Characteristics of Injuries Sustained by Snowboarders in a Terrain Park

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Objective: To determine injured body regions and injury type resulting from snowboarding on aerial and nonaerial terrain park features and the accuracy of ski patrol assessments compared with physician diagnoses.

Design: Case series study.

Setting: An Alberta terrain park during the 2008-2009 and 2009-2010 seasons.

Patients: There were 333 snowboarders injured on features (379 injuries).

Assessment of Risk Factors: Aerial or nonaerial terrain park feature used at injury, injured body region, injury type, and additional risk factors were recorded from ski patrol Accident Report Forms, emergency department medical records, and telephone interviews.

Measures: Odds of injury to body regions and injury types on aerial versus nonaerial features were calculated using multinomial logistic regression. Accuracy of ski patrol injury assessments was examined through sensitivity, specificity, and kappa (κ) statistics.

Results: The wrist was the most commonly injured body region (20%), and fracture was the most common injury type (36%). Compared with the upper extremity, the odds of head/neck [odds ratio (OR), 2.58; 95% confidence interval (CI), 1.37-4.85] and trunk (OR, 3.65; 95% CI, 1.68-7.95) injuries were significantly greater on aerial features. There was no significant association between aerial versus nonaerial feature and injury type. The accuracy of ski patrol injury assessment was higher for injured body region (κ = 0.65; 95% CI, 0.54-0.75) than for injury type (κ = 0.29; 95% CI, 0.22-0.37).

Conclusions: Snowboarders were significantly more likely to sustain head/neck or trunk injuries than upper extremity injuries on aerial features. Investigators should acknowledge potential misclassification when using ski patrol injury assessments.

Key Words: snowboarding, terrain park, injury, ski patrol, epidemiology

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INTRODUCTION

On regular slopes, snowboarders frequently injure wrists and upper extremities,[1–3] head,[4,5] knees, and ankles.[6–8] Compared with regular slopes, snowboarders in terrain parks (TPs) are significantly more likely to sustain trunk, severe upper and lower extremity injuries,[9] and fractures.[10] Terrain parks contain man-made features such as jumps, kickers, half pipes, and mushrooms that propel skiers and snowboarders into the air to perform aerial tricks and maneuvers. Nonaerial features include boxes, rails, and quarter pipes. Definitions of common TP features can be found at the Web site http://www.snowboard-coach.com/freestyle-snowboarding-features.html. Researchers found significantly more upper extremity injuries,[11] and head and back injuries and fractures[10] among skiers and snowboarders on the TP than on regular slopes. Snowboarders were significantly more likely to suffer an anterior cruciate knee ligament or clavicle injury in the TP.[12] It is unknown if injury types or injured body regions differ for aerial and nonaerial features.

Ski patrol Accident Report Forms (ARFs) are a frequently used data source for research. The accuracy of ski patrollers' injury assessments is not well established. Küpper et al[13] found that 89.5% of Swiss ski patrol injury diagnoses were at least "mostly correct." It has been suggested that although ski patrollers may have difficulty distinguishing between fractures and sprains, they can accurately report the injured body region.[14]

The study objectives were to (1) identify the most commonly injured body regions and injury types on aerial and nonaerial TP features, (2) calculate the odds of injury to body regions and injury types on aerial versus nonaerial features, and (3) determine the accuracy of ski patrollers' injury assessments when compared with emergency department (ED) physician diagnoses.

METHODS

Setting

This study was conducted at a resort in Alberta, Canada, between November 2008 and May 2010. There were 4 different TP designs throughout the 2 seasons.

Definition of Cases

Cases were snowboarders who sustained an injury in the TP during the 2008-2009 or 2009-2010 seasons and were identified by reviewing the resort's ski patrol ARF or ED medical records from the 2 closest hospitals. For the analysis of ski patrol diagnostic accuracy, cases were included if they presented to the ski patrol and ED.

Data Collection

In addition to ARFs and ED medical records, a telephone interview was conducted to collect supplemental information. Demographics (age, sex), snowboarding experience (self-reported ability and years of snowboarding in and out of the TP), previous snowboarding injury, safety-related issues (listening to music or wearing wrist guards at the time of injury), environmental characteristics (temperature, light, snow conditions), injured body region, type of injury, and feature used at the time of injury were collected. The ARFs, ED diagnoses, and telephone interviews of snowboarders who presented to the ski patrol and a participating ED were linked using name, date of birth, sex, and contact information. The number of snowboarders entering the TP and using each type of feature was recorded 3 to 4 times a week every week during each season. Data were collected in 3-hour intervals, and data were sampled a variety of times and days to obtain an overall estimate of TP usage.

