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Original Article

Incidence of skiing and snowboarding injuries over six winter seasons (2012–2018) in Japan

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Abstract:
Based on data from ski resort injury reports published annually by the Japan Association for Skiing Safety, six ski seasons, from 2012–2013 to 2017–2018, were surveyed. An analysis of skiing and snowboarding injuries at ski resorts in Japan was conducted using the injury rate per 1000 skier days as an international index. The skiing and snowboarding injury rates over the six seasons were 1.59 (95% Confidence Intervals:1.55-1.62) and 2.58 (95% Confidence Intervals:2.53-2.63) per 1000 skier days, respectively. The snowboarding injury rate was 1.62 times higher than the skiing injury rate ($P < 0.05$). Skiing was associated with the most lower limb injuries (53.2%, 0.91 per 1000 skier days, particularly knee injuries), and snowboarding with significantly more upper limb (49.5%, 1.40 per 1000 skier days, particularly shoulder and wrist injuries) and head and neck injuries (16.0%, 0.45 per 1000 skier days). Sprains (38.9%, 0.68 per 1000 skier days) were the most frequent in skiing, and fractures (29.5%, 0.84 per 1000 skier days) and contusions (27.9%, 0.79 per 1000 skier days) were the most frequent in snowboarding. Simple falls resulting from imbalance or falls from a jump or trick failure were significantly more common injury mechanism in snowboarding than in skiing, and most injuries occurred on groomed mild and moderate slopes. Snowboarding injuries were more common than skiing injuries regardless of the severity. A total of 68 fatal injuries (37 skiers, 31 snowboarders) occurred during the six seasons. Snowboarding resulted in most injuries among young people (especially aged 20-29 years), while skiing resulted in most injuries among middle-age people (40 years and older). Snowboarding often caused injuries to novices and beginners, while skiing often caused injuries to advanced skiers. Many injured skiers and snowboarders had not been wearing a helmet, especially non-helmet injuries were more common in snowboarding than in skiing. These findings suggest the importance of recognizing that skiing and snowboarding are high-risk sports that can lead to serious or fatal injuries. Therefore, it is essential for skiers and snowboarders to take appropriate safety measures at ski resorts. Especially, snowboarding should not be started before receiving adequate skill instruction and safety education.
Key Words: snow sports, injury rates, epidemiology, fatal injuries, safety education

Introduction

The popularity of skiing and snowboarding in Japan has been declining since reaching a peak of 18 million in 1998, and the numbers of skiers and snowboarders fell to 7.4 million in 2015, about 40% of the peak (Ministry of Land, Infrastructure, Transport and Tourism, 2015). With such a decline in the popularity, modules to perform tricks such as jumps, rails, half-pipes, and boxes have been installed on the slopes of ski resorts to attract more skiers and snowboarders (Hattori, 2007).

On the other hand, snow sports injuries, especially snowboarding injuries resulting from jumps, frequently occurred and spinal injuries accounted for 62.1% of all cases resulting from jumps in a previous study (Hattori, 2007). Another study (Sakamoto, Sakuraba, Obayashi, Kawakita, & Inoue, 2008) reported more snowboarding than skiing injuries during the 2000–2005 seasons, and an extremely high number of snowboarding injuries among young people in their late teens and early 30s. Despite the significant decrease in the numbers of skiers and snowboarders, many serious injuries, including head injuries, continue to occur (Fukuda, 2015; Uchida & Kato, 2016). To our best knowledge, there are no studies on skiing and snowboarding injuries in Japan using the injury rate (IR) per 1000 skier days (SDs) as an international index. In order to examine the actual conditions of skiing and snowboarding in Japan, research using this international index is essential. In order to establish appropriate injury prevention measures for skiing and snowboarding, it is necessary to examine long-term injury trends (5 seasons or more). Many of the previous studies on skiing and snowboarding were short-term (1-2 seasons), and their injury tendencies and characteristics have changed over time due to the development of ski and protective equipment, and the safer environment of ski resorts such as pisting and course designs (Burtscher et al., 2008; Coury et al., 2013; Hattori, 2007; Langran & Selvaraj, 2002;

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Patrick, Cooper, & Daniels, 2015; Xiang, Kelleher, Shields, Brown, & Smith, 2005). In recent years, even from an international perspective, there are few long-term studies of 5 seasons or more (Bianchi, Brugger, & Niemann, 2017; Costa-Scorse, Hopkins, Cronin, & Bressel, 2017; Stenroos & Handolin, 2015).

