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Helmet Use Among Skiers and Snowboarders in Southern Alberta

by

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A THESIS

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Abstract

Skiing and snowboarding are among the most popular winter activities in Canada.

Unfortunately, many injuries occur in these activities, including severe injuries often involving the head, which can result in death. These injuries, particularly severe head or brain injuries, are an important burden on the health care system, and may be prevented by encouraging helmet use. Helmet effectiveness is well established, but there are little recent data on ski and snowboard helmet prevalence at ski areas in southern Alberta, with no published reports on correct helmet fit.

This study determined the prevalence of helmet use and correct helmet use at a single ski area in Southern Alberta and examined the factors associated with helmet use and correct fit.

Information on helmet use and correct use, as well as environmental and behavioural characteristics was collected at the base of the ski hill by both interviewing and observing participants.

Age (<18 years old), skiing/snowboarding with companions, and skiing/snowboarding with companions also wearing helmets increased the likelihood of each wearing a helmet and wearing a helmet correctly.

The protective effect of helmets in skiers and snowboarders has been demonstrated convincingly. The education and promotion of helmet use and correct helmet use is paramount in reducing the risk of head injuries among skiers and snowboarders. Our findings will inform participants, parents, members of the ski-snowboard industry, and the stakeholders that seek to influence them to improve the safety of skiers and snowboarders of all ages.

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Dedication

This thesis is dedicated to my mom, for believing in me and supporting me throughout my entire life. She taught me the importance of perseverance and pushed me to complete this work. And to my brother, who continued to support me and provide the much-needed humour necessary to get through this.

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Chapter One: Literature Review

1.1 Injury Burden

In the past, injuries have been regarded as unavoidable “accidents”. Recently, however, improvements have been made towards understanding the nature of injuries, and today they are widely regarded as preventable events [1]. Identified as a major public health problem, injuries pose a significant threat to the health care system, the economy and above all the quality of life of those affected personally. Globally, injuries result in an estimated five million fatalities and cause harm to millions more each year [1]. In Canada, injuries are the leading cause of death for Canadians aged 1 to 44 and the fourth leading cause of death for all ages [2]. Nationally, injury ranks third behind cardiovascular and musculoskeletal diseases in terms of economic burden, costing an estimated \$19.8 billion annually [3]. In Alberta, each year, approximately 8,000 people are permanently disabled and over 1700 more are killed [4]. The economic burden of injuries in Alberta has been estimated to be \$2.9 billion annually, with unintentional injuries responsible for 77% of the total cost [4].

1.2 Sports and Recreation

A significant contributor to the injury burden is the participation in sport and recreational activities. Canadian children spend a considerable amount of time participating in sport and recreational activities [5]. Children between the ages of five and twelve years spend an average of 18 hours per week engaging in physical activity, while those thirteen to

seventeen years average 15 hours per week [5]. While participation in sports and recreation is important in building and maintaining an active, healthy lifestyle; the potential for sustaining an injury is substantial [6]. In Canada, more than 40% of child and youth injuries treated in emergency departments are sports and recreation related [2]. Thirty percent of those ages five to nine years, 68% of those ages ten to fourteen and 55% of those ages fifteen to nineteen years treated in emergency departments for injuries are a result of participating in sports and recreational activities [2]. The direct and indirect health care costs of child and youth injury in Canada are estimated to be \$5.1 billion annually [2]. In the U.S., a recent report from the Centres for Disease Control and Prevention found that there are 26 sports and recreation injury episodes per 1000 persons per year and that for those ages 5 to 24 years, sports injuries are responsible for one out of every five injury episodes [7]. Although injury is an unwanted side effect of participation, one that has the potential to reduce the benefits of involvement in sports and recreational activities and act as a barrier to future involvement [6], sports and recreational physical activity are an integral part of our society and are justifiably promoted as part of a healthy lifestyle [6].

1.3 Inactivity and Obesity

Participation in physical activity by means of sport and recreation involvement holds tremendous public health benefits [8]. The protective effect of physical activity on the risk for several chronic diseases has been demonstrated convincingly. Epidemiologic studies have shown protective effects of varying strength for chronic diseases that include coronary heart disease, hypertension, diabetes, osteoporosis and anxiety and depression [8]. Despite this, in 2004, approximately 6.8 million Canadian adults ages 20 to 64 were

overweight, while an additional 4.5 million were considered obese [9]. The prevalence of overweight and obesity in Canada has been increasing over time. Between 1970 and 1998, the proportion of overweight or obese adults increased from 40% to 50.7% [10]. Results from the 2004 Canadian Community Health Survey found approximately 58.8% of Canadian adults were either overweight or obese [9]. Data for children have been found to mirror the trend in adults, with 18.1% of children ages two to seventeen overweight, and an additional 8.2% classified as obese [9]. This is a global problem with World Health Organization (WHO) estimates of more than 1 billion overweight and 300 million obese adults [11].

Numerous factors influence overweight and obesity, with one of the major contributors being a lack of physical activity. In support of this perspective, increasing sedentary lifestyles resulting from urban planning and service-orientated economies contribute to the rising trend in obesity [6]. Furthermore, transportation infrastructure in developed countries that discourages walking or cycling in favour of using a motor vehicle has been identified as a major contributor to the rising trend in obesity [6].

The economic burden of overweight and obesity is enormous. In 2001, physical inactivity in Canada resulted in estimated direct and indirect cost of \$5.3 billion, whereas the direct and indirect costs of obesity were estimated to be \$4.3 billion [12]. This substantial health problem is due to several complex factors and has resulted in a large economic burden. Addressing the lack of physical activity by increasing participation in sport and recreational activities is a practical endeavour to mitigate the increasing trend of overweight and obesity.

1.4 Ski and Snowboard Participation

Skiing and snowboarding are two of the most popular recreational and competitive winter activities. There are more than 78 million visits to North American ski areas annually by skiers and snowboarders of all ages [13]. Approximately 20% to 30% of participants are children and youth [13]. In 2010, an estimated 11.5 million skiers and 8.2 million snowboarders participated in such activities in the United States [73]. Participation in Canada is common due to long winters and an abundance of snow and mountains. The most recent data from the Canadian Ski Council indicate there are over 1.7 million skiers and 1.1 million snowboarders in Canada [13], with approximately 18 million ski area visits in Canada and approximately 2.5 million visits in Alberta annually [13]. Data from a survey conducted at Calgary high schools indicate that snowboarding is one of the top sports for both males and females in the 14-19 year age range with approximately 20% of students participating [14]. Snowboarding and skiing combined rank eighth overall among participation sports in junior high school students aged 12-15 years [15]. Unfortunately, both sports have a risk for injury.

1.5 Ski and Snowboard Injuries

In U.S. emergency departments, an estimated 77,300 skiing and 62,000 snowboarding injuries were treated in 2002, of which 10,700 were traumatic brain injuries [16]. Skiing and snowboarding were ranked second and third behind hockey as leading causes for children to be admitted to emergency departments in Canada. However, when compared with hockey, skiers and snowboarders had higher rates of hospitalization [17]. In a junior high school survey conducted in the Calgary region, 7.1% of students indicated they had sustained a snowboarding/skiing injury in the past year [15]. For high school students in

the same region, snowboarding ranked 10th in terms of injury rate, but ranked 4th behind basketball, hockey and soccer when only serious injuries were considered [14]. Based on Quebec ski patrol data, among those aged 12 and older, snowboarding injury rates ranged from 1.06 per 1000 participants per year for trunk injuries to 6.6 per 1000 participants per year for upper extremity injuries [18]. For skiers, injury rates ranged from 0.33 per 1000 participants per year for trunk injuries to 2.56 injuries per 1000 participants per year for lower extremity injuries [18]. Head and neck injury rates per 1000 participants per year were estimated at 0.95 among skiers and 2.48 among snowboarders [18]. Kim et al. reported the most common injuries among snowboarders were wrist injuries, while the most common skiing injuries occurred to the lower extremities, predominantly affecting the anterior cruciate ligament (ACL) [74,75]. In addition, a 6 year retrospective study assessing injured recreational alpine skiers and snowboarders at the Levi Ski Resort in Finland found an average injury incidence of 0.98 injuries per 10,000 lift runs, with knee injuries to skiers constituting nearly one third of all cases, while snowboarders sustained more injuries to the upper extremities, primarily the wrist [75]. These estimates reflect the predominance of upper extremity injuries among snowboarders and lower extremity injuries among skiers with participants in both activities susceptible to head and neck injuries.

1.5.1 Ski and Snowboard Head Injuries

The leading cause of hospital admission, death and disability for skiers and snowboarders is traumatic brain injury (TBI), ranging from concussion to more severe forms of head injury [19]. Of the estimated 600,000 ski and snowboard injuries each year in North America, an estimated 15-20% constitute head injuries [20]. Furthermore, head injury is

responsible for 20-54% of hospital admissions for injury from skiing and snowboarding [20]. An estimated 50% to 88% of deaths in skiers and snowboarders can be attributed to TBI [19]. Morrow et al. reported on all ski related deaths in Vermont from 1979-80 through 1985-86 and found that all but two of the sixteen reported cases were the result of a lethal head/neck injury [21]. Tough et al. reported on all downhill skiing fatalities in Alberta, Canada from 1980 to 1990 and found that of 19 cases, 89.5% were the result of blunt trauma, with 7 cases resulting from severe head and neck injury [22]. Levy et al. reported on 1,214 patients admitted to a level 1 trauma center in Colorado for all types of injuries related to skiing and snowboarding from 1982 to 1998. Of this group, 350 patients had sustained a traumatic brain injury [23]. Furthermore, 16 fatalities occurred among the 1,214 injured skiers and snowboarders, with head injury responsible for the cause of death in all but two of the cases [23]. In general, the injury rate for all types of injury in skiers and snowboarders has been declining, with marked improvements in equipment design attributed to this reduction. However, head injuries in skiers and snowboarders have not declined. Rates of TBI in skiers and snowboarders appear to be increasing with one possible reason being the growing popularity of ski area terrain parks, which are areas of the ski hill that support acrobatic and aerial maneuvers [24].

1.6 Ski and Snowboard Helmets

The issue of ski and snowboard helmets remains controversial and their efficacy has been one of intense scrutiny. The following sections present evidence regarding ski and snowboard helmet effectiveness, prevalence, standards, fit, and arguments for and against their use.

1.6.1 Ski and Snowboard Helmet Effectiveness

Helmets have been proposed as an injury prevention strategy for skiers and snowboarders. Many studies on the relation between helmet use and head injuries among skiers and snowboarders have found a protective effect. Mueller et al. conducted a case-control study using ski patrol injury reports for the years 2000-2005 from three ski resorts in the western United States [25]. When comparing injured (to the head, face, or neck) skiers and snowboarders to skiers and snowboarders who sustained an injury other than to the head or neck, an odds ratio of 0.85 (95% CI: 0.76-0.95) was reported after adjusting for high fall, ski ownership, any collision, sex, age, season, ski school, ability, ski type, and ski resort [25]. Several other case-control studies using controls that sustained an injury other than to the head or neck have provided evidence in favour of helmets protecting against head injury. Hagel et al. conducted a matched case-control and case-crossover study at 19 ski areas in Quebec over the course of one season [26]. The reported adjusted injury odds ratio for helmet use in participants with any head injury was 0.71 (95% CI: 0.55-0.92), indicating a 29% reduction in the odds of a head injury with the use of a helmet [26]. Sulheim et al. conducted a case-control study at 8 Norwegian alpine resorts during the 2002 season [27]. They reported an adjusted odds ratio of 0.45 (95% CI: 0.30-0.55) indicating a 55% reduction in the odds of a head injury with use of a helmet [27].

Case-control studies that compared injured skiers and snowboarders to uninjured controls also find a protective effect of helmet use on head injury. Macnab et al. conducted a case-control study on children under 13 years old at a single, world class ski resort during the 1998-1999 season comparing injured skiers and snowboarders to

uninjured controls [28]. An odds ratio of 0.56 (95% CI: 0.31-1.01) was reported suggesting a protective effect of helmets against head injury [28]. In the same case-control study Sulheim et al conducted at 8 Norwegian alpine resorts during the 2002 season, a slightly stronger protective effect was found when comparing injured skiers and snowboarders to uninjured controls (OR 0.40; 95% CI: 0.30-0.55) [27]. One cohort study by Machold et al. on 2,579 snowboarders suggested a major protective effect of helmets after reporting that 7.6% of snowboarders were wearing a helmet, of which none sustained a head injury, while 0.7% of the snowboarders who weren't wearing a helmet did sustain a head injury [29].

