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Epidemiology of Feature-Specific Injuries Sustained by Skiers in a Snow Park

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Objective.—The objective of the present case series study was to analyze injury types and injured anatomic locations resulting from skiing in snow park (SP) features and to determine potential risk factors for ski injuries in an SP.

Methods.—The study was conducted during the 2013–2014 winter season in the SP of a major winter resort located in the Spanish Pyrenees. Cases involved skiers who experienced feature-related injuries in the SP. A total of 113 cases met the inclusion criteria. Logistic regression was used to calculate the odds of injury types and injury to anatomic locations on aerial versus nonaerial features.

Results.—The overall injury rate was 0.9 per 1000 skier runs. The proportion of injuries was higher for aerials (1.18% of uses) than for nonaerials (0.66% of uses). Results revealed that the upper extremities were the most commonly injured body region, and sprains/strains/dislocations and fractures were the most common injury type.

Conclusions.—The most commonly injured anatomic location on nonaerial features was the face, while on aerial features it was the head. A higher proportion of fractures was observed on aerial features, while a higher proportion of sprains/strains/dislocations was observed on nonaerial features. Prevention strategies to reduce injury risk include SP redesign, safety and communication policies, instruction on technical skills, and promotion of the use of protective equipment.

Key words: skiing, snow park, feature, anatomic location, injury type

Introduction

Snow parks (SPs) are delimited facilities designed to contain different manmade features that allow users, also known as "freestylers," to perform a wide range of maneuvers and stunts ("freestyling").[1,2] Russell et al[3] classify these features into 2 groups: aerial features and nonaerial features.

Aerial features consist of halfpipes and jumps (snow or snow-covered dirt piles) of various heights that allow users to project themselves into the air, where a variety of tricks such as twists, grabs (the freestylers grab their skis while in the air), somersaults, or spins may be performed. A halfpipe is a cut into a snow-covered slope to form a U-shaped structure resembling a half section of a large-diameter pipe in which 2 concave walls face each other across a flat transition. The freestyler launches off the lip of one of the walls and straight up into the air, performs a maneuver, lands on the same wall, rides down the wall, crosses the transition, and repeats on the opposite wall. The sequence can be repeated as many times as the length of the halfpipe permits.

Nonaerial features, also known as "jibs," commonly include different shapes of rails and boxes on which to slide. Rails are long (~15 to 20 feet in length), thin (~2.5 to 4.5 inches in diameter) metal bars overhanging the snow (~2 to 3 feet in height) that freestylers hop onto, slide along with their skis perpendicular to the ground, and drop themselves off. Rails can be of various shapes; the most common are "flat rail" (straight), "c-rail" (c-shaped), and "s-rail" (s-shaped).

Boxes are long (~15 to 20 feet in length), wide (~15 to 18 inches in width) rectangular structures, usually made out of wood with rounded metal edges and a plastic top, placed on the snow (~1.5 to 3.5 feet in height) that users slide along with their skis either parallel or perpendicular to the ground. These features include a small ramp leading straight onto the box and

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another ramp for exiting it leading straight onto the ground. Boxes can also be of various shapes; the most common are "flat box" (straight), "c-box" (c-shaped), and "rainbow box" (∩-shaped).

Previous research comparing skiing and snowboarding injuries sustained in SPs with those sustained on traditional slopes provides evidence that injuries sustained in the former were both proportionately more frequent and far more likely to be more severe than those sustained in the latter.[2,4–9] Researchers have found that, compared with traditional slopes, skiers in SPs are significantly more likely to sustain head and neck, trunk, and severe upper extremity injuries,[4] fractures, and concussions.[7] However, it is unknown whether feature-specific skier injury types or anatomic locations of injury differ for aerial and nonaerial features.

There is a dearth of research examining the characteristics of feature-specific injuries sustained by skiers in SPs. Consequently, the objectives of this study were to identify the most common types and anatomic locations of injury resulting from skiing on aerial and nonaerial SP features, determine potential risk factors for SP injuries, and calculate the odds of injury to body regions and injury types on aerial versus nonaerial features.

Methods

This study was conducted in the SP of a winter resort located in the Spanish Pyrenees, between December 2013 and April 2014. The SP was delimited, and its design did not vary during the season. Helmets were mandatory in the SP.