The injured body region and injury type were listed on the ARF, and/or the diagnoses in the ED records were extracted. The ED diagnoses were open ended, and the records did not systematically include any injury severity score. The injury type and injured body region recorded on the ARF was closed ended: fracture, sprain/strain, bruise/abrasion/laceration, dislocation, concussion, pain/soreness/swelling/other, and unknown; head/neck and trunk (chest/abdomen, back, hip/pelvis); upper extremity (clavicle, shoulder, upper arm, elbow, lower arm, wrist, hand); and lower extremity (foot, ankle, lower leg, knee, thigh).

Analysis

Stata/SE version 11 (College Station, Texas) was used for all analyses.[15]

Injury Rates

The total number of runs and number of times a feature was used was extrapolated from the 3-hour observation sessions. Injury rates were calculated as per 1000 snowboard runs.

Injuries

If a snowboarder sought treatment at a participating ED and had a ski patrol completed ARF, the ED diagnosis was used instead of the ski patrol assessment. If the snowboarder presented to the ski patrol and reported treatment elsewhere during their telephone interview, the diagnosis of that physician was used. If the snowboarder only presented to ski patrol, the ARF assessment was used. Because the options for injury type and body region were not separated into primary, secondary, or tertiary injury on the ARFs, the exact pairing of body region and injury type was not always obvious when snowboarders sustained multiple injuries. Based on the snowboarder's self-reported description of the injury and educated guesses, the most likely pairing of injured body region and injury type was established. When one injured body region was selected with more than one injury type on the ARF (eg, wrist, along with both fracture and sprain), the more severe injury was used based on the following hierarchy: fracture, dislocation, sprain/strain, bruise/abrasion/laceration. Thus, we likely captured the injury responsible for ski patrol or ED presentation.

The proportions of each injured body region and injury type, with Agresti-Coull 95% confidence intervals (CIs),[16] were calculated for aerial and nonaerial features. Aerial features (jumps, kickers, half pipe, mushroom) were those that propelled the snowboarder into the air to facilitate aerial maneuvers or resulted in a large drop to the ground. Nonaerial features (rails, boxes, quarter pipes) facilitate smaller drops to the ground. Pearson χ^2 test determined whether there was a statistically significant association between the exposure (aerial vs nonaerial features) and outcome (injured body region or injury type). A significance level (alpha) of 0.05 was set for statistical tests.

Multinomial regression analysis was used to calculate the relative "odds" of injury to body regions on aerial versus nonaerial features using forward selection.[17] A crude model was generated where the exposure was an aerial or nonaerial feature and the outcome was an injured body region, with upper extremity as the base outcome. Plausible confounders (age, sex, self-reported ability, listening to music, wearing wrist guards, previous snowboarding injury, temperature, light, and snow conditions) were independently added to the crude model, and whichever one produced the greatest percent change in the odds ratio (OR) was retained. This process was continued until either no variable changed the OR by more than 15%[18] or there was more than 1 variable for every 10 cases.[19]

The modeling process was repeated with injury type as the outcome and fracture/dislocation as the base outcome. Dislocations (n = 15) were combined with fractures because both injuries would likely present to the ED. Soft tissue injuries (n = 24) and "other" injuries (n = 9) were combined with pain/sore/swollen because this could encompass a variety of injury types.

A post hoc analysis was conducted to calculate the odds of sprain/strain versus fracture for upper extremity injuries by aerial and nonaerial features.

Diagnostic Accuracy

The test diagnosis was the ARF assessment and the gold standard diagnosis was the ED medical chart. Sensitivity and specificity with 95% CIs were also calculated. Kappa (κ) statistics and 95% CIs were calculated to measure the overall agreement corrected for chance between the ED medical records and ARFs. Kappa was interpreted as follows: slight, 0-0.20; fair, 0.21-0.40; moderate, 0.41-0.60; substantial, 0.61-0.80; and perfect agreement, 0.81-1.00.[20] Weighted κ (κ_w) was used for injured body region because a logical order to the body regions was agreed upon. Therefore, the disagreement between ankle and knee was less than the disagreement between ankle and elbow.

