

# BMJ Open Gender differences in snowboarding accidents in Austria: a 2005–2018 registry analysis

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**To cite:** Rugg CD, Malzacher T, Ausserer J, *et al.* Gender differences in snowboarding accidents in Austria: a 2005–2018 registry analysis. *BMJ Open* 2021;**11**:e053413. doi:10.1136/bmjopen-2021-053413

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-053413>).

Received 12 May 2021

Accepted 06 October 2021



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## ABSTRACT

**Objectives** To elucidate gender differences in snowboarding accidents.

**Design** Retrospective registry analysis within the Austrian National Registry of Mountain Accidents.

**Setting** Snowboard-related emergencies between November 2005 and October 2018.

**Participants** All injured snowboarders with documented injury severity and gender (3536 men; 2155 women).

**Primary and secondary outcome measures** Gender-specific analysis of emergency characteristics and injury patterns.

**Results** Over time, the number of mild, severe and fatal injuries per season decreased in men but not in women. Accidents most frequently were interindividual collisions (>80%) and occurred when heading downhill on a slope. Men more often suffered injuries to the shoulder (15.1% vs 9.2%) and chest (6.8% vs 4.4%), were involved in accidents caused by falling (12.9% vs 9.6%) or obstacle impact (4.3% vs 1.5%), while on slopes with higher difficulty levels (red: 42.6% vs 39.9%; black: 4.2% vs 2.5%), while snowboarding in a park (4.8% vs 2.1%) and under the influence of alcohol (1.6% vs 0.5%). Women more often sustained injuries to the back (10.2% vs 13.1%) and pelvis (2.9% vs 4.2%), on easier slopes (blue: 46.1% vs 52.4%) and while standing or sitting (11.0% vs 15.8%). Mild injuries were more frequent in women (48.6% vs 56.4%), severe and fatal injuries in men (36.0% vs 29.7% and 0.9% vs 0.4%). Male gender, age and the use of a helmet were risk factors for the combined outcome of severe or fatal injuries (OR (95% CI): 1.22 (1.00 to 1.48), 1.02 (1.02 to 1.03) and 1.31 (1.05 to 1.63)). When wearing a helmet, the relative risk (RR) for severe injuries increased while that for mild injuries decreased in male snowboarders only (RR (95% CI): 1.21 (1.09 to 1.34) and 0.88 (0.83 to 0.95)).

**Conclusions** Snowboard injuries are proportionally increasing in women and the observed injury patterns and emergency characteristics differ substantially from those of men. Further gender-specific research in snowboard-related injuries should be encouraged.

**Trial registration number** NCT03755050.

## INTRODUCTION

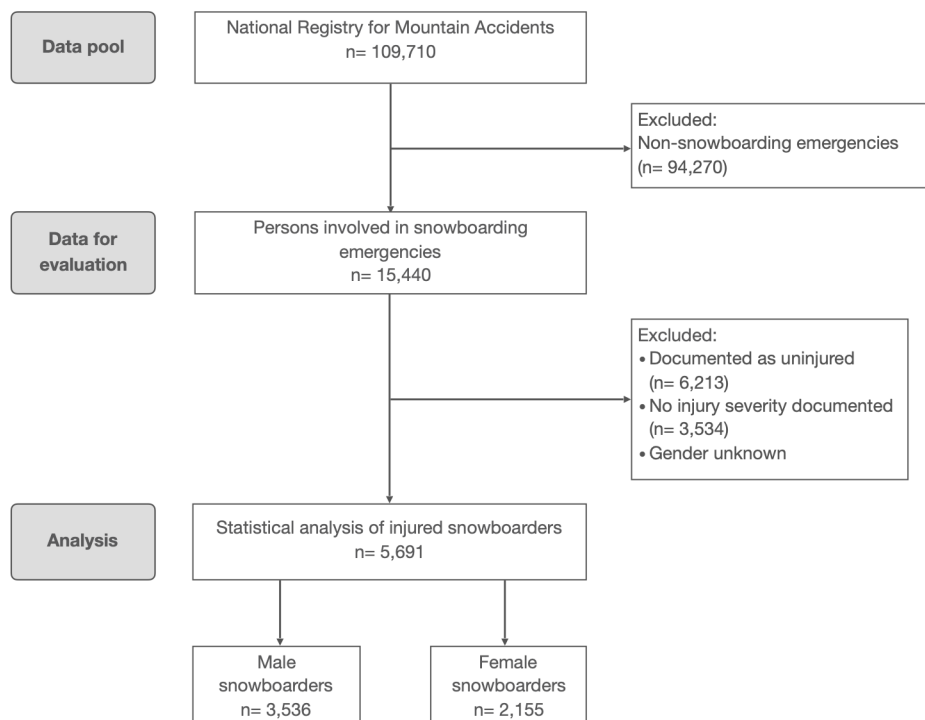
Recreational winter sport activities are numerously performed in the Austrian Alps. With fairly constant skier days per season in Austria

