were available to describe the distribution of these characteristics in the general snowboarding population, one can hypothesize that most snowboarders are recreational participants who tend to get to the slopes late in the day and on weekends suggesting that these factors may not actually be risk factors for injury.

Fatigue or the length of time on the slopes has been suggested as a factor contributing to snowboarding injury.[37,47,55] This study found that 42.9% of the injured snowboarders had been on the slopes for one to three hours. The hour of the injury event may also indicate fatigue or length of time on the slopes. Previous studies suggest that injuries occurred more often in the afternoon when fatigue is more likely after being on the slopes for a few hours.[37,47,55] The majority of injuries in this study, regardless of sport or severity, occurred in the afternoon between 1:00 p.m. and 6:00 p.m. This was not unexpected as not all ski centres are equipped to offer night skiing. Fatigue could very well have contributed to their injuries depending on the number of runs and the amount of time they spent waiting in line for lifts. The time of day and length of time on the slopes was not known for the general snowboarding population.

Investigators have hypothesized that snowboarding injuries are more likely in beginners and others of lower ability levels.[37,39,41,42,44,45,47,49,51,52] The majority of those who were injured in this study described themselves as "beginner" or "intermediate" snowboarders. This pattern holds regardless of sport (snowboarding or alpine skiing) or severity of injury. The skiing/snowboarding participation data were not broken down by ability but the Canadian Ski Council does report that 71% of Quebec snowboarders are on the slopes less than four times each month.[71] They offer three categories of response in their survey: occasionally/once per month, two to three times per month or four or more times per month. It is possible that those who snowboard less frequently have fewer opportunities to practice their sport and are of lower ability levels. This being true, the majority of Quebec snowboarders could be considered beginner or intermediate riders, suggesting that ability may not be a risk factor for snowboarding injury.

Some authors have recommended lessons to reduce the risk of injury or of severe injury.[37,40,41,44,47,52] In this study, over half the injured snowboarders report never having had formal instruction. This is two-fold higher than for injured alpine skiers who have never taken a lesson. This difference between the two sports is likely explained by the newness of the sport of snowboarding. A large number of novice snowboarders may not yet have had the opportunity to take lessons or may not feel the need for formal instruction. Contrary to the recommendations of other investigators, Shealy's case-control analyses did not find any evidence that taking lessons reduced the likelihood of snowboarding injury.[45] Data were not available to confirm or refute Shealy's conclusions.

Ganong and colleagues[41] examined snowboarding injuries by trail difficulty. In the current study, nearly three-quarters of the snowboarders were injured on easy or intermediate slopes, with a similar proportion of injury events occurring on each type of trail. Ganong's study found 56% had occurred on the intermediate slopes and 31% had occurred on the easy slopes. These investigators used clinical data and this may account for the different proportions.

High proportions in the injured groups are indications of potential risk factors for injury. However, since the distributions of factors like fatigue or length of time on the slopes, ability, history of lessons and difficulty of trails ridden were not available for the uninjured groups in this study, they are merely suggestions which require further study in order to determine if they actually pose an increased risk for injury.

6.1.4 Crude Injury Rates & Denominator Issues

Three sets of injury rates were calculated based on different denominators — the Quebec provincial population, the number of alpine skier and snowboarder visits and the number of Quebec alpine skiers/snowboarders. The rates based on the Quebec population are under-estimates of injury because only a portion of the population participates in alpine skiing and snowboarding.

The snowboarding injury rate based on snowboarder visits for this study was within the range of rates presented in other studies. Previous injury rates varied widely from 0.3[42] - 16.0[37] per 1,000 skier or snowboarder visits per season. In this study, a snowboarding injury rate of 2.1 per 1,000 snowboarder visits per season was calculated (95% CI 2.0, 2.2). This rate was based on conservative denominator information provided by the Canadian Ski Council that snowboarders constitute 20% of those on the slopes. The accuracy of this denominator could have been improved if random counts of alpine skiers and snowboarders had been taken throughout the ski season of interest. This procedure was used by Chow and colleagues[47] at two ski centres during the 1993/94 ski season in California. They found that snowboarders accounted for 20%-25% of slope users. Random counts were considered but dismissed for this study because counts from another ski season might not accurately reflect the season of interest. This is because of the rapid evolution of the sport and its participants. Since the industry estimate is considered conservative, the injury rates for snowboarders in this study are over-estimates of injury if, in fact, snowboarders account for a larger proportion than 20% of the ski centre visits.

This set of injury rates also has the potential to be under-estimates of injury. Ski centre visits are estimated by lift ticket sales. Ticket sales do not capture all slope users and do not account for levels of participation. Season pass holders, staff and members of the Ski Patrol do not purchase lift tickets. The impact of each group is unknown and, therefore, the rates were not adjusted.

The third set of injury rates was based on the number of alpine skiers and snowboarders. Quebec snowboarding and alpine skiing participation profiles were obtained by applying national estimates to the provincial population. It is believed that since a large portion of the sports participants are from that province, a large portion of the Canadian population lives in that province and the majority of injured alpine skiers and snowboarders live in Quebec, the provincial profiles would be similar to the national profiles. However, if Quebec participation is higher than the national estimates, the resulting rates are over-estimates of injury.