Thus, the purpose of this study was to clarify the actual situation of skiing and snowboarding injuries in Japan, using the IR per 1000 SDs as an international index, over six ski seasons, from 2012–2013 to 2017–2018.

Material & methods

Data source

Based on data from the "Ski Resort Injury Report," which is published annually by the Japan Association for Skiing Safety (JASS), six seasons (from the 2012–2013 to the 2017–2018 season) were surveyed. The JASS requested cooperation from major ski resorts nationwide, and 44 to 47 ski resorts (2012–2013: 44, 2013–2014: 46, 2014–2015 to 2017–2018: 47) were surveyed for each season. The survey period was the month of February each year, which is the peak skiing and snowboarding month in each season. The survey items included the date and time of injury, weather, injured personal data (age, sex), equipment (e.g., ski, snowboard), location of injury, cause of injury, injury site and type, severity of injury, slope condition, self-reported skill level, behavior before the injury event, helmet use, and snow conditions. In total, 20 items were recorded using an injury report sheet prepared by the JASS (Japan Association for Skiing Safety, 2014). When a skier or snowboarder had multiple injury sites and types, all were counted.

Definition of injury rates (IRs) In this study, we calculated the total number of lift transportations based on the definition of SDs used in previous studies (Bergstrøm & Ekeland, 2004; Stenroos & Handolin, 2015). Twenty lift transportations were defined as 1 SD (Bergstrøm & Ekeland, 2004), and the IR per 1000 SDs was calculated (Table 1). The IR and percentage of injuries, as well as their 95% confidence intervals (CIs), were also calculated.

Table 1. Lift transportations and skier days in skiing and snowboarding from 2012-2013 to 2017-2018 seasons

Season	Skiing		Snowboarding		Total
	Lift Transportations	Skier Days	Lift Transportations	Skier Days	
2012-2013	15.313.439	765.672	14.135.483	706.774	29.448.922
2013-2014	15.068.143	753.407	13.909.056	695.453	28.977.199
2014-2015	16.437.591	821.880	15.173.160	758.658	31.610.751
2015-2016	16.805.741	840.287	14.315.002	715.800	31.121.743
2016-2017	15.479.282	773.964	13.726.910	686.346	29.206.192
2017-2018	17.936.703	896.835	14.093.123	704.656	32.029.826
Total	97.040.899	4.852.045	85.353.734	4.267.687	182.394.633

*20 lift transportations defined as one skier day

Injury records Injury records were based on ski patrol reports at the surveyed ski resorts. After an injury, the ski patrol recorded each item using an injury report sheet after the individual received first aid at a ski resort and treatment at a medical institution. The injury data for February from each ski resort were deidentified and sent to the JASS. The JASS has been disclosing injury data related to skiing and snowboarding injuries since the 1998–1999 season. However, the original injury data from the 1998–1999 to the 2011–2012 season are unknown because they were not stored at the JASS. Therefore, the JASS provided us with original injury data from the 2012–2013 to the 2017–2018 season. This study was performed according to the Declaration of Helsinki and approved by the ethics committee of Aichi Toho University. Regarding the analysis of injury records, we included injuries related to skiing and snowboarding, but excluded injuries associated with sleds and other types of equipment. Injuries not directly related to skiing or snowboarding, such as illness or physical condition, were also excluded. Skiing equipment included alpine skis (e.g., conventional skis, carving skis, fan skis, fat skis, mogul skis), ski boards, telemark skis, and cross-country skis. Snowboarding equipment included freestyle and alpine snowboards.