## Strengths and limitations of this study

- The National Registry for Mountain Accidents in Austria is one of the biggest data sets regarding mountain sports activities.
- Data from a 13-year time frame were extracted leading to a considerable number of patients and allowing to also analyse changes over time.
- Literature focusing on gender-specific differences in snowboarding accidents is scarce.
- As the analysed accidents are preselected to include those that triggered emergency calls to dispatch centres, a bias towards more severely injured seems obvious.

(~50 million),<sup>1</sup> injury incidences in mountain winter sports are decreasing.<sup>2,3</sup> Nevertheless, at the national level, skiing and snowboarding continuously rank among the top five causes of sport accidents.<sup>4</sup> Among Austrian residents, approximately 20 000–25 000 people per year are involved in skiing-related or snowboarding-related accidents requiring hospital attention. About 20% are snowboarding related.

Snowboarding has long been predominated by men, but the rise in female participation is becoming more apparent.<sup>5–8</sup> By 1998, the female proportion had increased to approximately 30%,<sup>8</sup> obviously remaining in this range as seen in numbers from 2012<sup>9</sup> and 2019.<sup>10</sup> Up-to-date literature on gender-specific differences in injury patterns remains seldom and often incidental within general injury reports<sup>3,11</sup> or reports on particular injury types.<sup>12–14</sup> In summary, female snowboarders seem to suffer fewer shoulder,<sup>3,11,12</sup> head<sup>3,14</sup> and facial injuries<sup>13</sup> than their male counterparts. But, higher incidences in arm<sup>3</sup> and knee<sup>11</sup> injuries have also been reported. Furthermore, it is known that men are prone to suffer more severe as well as fatal injuries on ski slopes, when both skiing and snowboarding.<sup>1,15–17</sup> Often enough, a causal



**Figure 1** Study flow chart.

relationship is drawn to an increased risk-taking behaviour of men, not only on ski slopes but also in everyday life.<sup>18–23</sup>

To our knowledge, the following national registry analysis is the first to primarily focus on gender-specific differences in snowboarding-related accidents. Beyond mere incidences, injury severity distributions, injury patterns, emergency characteristics and risk factors for the composite outcome of severe or fatal injuries are elaborated. Using data collected nationally over a considerable period of 13 years made an extensive analysis possible.

## MATERIAL AND METHODS

Data were obtained from the digital National Registry for Mountain Accidents in Austria. This registry stores anonymised data on emergencies and rescue operations in the Austrian Alps and is maintained by officers of the Alpine Police. As qualified alpinists, these officers have basic medical training (first aid and basic life support). As soon as an emergency call is made to the dispatch centre and third-party negligence may be involved, as with trauma and rarely with internal medicine cases, the Alpine Police investigates and an entry is made in the registry. For this purpose, data are mainly obtained not only on-site, but also from the hospital, if necessary. Snowboarding emergencies from initiation of the registry on 1 November 2005–31 October 2018 were extracted (figure 1). Data analysis was performed after excluding patients not injured or with missing documentation of gender and injury severity.

Data analysed included gender, age, date, activity performed prior to the accident, terrain, difficulty level of the terrain, cause of the accident, helmet use,

alcohol influence, injury severity, mode of rescue, type and site of injury. A snowboard season was defined as 1 November–31 October of the following year, as this is comparable with a winter season. The term *other* included non-classifiable items as well as fall from heights, fall into a crevasse, avalanches and equipment failure as cause of accident; trails and glaciers as terrain. Injury severity was defined according to Austrian law: an injury was considered mild if the patient was able to resume work within 24 days and severe if any fracture, except a fracture of the nose, occurred or the patient was unable to work for at least 24 days after the accident.<sup>24</sup>