The national alpine skiing and snowboarding participation estimates are based on information from the Canadian Ski Council. The national participation estimates are based largely on a sample of approximately 2,000 people. The small sample size would have a large amount of variance which would increase the uncertainty of the national and, consequently, the Quebec participation estimates. Correction was not made for this in the calculation of the injury rates but the increased variance would widen the calculated confidence limits.

There are numerous influences on the injury rates calculated in this study. They are summarized in Figure 4. The extent of each is unknown and was, therefore, not accounted for in the rate calculations.

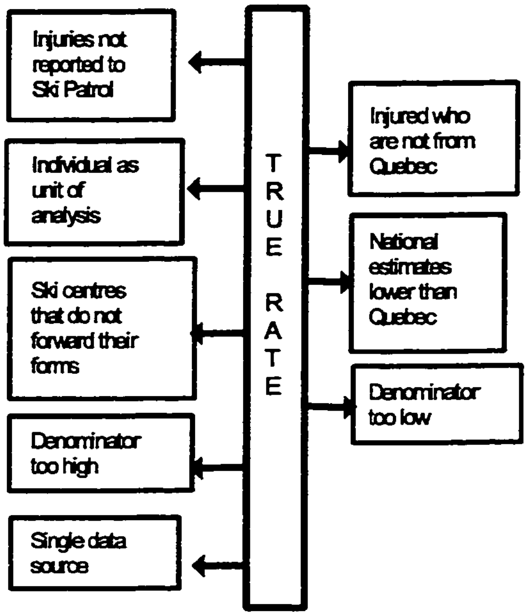

Figure 4 — Influences on Injury Rates

Each set of injury rates answers a different research question and would be useful in different situations. The rates based on the provincial population estimate the risk for snowboarding and alpine skiing injury in Quebec. These rates are useful in planning health care and rehabilitation services but they include the portion of the population that does not ski or snowboard. The second set of rates estimates the risk for snowboarding and skiing injury at Quebec ski centres. These rates are useful for management and other aspects of the industry. For example, ski centre owners and insurers would be interested in the risk for injury in those who frequent their resorts. The third set of rates estimates the risk for injury in Quebec skiers and snowboarders. These rates are the most meaningful, in an epidemiologic sense, because they are based on a more specific unit of exposure to risk.

The most appropriate denominators quantify exposure to risk. The three sets of rates that were calculated are applicable in different circumstances although other denominators could prove equally useful. More accurate estimates of the number of skiers/snowboarders in Quebec would help. However, each skier/snowboarder participates at a different intensity. The denominator could then take into account the number of ski centre visits along with the number of runs, length on time on the slopes or vertical height covered at each visit for a specified period of time.

6.1.5 Specific Injury Rates & Proportional Injury Ratios

The stratum-specific injury rates can be used to highlight groups at increased risk for injury. The alpine skiing injury rates based on the Quebec population were higher than the snowboarding injury rates in each sex and age group. Since the rates for both sports are based on the same population (i.e. the same denominator), the alpine skiing rates appear elevated due to higher injury counts in that sport. These rates suggest that females are at increased risk for alpine skiing injury, males are at increased risk of snowboarding injury, risk for injury in both sports is highest is those aged 12-17 years and decreases as age increases.

The risk pattern for injury is slightly different using the rates based on Quebec alpine skiers and snowboarders. The snowboarding injury rates are higher than the alpine skiing injury rates in all groups except for the oldest age group (over 35 years). Snowboarding injury rates decrease as age increases whereas alpine skiing injury rates decrease up to age 34 but then increase in the oldest age group where they surpass snowboarding injury rates.

Standardization of the rates controls for the different age and sex distributions in the two sports and allows the injury rates to be directly compared. An overall injury rate adjusting for both age and sex could not be calculated since the skiing/snowboarding participation data were not available by age within sex groups. Two directly standardized rates were calculated: one adjusted for sex and the other adjusted for age. Both of the adjusted rates suggest that snowboarders are at an increased risk for injury compared with alpine skiers.

The proportional injury ratios permit further investigation and comparison of the injuries in the two sports. Injured snowboarders, compared with injured alpine skiers, are more likely to experience injury to the torso and upper limbs. Injured snowboarders are also more likely to suffer simple fractures, dislocations, internal injuries, concussions and severe injuries. The wrist, in particular, is more likely to be fractured or sprained. Injured alpine skiers are more likely to suffer injuries to the head and neck and to the lower limbs. The types of injuries that an injured alpine skier is more likely to experience are strains/sprains, ecchymosis and cuts; specific injuries are thumb sprains and knee sprains.