When considering the effect of helmets on severe head injury, defined as referral to an emergency physician or hospital for treatment, Hagel et al. and Sulheim et al. both report a significant protective effect of helmets, with estimates indicating a 56% and 57% reduction in the odds of sustaining a severe head injury with use of a helmet [26, 27]. Conversely, Fukuda et al. reported a nonsignificant result of the effect of helmets on the risk of serious head injury overall, defined as an incident leading to traumatic amnesia, loss of consciousness, craniofacial fracture or intracranial lesion. (OR 0.66; 95% CI: 0.32-1.35) [30]. Although not statistically significant, with a wide confidence interval it cannot be assumed that there is no impact. In addition, Shealy et al. reported no difference in the incidence of serious head injury between helmet users and non-users [31]. Furthermore, using a cross-sectional analysis of a large national trauma registry, Bergmann et al. examined the frequency of concussion among helmeted and unhelmeted youth skiers and snowboarders and found no difference among helmeted and unhelmeted subjects, indicating that among youth skiers and snowboarders, helmet use is not

associated with a reduction in concussion [76].

Russell et al. performed the first systematic review on the effect of helmets on the risk of head and neck injury in skiers and snowboarders, and reported a pooled odds ratio of 0.65 indicating a 35% reduction in the odds of head injury with the use of a helmet. [32] A subsequent published review confirmed these findings [20]. The protective effect of helmets in skiers and snowboarders has been demonstrated convincingly and the debate on helmet use in winter sports has reached a critical point. Some suggest that participants would benefit from a reduced odds of head injuries with mandatory ski and snowboard helmet policies [20]. Recently, Nova Scotia has become the first Canadian province to legislate mandatory helmet use for all ages, making it illegal to ski or snowboard without a helmet (effective November 1st, 2012) [33]. An alternative solution would be to continue non-legislative helmet promotion strategies that have the potential to be strengthened by evidence related to factors associated with helmet use [34].

1.6.2 Ski and Snowboard Helmet Use

Few studies have examined the prevalence of helmet use, and those that have are either outdated, included only adults, did not include direct observation at ski areas, or were conducted in countries other than Canada [34-38].

In a ski area survey conducted in the eastern United States in 2005, Lawrence et al. observed the activity (skiing or snowboarding) and helmet use characteristics of children (5-17 years) [38]. The authors noted that helmet use was 37% in the entire sample, but was 63% in those 5-10 years old and 26% in those 11-17 years [38].

Based on self-reports from neurosurgeons, Jung et al. noted that approximately

half of the sample of individuals from neurosurgical departments in Germany, Switzerland and Austria and a non-TBI educated control cohort sampled at ski areas in Austria and sports stores in Germany reported that they wore helmets [37]. Further, the neurosurgeons reported that 87% and 79% of their own children wore helmets while skiing and snowboarding, respectively, compared with reported child skier and snowboarder helmet use of only 69% and 22% in the non-TBI educated control group [37].

Ruedl found that overall (skiers and snowboarders) helmet use on Austria ski slopes was 63% in 2008 [39, 40]. Further, the authors noted that among those under 20 years old, helmet use was 78%, but 53% in those 60 and older [39, 40].

In 2008, Cundy et al. found the prevalence of helmet use for skiers and snowboarders at a single resort in Australia to be 29% [34]. However, 16% of adults (>18 years old) and 67% of children (10-18 years old) were found to be wearing a helmet [34]. Cundy et al. also noted that helmet use had increased 2% per annum for adults and 5% per annum for children since 2003 [34].

In a series of studies in western North America on adult (≥ 18 years old) skiers and snowboarders, the authors found that helmet use increased from 12.1% in 2001[36] to 19.8% in 2002[35] reaching 23% in 2003 [41].

A number of case-control studies have reported helmet prevalence estimates in uninjured control groups. In a 2010 case-control study examining risk factors for injuries in snowboarders in Switzerland, Hasler et al. reported a helmet prevalence of 77% in the uninjured control group [42]. This represented an increase from the reported helmet prevalence of 70% in the uninjured control group Hasler et al. found in a 2009 case-

control study on risk factors for injuries in alpine skiing [43]. More recently, in 2011, Sulheim et al. reported a helmet prevalence of just 21.9% in the uninjured control group from their case-control study on skiing and snowboarding at 8 major resorts in Norway [44]. In Switzerland, helmet use steeply increased from 63% in 2008/2009 to 75% in 2009/2010 [77].

Based on telephone survey data, the Canadian Ski Council (CSC) estimates that helmet prevalence in Canada has increased in children 10-14 years old from 65% in 2006 to 95% in 2010 [13]. The figures for those 15-17 indicated that 85% wear helmets. For adults age 18-24, the prevalence of helmet use has remained the same since 2006 at 63% [13]. The greatest growth in helmet prevalence has been in those 55-64 years old, for whom helmet prevalence has increased from 39% in 2006 to 76% in 2010 [13]. Helmet use in skiers and snowboarders in Canada has increased from 67% in 2006 to 71% in 2010 [13]. According to the CSC, this is significantly higher than in the U.S., where 2010 reports indicated that helmet prevalence in skiers and snowboarders was 57% [13]. In 2013, Fenerty et al. conducted observations of helmet use at three ski hills in Nova Scotia and found a helmet prevalence of 74% and 72% among skiers and snowboarders, respectively [78].

1.6.3 Ski and Snowboard Helmet Standards and Fit

No study to date has examined the prevalence of ski and snowboard helmet standards. Several standards exist, such as the European CE 1077 standard, the American Society for Testing and Materials (ASTM) F2040 standard, the Snell Memorial foundation RS-98 standard and the recent Canadian Z 263.1. [45]. Despite the existence of these standards, ski and snowboard helmets available in the Canadian retail market are not required to

meet them. In addition, only one study to date has addressed the prevalence of correct helmet use and fit in skiers and snowboarders. In 2013, Fenerty et al. conducted observations of helmet fit, defined as fastened, fitted, and correct helmet type, at three ski locations in Nova Scotia [78]. Collecting observational data on 3,336 subjects, they reported that 99% of participants with helmets wore them correctly [78].

A detailed set of criteria outlined by ThinkFirst Canada (now part of Parachute Canada: www.parachutecanada.org/) defines a correctly fitted helmet as one that is snug and comfortable, with room for one finger under the chinstrap, pads touching the cheeks and forehead, without the back of the helmet touching the nape of neck, room for two fingers above the eyebrow, little or no gap between the top of goggles (if worn) and helmet, and no additional garments worn underneath the helmet. Little is known about the prevalence of correctly worn helmets and the factors associated with correct use and fit. If a helmet is worn incorrectly in skiing and snowboarding, as is the case among a significant proportion of young bicycle helmet users, [46] then, as for bicyclists, [47, 48] helmet effectiveness would likely suffer.

1.7 Arguments Against Helmet Use

Despite the evidence supporting the protective effect of helmets against sustaining a head injury, it has been suggested that helmets may contribute to the risk of injury due to impeding vision and hearing, potentially increasing the risk of sustaining a neck injury, and potentially providing a false sense of protection that can lead to skiing or snowboarding above one's ability level increasing the risk of sustaining an injury.

1.7.1 Risk of Cervical Spine Injury

An argument against helmet use is the uncertainty surrounding the potential risk of

sustaining a cervical spine injury, particularly in children under 13 years of age given the relative weight of the helmet to total bodyweight and neck strength [26-28, 49]. Several studies have attempted to report on this particular phenomenon. Macnab et al. reported on a case-control study on children under 13 years old comparing skiers and snowboarders who had sustained any injury to the head, face or neck to uninjured controls and found no evidence that helmet wearing increased the incidence or severity of neck injury (RR 2.0; 95% CI: 0.80-5.65) [28]. Macnab et al. also noted that of 22 reported cervical spine injuries, none were considered major [28]. Hagel et al. conducted a matched case-control and case-crossover study at 19 ski areas in Quebec over the course of one season and reported an adjusted odds ratio of 0.62 (95% CI: 0.22-1.19) for helmet use for participants with any neck injury and an adjusted odds ratio of 1.29 (95% CI: 0.41-4.04) for participants who required evacuation by ambulance for neck injuries [26]. It was concluded that while the possibility of an increased risk of neck injury with the use of a helmet could not be ruled out, the estimates based on this conclusion are imprecise [26]. Similarly, Sulheim et al. conducted a case-control study at 8 Norwegian alpine resorts during the 2002 season [27] and reported an adjusted odds ratio of 0.68 (95% CI: 0.34-1.35) for helmet use for participants who sustained a neck injury [27]. Of the 62 reported neck injuries, 14 participants were wearing a helmet and 46 were not [27]. Mueller et al. conducted a case-control study using ski patrol injury reports for the years 2000-2005 from three ski resorts in the western United States [25] and reported an adjusted odds ratio of 0.91 (95% CI: 0.72-1.14) for neck injury among participants wearing a helmet compared to those who were not [25]. Furthermore, when compared to the studies conducted by Hagel et al. [26] and Sulheim et al. [27], Mueller et al. found little evidence

of heterogeneity across all three studies, reporting a summary odds ratio estimate of 0.85 (95% CI: 0.65-1.05) for neck injury among participants wearing a helmet compared to those who were not [25], indicating no evidence of a significant relationship between helmet use and risk of neck injury. In the first systematic review on the effect of helmets on the risk of head and neck injury in skiers and snowboarders, Russell et al. reported a pooled odds ratio of 0.89 (95% CI: 0.72-1.09) indicating no increased risk of neck injury with the use of a helmet [32]. Furthermore, after pooling results from two studies that examined the risk of neck injury among children, Russell et al. concluded there was no significant association between helmet use and risk of neck injury (OR 1.08; 95% CI: 0.98-1.20) [32]. Although there is concern over the potential increased risk of neck injury with use of a helmet, the systematic review by Russell et al. and individual studies do not support a significant association between helmet use and an increased risk of neck injury.

1.7.2 Risk Compensation Theory

The framework of the risk compensation theory involves a “target level of risk” and “risk thermostat”, both of which individuals regulate in tandem [50]. Individuals will modify their behaviour based on changes in perceived injury risk, such that if the perceived level of risk is reduced due to an intervention, such as wearing protective equipment, the individual will subsequently indulge in riskier behaviour, i.e. the “risk thermostat” will increase the risk of the individual back to the target level [50].