Cases involved skiers injured in the SP while performing a maneuver on a feature. They were chosen after a detailed check of the resort's ski patrol accident forms and the records of the only nearby emergency, trauma, and medical hospital (ETMH). Non–feature-related injuries were excluded because these are not related to the specific risks of using freestyle elements. If a skier had a ski patrol accident form and was also examined at the ETMH, the physician's diagnosis was used.

Data collection included contact information, demographics (sex and age group), self-reported skill level, environmental circumstances (visibility and snow, weather, and wind conditions), feature used at the time of accident (aerials: halfpipe, big jump [∼4 m], or jump [∼1 m]; nonaerials: flat rail, c-rail, flat box, or rainbow box), type of injuries (fracture, concussion, sprain/strain/dislocation, abrasion/laceration/bruise, and pain/swelling), and injured anatomic locations, which were classified into 4 "body regions": 1) head/neck (head, face, and neck); 2) trunk (back, chest, and pelvis/hip); 3) upper extremity (shoulder, clavicle, upper arm, elbow, lower arm, wrist, and hand); and 4) lower extremity (thigh, knee, lower leg, and ankle/foot). In addition to accident forms and ETMH records, telephone interviews were conducted to collect missing data.

The total number of runs and the total number of times each feature was used were estimated to obtain denominator data on skier runs and feature use. For that purpose, 2 teams of 3 observers took turns to cover the 6 hours per day (10:00–16:00) during which the SP was open. Skier runs were counted by 1 member at the entrance to the SP, while the 2 remaining members, in the middle and at the bottom of the SP, respectively, recorded use of those features allotted to each of them.

This procedure was repeated for each and every day in the sample period. These days were chosen according to 2 sets of computer-generated random numbers: 1 set of random numbers was generated to select a subsample among the population of working days in the season, and a second set of random numbers was generated to select a subsample from among the population of public holidays (weekends, Christmas, and Easter).

The overall injury rate was calculated as injuries per 1000 runs; the numerator was the number of injured skiers over the season, and the denominator was the estimated total runs. Feature-specific injury rates were also calculated; the numerators were the number of skiers injured on each particular type of feature, and the denominators were the estimated total number of times each had been used.

The proportions of injured anatomic locations, body regions, and injury types, with 95% CIs, were calculated for aerial (halfpipe, big jump, and jump) and nonaerial (flat rail, c-rail, flat box, and rainbow box) features. Multinomial regression was used to determine the associations between aerial versus nonaerial feature exposure and injured body region.

Variables tested were sex (male or female), age group ($<$20, 20–40, or $>$40 years), self-reported skill level (novice, intermediate, advanced, or expert), snow (grippy, icy, or slushy), weather (sunny, overcast, or snowy), wind (calm [$\leq$10 km/h], moderate [11–35 km/h], or strong [$\geq$36 km/h]), and visibility (good, moderate, or poor), all of them multitiered except for sex. According to the information provided by the variables to generate the model, the self-rated skill had the greatest impact in the model.

A crude model was generated in which the exposure was a feature and the outcome was an injured body region, with upper extremity as the base outcome. The modeling process was repeated with injury type as the outcome and sprain/strain/dislocation as the base outcome. Analyses were conducted in SPSS 22.0. This study was conducted with the approval of the University of Zaragoza research board.

Results

Once the 11 non–feature-related ski injuries that had taken place in the SP were excluded, a total of 113 cases met the inclusion criteria. For an estimated number of 125,500 skier runs in the SP during the season, the overall injury rate was 0.9 per 1000 skier runs. The proportion of injuries was higher for aerials (1.18% of uses) than for nonaerials (0.66% of uses), and was highest for big jumps (2.91% of uses) and lowest for boxes (0.17% of uses).

A summary of injured anatomic locations, grouped by body regions, for nonaerial and aerial features is shown in Table 1. The most commonly injured anatomic locations on nonaerial features were the face, shoulder, and lower arm, while on aerial features they were the head, shoulder, and wrist. However, when collapsed into 4 categories (head/neck, trunk, upper extremity, and lower extremity), the profiles of the injured body regions did not vary by aerial and nonaerial features. In both cases injured skiers had more upper extremity and head/neck injuries, although the former doubled the latter when accidents occurred on nonaerial features.