The significant PIRs coincide with the higher proportions in the descriptive studies. It is believed that falls in combination with the non-releasable snowboarding bindings lead to upper limb injuries.[16,23,41,42,45,47,49] The outstretched arms are used to stop the fall and thereby absorb the impact of the fall. For alpine skiers, it is believed that falls in combination with the equipment lead to thumb and knee injuries.[22,95,96] Depending on how the straps are held, the ski poles can cause thumb injuries while the hard ski boots protect the foot and lower leg but transfer energy further up the leg usually to the knee.[22,95-97]

The PIRs offer a novel view of snowboarding and alpine skiing injuries but there is a level of uncertainty in their interpretation. The PIR does not directly measure the risk for injury; it is a comparative measure of risk.[98] For example, a significant PIR for lower limb injury in injured alpine skiers compared with injured snowboarders could be explained by a number of alternatives. First, there may actually be an increased risk for that injury in that sport. Second, it may be due to a lower risk for lower limb injury in snowboarding while the risk for injury to other anatomic regions and body parts is similar. In that respect, there may be a protective effect of the use of a single board in combination with the non-releasable bindings of snowboarding. This protective effect has been suggested by other authors.[37,39,42,79,99] Third, there may be similar lower limb injury rates in both sports but an increased injury rate in other anatomic regions and body parts in snowboarding. This thesis study and other studies found not only a large proportion of lower limb alpine skiing injuries but also a large proportion of upper limb snowboarding injuries.[47,51] Finally, a differential occurrence may be due to some combination of these situations.

6.2 Risk Factors for Severe Snowboarding Injuries

The second objective of the thesis was to explore and identify risk factors for severe snowboarding injuries. Injuries were classified as severe/not severe based upon clinical opinions. Risk factors were suggested via exploratory logistic regression analyses. This portion of the study is preliminary and exploratory. Previous work has only been descriptive in nature. The results do not model the risk of suffering a severe snowboarding injury but the model does identify risk factors for severe injury given that a snowboarding injury has already been experienced. The model is most useful to fuel discussion and generate hypotheses.

The model suggests that lower ability levels and those injured on Wednesdays are at increased risk for severe injuries, approximately twice the risk for severe injury as those of advanced ability and those injured on Sundays. Other potentially significant factors were young age and trail difficulty. The model suggests that these factors may have a protective effect against more severe snowboarding injuries. Those injured on the easier slopes are at reduced risk compared with those injured on the most difficult runs. Injured snowboarders aged 12-17 years are at reduced risk for severe injury compared with older snowboarders. There are methodological and real explanations for the findings. Any of the findings could be due to chance yet all of the risk factors in the model had been suggested by previous descriptive studies as potential risk factors for injury.

The model's suggestion that younger snowboarders are at reduced risk for more severe injury is contrary to the descriptive findings. Sixty percent of severely injured snowboarders were aged 12-17 years but the proportion of severe injuries within each age group increased with age. Severe snowboarding injuries accounted for eight percent of those aged 12-17 years and 12% of those over age 35 years. Older snowboarders may not be as flexible or resilient. Aging leads to weaker bones, slower reactions and less endurance; these all lead to increased injury in alpine skiing.[100] The same may hold true for snowboarding injuries.

The model suggests that beginner and intermediate snowboarders are at increased risk for severe injury compared with advanced snowboarders. Snowboarders of lower ability levels are mounting the learning curve and in doing so there can be a great deal of risk-taking behaviour and failure until the skill is mastered.

Snowboarding on blue/difficult trails may protect against severe injury compared to snowboarding on double-diamond runs. Beginners and first-time snowboarders are likely on the green/easy trails. Because they are learning the techniques of the sport, they are probably spending a lot of time falling and they have less control. The more difficult runs (i.e. blue trails) would be used by more experienced snowboarders who are able reach higher speeds and do more difficult manouevres. The more advanced snowboarders would be on the diamond and double-diamond trails.

The model suggests that the day of the week may affect the risk for severe injury. Snowboarding on Wednesdays poses an increased risk for severe injury compared to snowboarding on Sundays. Midweek there are likely fewer people on the slopes. Less hill traffic permits higher speeds, ample opportunity for riskier manouevres and the potential for more severe injury. Furthermore, there may be other characteristics of the snowboarders out during midweek that put them at increased risk.

The multivariate model addresses the multifactorial nature of injuries. A Haddon's Matrix for severe snowboarding injury can be constructed from the results of this and previous studies (Figure 5). Based on these thesis findings, interventions might target the novice/beginner snowboarders and the older snowboarders . Prior to the implementation of any interventions these findings need to be replicated and investigated further.

		Factors		
		Human	Vehicle	Environment
Phases	Pre-Injury	- age and sex - lessons - ability - hours on hill - number of runs	- type of equipment - own/rent equipment - activity - manufacturing regulations	- trail difficulty - snow conditions - weather conditions - lighting
	Injury	- age - right or left lead - direction of fall	- protective gear - bindings - boot type	- traffic on trails - (un)groomed trail
	Post-Injury	- age - physical condition - other medical conditions	- releasable bindings - type of board	- transport on/away from ski centre - clinic nearby - emergency response/Ski Patrol

Figure 5 — A Haddon's Matrix for Severe Snowboarding Injury

6.2.1 Injury Severity Classification

The severity classification scheme is crude. Grouping the injury data by severity is limited by the data itself. The members of the Ski Patrol are trained in first-aid and assessment but they are not clinicians nor do they have facilities to confirm suspected diagnoses.