For comparison over time, data were dichotomised into two time frames (2005/2006–2010/2011 vs 2011/2012–2017/2018). In general, due to non-normal distribution, data are presented as median and IQR or count and percentage, as appropriate. The  $X^2$  test was performed to detect group differences in frequencies, the Mann-Whitney U test for group differences of continuous data. With regard to injury frequencies per season, linear modelling was performed for graphical presentation. Logistic regression analysis was performed to analyse independent variables (gender, age, activity prior to accident, terrain, cause of accident and helmet use) with regard to a possible prediction of the combined outcome of severe or fatal injuries. The association was quantified by ORs adjusted for the above-mentioned variables. In order to reduce family-wise error rates and strengthen our analysis, we decided to rely on a 99% CI concerning significance. Relative risk (RR) to sustain mild, severe or fatal injuries when wearing a helmet or not was quantified, separately for all injuries and for head injuries only, by risk ratios

**Table 1** Injury frequencies and female share over time

	2005/2006–2010/2011 (n=2884)	2011/2012–2017/2018 (n=2809)	P value
<b>Male (median n per season)</b>			
All accidents	304 (298–316)	241 (233–254)	0.001
Mild injuries	163 (139–182)	111 (101–118)	0.001
Severe injuries	112 (109–117)	87 (85–88)	0.026
Fatal injuries	4 (3–5)	2 (1–2)	0.046
<b>Female (median n per season)</b>			
All accidents	173 (161–188)	151 (145–172)	0.252
Mild injuries	98 (90–119)	85 (75–95)	0.073
Severe injuries	51 (41–59)	47 (41–49)	0.667
Fatal injuries	1 (0–1)	1 (0–1)	1
<b>Female (% per season)</b>			
All accidents	36.8 (35.2–37.5)	37.3 (37.1–42.4)	0.181
Mild injuries	39.4 (38.8–40.4)	43.4 (40.6–47.0)	0.038
Severe injuries	31.5 (29.6–33.2)	35.6 (34.2–37.6)	0.035
Fatal injuries	8.3 (0–20.8)	33.3 (8.3–33.3)	0.405

in a gender-dependent manner. Data were stored with Excel 2019 (Microsoft, Seattle, Washington, USA) and processed with R (V.4.0.2, R Core Team, <https://www.R-project.org/>, Vienna, Austria) and RStudio (V.1.2.5001, RStudio, Boston, Massachusetts, USA). Patients were not involved in the conception, design or conduct of this research.

### Patient and public involvement

Patients and/or the public were not involved in the design, conduct of this study or the reporting of this research.

## RESULTS

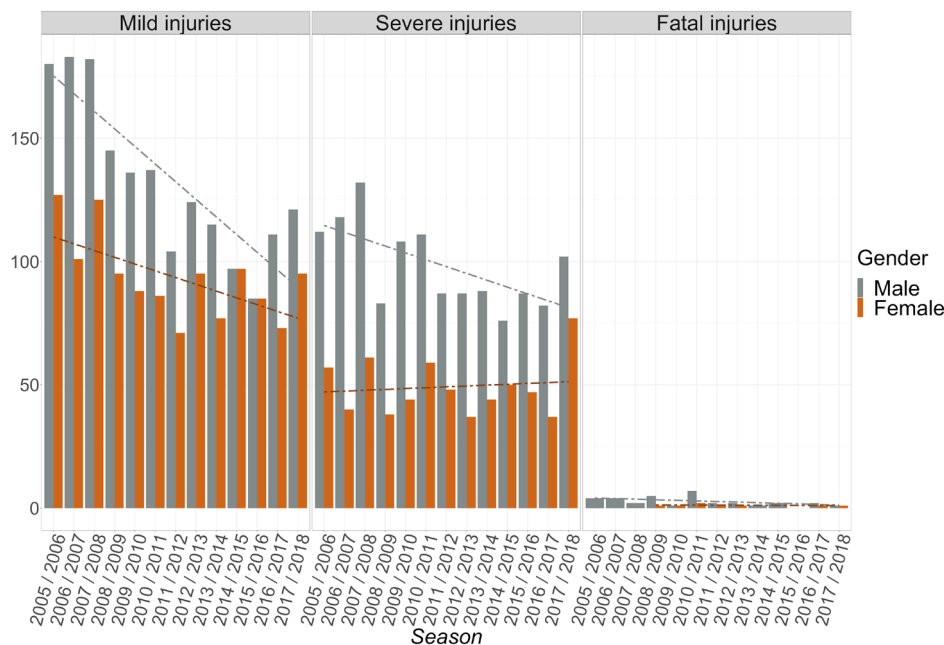
### Gender distribution of snowboarding accidents over the years