Statistical analysis For the statistical analysis, the number of injuries caused by skiing and snowboarding, the percentage (%), the IRs of skiing and snowboarding and their 95% CIs were calculated. The χ^2 test was used to compare between the number of skiing and snowboarding injuries. We also calculated the incidence rate ratio of snowboarding to skiing and its 95% CI. Generally, when the 95% CI includes 1, no statistically significant difference is present at the 5% level, and when the 95% CI does not include 1, a significant difference is present at the 5% level (Albright et al., 2004). Excel Statistics 2015 (version 1.03, Social Survey Research Information, Tokyo, Japan) was used for the data analysis, and the significance level was set at the 5% level in each case.

Results

The IRs of skiing and snowboarding during the six seasons surveyed were 1.59 and 2.58 per 1000SDs, respectively. The snowboarding IR was 1.62 times higher than the skiing IR, representing a significant

difference ($P < 0.05$; Table 2). The overall IRs for skiing and snowboarding were 1.90–2.21 per 1000SDs, and the average overall IR for the six seasons was 2.05 per 1000SDs. The upper limb (49.5%, 1.40 per 1000SDs, $P < 0.001$), head and neck (16.0%, 0.45 per 1000SDs, $P < 0.05$), and trunk (14.8%, 0.42 per 1000SDs, $P < 0.001$) were significantly higher in snowboarding than in skiing (Table 2). Especially, the most frequently injured areas in snowboarding were the shoulder (16.3%, 0.46 per 1000SDs) and wrist (15.5%, 0.44 per 1000SDs). On the other hand, the lower limb (53.2%, 0.91 per 1000SDs) was significantly higher in skiing than in snowboarding ($P < 0.001$; Table 2).

Table 2. Injury-related factors for skiing and snowboarding from 2012-2013 to 2017-2018 seasons