The classification scheme is also limited by the process used to obtain it. It was based on the opinions of a small sample of clinicians (n=10) who attended the Emergency Medical Rounds at a single hospital. A very general definition of severe injury was used. It was decided to group together those injuries that would require medical attention because this group was most likely to require clinical diagnosis, treatment and rehabilitation. It would, therefore, be worthwhile to identify, investigate and perhaps intervene in these injury situations. None of the injury and body part combinations were blacked out in the exercise. Therefore, it is not known if a combination was left blank because it was felt to be less severe or because it was felt to be an illogical combination (e.g. compound fracture of the eye). Despite the limitations of the classification exercise, the resulting severity dichotomy was similar to the emergent and non-emergent snowboarding and alpine skiing injuries studied by O'Neill and McGlone.[91]

6.2.2 Bias in the Model

This model of risk factors for severe snowboarding injury is potentially biased because it was built using a subset of the data. The statistical software builds a model with records of complete information. Any records with missing variables are excluded from the analyses. Only 69% (1,717 out of 2,501) of the snowboarding injury records were included in the model. Of the 11 variables of interest, most were missing values in less than 5% of records but activity and trail difficulty were missing values in 11% and 20% of records.

The model may be biased by the omission of significant risk factors. There are potential risk factors that were not candidates for the model. Weather conditions, trail/snow conditions and the use of safety equipment were excluded because they were too subjective, had overlapping response categories or were missing a large amount of information. Furthermore, details on the type of bindings (releasable, non-releasable), type of boots (hard, soft or inserts) and left/right lead foot are not available in the Ski Patrol injury data.

6.3 Limitations of the Thesis

Some of the limitations of this thesis have already been discussed. There are several issues with the injury rates, particularly surrounding the choice of denominator. Injury rates based on the provincial population include people who do not ski or snowboard. A conservative industry estimate was used for the number of snowboarder visits. Injury rates based on lift ticket sales (i.e. snowboarder visits) do not capture all slope users. Caution must be expressed in the interpretation of the descriptive proportions and the proportional injury ratios since increased occurrence may be real increased risk or may be due to a masking of effects of other injuries. The injury severity classification that was used was crude and the identification of risk factors was exploratory.

There are further limitations to address. Potential sources of bias could be selection, recall, reporting or observer variation. While these biases are likely present, it is unlikely that they had differential effects on the various study groups since all groups and injury data were from a single source - the Quebec Ski Patrol. The biases would then have minimal net impact on results. The main limitation of the study is the lack of an uninjured comparison group of snowboarders. Other issues are related to the unit of analysis.

6.3.1 Selection Bias & Other Numerator Issues

Selection bias is introduced by differences between those who are included in a study and those who are not studied.[101] This project was limited to a single source of injury data which could be criticized as a weakness. There are four possible courses of action after an individual is injured while snowboarding at a ski centre; for each course of action the injury is captured by a different data source, it may be captured by more than one source and some injuries are not captured at all. Using a single injury data source under-estimates injury because a single source cannot capture all injuries.[1,54] The four courses of action after injury are:

1. A minor injury (e.g. bump, bruise or scrape) is probably dismissed and not reported to any health professional nor does it result in any limitation of regular, daily activities or sports participation.

2. The injury may be assessed by a member of the Ski Patrol either on the hill or at the first-aid station. In Canada, these injuries and the circumstances surrounding them are recorded on an accident report form for insurance purposes.

3. The injury may be examined at an emergency department. The injured person may go the hospital either directly from the ski centre or after a period of time, perhaps to return home and visit a hospital there. In this instance, the injury is captured on the Ski Patrol accident report form and/or in the hospital records.

4. The injury may not require immediate attention but the individual may later visit their family physician or another health professional due to persistent symptoms of pain, swelling or restricted movement. These injuries are recorded in physician billings and patient files but there will be little, if any, information about the factors and phases of the injury (i.e. the circumstances of the injury).

There may be differential reporting of injuries to the Ski Patrol. Factors of age, sex and sports experience/ability influence injury reporting. Studies of unreported injuries suggest that females, those of younger ages and lower abilities are more likely to report their injuries to the Ski Patrol.[102,103,104] Although Ski Patrol data captures injuries which are not captured by other data sources, there are estimates that 20% to 50% of alpine skiing and snowboarding injuries are not reported to the Ski Patrol.[103,104] Minor injuries which do not interfere with activity are unlikely to be reported but are equally unlikely to be captured by any other data sources. Since this project was based upon Ski Patrol injury reports, it, therefore, under-estimates the risk for and impact of snowboarding and alpine skiing injuries.

The use of Quebec ski centres is not limited to Quebec residents or Quebec skiers/snowboarders. Some of the injuries seen by the Ski Patrol are suffered by individuals from outside of the province. Postal codes are known for 80.4% of the injured with 80.6% being from the province of Quebec. Therefore, the majority of injured alpine skiers and snowboarders in the study are from Quebec.

Not all Quebec ski centres forward their injury report forms to the Quebec Sports Safety Board. Compliance is not actively enforced even though they are required by law to submit the forms. Approximately three-quarters of the ski centres comply and they account for the majority of provincial ski centre visits. No correction was made in the rate calculations and without correction the rates are under-estimates of the risk for injury.

Selection bias and the other numerator issues bias the rate calculations. The extent of each is unknown. Therefore, the rates were not corrected. Theses influences are summarized in Figure 4.