The crude odds of trunk injuries, when compared with the upper extremity injuries, were higher on aerial than on nonaerial features (Table 2). Adjusted ORs show a significant association between lower extremity (OR 1.9; 95% CI 0.89–4.2) versus upper extremity injuries and feature type. There were no significant associations between head/neck or trunk versus upper extremity injuries and feature type.

Table 2. Crude and adjusted associations between injured body regions and aerial versus nonaerial feature use among skiers injured in an SP

*Body region**	*Crude OR*	*95% CI*	*Adjusted OR*†	*95% CI*
Head/Neck	0.7	0–1.55	0.8	0.49–1.56
Trunk	1.1	0–1.96	0.8	0.41–1.71
Lower Extremity	0.8	0–1.7	1.9	.89–4.2

SP, snow park.

* Base outcome was Upper Extremity.

† Adjusted for self-rated skill.

A summary of injury types for nonaerial and aerial features is shown in Table 3. The most common injury types were sprains/strains/dislocations, fractures, and abrasions/lacerations/bruises. A higher proportion of fractures was observed on aerial features, while a higher proportion of sprains/strains/dislocations was observed on nonaerial features.

Table 1. Injured anatomic locations, grouped by body regions, for nonaerial and aerial features among skiers in an SP

		Nonaerial (n = 47)		*Aerial (n = 66)*	
Body region	*Anatomic location*	*%*	*95% CI*	*%*	*95% CI*
Head/Neck	Head	8.5	0.5–16.5	13.6	5.3–21.9
	Face	12.8	3.2–22.4	9.1	2.2–16.0
	Neck	2.1	0–6.2	7.6	1.2–14.0
	All	23.4	11.3–35.5	30.3	21.8–38.8
Trunk	Back	8.5	7.6–16.5	7.6	1.2–14.0
	Chest	2.1	3.0–6.2	3.0	0–7.1
	Pelvis/Hip	6.4	3.0–13.4	3.0	0–7.1
	All	17.0	6.3–27.7	13.3	5.1–21.5
Upper Extremity	Shoulder	10.6	1.8–19.4	9.1	2.2–16.0
	Clavicle	8.5	0.5–16.5	4.5	0–9.5
	Upper arm	2.1	0–6.2	7.6	1.2–14.0
	Elbow	2.1	0–6.2	3.0	0–7.1
	Lower arm	10.6	1.8–19.4	3.0	0–7.1
	Wrist	8.5	0.5–16.5	9.1	2.2–16.0
	Hand	4.3	0–10.1	6.1	0.3–11.9
	All	46.7	32.4–61.0	42.4	33.3–51.5
Lower Extremity	Thigh	2.1	0–6.2	3.0	0–7.1
	Knee	8.5	0.5–16.5	6.1	0.3–11.9
	Lower leg	2.1	0–6.2	3.0	0–7.1
	Ankle/Foot	.0	0–0	1.5	0–7.1
	All	12.7	6.6–18.8	13.6	5.3–21.9

SP, snow park.

Table 3. Injury types for nonaerial and aerial features among skiers injured in an SP

	Nonaerial (n = 47)		*Aerial (n = 66)*	
Injury type	*%*	*95% CI*	*%*	*95% CI*
Fracture	25.5	13.0–38.0	34.8	23.3–46.3
Concussion	4.3	0–10.1	13.6	5.3–21.9
Sprain/Strain/Dislocation	38.3	24.4–52.2	27.3	16.6–38.0
Abrasion/Laceration/Bruise	21.3	9.6–33.0	15.2	6.5–23.9
Pain/Swelling	10.6	1.8–19.4	9.1	2.2–16.0

SP, snow park.

The crude odds of a concussion, when compared with sprain/strain/dislocation, were significantly lower on aerial versus nonaerial features (Table 4). Adjusted values show a significant association between pain/swelling (OR 1.8; 95% CI 0.7–4.4) versus sprain/strain/dislocation and feature type. There was no other significant association between type of feature used and injury type in the crude or adjusted models.

Discussion

The aim of the present study was to analyze the records of feature-specific ski accidents sustained in an SP to identify the most common types and anatomic locations of injury and to calculate the odds of injury types and injury to body regions on aerial versus nonaerial SP features.