In the observed time frame, 3536 men (62.1%) and 2155 women (37.9%) were injured while snowboarding and triggered a call to the dispatch centre. When comparing the first six seasons (2005/2006–2010/2011) and the latter seven seasons (2011/2012–2017/2018), the median number of involved men per season was seen to decline significantly in total (304 (298–316) vs 241 (233–254);  $p=0.001$ ) and with regard to mild (163 (139–182) vs 111 (101–118);  $p=0.001$ ), severe (112 (109–117) vs 87 (85–88);  $p=0.026$ ) and fatal injuries (4 (3–5) vs 2 (1–2);  $p=0.046$ ; [table 1](#)). In women, however, no significant differences were present, thus giving a proportional increase in women involved in mild (39.4% (38.8%–40.4%) vs 43.4% (40.6%–47.0%);  $p=0.038$ ) and severe injuries (31.5% (29.6%–33.2%) vs 35.6% (34.2%–37.6%);  $p=0.035$ ; [table 1](#)). [Figure 2](#) illustrates this relation in a season-dependent and injury severity-dependent manner. Fatal injuries were rare and amounted to a median of three (1–4) per season (men: 2 (1–4); women: 1 (0–1)).

### Emergency and injury characteristics

[Table 2](#) depicts general demographics and emergency characteristics. Men were older than women (24 (16–34) vs 21 (15–31);  $p<0.001$ ) and more frequently involved in accidents while actively on a downhill run (83.9% vs 78.4%;  $p<0.001$ ), while snowboarding in a park (4.8% vs 2.1%;  $p<0.001$ ) and alcoholised (1.6% vs 0.5%;  $p<0.001$ ). Accidents while snowboarding on a slope were most frequent in both genders, but men were more frequently affected on slopes with higher difficulty levels (red: 42.6% vs 39.9%;  $p=0.037$ ; black: 4.2% vs 2.5%;  $p=0.003$ ). Inactively standing or sitting when involved in an accident was more prevalent in women (15.8% vs 11.0%;  $p<0.001$ ), as was an interindividual collision as accident cause (87.9% vs 80.8%;  $p<0.001$ ). Men more often sustained injuries from falling (12.9% vs 9.6%;  $p<0.001$ ) or obstacle impact (4.3% vs 1.5%;  $p<0.001$ ) than did women. Injury severity differed between the two genders. Women more commonly suffered mild (56.4% vs 48.6%;  $p<0.001$ ) and men severe (36.0% vs 29.7%;  $p<0.001$ ) or fatal injuries (0.9% vs 0.4%;  $p=0.023$ ). Women more often required ground-bound rescue (56.1% vs 49.0%;  $p<0.001$ ) and men were more often transported by helicopter (25.4% vs 22.1%;  $p=0.002$ ) or were not transported at all (25.6% vs 21.7%;  $p<0.001$ ).

With regard to injury characteristics ([table 2](#)), contusions, strains or sprains were more prevalent in women (45.5% vs 37.4%;  $p<0.001$ ), while men more frequently sustained fractures (26.3% vs 23.5%;  $p=0.017$ ), wounds (17.1% vs 11.4%;  $p<0.001$ ) and dislocations (5.2% vs 3.6%;  $p=0.006$ ). Head injuries were most prevalent in both genders (21%), but shoulder and chest injuries were more common in men (15.1% vs 9.2%;  $p<0.001$  and 6.8% vs 4.4%;  $p<0.001$ ); back and pelvis injuries in women (13.1% vs 10.2%;  $p<0.001$  and 4.2% vs 2.9%;  $p=0.009$ ).



**Figure 2** Gender-dependent and injury severity-dependent presentation of absolute number injured per season. Dashed lines derived from linear modelling.

### Risk factors for severe and fatal injuries

Logistic regression analysis adjusted for gender, age, performed activity, terrain, cause of accident and helmet use (table 3) revealed male sex to be an independent risk factor for severe or fatal injuries in the observed setting (OR 1.22 (1.00 to 1.48);  $p=0.009$ ). Further risk factors with increased ORs were age (OR 1.02 (1.02 to 1.03) per year;  $p<0.001$ ), performing a downhill run as compared with standing or sitting (OR 1.41 (1.04 to 1.90);  $p=0.004$ ), snowboarding in a park compared with on a slope (OR 1.83 (1.14 to 2.93);  $p=0.001$ ), falling and obstacle impact as compared with an interindividual collision (OR 1.75 (1.27 to 2.43);  $p<0.001$  and OR 4.11 (2.33 to 7.26);  $p<0.001$ ) and the use of a helmet (OR 1.31 (1.05 to 1.63);  $p=0.001$ ).