6.3.2 Recall & Reporting Bias

Recall bias is introduced when there are inaccuracies and incompleteness in participants' memories of past events.[101] Reporting bias is introduced when participants selectively reveal or suppress information.[101] Reporting on ability or level of experience, length of time on the slopes that day and receipt of formal instruction or lessons are subject to recall and reporting bias. The extent of this cannot be determined but it is not believed to differentially affect the injured snowboarders and injured alpine skiers since data were collected from all study groups in a similar fashion and since all study groups had suffered an injury.

6.3.3 Observer Variation

There will be individual variation in the completion of the accident report forms. However, it is assumed to be minimal due to the extensive training received by the members of the Ski Patrol. Furthermore, only the most objective factors from the accident report form were used in the analyses.

Injury data collected by the members of the Ski Patrol are limited in accuracy (with respect to the nature of injury) and coverage. Quebec Ski Patrol training is intensive: members are required to have CPR at level C; they must complete 60 hours of first-aid instruction followed by a practical and written examination; they receive on-hill instruction for evacuation and hazard assessment including two hours on completion of the accident report form which is complemented by a manual produced by the Quebec Sports Safety Board (Personal Communication, Canadian Ski Patrol Association and members of the Quebec Ski Patrol). Even if a member of the Ski Patrol has received clinical training and designation, they are often unable to make a clinical diagnosis of the nature of the injury because the equipment and facilities are not available on site. Accurate diagnoses may be restricted but Ski Patrol data captures injuries and circumstantial details of injuries which are not available from other data sources.

6.3.4 Lack of a Comparison Group

The key methodological limitation in this study is the lack of an uninjured comparison group of snowboarders. It has been alluded to throughout but merits reiteration. High proportions of certain host, vehicle and environmental factors in the injured study groups are indications of potential risk factors for injury. However, since the distributions of factors like fatigue or length of time on the slopes, ability, history of lessons and difficulty of trails ridden are unknown in all alpine skiers and snowboarders, they are merely suggestions which require further study in order to determine whether they actually pose an increased risk for injury.

Assessment of these potential risk factors could be obtained from a case-control study or a sports participant survey. A case-control study is ideal but the selection of controls is critical. An alternative is a case-crossover design in which a case can be its own control.[99] Cases could be identified from Ski Patrol or clinical data. Exposure and risk factor information is collected for the time just prior to injury (case data) and from some established time frame in the past (control data). However, such a study is limited to the investigation of environmental factors since host and vehicle factors would be identical in each case and control. Another option is a cohort or nested case-control study. A cohort of snowboarders is assembled at the start of the ski season, those who suffer injury become cases and controls can be sampled from the remainder of the cohort or it can be analyzed as a cohort study.

The lack of uninjured comparison data led, in part, to the design of the etiologic component. Alpine skiing injuries were deemed inappropriate comparisons. This reference group would be used with the intent of the identification of risk factors for snowboarding injury although it would prevent the identification of risk factors that are common to injury in both sports. Risk factors that were identified could be determinants of sports participation rather than risk factors for injury.

The investigation of severe versus less severe injuries is not pure etiology. A conventional case-control study identifies risk factors for injury. The case-case study identifies risk factors for severe injury given that a snowboarder has suffered an injury. These methods are based on those used in cancer etiology and have been applied to the investigation of motor vehicle crashes and bicycle injuries.[80,81,82] This comparison group suffers the same limitation as alpine skiing injuries in that risk factors common to both groups are masked. It is essential that the comparison group be considered in the interpretation of the model. Any suggestion of increased or reduced risk is relative to the fact that the snowboarder has already suffered an injury.

6.3.5 Unit of Analysis

Analyses were limited to the primary site of injury. Approximately 14% of the subjects had two injuries recorded and approximately 2% of them had three injuries recorded. These proportions were similar for both injured snowboarders and injured alpine skiers. Using only the primary injury results in an under-estimation of the overall risk for injury as well as an under-estimation of the frequency of the sites and nature of injuries. However, it simplifies the conduct and understanding of the analyses as the unit of analysis is the individual.

6.4 Conclusions & Recommendations

In the sports of snowboarding and alpine skiing, there are marked differences in the risk for injury. Those injured are significantly different in age and sex than the sports participants. The risk for snowboarding injury is up to twice the risk of alpine skiing injury after adjusting for the differing age and sex distributions in the two sports.

Lift ticket sales under-estimate the total number of ski centre visits because there are groups that do not purchase lift tickets. Lift ticket sales do not distinguish between sports. Alpine skier and snowboarder visits were estimated based on industry advice. Future studies should take random counts at the lifts during the study period to determine the proportion of alpine skiers and snowboarders on the slopes. The managers of the ski centres might know the proportion of visitors who do not purchase lift tickets. Otherwise, the conduct of slope-user surveys could specify these details. These methods would be difficult to implement and apply to studies covering large geographical areas and might lend themselves to more focussed research studies.

National participation rates were applied to the Quebec census population to estimate provincial skiing/snowboarding participation counts. Future studies could purchase provincial participation estimates from the Canadian Ski Council.