Factors	Skiing			Snowboarding			IRR (95%CI) (Snowboarding/Skiing)	P-Value
	N	%	IR (95%CI)	N	%	IR (95%CI)		
Seasons								
2012–2013	1171	37.9	1.53 (1.44–1.62)	1917	62.1	2.71 (2.59–2.83)	1.77 (1.65–1.91)	P < 0.001
2013–2014	1208	38.3	1.60 (1.51–1.69)	1950	61.7	2.80 (2.68–2.93)	1.75 (1.63–1.88)	P < 0.001
2014–2015	1266	41.4	1.54 (1.46–1.63)	1789	58.6	2.36 (2.25–2.47)	1.53 (1.42–1.65)	0.7687
2015–2016	1286	40.9	1.53 (1.45–1.61)	1862	59.1	2.60 (2.48–2.72)	1.70 (1.58–1.82)	0.6872
2016–2017	1439	44.5	1.86 (1.76–1.96)	1793	55.5	2.61 (2.49–2.73)	1.41 (1.31–1.51)	P < 0.001
2017–2018	1339	44.1	1.49 (1.41–1.57)	1696	55.9	2.41 (2.29–2.52)	1.61 (1.50–1.73)	P < 0.001
Total	7709	41.2	1.59 (1.55–1.62)	11007	58.8	2.58 (2.53–2.63)	1.62 (1.58–1.67)	
Body Area Injured								
Head & Neck	[1235]	[14.8]	[0.25 (0.24–0.27)]	[1937]	[16.0]	[0.45 (0.43–0.47)]	[1.78 (1.66–1.92)]	0.0242
Head	635	7.6	0.13 (0.12–0.14)	1165	9.6	0.27 (0.26–0.29)	2.09 (1.89–2.30)	P < 0.001
Face	489	5.9	0.10 (0.09–0.11)	611	5.1	0.14 (0.13–0.15)	1.42 (1.26–1.60)	0.0130
Neck	111	1.3	0.02 (0.02–0.03)	161	1.3	0.04 (0.03–0.04)	1.65 (1.29–2.10)	0.9960
Trunk	[744]	[8.9]	[0.15 (0.14–0.16)]	[1783]	[14.8]	[0.42 (0.40–0.44)]	[2.72 (2.50–2.97)]	P < 0.001
Chest	163	2.0	0.03 (0.03–0.04)	305	2.5	0.07 (0.06–0.08)	2.13 (1.76–2.57)	0.0080
Back	120	1.4	0.02 (0.02–0.03)	242	2.0	0.06 (0.05–0.06)	2.29 (1.84–2.85)	0.0028
Abdomen	72	0.9	0.01 (0.01–0.02)	105	0.9	0.02 (0.02–0.03)	1.66 (1.23–2.24)	0.9685
Lower back	262	3.1	0.05 (0.05–0.06)	813	6.7	0.19 (0.18–0.20)	3.53 (3.07–4.06)	P < 0.001
Pelvis	127	1.5	0.03 (0.02–0.03)	318	2.6	0.07 (0.07–0.08)	2.85 (2.32–3.50)	P < 0.001
Upper Limb	[1742]	[20.9]	[0.36 (0.34–0.38)]	[5981]	[49.5]	[1.40 (1.37–1.44)]	[3.90 (3.70–4.12)]	P < 0.001
Shoulder	920	11.0	0.19 (0.18–0.20)	1975	16.3	0.46 (0.44–0.48)	2.44 (2.26–2.64)	P < 0.001
Upper arm	171	2.1	0.04 (0.03–0.04)	406	3.4	0.10 (0.09–0.10)	2.70 (2.26–3.23)	P < 0.001
Elbow	113	1.4	0.02 (0.02–0.03)	766	6.3	0.18 (0.17–0.19)	7.71 (6.33–9.39)	P < 0.001
Forearm	113	1.4	0.02 (0.02–0.03)	558	4.6	0.13 (0.12–0.14)	5.61 (4.59–6.87)	P < 0.001
Wrist	173	2.1	0.04 (0.03–0.04)	1874	15.5	0.44 (0.42–0.46)	12.32 (10.54–14.39)	P < 0.001
Hand/Finger	252	3.0	0.05 (0.05–0.06)	402	3.3	0.09 (0.08–0.10)	1.81 (1.55–2.12)	0.2294
Lower Limb	[4435]	[53.2]	[0.91 (0.89–0.94)]	[2147]	[17.8]	[0.50 (0.48–0.52)]	[0.55 (0.52–0.58)]	P < 0.001
Thigh	239	2.9	0.05 (0.04–0.06)	204	1.7	0.05 (0.04–0.05)	0.97 (0.81–1.17)	P < 0.001
Knee	2599	31.2	0.54 (0.52–0.56)	823	6.8	0.19 (0.18–0.21)	0.36 (0.33–0.39)	P < 0.001
Lower leg	963	11.6	0.20 (0.19–0.21)	451	3.7	0.11 (0.10–0.12)	0.53 (0.48–0.60)	P < 0.001
Ankle	564	6.8	0.12 (0.11–0.13)	585	4.8	0.14 (0.13–0.15)	1.18 (1.05–1.32)	P < 0.001
Foot	70	0.8	0.01 (0.01–0.02)	84	0.7	0.02 (0.02–0.02)	1.36 (0.99–1.87)	0.2414