Further analysis of RRs for mild, severe or fatal injuries when wearing a helmet or not (table 4) revealed for both genders that wearing a helmet was accompanied by an increased risk for severe (RR 1.15 (1.06 to 1.25);  $p=0.001$ ), but a decreased risk for fatal (RR 0.43 (0.21 to 0.91);  $p=0.026$ ) and mild injuries (RR 0.93 (0.88 to 0.97);  $p=0.003$ ). Gender-specific analysis showed that primarily men contributed to the mentioned significant decrease in mild and increase in severe injuries. Regarding head injuries only, counterintuitively no significant effects of helmet use on any injury severity were detectable.

### DISCUSSION

A substantial decrease was detected in the total number of men involved in snowboarding accidents over the years, and a proportional increase in the number of women suffering mild and severe injuries. Fatal injuries were rare and amounted to a median of two men and one woman

per season. Most snowboarding accidents were interindividual collisions and occurred during a downhill run on a slope. When comparing both genders, proportionally more men suffered injuries to the shoulder and chest, were involved in accidents caused by falling or obstacle impact, while heading downhill, while on slopes with higher difficulty levels, while snowboarding in a park and under the influence of alcohol. Proportionally more women sustained injuries to the back and pelvis, due to interindividual collisions, on easier slopes and while standing or sitting. Mild injuries were more frequent in women, severe and fatal injuries in men. Male gender, age and helmet use were independent risk factors for the combined outcome of severe or fatal injuries. With regard to helmet use, further analysis revealed that the RR for severe injuries increased, while that for mild injuries decreased with the use of a helmet in male, but not significantly in female snowboarders. When analysing both genders, the RR for fatal injuries decreased when wearing a helmet. Noteworthy, the RR for head injuries in particular was not significantly influenced by helmet use, regardless of gender.

### Gender distribution of snowboarding accidents over the years

Following the initial hype in snowboarding, an inevitable increase in snowboarding accidents was also detectable until the early 2000s.<sup>25 26</sup> Meanwhile, the number of active snowboarders seems to be quite stable,<sup>25</sup> implying that the presented decrease in snowboarding accidents per season is most likely a result of decreased injury incidences. In Austria, the number of skier days per season, particularly in the observed time frame, remained more or less constant (~50 Mio),<sup>1</sup> but a decreased injury incidence in mountain winter sports was reported over the

**Table 2** General demographics and emergency characteristics of injured snowboarders in Austria (2005–2018)

	Male (n=3536)	Female (n=2155)	P value
<b>Age</b>			
Median (IQR)	24 (16–34)	21 (15–31)	<0.001
<b>Activity prior to accident</b>			
Downhill run	2406 (83.9%)	1334 (78.4%)	<0.001
Standing/sitting	314 (11.0%)	268 (15.8%)	<0.001
Other	147 (5.1%)	99 (5.8%)	0.472
Missing	669	454	
<b>Terrain</b>			
Slope	2923 (87.6%)	1807 (91.4%)	0.261
Park	161 (4.8%)	42 (2.1%)	<0.001
Other	252 (7.6%)	127 (6.4%)	0.079
Missing	200	179	
<b>Difficulty level of terrain</b>			
Blue	1277 (46.1%)	869 (52.4%)	0.002
Red	1180 (42.6%)	661 (39.9%)	0.037
Black	116 (4.2%)	41 (2.5%)	0.003
Other	195 (7.0%)	87 (5.2%)	0.015
Missing	923	343	
<b>Cause of accident</b>			
Interindividual collision	2717 (80.8%)	1766 (87.9%)	<0.001
Fall	435 (12.9%)	193 (9.6%)	<0.001
Obstacle impact	146 (4.3%)	31 (1.5%)	<0.001
Other	63 (1.9%)	18 (0.9%)	0.005
Missing	175	147	
<b>Helmet use</b>			
Yes	2031 (67.0%)	1231 (69.4%)	0.09
No	1001 (33.0%)	544 (30.6%)	
Missing	504	380	
<b>Alcohol influence</b>			
Yes	51 (1.6%)	10 (0.5%)	<0.001
No	3133 (98.4%)	1909 (99.5%)	
Missing	352	236	
<b>Injury severity</b>			
Mild	1720 (48.6%)	1215 (56.4%)	<0.001
Severe	1273 (36.0%)	639 (29.7%)	<0.001
Fatal	33 (0.9%)	8 (0.4%)	0.023
Undefined	510 (14.4%)	293 (13.6%)	0.407
Missing	0	0	
<b>Mode of rescue</b>			
Ground-bound	1645 (49.0%)	1124 (56.1%)	<0.001
Helicopter	854 (25.4%)	443 (22.1%)	0.002
No rescue	861 (25.6%)	435 (21.7%)	<0.001
Missing	221	108	
<b>Type of injury</b>			
Contusion/strain/sprain	1324 (37.4%)	981 (45.5%)	<0.001