The proportional injury ratios suggest injured snowboarders are more likely than injured alpine skiers to suffer upper limb injuries and injured alpine skiers are more likely than injured snowboarders to suffer lower limb injuries. This could be due to a protective effect offered by the equipment and motions of the other sport. These findings may generate hypotheses for biomechanical studies of the mechanisms of injury and equipment development in these sports. Due to the intrinsic difficulties in interpreting the proportional injury ratios, methodological alternatives have been proposed. Miettinen and Wang suggest a ratio of the odds for the cause of interest (exposed over unexposed) or a ratio of the exposure-odds for the cause of interest over other causes.[105]

Severe snowboarding injuries account for nearly one in ten snowboarding injuries. Concussions account for 6.0% of all snowboarding injuries and over 60% of the severe snowboarding injuries. Potential risk factors for severe snowboarding injuries were explored. Results suggest that, given that a snowboarder suffers an injury, there are factors which may contribute to the severity of the injury. The risk factor model indicates that those of lower abilities and snowboarding on certain days poses an increased risk for severe injury; approximately twice the risk for severe injury as advanced snowboarders and using the slopes on Sunday. Younger snowboarders and those riding the blue trails are at reduced risk for severe injury compared with older snowboarders and those using the double-diamond runs.

Due to the exploratory nature of these analyses, the results should fuel further discussion and research prior to the implementation of any intervention. These risk factors could be investigated in case-control studies, case-crossover studies, cohort or nested case-control studies.

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APPENDIX A — QUEBEC SKI PATROL ACCIDENT REPORT FORM

Régie de la sécurité
dans les sports
du Québec

Nº 01062

ACCIDENT REPORT

SKI AREA : ____________________

IDENTIFICATION OF PATIENT			TRAIL	LOCATION ON TRAIL	DATE OF ACCIDENT: YEAR	MONTH	DAY	TIME
FIRST NAME	LAST NAME							
ADDRESS	CITY	PROVINCE	(grid letter)	(grid number)	DIV	ZONE	AREA	h. min. 24 hrs
POSTAL CODE	TELEPHONE ( )							
REGISTRATION NUMBER OF FIRST-AIDER(S)			TRAIL NAME :					
			POSTED DIFFICULTY : N/A					

AGE	TYPE OF ACTIVITY-EQUIPMENT	SKIING TIME TODAY	SKIING TIME THIS SEASON	LESSONS	GOGGLES	ACCIDENT INVOLVED
	1 COMPETITION 2 TRAINING 3 LESSON 4 RECREATION 1 ALPINE SKIING 2 FREE-STYLE SKIING BALLET__ AERIALS__ MOGULS__ 3 CROSS-COUNTRY SKIING 4 TELEMARK 5 SNOWBOARD HALFPIPE__ PARK__ TRAIL__ 6 MONOSKI 7 LIFT 8 OTHER, SPECIFY	1 UP TO 1 HOUR 2 1-3 HOURS 3 3-5 HOURS 4 5-7 HOURS 5 MORE THAN 7 HOURS 6 N/A	1 FIRST DAY 2 2-10 DAYS 3 11-20 DAYS 4 MORE THAN 20 DAYS 5 N/A	1 NEVER 2 THIS YEAR 3 1-2 YEARS AGO 4 3-4 YEARS AGO 5 5 OR MORE YEARS AGO	1 WAS WEARING GOGGLES 2 WAS NOT WEARING GOGGLES 3 WAS WEARING SUN GLASSES 4 WAS WEARING CORRECTIVE GLASSES 5 N/A	1 LIFT 2 SNOW CONDITION 3 TOO FAST 4 COLLISION WITH TREE 5 COLLISION WITH PYLON, POST, HYDRANT SNOWMAKING MACHINE 6 COLLISION WITH FENCE 7 COLLISION WITH MACHINERY 8 COLLISION WITH SKIER 9 POOR VISIBILITY 10 SKIER ERROR 11 OUTSIDE THE SKI SLOPES 12 BINDINGS IMPROPERLY SECURED
SEX MALE ☐ FEMALE ☐		ABILITY 1 NOVICE 2 INTERMEDIATE 3 ADVANCED 4 DOES NOT KNOW		SAFETY EQUIPMENT 1 HELMET 2 OTHER, SPECIFY		

SNOW CONDITION	LIGHT	WEATHER	TEMPERATURE	BINDING TYPE	AUTO RELEASE	EQUIPMENT (SKI OR BOARD)	TRANSPORT EVACUATION: In area	Off area
1 0"-4" DRY POWDER 2 DEEP POWDER 3 WET SNOW 4 GROOMED ON HARD PACK 5 ICE 6 CORN, CRUD 7 CRUSTY 8 GROOMED	1 GOOD 2 AVERAGE 3 FAIR TYPE OF LIGHT 1 ARTIFICIAL LIGHT 2 NATURAL LIGHT	1 CLEAR 2 SUNNY 3 SNOWING 4 RAINING 5 FOGGY 6 WINDY 7 BLOWING SNOW 8 FREEZING RAIN 9 CLOUDY	1 ABOVE 30°C 2 10°C TO 30°C 3 0°C TO 9°C 4 -1°C TO -10°C 5 -11°C TO -30°C 6 BELOW -30°C	1 TOE-HEEL 2 PLATE 3 CABLE 4 PIN 5 FLEXIBLE SNOWBOARD 6 RIGID SNOWBOARD 7 TELEMARK 8 CROSS-COUNTRY	1 RIGHT SIDE 2 LEFT SIDE 3 BOTH SIDES 4 DID NOT RELEASE 5 PRE-RELEASED 6 NOT RELEVANT TO ACCIDENT 7 SNOWBOARD 8 DOES NOT KNOW	1 OWN 2 AREA RENTAL 3 OTHER RENTAL 4 DEMO 5 BORROWED For 3, 4 and 5 from whom.	1 TOBOGGAN 2 SNOWMOBILE 3 TRACTION VEHICULE 4 SKI 5 WALKING 6 OTHER	1 SELF 2 PARENT 3 GUARDIAN 4 INSTRUCTOR 5 FRIEND 6 AMBULANCE 7 OTHER