For skiers and snowboarders, the risk compensation theory suggests that wearing a helmet would be counterproductive by providing a false sense of security [51]. Several studies have recently reported on this concept. Hagel et al. conducted a matched case-

control study at 19 ski areas in Quebec over the course of one season examining the effect of helmet use on non-head-neck injury severity and crash circumstances in skiers and snowboarders [52]. Cases included individuals evacuated by ambulance, admitted to hospital, with restriction of normal daily activities > 6 days, with non-helmet equipment damage, fast self-reported speed, participated on a more difficult run than usual, and jumping related injury [52]. Controls were injured participants without severe injuries and matched to cases on ski area, activity, day, age, and sex [52]. It was concluded that there was no evidence of an increase in the severity of non-head-neck injury with helmet use in terms of evacuation by ambulance (OR 1.17; 95% CI: 0.79-1.73), need for admission to hospital (OR 0.79; 95% CI: 0.53-1.18) or having restriction of normal daily activities ≥ 1 week (OR 0.93; 95% CI: 0.63-1.34) [52]. Similarly, no evidence was found regarding the association between helmet use and non-helmet equipment damage (OR 1.20; 95% CI: 0.71-2.04), fast self-reported speed (OR 1.06; 95% CI: 0.68-1.66), participating on a more difficult run (OR 1.28; 95% CI: 0.79-20.8) and jumping as a mechanism of injury (OR 1.19; 95% CI: 0.77-1.83) [52]. Scott et al. conducted a cross-sectional study at 34 ski areas in 10 western states and British Columbia, Canada to determine the prevalence of helmet use and assess self-reported risk taking when wearing a helmet [41]. 1850 participants over 18 years of age were approached to complete a survey, of which 1779 consented [41]. 23% of the sample were observed to be wearing a helmet, and when responses from both helmet and non-helmet wearing participants were combined, approximately one-third reported engaging in more risky behaviours, with 33.6% skiing/snowboarding faster than usual and 35.7% challenging themselves more [41]. There was no evidence to support the risk compensation hypothesis, as helmet

wearers skied/snowboarded at lower speeds (OR 0.51; 95% CI: 0.38-0.65), and challenged themselves less than non-helmeted participants (OR 0.67; 95% CI: 0.50-0.88) [41]. Another cross-sectional study from Austria sampled 527 skiers and snowboarders >12 years old and had the participants subjectively classify themselves as cautious (n=369) or risk taking (n=168), while also objectively measuring maximum speed reached on the slope with a radar gun [53]. The two groups were not significantly different in regards to helmet use ($p > 0.1$). Rather, risky skiers were more likely to be >40 years old (OR 2.4; 95% CI: 1.5-3.8), had a higher skill level (OR 2.1; 95% CI: 1.3-3.5), and were male (OR 2.0; 95% CI: 1.2-2.3) [53]. More recently, Cundy et al. conducted a retrospective case series at a single ski resort in Australia and found that helmet use was more likely in those who felt that helmets reduce the chance of severe injury (OR 3.6; 95% CI: 2.1-6.4) and among those who thought that helmet use should be mandatory (OR 4.8; 95% CI: 2.7-8.5) [34]. In contrast, a case-control study by Sulheim et al. found that participants who indicated they are risk takers were more likely to use a helmet for both skiers and snowboarders, all age groups, and all skill levels [27]. Furthermore, a recent study by Ruedl et al. examined whether self-reported risk taking behaviour and self-reported risk compensation are associated with the personality trait sensation seeking in skiers and snowboarders [54]. 683 individuals completed an online survey regarding attitudes and use of protective gear that included the German version of the sensation seeking scale V [54]. It was found that risker behaviour increased in males (OR 2.9; 95% CI: 2.0-4.0), those ages <25 years (OR 1.58; 95% CI: 1.08-2.30), for skiers (OR 1.26; 95% CI: 1.03-1.54), higher skill level (OR 5.65; 95% CI: 2.57-12.41), and a mean skiing time >28 days per season (OR 2.18; 95% CI: 1.21-3.92) [54]. In addition, sensation seeking total score

was significantly higher in individuals who considered themselves more risky compared to those who considered themselves cautious (23.8 vs. 20.3, $p < 0.001$) [54]. However, ski helmet use was not found to be associated with an increase in risky behaviour [54].

1.8 Limitations of the Existing Literature

The studies above, of course, are not perfect. Several limitations, especially concerning helmet prevalence estimates should be considered. Several of the studies made no mention of refusals to participate. This could result in a form of selection bias related to non-response that could potentially affect helmet prevalence estimates. If, for example, those that refuse to participate in the study were more likely to not be wearing a helmet, then helmet prevalence would be overestimated. Furthermore, several helmet prevalence estimates come from making observations by the researchers at the base of the ski hill. Because of this, the possibility of repeat observations may distort the prevalence of helmet use. In this case, if helmet users were to be repeatedly counted then the prevalence of helmet use would be overestimated. Individuals in groups taking lessons may have been included in these studies as well. If helmet use is required while taking a lesson, then the prevalence of helmet use may have been overestimated. In addition, self-reporting of helmet use was common. Social desirability has the potential to increase the prevalence of helmet use in these studies. Finally, several helmet prevalence estimates come from studies conducted at a single resort, often conducted over a short period of time. This limits the generalizability of these studies findings. In light of these limitations, I present several helmet prevalence estimates that vary from as low as 16% in adults [34] to as high as 95% in children ages 10-14 [13]. The study by Fenerty et al., in which observations were made at three ski hills over a two-month period, identified the

prevalence of helmet use for skiers and snowboarders at 74% and 72%, respectively [78]. Directly observing helmet use at multiple locations on the ski hills, and for a specified period of time so as to minimize the potential for repeat observations is a good indication of helmet prevalence.

1.9 Summary and Rationale

No study to date has addressed the prevalence of correct helmet use and fit in skiers and snowboarders. Little is known about the prevalence of correctly worn helmets and the factors associated with correct use and fit. If a helmet is worn incorrectly in skiing and snowboarding, as is the case among a significant proportion of young bicycle helmet users, [46] then, as for bicyclists, [47, 48] helmet effectiveness would likely suffer. Bicyclists who reported that their helmet fit poorly had a 2-fold greater risk of a head injury compared with bicyclists who reported their helmet fit was excellent. This kind of risk information is critical to ensure the full public health benefit of ski and snowboard helmet use is realized, particularly in light of mandatory helmet use policies at many ski areas that apply to children, those taking lessons and those participating in ski area terrain parks and with the introduction of provincial legislation in Nova Scotia. This study will expand on the evidence that currently exists on helmet use among skiers and snowboarders, and will provide information specific to the Canadian and Albertan context. I will be able to provide a comprehensive understanding of the factors that influence helmet use and correct helmet use, and provide evidence on the prevalence of helmets that meet certification standards.

1.10 Objectives

1. To determine the prevalence of helmet use and prevalence of correct helmet use in skiers and snowboarders at an Alberta ski area.
2. To assess for factors associated with helmet use and those associated with correct helmet use in skiers and snowboarders at the ski area.

Chapter Two: Methods

2.1 Study Design

This study used a cross-sectional design. A sample of skiers and snowboarders were selected from the population and the prevalence of helmet use and correct helmet use were estimated simultaneously with exposure variables (e.g. age, sex, activity).

2.2 Setting

This research was conducted at a single ski and snowboard resort in Southern Alberta. In the winter months, this resort is host to a high volume of skiers and snowboarders each season (~290,000 skiers and snowboarders) and offers weekend and weeknight lessons. Schools in the area often make day trips as part of the physical education curriculum and the resort is designed as a multi-purpose competition, training and recreational area used by both high performance athletes and the general public. In addition, this resort is in close proximity to many of Western Canada's most popular ski resorts, including Lake Louise, Whistler, and Sunshine. It is hypothesized that many users at this particular resort in Southern Alberta also ski and snowboard at several major resorts in Western Canada. This particular resort had four generally distinct areas for skiing and snowboarding. These include the "west main" area that contains the main chair lift, the "east main" area, the "first turns" area and the terrain park.

This study was conducted during the 2012-2013 winter season. Normally, the resort opens in mid-November and closes in early April. This, however, depends on the natural snowfall, temperature, and ability to make snow.

2.3 Data Collection Sampling Schedule

Three sampling schedules were developed to account for variations in ski hill use for time of day (morning, noon, and evening) and the day of the week (weekday and weekend). It was hypothesized that ski hill users would be different throughout the day, with older users typically participating during the weekday morning and noon hours compared with those participating during after school hours. To capture this, we decided to collect data on weekdays, weekends and weekday evenings. Weekday data collection included Monday to Fridays and was divided into two time slots (09:00-10:00 and 01:00-2:00) and weekend data collection included Saturday and Sundays and was divided into two time slots (09:00-10:00 and 01:00-2:00). Weekday evenings consisted of one time slot (18:00-19:00). We conducted a sample with random start to determine when data collection would begin. I counted the number of weekdays in each month from December 1st, 2012 to March 31st, 2013. This resulted in 85 weekdays to sample from. I then entered an excel file numbered 1-85 and using STATA statistical software version 12.0[55] I randomly selected 16 numbers without replacement. Each number selected then corresponded to one of the 85 weekday dates that were numbered. This process was repeated for both weekend days and weekday evenings for a total of 48 data collection days. In the event that a weekday evening hour of data collection was selected on the same day as weekday data collection, we did not resample and that particular day consisted of three separate hours of data collection. In addition, in the event that data collection was not completed

due to the resort being closed owing to inclement weather or a scheduling conflict between research assistants (RA's), we did not reschedule the sampling and continued with the proposed schedule. This resulted in 41 independent data collection dates, consisting of 26 weekday/evening data collection days and 15 weekend days.

2.4 Data Collection Sampling

For the first three days of data collection, we initially decided two research assistants (RAs) would independently collect data at the entrance to the main chairlift and magic carpet lift (i.e., in the lineups). The RAs were trained to identify correct helmet fit according to the guidelines by Parachute Canada. One of the RAs was blinded to the study objectives and the information from both the blinded and un-blinded RAs would be compared to guard against the possibility of selection bias based on whom the RAs approached for inclusion. Any skier or snowboarder at the ski area was eligible to participate. Individuals who did not speak English were not interviewed, but their characteristics were recorded based on visual observation (approximate age, sex, activity, helmet use, helmet fit, type of helmet, headphone use). The RAs approached skiers and snowboarders and provided a brief background to the study and requested their permission (or their parent's permission if <10 years old) to conduct a short interview (5 minutes maximum) (Appendix A- Study Information and Consent Form). If the skier or snowboarder was under 10 years old and we could not get parental consent, we would not interview them, but we still recorded their details based on visual observation only (approximate age, sex, activity, helmet use, helmet fit, type of helmet, headphone use). Similarly, if the skier or snowboarder refused to participate, the RA still recorded information based on visual observation only. This way, we captured information on non-

responders to address the main objectives of the study (helmet use, correct helmet use according to age, sex and activity) and reduce or eliminate the likelihood of selection bias related to non-response. Once the RA completed the interview, they attempted to count three skiers and/or snowboarders and then approach the fourth one entering the chair lift line.

Unfortunately, it became apparent this approach would not work. We found it very difficult to accurately count every 4th person entering the lift line as many participants would accumulate at the base of the hill and then proceed through the line up in groups. We decided on a more practical approach to data collection, in which, for every hour of data collection three research assistants, one blinded to the study objectives, independently collected data. The blinded research assistant interviewed individuals by convenience for the full hour as they approach the entrance to the main chair lift.

The second research assistant recorded visual observation information for 30 minutes on the individuals that the blinded RA had approached to interview. This second RA only recorded visual observations when it was clear who the blinded RA was interviewing in the event that groups or parents with children had stopped during the interview (i.e., when the individual being interviewed could not be determined). For the last 30 minutes of the one hour of data collection, the second research assistant would then leave the chair lift and collect visual observation information on every fourth person exiting the magic carpet lift and attempt to conduct interviews on individuals who were not taking lessons. Individuals who were taking lessons were easily identified by the

research assistant (they traveled in groups with a supervisor and had a large tag on their jacket indicating they were in a lesson).

A third RA collected visual observation information on every fourth person entering the main chairlift for the first 30 minutes of the one hour of data collection. For the last 30 minutes of the first hour of data collection the third RA would conduct interviews by convenience at the entrance to the main chair lift alongside the blinded RA. This way we achieved a sample of study participants addressing the main objectives of the study and collected an adequate amount of interviews.

In the event that only two RA's were able to collect data due to scheduling issues, the reliability component of data collection was removed and one blinded RA conducted interviews by convenience at the entrance to the main chairlift for the full hour of data collection. The second RA collected visual observation information on every fourth person entering the chair lift for the first 30 minutes of data collection. For the remaining 30 minutes of data collection, the second RA then conducted interviews at the entrance to the main chair lift along with the blinded RA.

In the event an individual refused to participate and was not asked to be interviewed before, we indicated on the data collection form that they did not give consent and had not been interviewed before; however, the RA still recorded information based on visual observation only. This way, we had information on non-responders that could be used to address the main objectives of the study (helmet use, correct helmet use according to age, sex and activity) and reduce or eliminate the likelihood of selection bias related to non-response. Similarly, in the event an individual had been interviewed before and did not want to be interviewed again, we indicated on the data collection form

that they had been interviewed before and again the RA still recorded information based on visual observation only. This way we had information on how many individuals were approached and refused to participate and could get a sense of the number of approaches to people that may have been approached before.

A second chairlift opened at the area in March, 2013. When the second chair lift opened, we used the same sampling approach as above; however, we alternated doing data collection at each chairlift for each day of data collection. (e.g. if we had 2 days of data collection in one week, 1 day we collected data at the original lift and 1 day we collected data at the new lift).

