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Abstract: Previous research suggests that snow park (SP) injuries are proportionally more frequent and more likely to be more severe than those sustained on traditional slopes. The aim of this study was to calculate skiers' overall and feature-specific injury rates and determine potential risk factors for severe injury in an SP.
This is a retrospective study conducted during the 2013/2014 winter season in the SP of a major winter resort located in the Spanish Pyrenees. Cases were skiers who suffered feature-related injuries in the SP. Denominator data consisted of the estimated total number of skier runs and the estimated total number of times each feature was used by a skier. Injury rates were calculated and logistic regression used to determine the feature-specific odds of injury.
A total of 113 cases met the inclusion criteria. The overall injury rate was of 0.9 per 1000 skier runs. Rates of injury were highest for Big jumps (2.9/1000 uses) and lowest for Rainbow boxes (0.1/1000 uses). Compared with Boxes, there were increased odds of severe injury versus minor injury for C-rails (OR 9.1; 95% CI 0.6 to 13.18), Half-pipe (OR 4.5; 95% CI 0.3 to 6.27) and Big jumps (OR 3.0; 95% CI 0.3 to 3.53).
Higher feature-specific ski injury rates and increased odds of injury were associated with features that require a very clean technique or promote aerial maneuvers and result in a larger drop to the ground.

***Highlights**

- In this study, the overall injury rate for skiing snow park (SP) injuries is 0.9 injuries per 1000 runs.
- The injury rates are highest for Big jumps (2.9/1000 uses) and lowest for Rainbow boxes (0.1/1000 uses).
- Compared with Boxes, there were increased odds of injury for C-rails and Big jumps.
- Injury prevention programs in SPs can be tailored to those at greatest risk of severe injury.

Feature-specific ski injuries in snow parks

ABSTRACT

Previous research suggests that snow park (SP) injuries are proportionally more frequent and more likely to be more severe than those sustained on traditional slopes. The aim of this study was to calculate skiers' overall and feature-specific injury rates and determine potential risk factors for severe injury in an SP.

This is a retrospective study conducted during the 2013/2014 winter season in the SP of a major winter resort located in the Spanish Pyrenees. Cases were skiers who suffered feature-related injuries in the SP. Denominator data consisted of the estimated total number of skier runs and the estimated total number of times each feature was used by a skier. Injury rates were calculated and logistic regression used to determine the feature-specific odds of injury.

A total of 113 cases met the inclusion criteria. The overall injury rate was of 0.9 per 1000 skier runs. Rates of injury were highest for Big jumps (2.9/1000 uses) and lowest for Rainbow boxes (0.1/1000 uses). Compared with Boxes, there were increased odds of severe injury versus minor injury for C-rails (OR 9.1; 95% CI 0.6 to 13.18), Half-pipe (OR 4.5; 95% CI 0.3 to 6.27) and Big jumps (OR 3.0; 95% CI 0.3 to 3.53). Higher feature-specific ski injury rates and increased odds of injury were associated with features that require a very clean technique or promote aerial maneuvers and result in a larger drop to the ground.

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1. INTRODUCTION

In an attempt to address safety issues by reducing collisions between regular slopes users and freestylers, ski resorts began to delimit specific areas for the latter called snow parks (SPs) (Langran, 2014). Before long, resorts worldwide were competing to create the best SP and the vast majority now have one (Carús, 2014). SPs are facilities designed to contain a variety of man-made features that allow users to perform a wide range of maneuvers and stunts (Audema et al., 2007; Langran, 2014; Moffat et al., 2009). Russell et al. (2011) classify these features into two groups: aerial features or ‘jumps’ and non-aerial features or ‘jibs’.

Aerial features comprise half-pipes and several forms of jumps. Various tricks, such as twists, grabs, somersaults or spins, may be performed while airborne after jumping. Jibs commonly include different shapes of rails and boxes on which to slide that can be ridden parallel or perpendicular to the ground, or while spinning around (Moffat et al., 2009). In both cases design variables, such as height, width, length, shape or launch and landing angles, condition their complexity and, therefore, the amount of risk involved in maneuvering in them (Carús, 2014). Descriptions of the various features are available at: http://www.whitelines.com/trick-tips/how-to-freestyle/snowpark-features.html/13, and at http://www.arenasnowparks.com /rails-and-boxes/overview/

Freestyling in SPs involves serious risks to freestylers. According to Brooks et al. (2010) no less than 26.7% of all injuries registered at two US ski areas over five seasons occurred in SPs, and Goulet et al. (2007) deduce that the increase in the rate of injuries experienced in Québec ski resorts from 1995 to 2000 coincides with an increase in the number of ski areas where SPs are offered, suggesting an association between them and an increased risk of injury.