1a	2a	3a	SUSPECTED INJURY	1a	2a	3a	INJURED LOCATION			SKIER'S CONDITION
01	01	01	SPRAIN	01	01	01	HEAD			1 UNCONSCIOUS
02	02	02	SIMPLE FRACTURE	02	02	02	FACE			2 CONSCIOUS
03	03	03	COMPOUND FRACTURE	03	03	03	EYE	L	R	CALM ☐
04	04	04	DISLOCATION	04	04	04	NOSE			CONFUSED ☐
05	05	05	ECCHYMOSIS	05	05	05	MOUTH			AGITATED ☐
06	06	06	CUT	06	06	06	NECK			FINDINGS
07	07	07	SCRATCH	07	07	07	RIBS	L	R	1 PAIN
08	08	08	FROSTBITE	08	08	08	THORAX	L	R	2 DEFORMATION
09	09	09	HYPOTHERMIA	09	09	09	CERVICAL SPINE			3 HEMORRHAGE
10	10	10	INTERNAL INJURY	10	10	10	DORSAL SPINE			4 LOSS OF MOTRICITY SENSATION
11	11	11	CONCUSSION	11	11	11	LUMBAR SPINE			
12	12	12	DIZZINESS	12	12	12	COLLAR BONE	L	R	
13	13	13	HEART PROBLEM	13	13	13	SHOULDER BLADE	L	R	
14	14	14	CEREBROVASCULAR ACCIDENT	14	14	14	SHOULDER	L	R	
15	15	15	BURN	15	15	15	UPPER ARM	L	R	
16	16	16	HYPERVENTILATION	16	16	16	FOREARM	L	R	
OTHER				17	17	17	ELBOW	L	R	
				18	18	18	WRIST	L	R	
				19	19	19	HAND	L	R	
				20	20	20	THUMB	L	R	
				21	21	21	ABDOMEN			
				22	22	22	HIP - PELVIS			
				23	23	23	THIGH	L	R	
				24	24	24	LOWER LEG	L	R	
				25	25	25	KNEE	L	R	
				26	26	26	ANKLE	L	R	
				27	27	27	FOOT	L	R	

DESCRIPTION OF THE ACCIDENT :

FIRST AID APPLIED :

COMMENTS :

HOSPITAL, LCSC OR FIRST AID CENTRE WHERE PATIENT WAS BROUGHT

ACCIDENT WITNESSES

NAME :
ADDRESS : TEL. : ( )
NAME :
ADDRESS : TEL. : ( )

EQUIPMENT SENT WITH PATIENT			
SKIS, SNOWBOARD	YES	NO	
BOOTS	YES	NO	
POLES	YES	NO	
SPLINTS	YES	NO	
CERVICAL COLLAR	YES	NO	QUANTITY :
BLANKETS	YES	NO	QUANTITY :
PILLOWS	YES	NO	QUANTITY :
TRIANGULARS	YES	NO	QUANTITY :
DORSAL BOARD	YES	NO	QUANTITY
OTHER :			

APPENDIX B — GLOSSARY OF TERMS & FORMULAE

injury

Definition was provided by the Quebec provincial legislation concerning safety in alpine ski centres. In the legislation, an injury is the result of an incident which occurred on a ski slope and for which a first-aider's assistance was required or provided. In essence, an injury was defined as any event brought to the attention of and recorded by a member of the Ski Patrol.

injury rate

Injury rate per 10,000 population per season calculated as:

$$\frac{\#injuries}{\#@\,risk} \times 10{,}000$$

Where the injury rate, injury count and population at risk are for a given sport, sex or age group

95% Confidence Limits calculated as:

$$rate \pm (1.96 \times SE)$$

And Standard Error (SE) calculated as:

$$\sqrt{\frac{rate \times (1 - rate)}{pop'n@\,risk}}$$

Where

rate = injury rate calculated
pop'n@risk = denominator used for rate calculation

Proportional Injury Ratio (PIR)

Proportional Injury Ratio (PIR) calculated as:

$$\frac{a}{\sum_{males}^{females}\left[\sum_{age1}^{age4}\left(\frac{b}{c}\times d\right)\right]}$$

Where
- PIR is for SB head and neck injuries
- SB = snowboarding
- SK= alpine skiing
- age1 = first age group 12-17 years
- age4 = fourth age group 35+ years
- a = # SB head and neck injuries observed
- b = # SK head and neck injuries for an age and sex group
- c = # SK injuries for the sex and age group
- d = # SB injuries for the sex and age group