2.5 Data Collection Tools

The full survey was designed to capture socio-demographic variables, environmental conditions, experience, ability level, previous skiing or snowboarding injury requiring medical attention, parent accompaniment (if <10 years old), helmet use and companion helmet use (Appendix B). We captured information on all aspects of helmet use, including the type, certification, brand, model, fit, whether the individual was wearing goggles, an article of clothing underneath the helmet (e.g., knit cap, toque) or any electronic devices (e.g., earphones, Bluetooth[®] compatible headphones, camera mounted to helmet). We collected information on how long the individual had been wearing a helmet, how long they owned their current helmet, including helmet age, and whether it had sustained a prior impact. We also asked participants about their reasons for using or not using a helmet, as the case may be. Helmet fit was determined on location by the interviewer guided by a set of detailed, objective criteria from ThinkFirst Canada (now

part of Parachute Canada: www.parachutecanada.org/) used to correctly determine proper ski and snowboard helmet use.

A second data collection form was used to collect both reliability and systematic observations (Appendix C&D). This particular form contained every observational question the full survey contained (i.e. ski location, run difficulty, age, sex, activity, companions and companion helmet use, wearing goggles, helmet use, type of helmet, helmet fit, and listening to music).

2.6 Data Management

2.6.1 REDCap

REDCap (Research Electronic Data Capture) is a secure web application that allows users to build and manage online surveys and databases. REDCap provides audit trails for tracking data manipulation and user activity, as well as automated export procedures for seamless data downloads to Excel, PDF, and common statistical packages (SPSS, SAS, Stata, R). Also included are a built-in project calendar, a scheduling module, ad hoc reporting tools, and advanced features, such as branching logic, file uploading, and calculated fields [56]. For this particular study, we developed three separate databases, one for each data collection form (ski area interviews, systematic observations, and reliability).

2.6.2 Data Entry

Study materials and data collection forms were collected by the research coordinator following each hour of data collection at the ski hill. The research coordinator checked that the information was complete and clarified with the RAs if any information was

missing or unclear. Several RAs entered the data from the three forms into their respective databases using REDCap. The data entry forms for each database were designed to look like the paper forms. The databases contained free text, checkboxes, and pre-set response choices. Free text fields were used for items such as reasons for wearing or not wearing a helmet and for describing “other” options that did not fit into a pre-conceived category. Checkboxes were used when multiple response choices could be selected, such as the weather or helmet fit items. Pre-set choices were available for mutually exclusive response choices, such as whether or not the participant was wearing a helmet (yes or no). When the data were entered into the database, the RA would generate a unique identifier that contained 7 digits. This number was generated using the date, the interview or observation number, and which hour of data collection the form was used (e.g. December 12, 5th interview of the morning would have the unique id 12-12-05-1). This unique identifier provided a descriptive, easy method of linking the paper copies to the database copies, as well as providing a link between the interviews and reliability forms. Paper copies of the data were stored in locked cabinets in the research office at the Alberta Children’s Hospital in Calgary.

2.6.3 Data Cleaning

In addition to checking the paper copies for completeness prior to data entry, the data were checked for accuracy once data entry was completed. This was done by generating queries in REDCap, and by examining graphical representations (histograms, box plots) of the data. In the event of outlying observations, the original paper copies of the forms were re-examined. This reduced the likelihood of data entry errors and certainly prevented systematic errors.

When information was found to be missing, we closely examined the data collection forms to try to identify why the information was not entered, and if it had in fact been recorded. If the information was missing because of a data entry error, this was corrected. If the information was missing on the paper copy, but we could easily discern the appropriate response, we entered the correct information into the database. For example, if helmet use was not recorded but the following questions (e.g., questions on helmet fit or helmet standards) that could only be answered if the participant was wearing a helmet were recorded, we assumed the individual was in fact wearing a helmet. In other cases, we could not positively determine an appropriate response beyond a reasonable doubt and the items were recorded as missing.

2.7 Data Analysis

The following sections outline the analysis completed for each component of the project. All statistical analyses were completed using Stata statistical software version 12.0 [55].

2.7.1 Accuracy of Observational Data

Data were compared between those conducting full interviews and those who collected visual observations on the skier or snowboarder being interviewed. Sensitivity and specificity estimates were calculated for each item that could be considered a “gold standard”. These included every item except for those items with a subjective component (i.e. weather, light conditions, and surface conditions).

2.7.2 Tabulated Analysis

Tables with counts and proportions of participant characteristics were presented by method of data collection (i.e. Interview and Systematic observations).

2.7.3 Poisson Regression with Robust Error Variance

The most common method of modelling binary outcomes, particularly in cross-sectional studies, is logistic regression [58]. This often results in the odds ratio being reported in situations where prevalence ratios can be estimated [58]. Supporters of logistic regression cite the fact that if the outcome is rare, then the odds ratio is a close approximation of the relative risk (RR) [59-61]. However, when working with common outcomes (e.g., greater than 10%), the odds ratio can strongly overestimate the prevalence ratio [58]. The use of odds ratios is fine, there is nothing inherently wrong with them; however, when interpreting them it is common to discuss them as if they were relative risks and this mistake can be misleading [58]. In one example, a study published in the New England Journal of Medicine (NEJM) attempted to determine differences in the use of cardiovascular procedures according to the patient's race and gender [59, 62]. Using logistic regression, the authors reported that at equal risk women (defined as low or high on the basis of blood pressure, blood cholesterol concentrations, and smoking history) (OR=0.60), male black patients (OR=0.60) and female black patients (OR=0.40) were less likely to be referred for catheterisation compared with white men [62]. These results were then overstated by the authors, and subsequently by the media, by interpreting the odds as if they were relative risks, leading to headlines like "Black women are 60% less likely to be catheterised" [59, 63]. In reality, the corresponding risk ratio was 0.87 for black women, and the appropriate conclusion would have been that black women are only 13% less likely to be referred for catheterisation compared with white men [63]. Additionally, logistic regression is used for the control of confounding and detection of interactions [58]. However, confounding and interaction are dependent

on the measure of effect, so controlling for confounding for the odds ratio is not the same as doing so for the risk ratio [58]. Hence interpreting the odds ratio as if it were a risk ratio is not only incorrect in terms of overestimation, but also because confounding of the parameter of most interest, the prevalence ratio, may not be appropriately controlled for [58]. However, Barros et al. found that using the same modelling strategies with logistic regression and robust Poisson regression resulted in the final sets of selected variables being the same and suggest that until more experience is gathered it may be a useful strategy to help identify anomalous results with robust Poisson regression [58]. However, in this study I did not compare logistic regression and robust Poisson regression to identify the possibility of anomalous results. Logistic regression is a valuable tool for health researchers and can produce a valid measure of association. However, in light of this, it seems odds ratios will be interpreted by the general public, and perhaps by health researchers as relative risks or prevalence ratios and alternative options directly estimating the parameters of most interest should be considered [59]. The current study, cross-sectional in nature, is suitable for reporting prevalence ratios over odds ratios, especially considering the prevalence of our outcomes of interest (helmet use and correct helmet use) are much greater than 10%.

Several alternatives are available for the analysis of binary outcomes in cross-sectional studies using the prevalence ratio rather than the odds ratio. These include the Mantel-Haenszel method, log-binomial regression, and Poisson regression [79]. These alternative methods are subject to problems, however, as the Mantel-Haenszel method cannot provide a measure of interaction, the log-binomial regression does not always converge, and the Poisson regression provides a wider 95% confidence interval [79]. To

solve these issues, Poisson regression with robust error variance was proposed [79, 80]. This method converges more reliably than log-binomial regression and provides more accurate 95% confidence intervals than Poisson regression [79]. Since its introduction, Poisson regression with robust error variance has become popular in medical and public health research [79, 81]. However, a number of limitations in the use of Poisson regression with robust error variance have been identified. In a study comparing methods for the analysis of binomial proportion data, Poisson regression was applied to datasets with strong over dispersion, finding type 1 error rates as high as 43% [82]. Although this was fixed when standard error estimators were applied, it came at a considerable loss of power compared to other methods [82]. In addition, Poisson regression with robust error variance permits probability estimates greater than one or less than zero, which is outside of the allowable range [79]. Furthermore, Zhu et al. identified that choosing Poisson regression with robust error variance over the log-binomial model due to convergence issues is problematic, as this solves the problem of non-convergence, but can result in errors in the coefficient estimates that may be substantial when the maximum fitted value is large [83]. This is described as a paradox, in that the circumstances that would lead to the use of Poisson regression with robust error variance to overcome convergence problems are the same in which the error in applying the modified Poisson approach is the greatest [83]. In light of this, Poisson regression has been highly cited and has been applied across a broad range of observational and intervention studies [79, 81]. This Poisson approach was proposed in the context of independent data and has been shown both analytically and by simulation to be appropriate for use in this setting [80, 81, 84, 85]. Thus, factors for both helmet use and correct helmet use were examined using

Poisson regression analysis with robust error variance and the prevalence and prevalence ratio of helmet use and correct helmet use with 95% confidence intervals were calculated. Subsequently, Poisson regression analysis with robust error variance was used to examine the effect of each exposure variable on the outcomes of interest while controlling for potential confounders.

2.7.4 Ski Area Interviews Analysis

For each outcome of interest (helmet use and correct helmet use), potential risk factors were categorized as personal, environmental, and behavioural characteristics. Subsequently, Poisson regression with robust error estimator was used to examine the effect of each exposure (i.e. personal, environmental, and behavioural characteristics) variable on the outcomes of interest while controlling for potential confounders. The analysis was adjusted for factors known to predict helmet use (or non-use) including age, sex, skiing ability, and activity (skiing vs. snowboarding) [64-66]. The sample size in this study limited the number of potential independent variables that could be examined using Poisson regression. It is important to note that as a general guideline, it has been suggested that the number of independent variables in the model should not exceed 10% of the number of subjects in the least frequent outcome category (in this analysis, helmet non-users and incorrect helmet fit) [67]. In small samples, inaccuracies in the coefficients and corresponding confidence intervals can lead to inaccurate inferences about the true covariate-outcome associations [88]. These problems are expected to become less likely with increasing sample size and increasing the number of events per predictor variable (EPV) [88]. The models that were generated followed the 10% guideline as a general rule; however, it has also been suggested that the rule can be relaxed, allowing for a more

comprehensive assessment of confounding [68]. Despite the wide use of the minimal 10 EPV guideline in medical literature, the results of three simulation studies examining the minimal EPV criterion for binary logistic regression were highly discordant [88].

Vittinghoff et al. conducted a large simulation study of other influences on confidence interval coverage, type 1 error, relative bias and other model performance measures and found that problems (defined as confidence interval coverage less than 93 percent, type 1 error greater than 7 percent, or relative bias greater than 15% are uncommon with 5-9 events per predictor variable (EPV) and still observed with 10-16 EPV [86]. Furthermore, Courvoisier et al. showed that substantial problems may still occur even if the number of EPV exceeds 10 [87]. They showed that the performance of the model may depend on various factors other than EPV, including the strength of associations between covariates and outcome and the correlation between covariates [87]. First, crude estimates were calculated for each personal, environmental, and behavioural characteristic. Then, the potential confounders age, sex, ability and activity were added to the crude models. Using a backwards selection approach, the prevalence ratios (PRs) of each variable were compared with the PRs from the model with one of the potential confounders removed. The percent change in the PRs for each variable was calculated and whichever variable produced the smallest change in the PRs, which was defined as less than 15% [68] was removed from the model. Variables that did not result in a change of 15% or more but were found to be significant remained in the model. This process was repeated until all the remaining potential confounders that produced a change in the remaining PRs of less than 15% were removed. The variables that resulted in a change of 15% or more in any of the PRs, or those that were found to be significant remained in the model and it was

concluded they confounded the relationship between helmet use or correct helmet use and the remaining variables in the model.

2.7.5 Sample Size

This study was conducted over the course of one season (December 2012 to April 2013). Based on our previous work at the same ski area, we expected to obtain approximately 6 to 7 interviews per hour. In the proposed study, there were three, one hour time periods (morning, after lunch and early evening). Therefore, with two RAs and a total of sixteen weekend and sixteen weekday visits, we expected 1152 interviews (two RAs * 32 days * three hours * six interviews per hour). With a worst-case scenario (from a statistical variability perspective) helmet prevalence of 50 percent, the margin of error would be approximately $\pm 2.9\%$ over all age groups. In addition, we expected approximately 20% of participants to be under the age of 18 based on CSC data (though the CSC data had a minimum age of 12 years, so the proportion of children <18 would be even greater in our study) [13]. This would represent a minimum of 230 skiers and snowboarders for a $\pm 6.5\%$ margin of error around a helmet prevalence estimate of 50%. Using the CSC reported adolescent helmet use rate of 85% [13] would allow us to examine up to 3 independent predictors of helmet use [67, 68]. Prior work on correct bicycle helmet use found that 21% of children under 13, 17% of adolescents and 12% of adults used their helmet incorrectly [69]. If we found at least 12% were using their helmets incorrectly, then we would have approximately 118 individuals with incorrect helmet use ($12\% * 980$ who were wearing their helmet incorrectly). This would produce a 95% confidence interval width around the 12% prevalence estimate of $\pm 2.0\%$. It would also allow us to examine up to 11 risk factors for incorrect helmet use [67, 68].