Furthermore, specific studies comparing skiing and snowboarding injuries sustained in SPs with those sustained on regular slopes provide evidence that injuries sustained in the former were more likely to be more severe than those sustained in the latter (Goulet et al., 2007; Laporte et al., 2011; Greve et al., 2009; Moffat et al., 2009; Brooks et al., 2010; Ekeland and Rodven, 2011; Henrie et al., 2011).

While pioneering research enables us to begin describing injury patterns seen in SPs (Goulet et al., 2007; Moffat et al., 2009; Ruedl et al., 2013; Russell et al. 2013), authors such as Brooks et al. (2010) and Russell et al. (2011) observed that rather less was known about risk factors for SP features in particular and feature-specific injury profiles in SPs had yet to be examined.

A first step into this line of research was taken by Russell et al. (2014). Their study began to help to bridge this gap through insights into snowboarders’ overall and feature-specific SP injury rates and through determining potential risk factors for snowboard injuries in an SP. They found that the overall injury rate was 0.75/1000 runs; feature-specific injury rates were highest for jumps and half-pipe, and lowest for rails and quarter-pipes. They concluded that higher feature-specific snowboard injury rates and increased odds of injury were associated with features that promote aerial maneuvers or a large drop to the ground.

Further research is now needed to identify injury rates and risk factors for skiers in SPs in relation to injury mechanisms. Consequently, the aim of the present study is to add feature-specific SP injuries in skiers to the literature by investigating skiers’ overall and feature-specific SP injury rates and determining potential risk factors for severe injuries in an SP.

2. METHODS

This is a retrospective study conducted during the 2013/2014 winter season in the SP of a major winter resort located in the Spanish Pyrenees. The SP was delimited, its layout and the type and number of features remained unchanged during the season, and its grounds were groomed daily. Helmets were mandatory in the SP.

Cases were skiers injured in the SP who were examined by either an experienced and medically trained ski patroller and/or by an emergency physician at the only nearby (five kilometers by road) emergency, trauma, and medical hospital (ETMH). If a skier was examined by both, the physician's diagnosis was used instead of the ski patroller's assessment. Severe cases were defined as fractures of any type or location, concussions, ruptures, sprains, strains, and dislocations, while minor injuries were defined as abrasions, lacerations, bruises, grazes, and swellings. Non-feature related injuries (e.g., collisions with people or objects other than features) were not included because these are not related to the specific risks of using freestyle elements.

Case data were collected from ski-patrol Accident Forms (AF), which are mandatory for anyone injured and assisted by patrolmen, and ETMH medical records. Data collection included contact information, date, and time of injury, gender (male or female), age group (<20, 20-40 or >40), self-reported skill level (novice, intermediate, advanced or expert), type of feature used when the injury occurred (Half-pipe, Big jump [~4 m], Jump [~1m], Flat rail, C-rail, Flat box or Rainbow box), type of injury, and injured anatomic location. Missing data were collected by telephone.

Actual data on environmental conditions—snow, weather, visibility, and wind—were obtained from the resort's daily weather forecasts issued online on a three-hour basis (~07:30, ~10:30, and ~13:30) and recorded on a daily basis. Snow, weather, and visibility conditions were checked onsite on the days making up the sample.

Similar to the methodology used by Russell et al. (2014) for collecting data on SP and feature use, two teams of three observers took turns to cover the six hours (10:00–16:00) the SP opened to gather denominator data on skier runs and on feature use. Skier runs were counted by one member at the entrance to the SP, who also checked skier gender and asked skiers entering the SP about their skill level and, when in doubt, about the age group they belonged to. The two remaining members were located in the middle of the upper half of the hill and in the middle of the lower half of the hill, respectively, so that every feature was fully visible to one or the other. They recorded use of those features allotted to each of them as they were within their domain.

Data were gathered as described above for the days that made up the sample. These days were chosen on the basis of two sets of computer-generated random numbers: one set of random numbers was generated to select a representative subsample among the population of working days in the season, and the other set was generated to select a representative subsample from among the population of public holidays—weekends, bank holidays, Christmas, and Easter—. Denominators were calculated as the addition of the subsample means multiplied by their respective populations (working days/public holidays).

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 type had been used. Gender, age group, and self-rated skill level injury rates were also calculated; the numerators were the number of injured skiers belonging to each gender/age group/self-rated skill level, and the denominators were the total number of runs estimated for each gender/age group/self-rated skill level, respectively.

