Understanding Clinical Snow Sport Head Injury and Design of a Relevant Helmet Testing Apparatus

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I. INTRODUCTION

With approximately 650 ski resorts in North America seeing over 75.9 million visits per year, skiing and snowboarding are popular and are identified as the second most practiced winter sports in Canada [1-3]. Helmets have been found to protect snow sport users against severe head injury. However, little is known about the sport-specific injury mechanisms and their implications on head injury severity, leaving manufacturers with the challenge of tailoring technology for an anticipated impact scenario [4-6]. Although helmets used for snow sports are certified through standardised testing, most of the impact attenuation test protocols involve linear, vertical impact and may not be biomechanically representative of typical snow sport impacts [7]. These impact attenuation tests involve impact velocities between 1.5 m/s and 2.0 m/s [8-11]. This is in contrast to previous studies where typical velocities of intermediate snowboarders were found to be 30.9 km/h (8.6 m/s), on average [12], while skiers wearing helmets had velocities of 45.8 km/h (12.7 m/s), on average [13]. In the event of a crash at this velocity, an oblique or glancing head impact is most likely, and this can cause significant angular acceleration which has been identified as a potential cause of concussion and a direction of progress for future injury mitigation technologies [14-16].

The purpose of this study was to describe the severity and nature of head injuries suffered while participating in alpine skiing and snowboarding for both helmeted and un-helmeted participants, as well as identify a need for a snow sport specific helmet test protocol. In addition, a detailed case review will provide a more detailed understanding of the benefits of helmet use as well as give insight into scenarios for which helmet testing standards can be tailored. This insight will then be applied through design and fabrication of an in-field helmet test apparatus with direct relevance to both helmet certification protocols as well as development of technology to mitigate head injury.

II. METHODS

A retrospective, multi-centre chart review of snow sport head injuries over five years (1 January 2009 to 31 December 2014) was performed. The study centres include Lions Gate Hospital (LGH; North Vancouver, British Columbia, Canada) and the Vancouver General Hospital (VGH; Vancouver, British Columbia, Canada) as they are in close proximity to the local skiing and snowboarding recreation sites and service the most severe trauma for the area. Incidents that resulted in fatality will be reviewed through the BC Coroner's Office records. Information collected includes demographic data, any incident specific data (i.e., nature, level of control prior to the incident, location, ability level, helmet use) as well as any relevant information pertaining to the head injury. Injury severity was scored using the Abbreviated Injury Scale (AIS). Maximum Abbreviated Injury Score (MAIS), the highest AIS score for each particular region, was also used to quantify the severity of each incident. Descriptive and relative risk statistics have been generated to understand the relationships between discipline (i.e. skiing vs. snowboarding), head injury severity, helmet use, demographic and injury mechanism. Additionally, prevalence of each AIS severity level, frequency of particular injury mechanisms and prevalence of specific head injury characteristics have been investigated.

When the documentation allows, a case-by-case investigation will be conducted for head injuries scoring AIS4+ with the goal of achieving a better understanding of the mechanism of injury and the factors that led to the severe injury outcome. This information will also be used to investigate the biomechanical implications of helmet use on injury outcome. Using the clinical database, common head injury mechanisms will be determined and used in the design of an in-field test apparatus. The apparatus will be built to represent common head injury mechanisms and will be portable to allow for the tests to be conducted on different impact surface characteristics (i.e., types of snow and ice) and angles.

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III. INITIAL FINDINGS

TABLE 1

BASIC DESCRIPTIVE STATISTICS FOR THE SNOW SPORT HEAD INJURY DATABASE (TO DATE)

Category	Statistic Descriptor	LGH (Totals)	LGH (Percent)	VGH (Totals)	VGH (Percent)	Total	Percent of Total Cases Included
Overall	Cases Included	452	59.2%	311	40.8%	763	100.0%
Discipline	No. of Skiing	137	46.9%	155	53.1%	292	38.3%
	No. of Snowboarding	311	67.2%	152	32.8%	463	60.7%
Location	Whistler	39	18.8%	169	81.3%	208	27.3%
	Local Mountains (Cypress, Grouse, Seymour)	265	72.6%	100	27.4%	365	47.8%
	Other Locations	148	77.9%	42	22.1%	190	24.9%
Injury	MAIS2+ Head/Face	101	52.9%	90	47.1%	191	25.0%
	MAIS3+ Head/Face	7	20.0%	28	80.0%	35	4.6%
Helmet	Helmet Use	271	64.4%	150	35.6%	421	55.2%
	Helmet Not Used	128	57.7%	94	42.3%	222	29.1%
	Not Recorded	53	44.2%	67	55.8%	120	15.7%

Compared to helmeted skiers and snowboarders, un-helmeted participants that reported to the Emergency Department (ED) were 1.06 times (95% CI; 1.01-1.11) more likely to suffer a MAIS3+ head/face injury and 1.03 times more likely to fracture their skull (95% CI; 1.01-1.05). Similarly, compared to helmeted skiers reporting to the ED, un-helmeted skiers were 1.12 times more likely to suffer a MAIS3+ head/face injury (95% CI; 1.01-1.24) and 1.08 times more likely to suffer a MAIS3+ head/face injury in a fall compared to impact with another object (95% CI; 1.03-1.12). These statistics were not significant for snowboard participants. However, un-helmeted snowboarders reporting to the ED were 1.03 times more likely to suffer a skull fracture than helmeted snowboarders (95% CI; 1.00-1.05). Falls were observed to be the most common mechanism (54% of total incidents) with *jump impacts/fall from height* and *impact with object or other people* representing 17% and 15% of incidents, respectively. It was also determined that head/face injuries to skiers and snowboarders reporting to the ED represent 38% and 61%, respectively, of the injured participants. It should be noted that this dataset does not yet include fatal incidents.

IV. DISCUSSION

Our findings of the percentage of skiers and snowboarders presenting to the ED with head/face injuries differ from previous studies in that we found skiers and snowboarders to represent 38% and 61%, compared to 50% and 43%, respectively [5]. Despite helmet use being found to decrease the chance of MAIS3+ head/face injury as well as skull fracture in cases reported to the ED, the effect appears to be minimal. Mechanisms were grossly defined as falls, impact with object, fall from height/jump impact and edge catch, but further analysis is being conducted to further specify the nature of the more severe incidents.

Initial investigation of the database has shown sufficient reporting depth for general categorisation of gross injury mechanism, something not previously described in the literature. With this clinical understanding of how head injuries are occurring, helmet testing standards and protective technology can be tailored to the specific nature of the injury mechanism through relevant testing protocols. Although the database does not represent the entire skiing and snowboarding population, only those who report to the ED or are fatally injured, we are studying the population who suffer the most severe and fatal injuries, which we believe is most relevant for injury prevention.

Future work will include further statistical analysis (including adjustment for age, gender and mechanism), in depth case reviews and reconstructions for the most severe of the incidents and design and construction of an in-field test apparatus to recreate relevant injury mechanisms.

V. REFERENCES

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