2.8 Ethical Considerations

Ethical approval was obtained from the University of Calgary Conjoint Health Research Ethics Board. Confidentiality was ensured by keeping all paper versions of completed data collection forms in a locked filing cabinet and storing electronic data on a password-protected computer. Electronic data were linked to the original data by a unique identification number. We were given permission from the University of Calgary Conjoint Health Research Ethics Board to interview children and adolescents without parental consent, provided we provide them with a study information sheet for their parents.

Chapter Three: Results

3.1 Accuracy of Observational Data

Two observers recorded 221 observations on skiers and snowboarders at the bottom of the main chair lift. As previously described, sensitivity and specificity estimates were calculated, along with 95% confidence limits for each item that could be considered a “gold standard”. These included every item except for those with a subjective component (i.e. weather, light conditions, and surface conditions).

There were three trained research assistants conducting observations that were not always paired with the same person. We examined agreement for the one pair that conducted the most observations. This pair (KP & JJ) conducted 63 observations. Pairings and the number of observations conducted are presented in table 3.1.

Table 3.1 Pairs and number of observations conducted

Observer 1	Observer 2								Total
	BB	JW	JJ	KP	MM	NE	TE	VS	
KP	13	11	63	0	9	8	0	28	132
NR	0	5	0	12	5	0	8	44	74
VS	0	0	15	0	0	0	0	0	15
Total	13	16	78	12	14	8	8	72	221

- Observer 1 was the observation recorder and Observer 2 was the blinded ski area interviewer
- VS acted as observer 1 on one occasion but remained blinded to the study objectives.

3.1.1 *Validity of Items Considered a Gold Standard*

There were 12 characteristics for which sensitivity, specificity and 95% confidence limits could be calculated. For characteristics containing 3 or more options, these items were dichotomized in order to calculate sensitivity and specificity. For example, age contains four categories (<13, 13-17, 18-54, and 55+). In this case, age was dichotomized to <18 and 18+. This was chosen because we felt it was important to determine whether we could tell if an individual was an adult or not. Table 3.3 presents the sensitivity; specificity and 95% confidence limits for pair KP & JJ.

Sensitivity ranged from 0% for music to 100% for several items. Specificity ranged from 100% for music to 0% for several items. Whether the individual was with companions and whether helmets were on companions had high sensitivity (92%), but low specificity (~25%) and both showed significant differences between proportions.

Table 3.2 Sensitivity and Specificity for Pair KP & JJ.

Variable	Sensitivity (%)	95% CI	Specificity (%)	95% CI
Ski Location	100	0.90-1.00	0	0.00-0.17
Run Difficulty	100	0.90-1.00	0	0.00-0.17
Sex	95.50	0.85-0.99	93.75	0.72-0.99
Age <18/ Age > 18)	96.43	0.82-0.99	78.13	0.61-0.89
Activity	97.30	0.86-0.99	91.30	0.72-0.98
Companions (with vs. w/o)	92.00	0.75-0.98	25.71	0.14-0.42
Helmets on companions	92.00	0.75-0.98	25.71	0.14-0.42
Goggles (yes vs. no)	91.11	0.79-0.96	86.67	0.62-0.96
Goggles (Over vs. Under)	73.53	0.59-0.85	66.67	0.30-0.90
Helmet	100	0.93-1.00	75	0.41-0.93
Ski/SB Helmet	98.04	0.90-0.99	0	n/a
Helmet Fit	77.77	0.62-0.88	75	0.51-0.90
Music (yes vs. no)	0	0.00-0.66	100	0.87-1.00

3.2 Participant Characteristics

The following section presents the characteristics of the participants for the ski area interviews and systematic observations, and highlights some of the differences between

the two data sets. Table 3.5 presents the characteristics for the ski area interviews and systematic observations.

There were 914 ski area interviews and 2024 systematic observations made. A greater proportion of observed participants were <13 years old compared with those being interviewed (36% vs. 15%). Also, a lower proportion of observed participants were aged 18-54 compared with interviewed participants aged 18-54 (38% vs. 58%). The proportion of males who were observed was lower than the proportion of males who were interviewed (64% vs. 72%) and a greater proportion of observed participants were skiers compared with the proportion of interviewed participants who were skiers (67% vs. 51%).

The majority of participants who were interviewed were participating for recreational purposes (69%) compared with those participating in a competition or as part of a school group. A greater proportion of participants were observed to be with adults and children compared with those who were interviewed (26% vs. 9%). The use of goggles was similar between those being interviewed and those observed (69% vs. 68%). The majority of participants who were interviewed were not wearing wrist guards (79%) and nearly half (46%) indicated that they had skied at other areas in Alberta and/or British Columbia. Figures 1 and 2 present helmet use and correct helmet fit by age, sex and activity for the ski area interviews and systematic observations, respectively. It is important to note that observations made on an individual could have been repeated these may not reflect real proportions. Because helmet prevalence was found to be high in this sample, it is possible that it may have been overestimated in the observed sample. In light

of this, the proportions presented for the observational data are not to be considered true proportions.

Table 3.3 Participant Characteristics

Variable	Interviews		Observations	
	n/N	%	n/N	%
Personal Characteristics				
Local				
No	156/914	17.07	*	
Yes	610/914	66.74		
Missing	148/914	16.19		
Education				
< High School	17/914	1.86		
High school	81/914	8.86		
Technical/trade	119/914	13.02		
University degree	396/914	43.33		
Graduate degree	76/914	8.32		
Don't know	42/914	4.60		
Missing	183/914	20.02		
Previous Injury				
Yes	514/914	56.24		
No	244/914	26.70		
Don't know	2/914	0.22		
Missing	154/914	16.85		
Age				
<13	134/914	14.66	735/2024	36.31
13-17	215/914	23.52	457/2024	22.58
18-54	529/914	57.88	767/2024	37.90
55+	33/914	3.61	57/2024	2.82
Missing	3/914	0.33	8/2024	0.40
Gender				
Male	661/914	72.32	1293/2024	63.88
Female	243/914	26.59	712/2024	35.18
Missing	10/914	1.09	19/2024	0.94
Activity				
Skiing	469/914	51.31	1350/2024	66.70

Snowboarding	434/914	47.48	642/2024	31.72
Missing	11/914	1.20	32/2024	1.58
Ability				
Beginner	154/914	16.85		
Novice	84/914	9.19		
Intermediate	250/914	27.35		
Advanced	205/914	22.43		
Expert	70/914	7.66		
Don't know	2/914	0.22		
Missing	149/914	16.30		
<hr/> Environmental Characteristics				
New Snow				
no new	741/914	81.07	1687/2024	83.35
0-5cm	173/914	18.93	337/2024	16.65
Weather				
Clear	464/914	50.77	1008/2024	49.80
Overcast	357/914	39.06	871/2024	43.03
Snowing	93/914	10.18	145/2024	7.16
Temperature				
<-10	179/914	19.58	433/2024	21.39
-10 to -1	358/914	39.17	731/2024	36.12
0 to 10	377/914	41.25	860/2024	42.49
Light				
Sharp	471/914	51.53	1013/2024	50.05
Flat	306/914	33.48	640/2024	31.62
Lights	137/914	14.99	371/2024	18.33
Location				
First turns	38/914	4.16	550/2024	27.17
East main	121/914	13.24	221/2024	10.92
West main	565/914	61.82	1213/2024	59.93
Terrain park	142/914		32/2024	1.58
Competition terrain	1/914	0.11	0/2024	0.00
Don't know	22/914	2.41	0/2024	0.00
Missing	25/914	2.74	8/2024	0.40
Compared Difficulty				
Same difficulty	362/914	39.61		

Less difficult	241/914	26.37
More difficult	101/914	11.05
Don't know	133/914	14.55
Missing	77/914	8.42

Companions

Alone	249/914	27.24	356/2024	17.59
With children	355/914	38.84	637/2024	31.47
With adults	212/914	23.19	492/2024	24.31
With adults and children	86/914	9.41	525/2024	25.94
Don't know	1/914	0.11	9/2024	0.44
Missing	11/914	1.20	5/2024	0.25

Helmets on companions

Children only	348/914	38.07	640/2024	31.62
Adults only	171/914	18.71	384/2024	18.97
Both	70/914	7.66	486/2024	24.01
Some	23/914	2.52	55/2024	2.72
None	40/914	4.38	80/2024	3.95
Don't know	4/914	0.44	12/2024	0.59
Missing	10/914	1.09	11/2024	0.54
N/A (alone)	248/914	27.13	356/2024	17.59

Behavioural Characteristics

Goggles

Yes, over helmet	509/914	55.69	1123/2024	55.48
Yes, under helmet	122/914	13.35	257/2024	12.70
Yes, no helmet	51/914	5.58	83/2024	4.10
No	215/914	23.52	553/2024	27.32
Missing	17/914	1.86	8/2024	0.40

Music

No	671/914	73.41	1401/2024	69.22
Yes	108/914	11.82	24/2024	1.19
Don't know	3/914	0.33	478/2024	23.62
Missing	132/914	14.44	121/2024	5.98

Alcohol

Yes	47/914	5.14
No	412/914	45.08
Don't know	3/914	0.33
Missing	146/914	15.97

N/A (< 18)	306/914	33.48
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Type of activity

Recreation	632/914	69.15
Lessons	30/914	3.28
School	30/914	3.28
Training	46/914	5.03
Competition	14/914	1.53
Other	11/914	1.20
Missing	151/914	16.52

Electronic Devices

No	525/914	57.44
Yes	255/914	27.90
Don't know	2/914	0.22
Missing	162/914	17.72

Wrist guards

No	726/914	79.43
Yes	42/914	4.60
Don't know	1/914	0.11
Missing	145/914	15.86

Binding adjustments

No	411/914	44.97
Yes	308/914	33.70
Don't know	48/914	5.25
Missing	147/914	16.08

Other Ski

Yes	423/914	46.28
No	339/914	37.09
Missing	152/914	16.63

Pass type

Day Ticket	387/914	42.34
Other	377/914	41.25
Missing	150/914	16.41

Lessons

Never	276/914	30.20
This year	113/914	12.36
Yes (not this year)	371/914	40.59

Don't know	9/914	0.98
Missing	145/914	15.86

Alpine Code

Yes	441/914	48.25
No	292/914	31.95
Don't know	31/914	3.39

Helmet Use

Yes	807/914	88.29	1835/2024	90.66
No	103/914	11.27	187/2024	9.24
Missing	4/914	0.43	2/2024	0.10

Helmet Fit

Correct	502/914	54.92	1194/2024	58.99
Incorrect	351/914	38.40	752/2024	37.15
Missing	61/914	6.67	78/2024	3.85

*Not available from observed sample

Figure 1. Helmet use and correct fit by age, sex and activity for ski area interviews.

* Helmet fit estimates are based on the total helmet prevalence for each category.

Figure 2. Helmet use and correct fit by age, sex and activity for systematic observations.

3.3 Helmet Use

A high prevalence of helmet use (88%) was found in this sample. Table 3.5 presents the results of the Poisson regression analysis with robust error variance for the ski area interviews.

3.3.1 Ski Area Interviews

Education was significantly related to helmet use. Compared with having an undergraduate degree, those with a graduate degree had a lower prevalence of helmet use (PR 0.77; 95% CI: 0.66-0.89). After adjusting for age, sex, activity, and ability; the high school or less category became significant with an adjusted estimate (aPR) of 0.90 (95% CI: 0.83-0.99). Age was also significantly related to helmet use. Compared with those ages 18-54, those <13 years old (PR 1.16; 95% CI: 1.11-1.21) and 13-17 years old (PR 1.15; 95% CI: 1.10-1.20) had a higher prevalence of helmet use. Although it wasn't statistically significant, those ages 55+ seem to be that a lower percentage of them are wearing a helmet compared with those ages 18-54 (PR 0.80; 95% CI: 0.62-1.01).