The distributions of potential risk factors between severe cases and minor cases were compared using proportions for dichotomous/polytomous variables. Unadjusted OR with

95% CIs were calculated. Logistic regression was used to determine the association between severe injury versus minor injury and feature using backwards elimination (Visauta, 2007). Potential confounders were gender, age group, self-rated ability, and environmental conditions (snow, weather, visibility, and wind). These were entered into the model containing the feature (Half-pipe, Big jump, Jump, Flat rail, C-rail, Flat box, and Rainbow box). A crude model was generated where the exposure was an injury and the outcome was a feature, with boxes as the base outcome. Data on the features with the lowest injury rates (Rainbow box and Flat box) were regrouped. Analyses were conducted in SPSS 22.0.

3. RESULTS

A total of 113 cases (21 ski patrol only, 82 ski patrol and ETMH and 10 ETMH only) met the inclusion criteria, reflecting an overall injury rate of 0.9 per 1000 skier runs. When skiers that had only been assisted by the ski patrol were contacted, they were asked whether they had seen another health-care provider on account of their injury, but none of them acknowledged having done so.

A summary of the characteristics of all injured skiers is shown in Table 1. Substantially, the highest proportions of the skiers that sustained feature-specific injuries were male (81.4%), were younger than 20 years of age (54%), and were self-rated as having an advanced level (46%). Predominant environmental conditions when injuries occurred included grippy snow (63.7%), sunny weather (52.2%), good visibility (62.8%), and calm wind (77%). The odds of severe versus minor injuries were significantly higher for novice skiers (OR 2.4; 95% CI 1.2 to 3.6) compared with advanced skiers, and in medium wind conditions (OR 4.3; 95% CI 2.4 to 6.1) compared with calm wind conditions.

Jumps are the most used features in the SP. The highest percentage of all injuries (29.2%) and also of both severe and minor injuries occurred while skiers were using them (Table 2).

Females had a slightly lower injury rate than males, and visibly lower rates of severe versus minor injuries, and of severe injuries compared to males. Though skiers under 20 years of age had the highest rates of severe injuries, injury rates were similar across the age groups. Regarding skill level, expert skiers had the lowest rates of both all and severe injuries (Table 3).

Big jumps, features that promote aerial maneuvers and result in the largest drop to the ground, and C-rails, features that require a very clean technique, had higher injury rates than easier features (boxes) or features that result in smaller drops (jumps) (Table 4). Big jumps and C-rails registered the highest overall—2.9/1000 runs and 1.7/1000 runs, respectively—and severe injury rates. Compared with Rainbow boxes, the features with the lowest injury rates of both all and severe injuries, overall and severe injury rates were higher for Big jumps, C-rails and Flat rails (Table 5).

For severe injury versus minor injury, the adjusted associations between injury and feature use (Table 6) showed significantly higher odds of injury for C-rails and Half-pipe compared with boxes, and lower odds of injury for Flat rails.

4. DISCUSSION

Prior data have shown that injuries in SPs account for a significant proportion of the total number of injuries sustained in ski resorts, result in relatively more severe injuries than those sustained on the slopes (Goulet et al., 2007; Greve et al., 2009; Brooks et al., 2010) and that it is primarily the nature of the features and the design of SPs that leads to severe injury (Goulet et al., 2007; Brooks et al., 2010). Therefore, the health and safety of skiers are important issues for SP management. To the best of our knowledge, no other study has investigated feature-specific injury rates and potential risk factors for SP skiing injuries.

The overall injury rate of SP skiers was estimated at 0.9 per 1000 skier runs, which falls ahead of the estimates made by Russell et al. (2014) for snowboarders (0.75/1000 runs). Similar to their findings for snowboarders, higher feature-specific injury rates were associated with features that promote aerial manoeuvers. We agree with the hypothesis that since aerial features, such as Big jumps, Jumps or Half-pipes, afford more air time, their users may have more opportunity to lose their sense of body position/orientation and land with more force, which would increase the likelihood of injury (Russell et al., 2014).

However, as far as skiers are concerned, higher feature-specific injury rates were also found to be associated with C-rails, features that require a very clean technique. Riding C-rails involves the difficult exercise of making the skis slide perpendicularly to the ground on a narrow metal railing that bends sharply. It requires users to be skilled at maintaining their balance to avoid falling to the ground or hitting a body part on the feature, which would increase the likelihood of injury.

Similar to previous research on ski injuries on regular slopes (Langran and Selvaraj, 2002 and 2004), and in contrast to research on snowboard injuries in SPs (Russell et al., 2014), the odds of severe versus minor injuries in this study were significantly higher for novice skiers compared with advanced skiers. Novices may have ignored their skill level and attempted maneuvers beyond their ability and may have chosen difficult features or have not used them as intended, for example, trying to jump when attempting a rainbow box.