Continued

Table 2 Continued

	Male (n=3536)	Female (n=2155)	P value
Fracture	930 (26.3%)	506 (23.5%)	<b>0.017</b>
Wound/lesion	603 (17.1%)	245 (11.4%)	<b>&lt;0.001</b>
Concussion	271 (7.7%)	178 (8.3%)	0.419
Dislocation	183 (5.2%)	78 (3.6%)	<b>0.006</b>
Internal	57 (1.6%)	22 (1.0%)	0.064
Polytrauma	38 (1.1%)	17 (0.8%)	0.285
Other	41 (1.2%)	13 (0.6%)	
Site of injury			
Head	748 (21.2%)	452 (21.0%)	0.872
Back/spine	360 (10.2%)	283 (13.1%)	<b>&lt;0.001</b>
Knee	313 (8.9%)	207 (9.6%)	0.338
Shoulder	533 (15.1%)	198 (9.2%)	<b>&lt;0.001</b>
Lower leg	245 (6.9%)	123 (5.7%)	0.069
Forearm	182 (5.1%)	116 (5.4%)	0.699
Wrist	133 (3.8%)	101 (4.7%)	0.088
Chest	239 (6.8%)	95 (4.4%)	<b>&lt;0.001</b>
Pelvis	102 (2.9%)	90 (4.2%)	<b>0.009</b>
Thigh	168 (4.8%)	85 (3.9%)	0.152
Hand	123 (3.5%)	83 (3.9%)	0.465
Upper arm	89 (2.5%)	72 (3.3%)	0.069
Entire body	64 (1.8%)	47 (2.2%)	0.326
Neck	59 (1.7%)	47 (2.2%)	0.165
Ankle	56 (1.6%)	38 (1.8%)	0.606
Foot	66 (1.9%)	34 (1.6%)	0.421
Abdomen	51 (1.4%)	30 (1.4%)	0.877
Hip	30 (0.8%)	28 (1.3%)	0.1

Bolded entries mark the significant results.

past decades.<sup>2 3</sup> Besides improved slope preparation and technical gear, higher acceptance of personal protection equipment may be pivotal.<sup>3 27 28</sup> Confirming the latter and partially explaining the pronounced decline in mild injuries in this study, helmets have particularly reduced mild head injuries (eg, lacerations)<sup>28 29</sup> and hip pads have reduced the overall risk of injury in recreational snowboarders.<sup>27</sup>

Unexplained remain the observed gender differences in injury decline. The absolute number of mild injuries decreased less steeply in women than in men and the number of severe injuries even rose. However, the overall proportion of female participation in snowboarding seems to have been quite stable (~30%) since the late 1990s<sup>8-10</sup> and so has the total number of active snowboarders per year.<sup>1</sup> A proportional increase in female snowboarders does not seem causative leaving an altered risk profile over the years as possible explanation. In men, fatalities declined as well, but in women, they were too rare to detect any changes over time. A decreasing incidence of

traumatic and non-traumatic deaths on Austrian slopes was recently described elsewhere.<sup>1</sup>

### Emergency and injury characteristics

A rather young age and a male predominance, as described in this study, are well known with regard to active snowboarders.<sup>5-7</sup> Due to the nature of this study, the analysed accidents are preselected towards those that triggered a distress call. Compared with in-hospital or self-reporting studies, a bias towards more severely injured, or towards accidents, where official documentation might be crucial for legal reasons or insurance claims, seems evident. A study from Los Angeles, California reported that even among severely injured snowboarders (Injury Severity Score >15) merely 80% used emergency medical services to reach the emergency department.<sup>30</sup> Interindividual collisions and accidents occurring during a downhill run on a slope were most prevalent in this study. In contrast, an in-hospital interview study from France revealed that falls were the most frequent injury mechanisms (54%)