Several environmental characteristics were related to helmet use. Compared with clear skies, a higher proportion of participants were wearing helmets when conditions were snowy (PR 1.08; 95% CI: 1.02-1.14). Similarly, compared with temperatures above 0 degrees, temperatures ranging from <-10° celcius (C) and -10°C to -1°C increased the prevalence of helmet use (PR 1.07; 95% CI: 1.07-1.13; PR 1.07; 95% CI: 1.07-1.13).

Skiing/snowboarding with companions was significantly related to helmet use. Compared with skiing/snowboarding alone, the presence of adults only lowered the prevalence of helmet use (PR 0.92; 95% CI: 0.85-0.99). Skiing/snowboarding with companions that were also wearing helmets had a significantly higher prevalence of helmet use. Compared

with no companions wearing a helmet, child helmet use (PR 2.64; 95% CI: 1.73-4.04), adult helmet use (PR 2.67; 95% CI: 1.75-4.09) and both adult and child helmet use (PR 2.65; 95% CI: 1.73-4.07) increased the prevalence of helmet use.

Wearing goggles had a higher prevalence of helmet use (PR 1.19; 95% CI: 1.10-1.28). Skiing/snowboarding at other areas in Alberta and/or British Colombia had a higher prevalence of helmet use (PR 1.08; 95% CI: 1.02-1.14). The use of a day pass, relative to a season's pass or other type (competition, work etc.) had a higher prevalence of helmet use (PR 1.15; 95% CI: 1.09-1.21). Furthermore, having taken lessons within the past year (but not currently) relative to never having taken lessons had a higher prevalence of helmet use (PR 1.13; 95% CI: 1.06-1.21). Finally, compared with skiers, snowboarders had a higher prevalence of helmet use (PR 1.07; 95% CI: 1.02-1.12).

Table 3.4 Crude and adjusted estimates for helmet use-Ski Area Interviews

	Crude PR	95% CI	Adjusted PR	95% CI	Adjustment Factors
Personal Characteristics					
Local	1.06	0.99-1.14	1.07	0.99-1.16	Age, sex, activity, ability
Education					
High school or less	0.92	0.84-1.01	0.90	0.83-0.99	
Tech/Trade	0.84	0.91-1.05	0.98	0.91-1.05	
University degree	Ref				Age, sex, activity, ability
Graduate Degree	0.77	0.66-0.89	0.80	0.69-0.93	
Previous Injury	1.04	0.99-1.10	1.06	0.99-1.13	Age, sex, activity, ability
Age					
<13	1.16	1.11-1.21	1.17	1.11-1.24	
13-17	1.15	1.10-1.20	1.15	1.09-1.21	sex, activity, ability
18-54	Ref				

55+		0.80	0.62-1.01	0.75	0.55-1.02	
Sex		1.02	0.97-1.08	1.00	0.94-1.06	Age, activity, ability
Ability						
	Beginner	0.98	0.91-1.06	0.98	0.91-1.06	
	Novice	1.06	0.98-1.14	1.02	0.94-1.10	
	Intermediate	Ref				Age, sex, activity
	Advanced	1.00	0.94-1.07	0.99	0.93-1.06	
	Expert	0.97	0.88-1.08	0.99	0.90-1.10	
Environmental Characteristics						
New Snow		1.03	0.97-1.09	1.02	0.96-1.09	Age, sex, activity, ability
Weather						

Clear	Ref				
Overcast	1.00	0.95-1.06	1.00	0.95-1.06	Age, sex, activity, ability
Snowing	1.08	1.02-1.14	1.09	1.02-1.17	
Temperature					
0-10	Ref				
<-10	1.07	1.00-1.13	1.07	1.00-1.14	Age, sex, activity, ability
-10 to -1	1.07	1.01-1.13	1.07	1.01-1.13	
Light					
Sharp	Ref				
Flat	1.04	0.99-1.10	1.04	0.98-1.10	Age, sex, activity, ability
Lights	1.00	0.93-1.08	1.01	0.93-1.08	
Ski Location	1.04	0.97-1.11	1.03	0.95-1.12	Age, sex, activity, ability

Difficulty Compared						
Same	Ref					
Less	0.93	0.87-0.99	0.94	0.88-1.01	Age, sex, activity, ability	
More	1.02	0.95-1.09	1.00	0.94-1.07		
Companions						
Alone	Ref					
Children only	1.02	0.97-1.07	0.98	0.93-1.04	Age, sex, activity, ability	
Adults only	0.92	0.85-0.99	0.91	0.84-0.99		
Adults & children	0.98	0.90-1.07	0.95	0.85-1.05		
Helmets on Companions						
None	Ref					
Children only	2.64	1.73-4.04	2.74	1.74-4.31		
Adults only	2.67	1.75-4.09	2.82	1.79-4.44	Age, sex, activity, ability	
Both	2.65	1.73-4.07	2.72	1.72-4.31		
Some	1.61	0.93-2.81	1.55	0.86-2.82		

Behavioural Characteristics					
Goggles	1.19	1.10-1.28	1.18	1.08-1.28	Age, sex, activity, ability
Music	1.06	0.99-1.12	1.04	0.98-1.11	Age, sex, activity, ability
Electronic devices	0.98	0.93-1.04	0.99	0.93-1.05	Age, sex, activity, ability
Wrist guards	1.06	0.97-1.15	1.05	0.97-1.13	Age, sex, activity, ability
Binding adjustment	1.06	1.01-1.12	1.05	0.99-1.11	Age, sex, activity, ability
Alcohol	0.90	0.76-1.07	0.86	0.73-1.02	Age, sex, activity, ability
Activity type					
Other (Competition, Training)	1.05	0.99-1.11	1.03	0.96-1.10	Age, sex, activity, ability
Recreational	ref				
Other ski					
Skied other hills	1.08	1.02-1.14	1.06	0.99-1.12	Age, sex, activity, ability
Have not skied elsewhere	ref				

Pass type					
All other (Season pass, multi-day pass)	1.15	1.09-1.21	1.15	1.09-1.21	Age, sex, activity, ability
Day pass	Ref				
Lessons					
Never	Ref				
This year	1.13	1.06-1.21	1.07	0.99-1.14	Age, sex, activity,
Yes (not this year)	1.05	0.98-1.12	1.02	0.96-1.09	Ability
Alpine code					
Can recite 3 items	1.04	0.98-1.09	1.08	1.02-1.14	Age, sex, activity,
No knowledge of code	Ref				ability
Activity					
Snowboarding	1.07	1.02-1.12	1.04	0.99-1.09	Age, sex, activity, ability
Skiing	Ref				

3.4 Helmet Fit

The Prevalence of correct helmet use was 55% for those interviewed and 59% for those observed. Table 3.6 presents the results of the Poisson regression analysis with robust error variance for the ski area interviews. Each variable was analyzed separately and therefore no conclusions can be made about each variable having the same effect at the same time. Although adjusted for age, sex and activity, the message is not that all of the following put an individual at risk for wearing/not wearing a helmet, but rather consider each characteristic individually without consideration of the others.

3.4.1 Ski Area Interviews

Participants from Calgary had a higher prevalence of correct helmet use (PR 1.24; 95% CI: 1.01-1.51). However, after adjusting for age, sex, activity, and ability this effect was no longer statistically significant (aPR 1.20; 95% CI: 0.98-1.47). Compared with those ages 18-54, 13-17 year olds had a lower prevalence of correct helmet use (PR 0.68; 95% CI: 0.57-0.82).

Overcast weather, compared with clear skies, decreased the prevalence of correct helmet use (PR 0.74; 95% CI: 0.63-0.85). Compared with temperatures above 0°C, temperatures ranging from -10°C to -1°C lowered the prevalence of correct helmet use (PR 0.79; 95% CI: 0.68-0.92). Skiing/snowboarding on less difficult terrain than one is used to had a higher prevalence of correct helmet use (PR 1.18; 95% CI: 1.01-1.38).

Several behavioural characteristics were significantly related to helmet fit. Wearing goggles had a higher prevalence of correct helmet use (PR 1.28; 95% CI: 1.07-1.55). Skiing/snowboarding at other areas in Alberta or British Columbia lowered prevalence of correct helmet use (PR 0.85; 95% CI: 0.74-0.98). However, after

adjusting for age, sex, activity, and ability level this effect was no longer statistically significant (aPR 0.90; 95% CI: 0.78-1.05).

Compared with having a day pass, having a season pass or other pass type (competition, work etc.), lowered the prevalence of correct helmet use (PR 0.81; 95% CI: 0.70-0.93).

Finally, compared with skiers, snowboarders had a lower prevalence of correct helmet use (PR 0.77; 95% CI: 0.68-0.88).

Table 3.5 Crude and adjusted estimates for helmet fit-Ski Area Interviews

	Crude PR	95% CI	Adjusted PR	95% CI	Adjustment Factors
Personal Characteristics					
Local	1.24	1.01-1.51	1.20	0.98-1.47	Age, sex, ability, activity
Education					
High School or less	0.97	0.78-1.20	1.04	0.83-1.30	Age, sex, activity
Tech/trade	0.88	0.71-1.08	0.88	0.71-1.09	Age, sex, activity
University degree	Ref				Age, sex, activity
Graduate degree	0.96	0.73-1.25	0.82	0.63-1.08	
Previous Injury	0.91	0.77-1.07	0.97	0.81-1.16	Age, sex, ability, activity

Age						
	<13	0.90	0.75-1.08	0.93	0.77-1.12	
	13-17	0.68	0.57-0.82	0.75	0.62-0.91	sex, ability,
	18-54	Ref				activity
	55+	0.90	0.61-1.33	0.76	0.46-1.26	
Sex		0.99	0.85-1.14	1.02	0.87-1.21	Age, ability,
						activity
Ability						
	Beginner	0.98	0.81-1.19	0.93	0.76-1.13	
	Novice	0.92	0.72-1.17	0.96	0.75-1.23	
	Intermediate	Ref				Age, sex, activity
	Advanced	0.93	0.78-1.11	0.95	0.79-1.13	
	Expert	0.91	0.69-1.19	0.92	0.71-1.20	

Environmental Characteristics					
New Snow	0.99	0.84-1.17	1.02	0.86-1.21	Age, sex, ability, activity
Weather					
Clear	Ref				
Overcast	0.74	0.63-0.85	0.77	0.65-0.90	Age, sex, ability, activity
Snowing	0.91	0.74-1.12	0.97	0.79-1.20	
Temperature					
0-10	Ref				
<-10	0.97	0.82-1.14	0.99	0.84-1.19	Age, sex, ability, activity
-10 to -1	0.79	0.68-0.92	0.79	0.67-0.93	
Light					
Sharp	Ref				
Flat	0.97	0.84-1.12	0.97	0.83-1.13	Age, sex, ability,

Lights	0.98	0.81-1.18	1.00	0.82-1.24	activity
Ski Location	1.05	0.87-1.26	1.13	0.94-1.36	Age, sex, ability, activity
Difficulty Compared					
Same	Ref				
Less	1.18	1.01-1.38	1.20	1.02-1.41	Age, sex, ability,
More	1.03	0.82-1.29	1.06	0.84-1.35	activity
Companions					
Alone	Ref				
Children only	1.10	0.94-1.29	1.13	0.94-1.35	Age, sex, ability,
Adults only	1.04	0.86-1.26	1.08	0.88-1.33	activity
Adults & children	0.95	0.73-1.24	1.01	0.76-1.34	

Helmets on Companions

None	Ref				
Children only	1.02	0.64-1.62	0.86	0.54-1.36	Activity, ability
Adults only	0.94	0.58-1.52	0.81	0.51-1.30	Activity, ability
Both	0.90	0.54-1.51	0.77	0.46-1.29	Activity, ability
Some	0.64	0.26-1.57	0.52	0.20-1.36	Activity, ability

Behavioural Characteristics

Goggles	1.28	1.07-1.55	1.31	1.07-1.61	Age, sex, ability, activity
Helmet					
Own	Ref				
Rent/borrow	0.93	0.84-1.04	0.90	0.79-1.01	Age, sex, ability, activity
Music	0.87	0.71-1.08	0.92	0.74-1.15	Age, sex, ability, activity

Electronic devices	0.91	0.77-1.07	0.92	0.78-1.08	Age, sex, ability, activity
Wrist guards	0.97	0.71-1.32	1.03	0.75-1.41	Age, sex, ability, activity
Binding adjustment	1.00	0.86-1.15	1.00	0.87-1.16	Age, sex, ability, activity
Alcohol	1.03	0.78-1.36	1.06	0.81-1.41	Age, sex, ability, activity
Activity type					
Other (Competition, training)	0.83	0.68-1.02	0.83	0.67-1.03	Age, sex, ability, activity
Recreational	Ref				
Other ski					Age, sex, ability, activity
Skied other hills	0.85	0.74-0.98	0.90	0.78-1.05	
Have not skied elsewhere	Ref				

Pass type					
All other (Season pass, multi-day) Day pass	0.81 Ref	0.70-0.93	0.81	0.70-0.93	Age, sex, ability, activity
Lessons					
Never	Ref				
This year	0.91	0.72-1.15	0.95	0.75-1.21	Age, sex, ability, activity
Yes (not this year)	1.09	0.93-1.26	1.12	0.96-1.31	
Alpine code					
Can recite 3 items	0.98	0.85-1.14	0.98	0.84-1.14	Age, sex, ability, activity
No knowledge of code	Ref				
Activity					
Snowboarding	0.77	0.68-0.88	0.81	0.70-0.93	Age, sex, ability,

Chapter 4: Discussion

This study has provided insight into the prevalence of helmet use among skiers and snowboarders in Southern Alberta. Future studies can build on this foundation to enhance our understanding of the factors associated with helmet use. In addition, this study is the first to look at the prevalence of correct helmet fit in skiers and snowboarders and the factors that could potentially influence this outcome.