Also similar to SP and non-SP research on practicing snow sports in suboptimal environmental conditions (Hasler et al., 2010; Ruedl et al., 2013; Russell et al., 2014), in this study the odds of severe injury were affected by medium and high wind conditions. When using Jumps, Big Jumps or the Half pipe, a potential association between adverse wind conditions and severe injuries can be hypothesized. These aerial features promote aerial maneuvers whose performance is likely to be negatively affected by medium and high wind conditions, which in turn can result in faulty landings that would also increase the odds of injury.

Although a good number of variables (e.g. height, shape, launch and landing angles, etc.) condition feature complexity, at present there are no agreements on design standards governing their construction or location within SPs (Langran, 2014). Moreover, since no special qualifications are required to gain access to SPs or to especially dangerous features within them, it follows that safety and communication policies should aim to rationalize their use and restrict access to particularly hazardous features.

As Brooks et al. (2010) propose, injury programs might target at risk populations using SPs, and particularly aerial and difficult features. Such programs could lead to design changes that decrease injury, such as less difficult features for beginners and, following Hagel et al. (2004), marking the difficulty of SP features with ratings as in traditional slopes. Even formal instruction targeting skiers and focusing on technical jumping and landing skills may reduce injury (Hayes and Groner, 2008), and lessons could be mandatory before access to difficult features is granted.

Limitations

This study was conducted at only one 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.

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, 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 healthcare provider outside the resort's sphere of influence were not included in the study. This would result in rate underestimation and in associations between feature and injury overestimation if non-included skiers were injured on boxes.

Information on other possible confounders, such as type of stunt performed on a feature, first attempt at a new feature, fatigue, speed, drugs and alcohol consumption or the use of safety gear other than helmets (such as wrist guards or back protectors) was not obtained. However, some of these potential factors have probably been accounted for by other factors such as gender, age, and skill.

Conclusions

Feature-specific injury rates ranged from 2.9 injuries per 1000 uses (Big jumps) to 0.1 injuries per 1000 uses (Rainbow boxes). Big jumps and C-rails were significant risk factors for overall and severe injuries. This study's findings suggest that it is primarily the nature and design of features that leads to severe injury, and that there is an injury problem related to aerial and difficult features and the type of stunts skiers perform on them. Prevention strategies requiring thorough assessment have been proposed to reduce SP injury risk.

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Table 1 Summary of the characteristics of all injured skiers, severe injuries and minor injuries.

		All injuries n=113 (%)	Severe injuries N=82 (%)	Minor injuries N=31 (%)	Severe injuries crude OR (95% CI)*
Gender	Male	92 (81.4)	73 (89.0)	19 (61.3)	
	Female	21 (18.6)	9 (11.0)	12 (38.7)	0.2 (0.0 to 0.4)
Age					
	<20	61 (54.0)	44 (53.7)	17 (54.8)	1.00
	20-40	47 (41.6)	33 (40.2)	14 (45.2)	0.9 (0.6 to 1.2)
	>40	5 (4.4)	5 (6.1)	0	0.00
Skill level					
	Novice	7(6)	6 (7.3)	1 (3.2)	2.4 (1.2 to 3.6)
	Intermediate	37 (33)	29 (35.4)	8 (25.8)	1.5 (1.0 to 1.9)
	Advance	52 (46)	37 (45.1)	15 (48.4)	1.00
	Expert	17 (15)	10 (12.2)	7 (22.6)	0.6 (0.3 to 0.8)
Snow conds.					
	Grippy	72 (63.7)	49 (59.7)	23 (74.2)	1.00
	Icy	15 (13.3)	15 (18.3)	0	
	Slushy	26 (23)	18 (22.0)	8 (25.8)	1.01 (0.0 to 2.1)
Weather					
	Sunny	59 (52.2)	45 (54.9)	14 (45.2)	1.00
	Overcast	42 (37.2)	29 (35.4)	13 (41.9)	0.7 (-0.2 to 1.6)
	Snowy	12 (10.6)	8 (9.8)	4 (12.9)	0.6 (-0.1 to 1.3)
Visibility					
	Good	71 (62.8)	56 (68.3)	15 (48.4)	1.00
	Moderate	29 (25.7)	20 (24.4)	9 (29)	0.6 (-0.2 to 1.4)
	Poor	13 (11.5)	6 (7.3)	7 (22.6)	0.2 (-02 to 0.7)
Wind					
	Calm	87 (77)	59 (72)	28 (90.3)	1.00
	Medium	20 (17.7)	18 (22)	2 (6.5)	4.3 (2.4 to 6.1)
	High	6 (5.3)	5 (6)	1 (3.2)	2.4 (0.9 to 3.9)

*Compared with minor injuries.