Ethical Considerations

Ethical approval was obtained from the University of Calgary Conjoint Health Research Ethics Board. If a snowboarder did not consent or could not be contacted, ethical approval was granted to extract data from their ARF but not their ED medical record.

RESULTS

Patient Flow

There were 379 TP injuries among 333 snowboarders who presented to the ski patrol and/or a participating ED (Figure). Overall, 290 snowboarders had 1 injury, 34 snowboarders had 2 injuries, and 7 snowboarders had 3 injuries. Only 5 snowboarders (1.5%) were hospitalized. Thirteen snowboarders who sustained 19 injuries simply fell in the TP (eg, caught an edge) and were not using a feature at the time of injury. They were not included in the analysis of injuries by aerial or nonaerial TP feature. No snowboarders withdrew.

Injury Rate

There were approximately 444 000 snowboarder runs in the TP during the 2 seasons, and the overall injury rate was 0.75 per 1000 runs. The injury rate was highest for jumps and half pipe (both 2.56/1000 runs) and lowest for rails (0.43/1000 runs) and quarter pipe (0.24/1000 runs).

Injured Body Region

The most commonly injured body regions were the wrist, head, and shoulder (Table 1). A greater proportion of injuries occurred on the aerial features. When collapsed into 4 categories (upper extremity, head/neck, trunk, and lower extremity), the pattern of injured body regions differed by aerial and nonaerial features. Those injured on aerial features had proportionally more trunk or head/neck injuries. There was a significant association between injured body region and aerial versus nonaerial feature ($\chi^2 = 22.18$; $P < 0.001$).

Compared with the upper extremity, the crude relative odds of head/neck injury (OR, 2.69; 95% CI, 1.44-5.04) or trunk injury (OR, 3.58; 95% CI, 1.71-7.52) were significantly higher on aerial versus nonaerial features (Table 2). This association remained after adjusting for ability. There was no significant association between lower extremity versus upper extremity injuries and feature type.

Injury Type

The most common injury types were fractures, sprains/strains, and bruises/abrasions/lacerations (Table 3). Regardless of the feature type, fractures were the most common injury. A higher proportion of sprains/strains was observed on nonaerial features. There was no significant association between injury type and aerial versus nonaerial features ($\chi^2 = 11.3$; $P = 0.08$).

Compared with fracture/dislocation, the crude odds of a sprain/strain were significantly lower on aerial versus

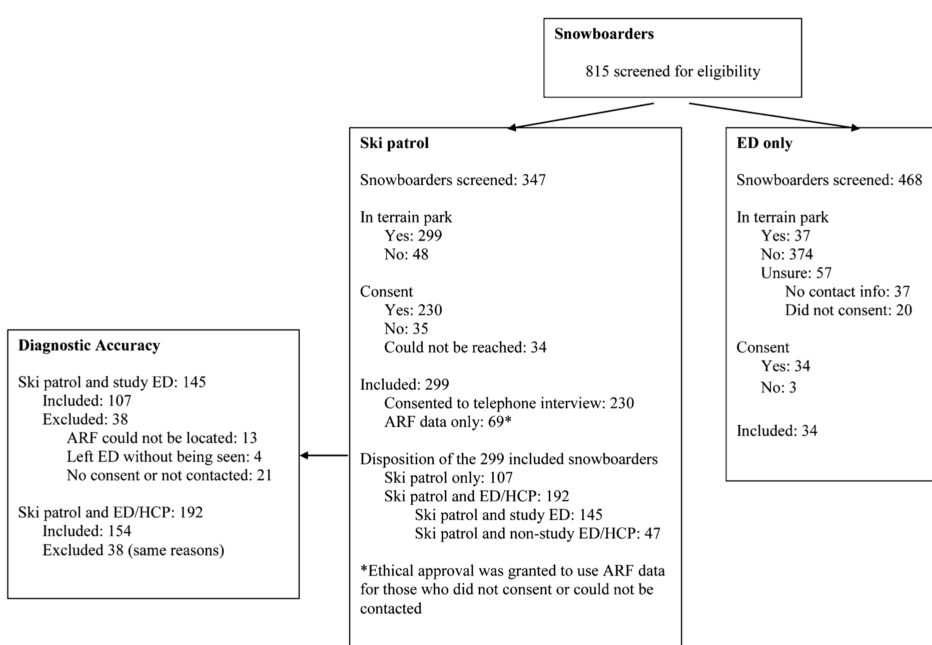

FIGURE. Patient flow.