4.1 Helmet Use

A high prevalence of helmet use (88%) was found in this sample. This is in contrast to several studies conducted in the early 2000s. In a series of studies in Western North America conducted in the early 2000s on adult (≥ 18 years old) skiers and snowboarders, researchers found that helmet use increased from 12.1% in 2001[36] to 19.8% in 2002 [35], reaching just 23% in 2003 [41]. In 2008, researchers found that helmet use on Austrian ski slopes among skiers and snowboarders was 63%; however, it reached 78% for those < 20 years old [39,40]. Interestingly, researchers from Australia found the prevalence of helmet use among skiers and snowboarders at a single resort to be 29% [34]. A more recent study (2011) reported a helmet prevalence of 21.9% among skiers and snowboarders in the uninjured control group of a case-control study at eight major resorts in Norway [44].

More recently, the Canadian Ski Council (CSC), based on telephone survey data from 2006 to 2010 found results similar to ours [13]. Across all age groups, the CSC estimates that helmet use among skiers and snowboarders in Canada has increased from 67% in 2006 to 71% in 2010 [13]. According to the CSC, this is significantly higher than in the U.S., where 2010 reports indicated that helmet use among skiers and snowboarders was 57% [13].

4.1.1 Ski Area Interviews

This study has identified numerous personal, environmental, and behavioural characteristics associated with helmet use. Factors associated with a lower likelihood of wearing a helmet included having a graduate degree compared with those with an undergraduate degree, and skiing and snowboarding in the presence of adults relative to skiing/snowboarding alone.

Factors associated with helmet use included being < 18-54 years old, skiing/snowboarding with a child companion using a helmet, an adult companion using a helmet, and both adult and child companions using a helmet. It appears that engaging in skiing/snowboarding with others that are also wearing a helmet is indicative of one's own helmet use. In addition, those using goggles were more likely to wear a helmet, as were snowboarders compared with skiers.

A study based on self-reports from neurosurgeons in Germany, Switzerland, and Austria found that half of those sampled indicated they wore helmets while skiing/snowboarding, and further that 87% and 79% of their own children wore helmets while skiing and snowboarding, respectively [37]. Furthermore, a study on helmet prevalence on Austrian ski slopes found that among those < 20 years old, helmet use was 78%, but was just 53% in those ages 60 and older [39,40]. Although not statistically significant, we found those ages 55 and older were less likely to be wearing a helmet compared with those ages 18-54. In addition, skiing/snowboarding with children who were wearing helmets and adults who were wearing helmets had a higher likelihood of wearing a helmet. While governments can send a strong message that helmet use is important and can reduce the risk of injury by mandating helmet use, legal complications and problems with enforcement are natural barriers. A salient theme in this work is companion helmet use as a strong predictor of helmet use. Perhaps efforts to promote helmet use and

especially correct helmet use should be focused on peer delivered educational programs to increase use and correct use.

4.2 Helmet Fit

We found that just over half of those interviewed and over half of those observed were wearing their helmets correctly. The prevalence of correct helmet fit was found to be 55% for those interviewed and 59% for those observed.

4.2.1 Ski Area Interviews

Several personal, environmental, and behavioural characteristics were found to be associated with correct helmet fit. Compared with those 18-54 years old, 13-17 year olds were less likely to be wearing a helmet correctly. In addition, overcast weather, temperatures ranging from -10°C to -1°C compared with temperatures above 0°C, and having a season pass compared with a day pass was associated with incorrect helmet use. Finally, snowboarders were less likely to be wearing a helmet correctly compared with skiers. Although helmet prevalence was high among those <18-54 years old, they are more likely to be found wearing it incorrectly. The future education and promotion of helmet use and correct fit should target younger individuals.

Furthermore, although snowboarders were found to have a higher prevalence of helmet use, they are more likely to wear one incorrectly. This may be explained by the mandatory helmet use requirement for the terrain park at the location this study took place. In this case, snowboarders may use a helmet reluctantly as a means to enter the terrain park with less concern for its proper use.

Factors associated with correct helmet use included skiing/snowboarding on less difficult terrain than usual, and wearing goggles. The use of goggles may have helped to maintain the proper position of the helmet and contributed to the increased prevalence of correct helmet use

This study is one of few to examine factors associated with the correct use of a helmet in skiers and snowboarders. If a helmet were worn incorrectly in skiing and snowboarding, as has been shown among a significant proportion of bicycle helmet users [46], helmet effectiveness would likely suffer [47,48].

4.3 Limitations

As is with any study, the possibility of confounding, selection bias, and misclassification bias must be considered.

4.3.1 Selection Bias

Selection bias can be described as distortions that result from procedures used to select subjects and from factors that influence the study population [71].

Three sampling schedules were developed to account for variations in ski-hill use for the time of day and the day of the week. It was hypothesized that users could be different throughout the day, with older individuals participating during the weekday morning and afternoon hours compared with those participating during after school hours. Data were collected during two time slots on weekdays (9-10am, 1-2pm), and again on weekends at the same time. In addition, data were collected on weekday evenings from 6-7pm. To guard against the possibility of selection bias, we used three research assistants (RAs), one of which was blinded to the study objectives so as not to influence who they approached to include in the study. If the RA conducting the interviews was aware of the outcomes under investigation, it's possible the prevalence estimates for helmet use and correct helmet use would either increase or decrease depending on the proclivity of the interviewer. It was initially decided that every 4th person entering the lift line would be approached for an interview; however, this was not practical as several participants would gather at the bottom of the hill and enter the lift line in groups. A blinded RA interview

individuals by convenience for the full hour of data collection as they approached the entrance to the main chair lift. A second RA would then record visual observation information for 30 minutes on the individuals the blinded RA was conducting interviews with. For the remaining 30 minutes of data collection, the second RA would then collect visual observation information on every 4th person exiting the “magic-carpet” lift line and conduct interviews on individuals when it was clear they were not participating in lessons. Finally, we had a third RA collect visual observation information on every 4th person entering the main lift line for the first 30 minutes of data collection, and then conduct interviews alongside the blinded RA for the remaining 30 minutes of data collection. The prevalence estimates for helmet use (88%, 91%) and helmet fit (55%, 59%) between those interviewed by convenience and those observed entering the lift line do not differ substantially and therefore selection bias is unlikely to have influenced our results.

In addition, if an individual refused to participate, we still captured visual observation information. This way we had information on non-responders that addressed the main objectives of the study to reduce the likelihood of selection bias related to non-response. 15% of those approached refused to participate; however, observations on helmet use and correct helmet fit (91%, 50%) for these individuals show that they do not markedly differ from those who agreed to participate.

4.3.2 Misclassification Bias

The full survey was designed to capture socio-demographic variables, environmental conditions, experience, ability level, parent accompaniment, helmet use, companion helmet use, and helmet fit. The second data collection form gathered reliability information and observations that the full survey contained (i.e. age, sex, activity, helmet use, companions, companion helmet use, and helmet fit).

For the main objectives of the study, determining helmet use was very accurate as it was clear if the individual was wearing a helmet or not. In some cases it was possible that the RA conducting observations on the person being interviewed could have misclassified helmet use if it was unclear who the interviewee was (i.e. a large group together). It is also possible that helmet use may have been overestimated since we were conducting the research at only one location where users may be less experienced and therefore more likely to be wearing protective equipment. As for helmet fit, the interviewer used a set of detailed criteria from ThinkFirst Canada (now part of Parachute Canada) to make a subjective determination of helmet fit. In light of this, identification of correct helmet fit may have been overestimated. Making a true assessment of correct helmet fit was difficult, so unless it was obvious the helmet fit incorrectly (e.g., too large or too far forward or back) that individual would have been classified as wearing the helmet correctly. This is unfortunate, as the prevalence of correct helmet fit was found to be low, and may be an overestimate at that. This is in stark contrast to the results that Fenerty et al. found while conducting observations on correct helmet fit at three ski locations in Nova Scotia [78]. However, in that study helmet fit was based on whether the chin strap was fastened, the helmet was fitted, and that it was the correct helmet type [78]. Furthermore, observations were made from afar, making a subjective determination of correct fit difficult, and at multiple intervals across various locations on the ski hill, possibly leading to the repeat counting of participants. In light of such disparate findings, not only should future interventions target the promotion and education of helmet use and correct use, but future research should focus on the prevalence of correct helmet use using procedures to identify correct helmet use more accurately. A more invasive approach, whereby a trained individual physically inspects the helmet wearer to determine proper fit may be needed.

Factors such as age and sex could have been misclassified by the RA conducting observations, especially if they were heavily dressed to avoid exposure to the weather conditions. In these cases, distinguishing features would be harder to detect. In addition, companionship and companion helmet use could have been misclassified by the RA conducting observations as, at times, it was unclear whether individuals in close proximity were together. Participant ability level also had the potential to be misclassified, as interviewers relied on the participants self-described ability level, and individuals have been shown to have a tendency for underestimation when terms such as “expert” and “advanced” are used. Conversely, assessing one’s activity was obvious as it was clear they were either skiing or snowboarding.

4.3.3 Confounding Bias

Confounding can be described as a mixing of effects, in which the effect of the exposure is mixed with the effects of a variable that is an independent risk factor for the outcome [71].

The survey was designed with the intent to capture as many relevant factors as possible that may relate to helmet use and fit. The sample size in this study limited the number of independent variables we could include in the Poisson regression model; however, the analysis was adjusted for factors known to predict helmet use. This included age, sex, activity, and ability level [10-12]. From the data, it was determined that none of age, sex, activity, or ability level confounded the association between other variables and both helmet use and helmet fit.

Although the questionnaire was designed to capture as many relevant factors as possible, certain variables were not collected that could potentially act as confounders. Socioeconomic information was not collected; however, previous research has shown that socioeconomic status has not shown to be a factor related to helmet use. In addition, risk-taking propensity was not

accounted for in the questionnaire. An argument against studies that have identified a protective effect of helmets in bicycling is whether cautious people are more likely to wear a helmet. A few studies have shown that helmet use is not associated with higher risk compensation behavior among skiers and snowboarders [34, 52].

4.4 Strengths

Few studies have examined the prevalence of helmet use in skiers and snowboarders, and those that have often included only adults and did not include direct observations at ski areas.

Furthermore, no study to date has examined the prevalence of correct helmet fit in skiers and snowboarders. The strengths of this study rely on the robust methods we used to collect the data. Many individuals spent several months collecting data at the ski hill conducting in depth interviews as well as making direct observations. The data collection tools used allowed us to capture comprehensive information in order to better understand the factors relating to helmet use and fit.