Table 2 Features used by all injured skiers

	All injuries N=113 (%)	Minor injuries N=31 (%)	Severe injuries N=82 (%)	Features used N= 229177(%)
Half-pipe	6 (5.3)	1 (3.2)	5 (6.1)	17908 (7.8)
Big jumps	27 (23.9)	7 (22.6)	20 (24.4)	9253 (4.0)
Jumps	33 (29.2)	8 (25.8)	25 (30.5)	72401 (31.6)
Flat rails	22 (19.5)	3 (9.7)	19 (23.2)	43073 (18.8)
C-rails	12 (10.6)	8 (25.8)	4 (4.9)	6963 (3.0)
Flat boxes	11 (9.7)	4 (12.9)	7 (8.5)	61251 (26.7)
Rainbow boxes	2 (1.8)	0	2 (2.4)	18328 (8.0)

Table 3 Overall, gender-specific, age-specific and skill-specific injury rates (per 1000 runs and 95% CI)

	N	All injuries rate (95% CI)	N	Severe injuries rate (95% CI)
Overall	113	0.9 (0.7 to 1.1)	82	0.7 (0.5 to 0.8)
Gender				
Males	92	0.9 (0.7 to 1.1)	73	0.7 (0.6 to 0.9)
Females	21	0.8 (0.5 to 1.1)	9	0.3 (0.1 to 0.6)
Age				
<20	61	0.9 (0.7 to 1.2)	44	0.7 (0.5 to 0.9)
20-40	47	0.9 (0.6 to 1.2)	33	0.6 (0.4 to 0.8)
>40	5	0.6 (0.1 to 1.1)	5	0.6 (0.1 to 1.1)
Skill Level				
Novice	7	1,1 (0,3 to 1,9)	6	1,0 (0,2 to 1,7)
Intermediate	37	1,2 (0,8 to 1,6)	29	0,9 (0,6 to 1,3)
Advanced	52	0,9 (0,6 to 1,1)	37	0,6 (0,4 to 0,8)
Expert	17	0,6 (0,3 to 0,9)	10	0,3 (0,1 to 0,6)

Table 4 All and severe injury rates (per 1000 feature expousures and 95% CI)

	All injuries rate (95% CI)	Severe Injuries rate (95% CI)
Half-pipe	0.3 (0.1 to 0.6)	0.3 (0.0 to 0.5)
Big jumps	2.9 (1.8 to 4.0)	2.2 (1.2 to 3.1)
Jumps	0.5 (0.3 to 0.6)	0.3 (0.2 to 0.5)
Flat rails	0.5 (0.3 to 0.7)	0.4 (0.2 to 0.6)
C-rail	1.7 (0.7 to 2.7)	0.6 (0.0 to 0.2)
Flat boxes	0.2 (0.1 to 0.4)	0.1 (0.0 to 0.2)
Rainbow boxes	0.1 (0.0 to 0.3)	0.1 (0.0 to 0.3)

Table 5 Feature-specific injury rate ratios and 95 % CI

	All injuries		Severe injuries	
	Cases	RR (95%)	Cases	RR (95%)
Half-pipe	6	3.1 (2.3 to 3.9)	5	2.6 (1.8 to 3.3)
Big jumps	27	26.7 (23.5 to 30.0)	20	19.8 (17.0 to 22.6)
Jumps	33	4.2 (4.0 to 5.3)	25	3.2 (2.8 to 3.6)
Flat rails	22	4.7 (4.0 to 5.3)	19	4.0 (3.4 to 4.6)
C-rails	12	15.8 (12.9 to 18.7)	4	5.3 (3.6 to 7.01)
Flat boxes	11	1.6 (1.3 to 2.0)	7	1.0 (0.8 to 1.3)

Table 6 Association between injury and feature type after controlling for confounders (OR and 95% CI))

	Severe injuries vs minor injuries*	
	Crude OR (95%CI)	Adjusted OR (95% CI)
Half-pipe	2.2 (1.5 to 2.9)	4.5 (0.3 to 6.27)
Big jumps	1.3 (0.5 to 2.0)	3.0 (0.3 to 3.53)
Jumps	1.4 (1.1 to 1.7)	2.7 (0.2 to 3.15)
Flat rails	2.8 (2.3 to 3.3)	0.9 (0.1 to 1.24)
C-rails	0.2 (-0.1 to 0.6)	9.1 (0.6 to 13.18)

*Adjusted for gender and visibility.
The rest of potential confounders did not change significantly any of the feature-specific estimates.