TABLE 1. Injured Body Regions for Aerial and Nonaerial Features Among Snowboarders in a TP

	Aerial (n = 236)		Nonaerial (n = 124)	
	%	95% CI*	%	95% CI*
Upper extremity				
Wrist	18.6	14.1-24.2	24.2	17.3-32.7
Shoulder	11.0	7.5-15.8	17.7	11.9-25.6
Clavicle	4.7	2.5-8.3	8.1	4.2-14.5
Lower arm	5.5	3.1-9.4	4.0	1.4-9.5
Hand	2.1	0.7-5.1	3.2	1.0-8.4
Upper arm	1.7	0.5-4.5	2.4	0.5-7.3
Elbow	0.4	0-2.7	1.6	0-6.2
All	44.1	37.9-50.4	61.3	52.5-69.4
Lower extremity				
Knee	5.1	2.8-8.9	2.4	2.0-10.5
Lower leg	2.1	0.7-5.1	7.3	3.6-13.5
Foot/ankle	2.1	0.7-5.1	3.2	1.0-8.4
Thigh	0.9	0-3.3	2.4	0.5-7.3
All	10.2	6.9-14.8	17.7	12.0-25.5
Trunk				
Back	7.2	4.4-11.4	4.0	1.4-9.5
Hip/pelvis	6.4	3.8-10.4	2.4	0.5-7.3
Chest/abdomen	7.2	4.4-11.4	1.6	0-6.2
All	20.8	16.1-26.4	8.1	4.3-14.4
Head/neck				
Head	15.3	11.1-20.5	8.9	4.8-15.5
Face	6.8	4.1-10.9	3.2	1.0-8.4
Neck	3.0	1.3-6.2	0.8	0-5.0
All	25.0	19.9-30.9	12.9	8.0-20.1

*For variables with more than 2 levels, the CIs are calculated based on a binomial distribution "per row," that is, taking the characteristic in the row versus all others collapsed into the other category.

nonaerial features (OR, 0.49; 95% CI, 0.27-0.89). However, after adjusting for music use, this association was not significant (OR, 0.55; 95% CI, 0.29-1.08) (Table 4). There was no other significant association between aerial versus nonaerial feature use and injury type in the crude or adjusted models.

When the injured body region was limited to upper extremities, nonaerial feature use was protective against fractures compared with sprains/strains (OR, 0.29; 95% CI, 0.13-0.65).

TABLE 2. Crude and Adjusted Associations Between Injured Body Region and Aerial Versus Nonaerial Feature Use Among Snowboarders Injured in a TP

Body Region*	Crude OR	95% CI	Adjusted OR†	95% CI
Head/neck	2.69	1.44-5.04	2.58	1.37-4.85
Trunk	3.58	1.71-7.52	3.65	1.68-7.95
Lower extremity	0.80	0.42-1.53	0.68	0.35-1.34

*Base outcome was upper extremity.
†Adjusted for ability.

TABLE 3. Injury Types for Aerial and Nonaerial Features Among Snowboarders Injured in a TP

	Aerial (n = 236)		Nonaerial (n = 124)	
	%	95% CI*	%	95% CI*
Fracture	37.7	31.8-44.1	34.7	26.9-43.4
Sprain/strain	14.0	10.1-19.0	25.8	18.9-34.2
Bruise/abrasion/laceration	14.4	10.5-19.5	17.7	12.0-25.5
Concussion	11.4	8.0-16.2	7.3	3.7-13.4
Soft tissue	7.2	4.5-11.3	3.2	1.0-8.3
Pain/sore/swollen/other	10.2	6.9-14.8	8.1	4.3-14.4
Dislocation	4.2	2.2-7.8	3.2	1.0-8.3
Missing	0.9	0-3.3	0	0-0

*For variables with more than 2 levels, the CIs are calculated based on a binomial distribution "per row," that is, taking the characteristic in the row versus all others collapsed into the other category.