Chapter Five: Conclusions and Future Directions

Given that the protective effect of helmets in skiers and snowboarders has been demonstrated convincingly, it is encouraging that the prevalence of helmet use in this study was relatively high.

This study is one of few to address the prevalence of correct helmet fit in skiers and snowboarders. Just over half the participants exhibited correct helmet use in this study. This is concerning given that it is reasonable to believe that the prevalence of correct helmet fit was overestimated. A recent systematic review on the relationship between bicycle helmet fit and head injury has shown a significantly increased risk of head injury for those considered to be

wearing poorly fitting helmets relative to those considered to be wearing excellent fitting helmets [72]. If a ski or snowboard helmet were worn incorrectly, as is the case among a significant proportion of bicycle helmet users [46], then, as for bicyclists [47, 48], helmet effectiveness would likely suffer.

As with helmet use, education on, and promotion of, correct helmet use are important areas for injury prevention. Those that participate in skiing and snowboarding, parents, and members of the ski-snowboard industry should be made aware and educated on correct ski and snowboard helmet use to reduce the risk of head injury. Ski/snowboard instructors and professionals working within the industry should be trained to identify proper fitting helmets and teach participants about the benefits of, and how to properly fit a helmet. Helmet manufacturers should consider adjustable helmet technology, especially for children, to discourage parents from buying helmets that are too large for children to grow in to. Resorts that offer rental helmets should also consider adjustable helmets in order to fit individual needs, as well as training staff on how to properly fit a helmet. The findings of this study will be shared with our collaborators at the ski hill in which the study was conducted so that this information can be disseminated to a broader audience. This information should be presented in a user-friendly format; highlighting the importance of helmet use and correct helmet fit to participants. We will attempt to publish our findings in peer-reviewed injury prevention and public health journals. This has the potential to encourage other researchers to undertake similar projects in other locations, allowing us to get a more comprehensive picture of helmet use and fit among skiers and snowboarders. This research should be replicated at other ski resorts in Western Canada and beyond in order to firmly establish helmet prevalence and correct helmet fit estimates, yet future research should

build on the groundwork we have established, and examine the relationship between helmet fit and head injury among skiers and snowboarders.

This study has expanded on the evidence that currently exists on helmet use among skiers and snowboarders, and has provided information that is critical to ensure the public health benefit of ski and snowboard helmet use is fully realized.

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Appendices

Appendix A- Study Information Sheet

Parent Information Sheet

TITLE: Helmet Use and Risk Factors for Injury among Skiers and Snowboarders in Southern Alberta

SPONSOR: Alberta Children's Hospital Research Institute for Child and Maternal Health

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Study Purpose:

Researchers at the University of Calgary are doing a study on skiing and snowboarding. They are talking with skiers/snowboarders at the ski area to find out about risk factors for injury.

Do I have to participate?

If you don't want to answer the questions, that's OK. Any information you provide will be kept private, and there is no need for any follow-up.

What do I have to do?

We would like to ask you some questions about your (your child's) participation in skiing/snowboarding. We are also getting information on injuries from the Ski Patrol, and talking to people who are injured and go to the emergency department. All this information will be examined to shed some light on why and how people get injured in these sports. The interview will take about 5 minutes.

How will my records be kept private?

Only the researchers will have access to your information and it will be kept in a locked filing cabinet at the Alberta Children's Hospital and the stored on a password protected computer.

What are the risks and benefits of participation?

There are no risks involved in participating, and the information you provide will be used to help prevent injuries in the future.

Do you have any questions?

Please contact Dr. Brent Hagel, Associate Professor in the Faculty of Medicine at the University of Calgary by phone (403-955-7403) or email (brent.hagel@albertahealthservices.ca). You can also contact the Conjoint Health Research Ethics Board at the University of Calgary at 403-220-7990

Appendix B- Ski Area Interview Forms

Ski Area Data Collection Form

OBSERVATION INFORMATION (to be filled out by each observer for each data collection period)

Interviewer: _____ Date (dd-mmm-yy): _____ Time period: 1. 9-10am 2. 1-2pm

Chairlift/carpet name: _____

Weather: 1. Clear 2. Overcast 3. Snowing 4. Raining 5. Fog
 Light: 1. Sharp 2. Flat 3. Whiteout 4. Lights 5. Dark
 Temperature: _____ °C

New snow? 1. No new 2. 0-5 cm 3. 5-10 cm 4. 10-15 cm 5. Over 15 cm
 Surface (select all): 1. Groomed 2. Moguls 3. Powder 4. Granular 5. Hard

Take Note: Some helmets are multi-impact and some are single impact. Read the instructions on when to discard your helmet. ● Helmet and head shape affect your helmet selection. Finding the right model and size helps. ● Determine correct size - Wrap tape around head, above eyebrows and ears. Your size is the point of overlap of the tape.

Ski Area Data Collection Form

Observation ID: AM or PM # _____
(circle)

Skier-Snowboarder (parent if child <10) consent: 1. Yes 2. No

Previously Participated in study? 1. Yes 2. No 3. Don't know

1. What part of the hill are you skiing/riding at the moment?

1. First turns area (i.e., near carpets)
2. East main (i.e., near new chairlift)
3. West main (i.e., near Legacy chairlift)
4. Terrain park
5. Competition terrain
6. Don't know

2. How difficult are the runs in that type of terrain?

1. Easiest (e.g., carpet area)
2. More difficult (e.g., main lifts)
3. Most difficult (e.g., terrain park)
4. Other (e.g., competition terrain)
5. Don't know

3. How difficult was the run compared with what you usually ski/ride?

1. Same difficulty
2. Less difficult
3. More difficult
4. Don't know

4. Sex: 1. Male 2. Female

5. Age: _____ years if refused agreement: 1. <13 2. 13-17 3. 18-54 4. 55+

6. Activity: 1. Skiing 2. Snowboarding

7. Companions: 1. Alone 2. With children 3. With adults (18+) 4. With adults and children 5. Don't know

8. Helmets on companions: 1. N/A (alone) 2. Children only 3. Adults only 4. Both 5. Some 6. None

9. Wearing goggles? 1. Yes, over helmet 2. Yes, under helmet 3. Yes, no helmet 4. No

10. Helmet: 1. Yes 2. No (if NO go to question 20)

11. Skiing-snowboarding helmet? 1. Yes 2. No If no, type (e.g., bicycle): _____

12. Helmet fit (check all that apply):
☐ correct fit (2-V-1) ☐ too far back ☐ too far forward
☐ strap not fastened ☐ toque or cap underneath ☐ too loose

13. How would you say the helmet fits you?

1. Excellent
2. Good
3. Fair
4. Poor
5. Don't know
6. Refused to answer

14. Own, rent or borrow helmet? 1. Own 2. Rent from hill 3. Rent from other 4. Borrow 5. Don't know

15. Helmet manufacturer and model (e.g. Smith Variant, Giro G10, etc)? _____ ☐ Don't know

16. Helmet year of manufacture or if purchased new, year of purchase (e.g. 2007 or late-2000's) _____ ☐ Don't know

17. List the certification standard (e.g. ASTM F-2040, Snell RS-98, S-98): _____ ☐ Don't know

18. Has the helmet had prior impact? 1. Yes 2. No 3. Don't know

19. How long have you used a helmet? _____ years

Ski Area Data Collection Form

20. Reason for using/not using a helmet as applicable: _____

21. Listening to music (presence of ear buds): 1. Yes 2. No 3. Don't know

22. Using other electronic device: 1. Yes (if yes please specify below) 2. No 3. Don't know

Type of device (check all that apply):

- ☐ Phone
- ☐ Helmet cam (e.g., GoPro)
- ☐ Walkie talkie/two-way radio
- ☐ Other (describe): _____

23. Wearing wrist guards: 1. Yes 2. No 3. Don't know

24. Ski binding adjustment this year? 1. Yes 2. No 3. Don't know

25. Any alcohol last 12 hours (≥ 18 years only)? 1. N/A (< 18 yrs) 2. Yes 3. No 4. Don't know

26. Are you from Calgary? 1. Yes 2. No If no, where are you from? _____

27. Own (22+ yrs) or mother's education: 1. < High sch. 2. High sch. 3. Technical/trade 4. Univ. degree 5. Grad. degree

28. Type of activity: 1. Recreation 2. Lessons 3. School 4. Training 5. Competition 6. Other

29. Years skied or snowboarded: _____ years ☐ Don't know

30. Days skied or snowboarded this year: _____ days ☐ Don't know

31. At this area? _____ days ☐ Don't know

32. Skied at other ski areas in Southern Alberta and/or British Columbia this year? 1. Yes 2. No 3. Don't know

33. Pass type: 1. Day ticket 2. Multi-day ticket 3. Season pass 4. Other pass specify: _____ 5. Don't know

34. Ability: 1. Beginner 2. Novice 3. Intermediate 4. Advanced 5. Expert 6. Don't know

35. Previous skiing/snowboarding injury requiring medical attention: 1. Yes 2. No 3. Don't know

36. Lessons: 1. Never 2. This year 3. _____ years ago? 4. Don't know

37. Skier-snowboarder able to name one item from the Alpine Responsibility Code?: 1. Yes 2. No 3. Don't know

Appendix C- Observational Data Form

RELIABILITY DATA COLLECTION – Please only record observations when the interviewer is talking to a skier or snowboarder

Observation ID: AM or PM # _____
(circle)

1. What part of the hill are you skiing/riding at the moment?
 1. First turns area (i.e., near carpets)
 2. East main (i.e., near new chairlift)
 3. West main (i.e., near Legacy chairlift)
 4. Terrain park
 5. Competition terrain
 6. Don't know
2. How difficult are the runs in that type of terrain?
 1. Easiest (e.g., carpet area)
 2. More difficult (e.g., main lifts)
 3. Most difficult (e.g., terrain park)
 4. Other (e.g., competition terrain)
 5. Don't know
4. Sex: 1. Male 2. Female
5. Age: 1. <13 2. 13-17 3. 18-54 4. 55+
6. Activity: 1. Skiing 2. Snowboarding
7. Companions: 1. Alone 2. With children 3. With adults (18+) 4. With adults and children
5. Don't know
8. Helmets on companions: 1. N/A (alone) 2. Children only 3. Adults only 4. Both 5. Some
6. None
9. Wearing goggles? 1. Yes, over helmet 2. Yes, under helmet 3. Yes, no helmet 4. No
10. Helmet: 1. Yes 2. No
11. Skiing-snowboarding helmet? 1. Yes 2. No If no, type (e.g., bicycle): _____
12. Helmet fit (check all that apply):
☐ correct fit (2-V-1) ☐ too far back ☐ too far forward
☐ strap not fastened ☐ toque or cap underneath ☐ too loose
13. Listening to music (presence of ear buds): 1. Yes 2. No 3. Don't know

Appendix D- Systematic Observations Form

SYSTEMATIC OBSERVATIONS DATA COLLECTION FORM - Please record observations on every 4th skier/snowboarder entering the lift line

Observation ID: AM or PM # _____

1. What part of the hill are you skiing/riding at the moment?

1. First turns area (i.e., near carpets)	4. Terrain park
2. East main (i.e., near new chairlift)	5. Competition terrain
3. West main (i.e., near Legacy chairlift)	6. Don't know

2. How difficult are the runs in that type of terrain?

1. Easiest (e.g., carpet area)	4. Other (e.g., competition terrain)
2. More difficult (e.g., main lifts)	5. Don't know
3. Most difficult (e.g., terrain park)	

3. Sex: 1. Male 2. Female

4. Age: 1. <13 2. 13-17 3. 18-54 4. 55+

5. Activity: 1. Skiing 2. Snowboarding

6. Companions: 1. Alone 2. With children 3. With adults (18+) 4. With adults and children 5. Don't know

7. Helmets on companions: 1. N/A (alone) 2. Children only 3. Adults only 4. Both 5. Some 6. None

8. Wearing goggles? 1. Yes, over helmet 2. Yes, under helmet 3. Yes, no helmet 4. No

9. Helmet: 1. Yes 2. No

10. Skiing-snowboarding helmet? 1. Yes 2. No If no, type (e.g., bicycle): _____

11. Helmet fit (*check all that apply*):

☐ correct fit (2-V-1)	☐ too far back	☐ too far forward
☐ strap not fastened	☐ toque or cap underneath	☐ too loose

12. Listening to music (presence of ear buds): 1. Yes 2. No 3. Don't know