Injury rates were higher for aerials than for nonaerials, although the patterns of the injured body regions did not vary by type of features. In both aerial and nonaerial features skiers experienced more upper extremity injuries, more commonly the wrist, which parallels previous findings on regular slopes.[4,10]

We found that the most commonly injured anatomic location on nonaerial features was the face, while on aerial features the head was the most commonly injured anatomic location. In this regard, Brooks et al[7] found head injuries to be more common in SPs compared with regular slopes, although exact results were not provided.

The crude odds of trunk injury, when compared with the upper extremity, were higher on aerial versus nonaerial features. We agree with the hypothesis that there is more opportunity to lose one's balance when airborne, and the tendency is for the center of gravity, located in the trunk region, to contact the ground first.[11]

A higher proportion of fractures was observed on aerial features, while a higher proportion of sprains/strains/dislocations was observed on nonaerial features. We hypothesize that aerial features, which facilitate more air time and a larger drop to the ground, afford skiers more chances of losing their balance and landing with more force, thus increasing the likelihood of fracture, while on nonaerial features, which are close to the ground and can be ridden while spinning around, skiers may experience crumpling falls.

Injury prevention should focus on risk mitigation through identifying ways to reduce injuries without sacrificing participation. Preventive strategies should be devised to target improving both the safety of the environment and the safety of skiers. It has been hypothesized that such strategies could lead to SP design changes that decrease injury, such as restricting access to particularly hazardous features, reducing the height of aerials and the length and/or complexity of nonaerials, controlling speed and slope into jumps for takeoffs, marking landings, and including less difficult features for beginners.[3,7,10–12] Most US ski resorts with larger SPs now count on "step-up" parks designed for

Table 4. Crude and adjusted association between injury type and aerial versus nonaerial feature use among skiers injured in an SP

Injury type[*]	*Crude OR*	*95% CI*	*Adjusted OR*[†]	*95% CI*
Fracture	0.52	0.43–.61	.9	0.5–1.6
Concussion	0.23	0.15–.30	1.15	0.5–2.7
Abrasion/Laceration/Bruise	0.98	0.97–1.01	1.4	0.7–2.8
Pain/Swelling	0.83	0.76–.90	1.8	0.7–4.4

SP, snow park.
* Base outcome was sprain/strain/dislocation.
† Adjusted for self-rated skill.

skill building prior to exposure to more dangerous features.

It has also been deemed advisable for safety and communication policies to be created with the aim at rationalizing SP use by providing the means and guidance necessary for freestylers to identify the difficulty, conditions, and dangers of each particular feature at all times and the skill levels required to use them (eg, with ratings, as in traditional slopes).[3,7] A good example of this is the National Ski Areas Association campaign used by most US ski resorts called "smart style," which emphasizes the proper use of terrain parks.

Promoting instruction focusing on technical jumping and landing skills and/or establishing mandatory lessons before granting access to difficult features has also been considered a possibility for decreasing injury.[7,11,12] However, these strategies still need to be rigorously evaluated.

A strategy that has already proved to be effective for injury prevention is advising the use of protective equipment, such as helmets and wrist guards, which have been shown to reduce head and arm injury risk.[10,11] The efficacy of other protective equipment, such as back protectors, padded pants, or ski airbags, still needs to be investigated.

LIMITATIONS

The study findings are limited by the fact that our results only apply to feature-specific ski injuries and thus cannot be extrapolated to freestyle snowboarders. Furthermore, this study was conducted at only 1 resort, and its SP layout and the type and number of features remained unchanged during the season, which may limit the generalizability of the results.

Only injuries reported to and seen by the ski patrol or the ETMH were analyzed, which means that data on injuries, probably minor, seen directly by another health care provider outside the resort's sphere of influence were not picked up by the study. This would lead to an underestimation of injuries and so to reduced odds of the minor injury groups of abrasion/laceration/bruise and graze/swelling.

Conclusions

To the best of our knowledge, no other study has identified types of ski injuries and injured anatomic locations on aerial and nonaerial SP features. Injury rates were higher for aerial than for nonaerial features. The upper extremity body region was the most commonly injured, and fractures and sprains/strains/dislocations were the most common injury type. The most commonly injured single anatomic location on nonaerial features was the face, while on aerial features it was the head. A higher proportion of fractures was observed on aerial features, while a higher proportion of sprains/strains/dislocations was observed on nonaerial features. Prevention strategies to reduce injury risk include SP redesign, safety, and communication policies, instruction on technical skills, and promotion of the use of protective equipment.

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