Diagnostic Accuracy

Compared with a medical diagnosis (including any EDs/health care providers [HCPs] and participating EDs), ski patrollers were generally able to correctly determine the injured body region: sensitivities were >85% for foot/ankle (any EDs/HCPs and participating EDs were both 100%), thigh (both 100%), elbow (both 100%), knee (89%-100%), wrist (both 87%), and head (89%-92%). Sensitivities were lowest for neck (both 0%) and lower arm (29%-33%). Ski patrollers were able to consistently rule out the body region that was not injured, and all specificities were greater than 90%.

Ski patrollers were most likely to correctly assess dislocation (sensitivities, 75%-83%), fracture (both 71%), and concussion (69%-70%) when compared with the ED diagnosis, but they had greater difficulty correctly identifying sprain/strain (29%-32%) or bruise/abrasion/laceration (38%-47%). They were able to recognize when an injury was not a concussion (specificities, 97%-98%), sprain/strain (91%-92%), dislocation (93%-94%), or bruise/abrasion/laceration (both 93%), but they had more difficulty recognizing when an injury was not a fracture (74%-75%).

There was substantial agreement between participating EDs and ski patrol ($\kappa_w = 0.65$; 95% CI, 0.54-0.75) for injured body region, and there was a fair agreement ($\kappa = 0.29$; 95% CI, 0.22-0.37) for injury type (Table 5).

TABLE 4. Crude and Adjusted Association Between Injury Type and Aerial versus Nonaerial Feature Use Among Snowboarders Injured in a TP

Injury Type*	Crude OR	95% CI	Adjusted OR†	95% CI
Sprain/strain	0.49	0.27-0.89	0.55	0.29-1.08
Bruise/abrasion/laceration	0.73	0.39-1.39	0.90	0.44-1.85
Concussion	1.42	0.62-3.27	1.50	0.59-3.83
Soft tissue/pain/other	1.39	0.69-2.80	1.59	0.75-3.37

*Base outcome was fracture/dislocation.
†Adjusted for music use.

TABLE 5. Summary of Agreement Between Ski Patrol and ED Physician for Injured Body Region and Injury Type Among Snowboarders Injured in a TP

		Agreement (%)	Expected agreement (%)	Kappa	95% CI	Interpretation*
Injured body region						
All EDs and HCPs vs ski patrol	Weighted	89.03	68.13	0.66	0.57-0.74	Substantial
Participating EDs vs ski patrol	Weighted	89.08	69.13	0.65	0.54-0.75	Substantial
Injury type						
All EDs and HCPs vs ski patrol	Nonweighted	47.29	23.47	0.31	0.25-0.37	Fair
Participating EDs vs ski patrol	Nonweighted	47.92	26.19	0.29	0.22-0.37	Fair

*Based on the interpretation by Landis and Koch.[18]

DISCUSSION

Regardless of feature type, upper extremity injuries were the most common, specifically the wrist. This parallels non-TP findings.[2,21,22] We observed a higher proportion of upper extremity injuries on nonaerial features. Conversely, there were more trunk and head/neck injuries on aerial features. There were significantly higher relative odds of head/neck and trunk injuries on aerial features. Jumping has been associated with a 4-fold increase in the injury rate,[23] and 52% to 77% of snowboarding spinal injuries involved jumping.[24,25] A possible explanation is that there is greater opportunity to lose balance when airborne, and the tendency is for the center of gravity (trunk region) to first contact the ground. This may be followed by striking the head.

Helmets were mandatory in the TP, and this was strictly enforced. Despite snowboarding in a riskier environment, the observed proportion of head injuries (14%) was no higher than the proportions reported in non-TP snowboarding research.[2,6,26,27] Brooks et al[10] found that concussion and head injuries were more common in the TPs compared with regular slopes and that the majority of injured TP users did not wear a helmet; however, the exact results were not reported.

It seems that snowboarders who fall from a greater height do not brace for impact with their arms or legs. Because nonaerial features are closer to the ground, the snowboarder may experience a crumpling fall and brace with an outstretched hand. The relative odds of injury to the head/neck and trunk were adjusted for ability. Therefore, the relationship cannot be explained by snowboarders who perceive themselves as experts choosing more challenging and intimidating features (ie, aerial features).