**Table 3** Logistic regression predicting severe or fatal injuries when involved in a snowboarding accident

	Crude OR (99% CI)	Adjusted OR (99% CI)	P value
<b>Gender</b>			
Male versus female	1.39 (1.15 to 1.68)	1.22 (1.00 to 1.48)	<b>0.009</b>
<b>Age</b>			
Per year	1.02 (1.01 to 1.03)	1.02 (1.02 to 1.03)	<b>&lt;0.001</b>
<b>Activity</b>			
Standing/sitting	Reference		
Downhill run	1.64 (1.23 to 2.20)	1.41 (1.04 to 1.90)	<b>0.004</b>
<b>Terrain</b>			
Park versus slope	2.15 (1.41 to 3.27)	1.83 (1.14 to 2.93)	<b>0.001</b>
<b>Cause of accident</b>			
Interindividual collision	Reference		
Fall	1.95 (1.46 to 2.60)	1.75 (1.27 to 2.43)	<b>&lt;0.001</b>
Obstacle impact	4.25 (2.43 to 7.43)	4.11 (2.33 to 7.26)	<b>&lt;0.001</b>
<b>Helmet</b>			
Yes versus no	1.23 (1.00 to 1.52)	1.31 (1.05 to 1.63)	<b>0.001</b>

Patients with undefined injury severity excluded.

followed by collisions with other persons or obstacles (18%).<sup>31</sup> Self-reporting data from Austria indicated that as many as 87% of all injuries were caused by self-inflicted falls.<sup>3</sup>

Snowboard-associated injuries typically include shoulder and upper more than lower extremity injuries, but also head and spine as well as chest and abdomen injuries.<sup>3 12 13 16 30–32</sup> Unfortunately, literature on gender-related differences in the course and consequences of snowboarding accidents is scarce. In general, men are prone to suffer more severe as well as fatal injuries on ski slopes.<sup>1 15–17</sup> Furthermore, shoulder injuries, particularly dislocations, but also

facial bone fractures are more prevalent in snowboarding men.<sup>2 11–13</sup> Regarding women, this study was able to show that back and pelvis injuries are more frequent.

The male prevalence in terrain parks in this study also confirms previous results.<sup>33</sup> Our data show higher rates of fractures and dislocations in men and more contusions, strains or sprains in women. The picture of men being more prone to suffer injuries while actively heading downhill, on more difficult slopes and more often under the influence of alcohol perfectly fits the perception of an increased risk-taking behaviour of men, not only on ski slopes but in everyday life.<sup>18–23</sup>

**Table 4** Relative risk for mild, severe or fatal injury when wearing a helmet and involved in a snowboarding accident

Helmet yes versus no	Injuries, all types (n=4108)		Head injuries only (n=918)	
	Relative risk (95% CI)	P value	Relative risk (95% CI)	P value
<b>Male injury severity (n=2574)</b>				
Mild	<b>0.88 (0.83 to 0.95)</b>	<b>&lt;0.001</b>	1.05 (0.94 to 1.17)	0.364
Severe	<b>1.21 (1.09 to 1.34)</b>	<b>&lt;0.001</b>	0.87 (0.66 to 1.14)	0.321
Fatal	0.52 (0.23 to 1.19)	0.122	1.23 (0.23 to 6.64)	0.813
<b>Female injury severity (n=1534)</b>				
Mild	0.98 (0.91 to 1.06)	0.678	1.11 (0.99 to 1.26)	0.082
Severe	1.05 (0.90 to 1.22)	0.515	0.69 (0.45 to 1.08)	0.106
Fatal	0.23 (0.04 to 1.27)	0.093	0.25 (0.02 to 2.76)	0.26
<b>Male and female injury severity (n=4108)</b>				
Mild	<b>0.93 (0.88 to 0.97)</b>	<b>0.003</b>	1.08 (0.99 to 1.17)	0.064
Severe	<b>1.15 (1.06 to 1.25)</b>	<b>0.001</b>	0.80 (0.64 to 1.02)	0.067
Fatal	<b>0.43 (0.21 to 0.91)</b>	<b>0.026</b>	0.71 (0.19 to 2.64)	0.615

Patients with undefined injury severity and missing information on helmet use excluded.