95% Confidence Interval calculated as:

$$e^{\ln PIR \pm (1.96 \times SE)}$$

Standard Error (SE) calculated as:

$$\frac{\sqrt{\sum_{males}^{females}\left[\sum_{age1}^{age4}\frac{e(d-e)}{d}\right]}}{a}$$

Where
- age1 = first age group 12-17 years
- age4 = fourth age group 35+ years
- e = # SB head and neck injuries observed for an age and sex group
- d = # SB injuries observed in the age and sex group
- a = # SB head and neck injuries observed

severe injury — For the purposes of this study and the severity classification exercise, a severe injury is one that would require medical attention

APPENDIX C — SEVERITY CLASSIFICATION TOOLS

Clinicians were consulted to categorize the Ski Patrol data into severe and not severe injuries using the information on nature of injury and injured body part. A convenience sample of emergency department clinicians provided the severity classification scheme. At a presentation to the Emergency Medical Rounds at the Children's Hospital of Eastern Ontario in Ottawa (09 September 1998), clinicians in attendance were asked which of the suspected injuries they would consider severe. A severe injury was defined as one that would require medical attention. The two variables (injured body part and nature of injury) were presented on a grid with one variable on each axis. Each combination of injury and body part was considered and if decided to be severe, was marked as such. These are the coding options for the two variables and the grid used to record severe injuries.

Legend for Injury Severity Classification Grid

Nature of injury:

A. Sprain
B. Simple Fracture
C. Compound Fracture
D. Dislocation
E. Ecchymosis
F. Cut
G. Scratch
H. Frostbite
I. Hypothermia
J. Internal Injury
K. Concussion
L. Dizziness
M. Heart Problem
N. Cerebrovascular Accident
O. Burn
P. Hyperventilation

Injured body part:

1. Head
2. Face
3. Eye
4. Nose
5. Mouth
6. Neck
7. Ribs
8. Thorax
9. Cervical Spine
10. Dorsal Spine
11. Lumbar Spine
12. Collar Bone
13. Shoulder Blade
14. Shoulder
15. Upper Arm
16. Forearm
17. Elbow
18. Wrist
19. Hand
20. Thumb
21. Abdomen
22. Hip-Pelvis
23. Thigh
24. Lower Leg
25. Knee
26. Ankle
27. Foot

Nature of Injury →

↓ Injured Body Part

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1																
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3																
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Appendix D — Design Variable Coding

Frequencies will add to 1641 since a model was built with all 11 variables to obtain codings. Frequencies for model building will vary depending on the step as SPSS builds models only with cases that contain complete information.

	Parameter Value	Freq	Coding (1)	(2)	(3)	(4)	(5)	(6)
DAY_WK								
Sun	1	291	.000	.000	.000	.000	.000	.000
Mon	2	157	1.000	.000	.000	.000	.000	.000
Tue	3	155	.000	1.000	.000	.000	.000	.000
Wed	4	159	.000	.000	1.000	.000	.000	.000
Thu	5	216	.000	.000	.000	1.000	.000	.000
Fri	6	287	.000	.000	.000	.000	1.000	.000
Sat	7	376	.000	.000	.000	.000	.000	1.000
HRSKI								
up to 1 hr	1	299	1.000	.000	.000	.000		
1-3 hrs	2	703	.000	1.000	.000	.000		
3-5 hrs	3	478	.000	.000	1.000	.000		
5-7 hrs	4	142	.000	.000	.000	1.000		
>7 hrs	5	19	.000	.000	.000	.000		
LSN								
never	1	933	1.000	.000	.000	.000		
this yr	2	323	.000	1.000	.000	.000		
1-2 yrs ago	3	236	.000	.000	1.000	.000		
3-4 yrs ago	4	50	.000	.000	.000	1.000		
5+ yrs ago	5	39	.000	.000	.000	.000		
POST								
easy-green	1	650	1.000	.000	.000			
difficult-blue	2	568	.000	1.000	.000			
very difficult-diamond	3	313	.000	.000	1.000			
extremely difficult-dbl diamond	4	110	.000	.000	.000			
AGE_GRP4								
12-17	1	1091	1.000	.000	.000			
18-24	2	357	.000	1.000	.000			
25-34	3	118	.000	.000	1.000			
35+	4	75	.000	.000	.000			
MONTH_ORD								
Dec	0	334	.000	.000	.000			
Jan	1	446	1.000	.000	.000			
Feb	2	403	.000	1.000	.000			
Mar	3	458	.000	.000	1.000			
ACTIV								
competition/training	1	30	.000	.000				
lesson	3	69	1.000	.000				
recreation	4	1542	.000	1.000				
EQUIP2								
own	1	1147	1.000	.000				
rental	2	369	.000	1.000				
borrowed	5	125	.000	.000				
ABIL								
beginner	1	720	1.000	.000				
intermed	2	664	.000	1.000				
advanced	3	257	.000	.000				
SEX								
male	1	1161	1.000					
female	2	480	.000					
HR_GRP2								
00h-12h	1	576	1.000	.000				
13h-17h	2	682	.000	1.000				
18h-24h	3	383	.000	.000				