Others	181	2.2	0.04 (0.03–0.04)	237	2.0	0.06 (0.05–0.06)	1.49 (1.23–1.81)	0.3002
Type of Injury								
Sprain	3282	38.9	0.68 (0.65–0.70)	2271	18.7	0.53 (0.51–0.55)	0.79 (0.75–0.83)	P < 0.001
Fracture	1400	16.6	0.29 (0.27–0.30)	3579	29.5	0.84 (0.81–0.87)	2.91 (2.73–3.09)	P < 0.001
Contusion	2146	25.4	0.44 (0.42–0.46)	3387	27.9	0.79 (0.77–0.82)	1.79 (1.70–1.89)	P < 0.001
Laceration	706	8.4	0.15 (0.13–0.16)	1172	9.7	0.27 (0.26–0.29)	1.89 (1.72–2.07)	0.0019
Dislocation	535	6.3	0.11 (0.13–0.16)	1459	12.0	0.34 (0.32–0.36)	3.10 (2.81–3.42)	P < 0.001
Others	376	4.5	0.08 (0.07–0.09)	268	2.2	0.06 (0.06–0.07)	0.81 (0.69–0.95)	P < 0.001
Mechanism of Injury								
Self-induced Fall								
Simple fall	5242	70.0	1.08 (1.05–1.11)	6594	59.9	1.55 (1.51–1.58)	1.43 (1.38–1.48)	P < 0.001
Fall from the course	132	1.8	0.03 (0.02–0.03)	235	2.1	0.06 (0.05–0.06)	2.02 (1.64–2.51)	0.0754
Jumping & trick mistake	212	2.8	0.04 (0.04–0.05)	1740	15.8	0.41 (0.39–0.43)	9.33 (8.09–10.76)	P < 0.001
Opposite edge	56	0.7	0.01 (0.01–0.01)	429	3.9	0.10 (0.09–0.11)	8.71 (6.59–11.51)	P < 0.001
Others	189	2.5	0.04 (0.03–0.04)	162	1.5	0.04 (0.03–0.04)	0.97 (0.79–1.20)	P < 0.001
Collision with another person	1289	17.2	0.27 (0.25–0.28)	1330	12.1	0.31 (0.29–0.33)	1.17 (1.09–1.27)	P < 0.001
Collision with stationary objects	219	2.9	0.05 (0.04–0.05)	394	3.6	0.09 (0.08–0.10)	2.05 (1.73–2.41)	0.0156
Others/Unknown	147	2.0	0.03 (0.03–0.04)	124	1.1	0.03 (0.02–0.03)	0.96 (0.76–1.22)	P < 0.001
Severity of Injury								
Light	2242	30.4	0.46 (0.44–0.48)	2783	25.8	0.65 (0.63–0.68)	1.41 (1.33–1.49)	P < 0.001
Moderate	4273	57.9	0.88 (0.85–0.91)	6937	64.4	1.63 (1.59–1.66)	1.85 (1.33–1.49)	P < 0.001
Severe	865	11.7	0.18 (0.17–0.19)	1058	9.8	0.25 (0.23–0.26)	1.39 (1.27–1.52)	P < 0.001
Location of Injury Event								
Slope Mild (< 10°)	2383	32.3	0.49 (0.47–0.51)	4426	41.1	1.04 (1.01–1.07)	2.11 (2.01–2.22)	P < 0.001
Moderate (10–20°)	3287	44.6	0.68 (0.65–0.70)	3584	33.3	0.84 (0.81–0.87)	1.24 (1.18–1.30)	P < 0.001
Steep (> 20°)	1153	15.6	0.24 (0.22–0.25)	752	7.0	0.18 (0.16–0.19)	0.74 (0.68–0.81)	P < 0.001
Jump areas	189	2.6	0.04 (0.03–0.04)	1385	12.9	0.32 (0.31–0.34)	8.33 (7.16–9.70)	P < 0.001
Others	357	4.8	0.07 (0.07–0.08)	629	5.8	0.15 (0.14–0.16)	2.00 (1.76–2.28)	0.0043
Slope Condition								
Smooth	5853	80.1	1.21 (1.18–1.24)	9298	87.0	2.18 (2.13–2.22)	1.81 (1.75–1.87)	P < 0.001
Unsmooth	830	11.4	0.17 (0.16–0.18)	828	7.7	0.19 (0.18–0.21)	1.13 (1.03–1.25)	P < 0.001
Mogul	280	3.8	0.06 (0.05–0.06)	129	1.2	0.03 (0.03–0.04)	0.52 (0.43–0.65)	P < 0.001
Deep snow	221	3.0	0.05 (0.04–0.05)	194	1.8	0.05 (0.04–0.05)	1.00 (0.82–1.21)	P < 0.001
Others	124	1.7	0.03 (0.02–0.03)	236	2.2	0.06 (0.05–0.06)	2.16 (1.74–2.69)	0.0166