### Risk factors for severe and fatal injuries

Besides male gender, predisposing factors for severe or fatal injuries included heading downhill as compared with standing or sitting, riding in a terrain park as compared with on a slope, falling or obstacle impact as compared with interindividual collision and also helmet use. Terrain park injuries have been previously described as being more severe, mainly due to falls after aerial manoeuvres.<sup>33–35</sup> Collisions with objects and other persons were responsible for half of all traumatic deaths in a 10-year analysis conducted on Austrian ski slopes.<sup>1</sup> The paradox of protective gear, like helmets, seemingly increasing injury rates has been addressed before.<sup>36</sup> In general, helmets have been shown to reduce the risk of head injuries.<sup>15 29 37</sup> However, conflicting data have also been published. A study from Canada reported no reduction in head injuries despite increased helmet use.<sup>28</sup> Bailly *et al* also reported that the effects of helmets on traumatic brain injury are limited.<sup>29</sup> Specifically concerning head injuries, no effects of helmet use on the occurrence of mild, severe or fatal injuries were evident in this study, regardless of gender. Sulheim *et al* analysed the effect of helmet use on head injuries in skiing and snowboarding over a 10-year period from 2002 to 2011.<sup>38</sup> While the odds for head injury were clearly reduced in 2002, the effect was attenuated in 2010 and even absent in 2011. They concluded that this unexpected change may be due to new skiing trends. A more recent study even indicated a relationship between helmet use and an increase in general injury severity.<sup>16</sup> Referring to all injury types, mild and fatal injuries were reduced by helmet use, while the odds for severe injuries were increased in our data. Gender-specific analysis revealed that particularly men were responsible for the observed effect. A reduction in mild injuries has also been concluded by previous studies, showing that particularly lacerations, bruises and face trauma were reduced among helmet wearers.<sup>28 29</sup> The association between an increased risk for severe injuries and helmet use has been demonstrated in other studies and finds its justification in a false sense of safety and consequently a riskier behaviour on the ski slopes.<sup>39–42</sup> Again, other studies failed to confirm these results.<sup>18 21 23 36 43</sup> Importantly, helmet users were shown to typically have specific characteristics (eg, male gender, younger age, expert skiing skills).<sup>34</sup> These conclusions were drawn in 2010. The proportion of people wearing a helmet in our data increased from 47% (2005/2006–2010/2011) to 89% (2011/2012–2017/2018). It seems likely that helmet-related user characteristics have altered over time, now including a broader range of skill levels, age groups and genders. Thus, conflicting results regarding helmet use and injury risk together with an association with risk-taking behaviour may be partially explained. Moreover, as men are known to tend to riskier behaviour,<sup>18–23</sup> gender-specific analyses as performed in this study may be the key.

The main limitation of this study certainly includes a possible selection bias, due to the chosen setting. The

analysed accidents were preselected to include those that triggered emergency calls to dispatch centres. A bias towards more severely injured or towards accidents where official documentation might be crucial for legal reasons or insurance claims seems evident. Missing in-hospital data impeded more precise identification of injuries. Furthermore, as neither the overall number nor the gender distribution of active snowboarders per season was known, exact incidences as well as proportional involvements could not be calculated. Finally, the validity of the study may be attenuated by its retrospective design.

### CONCLUSION

The share of mild and severe snowboard injuries in women is increasing, and the observed injury patterns and emergency characteristics differ substantially to those of men. Male gender is a risk factor for severe and fatal injuries and also responsible for an increased OR regarding severe injuries when wearing a helmet. An elevated risk-taking behaviour may be responsible. Further gender-specific research in snowboarding-related injuries should be encouraged.

**Acknowledgements** We acknowledge Dagmar Walter, formerly Österreichisches Kuratorium für Alpine Sicherheit (Austrian Mountain Safety Board, which runs the Austrian Alpine Police database), Hans Ebner of the Austrian Alpine Police as well as all contributing police officers who collected the data.

**Contributors** CDR, JA, PP and MS contributed to conception and design. CDR, AR and MS contributed to analysis. CDR, TM and MS contributed to data acquisition. CDR and MS drafted the manuscript. All authors critically revised the manuscript, contributed to interpretation, gave final approval and agreed to be accountable for all aspects of the work in ensuring integrity and accuracy. MS is the guarantor.

**Funding** This work was supported by departmental resources only.

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not required.

**Ethics approval** The Ethics Committee of the Medical University of Innsbruck approved the study (AN2015-0068 347/4.13 393/5.20).

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon reasonable request. Data may be obtained from a third party and are not publicly available. Participant data were obtained from the Digital National Registry for Mountain Accidents hosted by Österreichisches Kuratorium für Alpine Sicherheit–Austrian Mountain Safety Board. All data are deidentified. The data set was delivered containing only serial numbers for each participant. Access to hospital inpatient data was requested and accessed through Medical University of Innsbruck. Protocol and statistical analysis plans are available upon reasonable request from the corresponding author.

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