Prevention strategies of TP injury need to focus on improving the safety of the environment, such as reducing the size of the jumps and controlling speed into jumps, teaching proper falling technique, emphasizing gradual pursuit of more difficult features, promoting effective protective equipment (such as wrist guards[28] and helmets),[29] and evaluating emerging protective equipment use such as back protectors and padded ski pants. However, with the exception of helmets and wrist guards, these strategies need to be rigorously evaluated.

When compared with ED physician diagnoses, ski patrollers were better at determining injured body region than injury type. Ski patrollers have comparatively less training and receive no radiological confirmation. Ski patrollers may incorrectly assess many injuries as fractures, given that they are the first responders and are trained to err on the side of caution and assume the worst potential injury to ensure that medical treatment is sought. There were no on-site physicians at the resort.

Küpper et al[13] found that 78% of Swiss ski patrol diagnose ski and snowboard injuries "correctly" and another 12% were "mainly correct" when compared with physicians. Compared with ski patrollers at the study resort, the Swiss ski patrollers had more extensive training, and it was unknown if there was an on-site physician.

It is intuitive that ski patrollers would be better able to classify a body region than injury type. Injured snowboarders will inform ski patrollers where they are experiencing pain but may not be able to precisely indicate where the pain is occurring. For example, a ski patroller may assess a wrist injury, whereas the physician may diagnose a lower arm injury. From an injury prevention perspective, there may be little practical difference between these injuries because wrist guards could help prevent them both.[28] There were instances when the injuries reported on the ED medical record could not be placed into an ARF category, such as the ED diagnosis of soft tissue injury. This will have contributed to the reduced agreement for injury type.

There are limitations to this study. It is likely that not all eligible snowboarders were captured: those who did not seek ski patrol assistance and/or presented to a nonparticipating ED were missed. This would lead to an underestimation of injuries. If the missed injuries were minor and occurred on nonaerial features, this would explain the nonsignificant but reduced relative odds of the minor injury group of bruise/abrasion/laceration on nonaerial versus aerial features. Thirty-three snowboarders (38 injuries) did not consent and were not included in the diagnostic accuracy analysis.

There is the potential for misclassification by outcome for snowboarders who saw the ski patrol. This is a greater concern for injury type than body region because ski patrollers and ED physicians had better agreement for injured body region. In addition, when snowboarders had 1 body region and 2 injury types (generally fracture and sprain/strain) recorded on the ARF, the most severe injury type was chosen, which may have resulted in misclassification. If these snowboarders were classified as a fracture when they truly had a sprain/strain, then the odds ratio would be further from the null. This should have applied similarly to both those injured on aerial and nonaerial features, among a variety of injury type combinations, and only applied to 7 snowboarders. Therefore, it is unlikely to change the results. Also, a diagnosis reported by the injured snowboarder during the telephone interview obtained from a nonparticipating ED physician was considered correct, and this may have resulted in the misclassification if the snowboarder provided the wrong diagnosis. It is unlikely that any misclassification would be related to a particular feature type or a particular body region or injury type.

Although a wide variety of demographic and environmental characteristics were collected, important confounders may have been overlooked, such as the maneuver being attempted on the feature. Also, the ability confounded the relationship between feature type and injured body region, but the ability was self-reported, potentially leading to residual confounding.

We grouped injuries into homogeneous categories (eg, fractures). However, there may be variation within these categories (eg, certain types of fractures) related to aerial or nonaerial TP feature. The lack of detail provided on the ARFs precluded exploring this possibility. There is no on-site physician at the resort and ski patrollers assess injuries without diagnostic imaging.

This study was completed over 2 seasons at 1 resort. Although each resort designs its own TP, this resort changed the layout in the middle of each season, so 4 different TPs were used. We believe this enhances the generalizability of the results.

CONCLUSIONS

We believe that this is the first study to identify injured body regions and types of injuries on aerial and nonaerial TP features. The upper extremities were the most commonly injured body region, and fractures were the most common injury type. Although injury type did not vary by aerial and nonaerial features, there were relatively more head/neck and trunk injuries on aerial features, and injured body regions on nonaerial features tended to be the upper and lower extremities. When compared with ED medical records, ski patrollers were more accurate assessing injured body region than injury type. Previous studies have used ski patrol ARF data, and these findings highlight the potential for misclassification, particularly for injury type. Researchers and readers alike must remember this potential source of bias when the injury information is not obtained by a physician.

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