IR: injury rate, IRR: incidence rate ratio, CI: confidence interval

Regarding skiing, the most common injured area was the knee (31.2%, 0.54 per 1000SDs), followed by the lower leg (11.6%, 0.20 per 1000SDs). Among the injury types, fractures (29.5%, 0.84 per 1000SDs) and contusions (27.9%, 0.79 per 1000SDs) were the most common types of injuries in snowboarding, and were significantly higher in snowboarding than in skiing ($P < 0.001$; Table 2). On the other hand, sprains (38.9%, 0.68 per 1000SDs) were the most common in skiing, and were significantly higher in skiing than in snowboarding ($P < 0.001$; Table 2). Especially, knee sprains (32.0%, 0.44 per 1000SDs) were the most common in skiing, whereas wrist fractures (11.9%, 0.24 per 1000SDs) and shoulder dislocations (10.7%, 0.22 per 1000SDs) were the most common in snowboarding.

Simple falls were the most common mechanism in both skiing (70.0%, 1.08 per 1000SDs) and snowboarding (59.9%, 1.55 per 1000SDs), but simple falls from imbalance or falls from a jump or trick failure were significantly more common in snowboarding than in skiing ($P < 0.001$; Table 2).

Snowboarding injuries were more common than skiing injuries regardless of the severity of injury ($P < 0.001$; Table 2). Also, a total of 68 fatal injuries (37 skiers, 31 snowboarders) occurred during the six seasons. The most common cause of fatal injuries was collision with a standing tree on-/off-piste or along the piste (27.9%), followed by deviations and falls off-piste (26.5%). More snowboarding than skiing injuries significantly occurred on mild (41.1%, 1.04 per 1000SDs) to moderate (33.3%, 0.84 per 1000SDs) slopes ($P < 0.001$; Table 2). In addition, more snowboarding than skiing injuries significantly occurred in jump areas (12.9%, 0.32 per 1000SDs) ($P < 0.001$; Table 2). In terms of slope conditions, most injuries occurred on smooth (well-groomed) slopes in both skiing (80.1%, 1.21 per 1000SDs) and snowboarding (87.0%, 2.18 per 1000SDs), but snowboarding resulted in significantly more injuries on smooth slopes than did skiing ($P < 0.001$; Table 2).

Compared with skiing, snowboarding resulted in significantly more injuries among young people (10–19 to 30–39 years; 90.7%), especially among those aged 20–29 years (56.7%, 1.48 per 1000SDs) ($P < 0.001$; Table 3). On the other hand, skiing resulted in significantly more injuries among middle-age people (40 years and older; 45.3%, 0.21-0.25 per 1000SDs) than did snowboarding ($P < 0.001$; Table 3). Regarding sex, snowboarding resulted in significantly more injuries in both males (61.7%, 1.53 per 1000SDs) and females (38.3%, 0.95 per 1000SDs) than did skiing ($P < 0.001$; Table 3).

Table 3. Skier-related factors for skiing and snowboarding injuries from 2012-2013 to 2017-2018 seasons

Factors	Skiing			Snowboarding			IRR (95%CI) (Snowboarding: Skiing)	P-Value
	N	%	IR (95%CI)	N	%	IR (95%CI)		
Age								
< 10	518	6.9	0.11 (0.10–0.12)	146	1.3	0.03 (0.03–0.04)	0.32 (0.27–0.39)	P<0.001
10–19	1558	20.7	0.32 (0.31–0.34)	1752	15.8	0.41 (0.39–0.43)	1.28 (1.18–1.37)	P<0.001
20–29	1284	17.0	0.25 (0.23–0.26)	6305	56.7	1.48 (1.44–1.51)	5.88 (5.26–6.53)	P<0.001
30–39	766	10.2	0.16 (0.15–0.17)	2023	18.2	0.47 (0.45–0.49)	3.00 (2.76–3.26)	P<0.001
40–49	1204	16.0	0.25 (0.23–0.26)	678	6.1	0.16 (0.15–0.17)	0.64 (0.58–0.70)	P<0.001
50–59	1007	13.4	0.21 (0.19–0.22)	167	1.5	0.04 (0.03–0.05)	0.19 (0.16–0.22)	P<0.001
≧60	1201	15.9	0.25 (0.23–0.26)	44	0.4	0.01 (0.01–0.01)	0.04 (0.03–0.06)	P<0.001
Sex								
Male	4312	52.9	0.89 (0.86–0.92)	6909	61.7	1.53 (1.49–1.56)	1.72 (1.65–1.78)	P<0.001
Female	3845	47.1	0.79 (0.77–0.82)	4045	38.3	0.95 (0.92–0.98)	1.20 (1.14–1.25)	P<0.001
Self-Reported Skill Level								
Novice	615	8.3	0.13 (0.12–0.14)	1000	10.1	0.26 (0.24–0.27)	2.02 (1.83–2.22)	P<0.001
Beginner	2394	32.3	0.49 (0.47–0.51)	4572	42.2	1.07 (1.04–1.10)	2.17 (2.07–2.28)	P<0.001
Intermediate	2818	38.0	0.58 (0.56–0.60)	4164	38.4	0.98 (0.95–1.01)	1.68 (1.60–1.76)	0.1228
Advanced	1550	20.9	0.32 (0.30–0.34)	975	9.0	0.23 (0.21–0.24)	0.72 (0.66–0.77)	P<0.001
Others	32	0.4	0.01 (0.00–0.01)	33	0.3	0.01 (0.01–0.01)	1.17 (0.72–1.91)	0.5188
Behavior before Injury Event								
Self sliding	5963	79.1	1.23 (1.20–1.26)	10727	97.0	2.51 (2.47–2.56)	2.05 (1.98–2.11)	P<0.001
School Events	786	10.6	0.16 (0.15–0.16)	112	1.0	0.03 (0.02–0.03)	0.16 (0.13–0.19)	P<0.001
Lessons	352	4.7	0.07 (0.06–0.08)	118	1.1	0.03 (0.02–0.03)	0.36 (0.31–0.47)	P<0.001
Athletic Events	333	4.4	0.07 (0.06–0.08)	32	0.3	0.01 (0.00–0.01)	0.11 (0.08–0.16)	P<0.001
Others	99	1.3	0.02 (0.02–0.02)	74	0.7	0.02 (0.01–0.02)	0.85 (0.63–1.15)	P<0.001
Helmet Use								
Use	2251	30.6	0.46 (0.44–0.48)	1337	12.3	0.31 (0.30–0.33)	0.68 (0.63–0.72)	P<0.001
No use	5112	69.4	1.05 (1.02–1.08)	9520	87.7	2.23 (2.19–2.28)	2.12 (2.05–2.19)	P<0.001

IR: injury rate, IRR: incidence rate ratio, CI: confidence

Injuries among novices to beginners were significantly higher in snowboarding than in skiing, especially among beginners (42.2%, 1.07 per 1000SDs) ($P < 0.001$; Table 3). On the other hand, injuries among advanced skiers (20.9%, 0.32 per 1000SDs) were significantly higher in skiing than in snowboarding ($P < 0.001$; Table 3). Regarding behavior before the injury event, both snowboarders (97.0%, 2.51 per 1000SDs) and skiers (79.1%, 1.23 per 1000SDs) had the most injuries during self-sliding. However, injuries during self-sliding were significantly more frequent in snowboarding than in skiing ($P < 0.001$; Table 3). Concerning the use of helmets, many of the injured snowboarders (87.7%, 2.23 per 1000SDs) and skiers (69.4%, 1.05 per 1000SDs) had not been wearing a helmet. Non-helmet injuries were significantly more common in snowboarding than in skiing ($P < 0.001$; Table 3).

Discussion

In this study, we conducted an analysis of skiing and snowboarding injuries in Japan based on the IR per 1000SDs, which is an international index, and investigated the actual injury conditions. We found that the IRs in skiing and snowboarding during the six seasons surveyed were 1.59 and 2.58 per 1000SDs, respectively, revealing that the snowboarding IR was 1.62 times higher than the skiing IR. These results are consistent with previous studies that pointed out the higher risk of injury in snowboarding compared with skiing (Kim, Endres, Johnson, Ettlinger, & Shealy, 2012; Shealy, Ettlinger, Scher, & Johnson, 2015). In analyzing data from various countries, Bianchi, et al. (2017) also indicated that the risk of skiing injuries decreased, while the risk of snowboarding injuries slightly increased.

In this study, the overall IR for both skiing and snowboarding was 1.90–2.21 per 1000SDs, with an average IR of 2.05 per 1000SDs. In Norway, a decreasing trend, from 1.47 to 1.27 per 1000SDs over a 16-year period, has been reported (Ekeland, Rodven, & Heir, 2017); these IRs are substantially lower than those in this study. As in Norway, it is still considered necessary to review injury prevention measures to reduce IRs further.

In the present study, the most common anatomical areas injured during skiing and snowboarding were the lower limb and upper limb, respectively. This result is consistent with previous studies conducted in Northern Europe and North America (Davidson & Laliotis, 1996; Ekeland et al., 2017; Goulet, Hagel, Hamel, & Légaré, 2007; Hagel, Goulet, Platt, & Pless, 2004; Stenroos & Handolin, 2015). In particular, in this study, the knee was the most frequent site of injury in skiing, and the shoulder and wrist were the most frequent in snowboarding. In this study, the most frequent area injured during skiing, the knee, was consistent with previous studies in other countries (Burtscher et al., 2008; Costa-Scorse et al., 2017; Davidson & Laliotis, 1996; Ekeland et al., 2017; Kim et al., 2012; Stenroos & Handolin, 2015; Warme, Feagin, King, Lambert, & Cunningham, 1995; Xiang, et al., 2005). It has been pointed out that knee injuries are strongly associated with ski binding release settings (Costa-Scorse et al., 2017). However, previous studies have reported that the wrist is the most frequent injury site in snowboarding (Costa-Scorse et al., 2017; Ekeland et al., 2017; Kim et al., 2012; Stenroos & Handolin, 2015; Xiang et al., 2005), which differs from the results of this study. It is possible that snowboarders may have fallen from their shoulders when they fell out of balance or fell due to a jump or trick failure. As speculated in a previous study, the difference in injuries between skiing and snowboarding may be due to the different equipment and ways of falling in skiing and snowboarding (Xiang et al., 2005).

Among the injury types analyzed in this study, sprains were the most frequent in skiing, and fractures and contusions were the most frequent in snowboarding. These results are consistent with previous studies in North America (Coury et al., 2013; Rust, Gilmore, & Treme, 2013). The high incidence of knee sprains in skiing seen in this study are consistent with the results of numerous other studies (Coury et al., 2013; Davey, Endres, Johnson, & Shealy, 2019; Kim et al., 2012; Langran & Selvaraj, 2002; Rust et al., 2013), suggesting that knee sprains are a characteristic injury of skiing.

Simple falls were the most common injury mechanism in both skiing (70.0%) and snowboarding (59.9%); this result is also consistent with those of previous studies (skiing: 63.0–80.0%; snowboarding: 58.0–76.4%) (Bergstrøm & Ekeland, 2004; Nakaguchi & Tsutsumi, 2002; Stenroos & Handolin, 2015; Xiang et al., 2005). In this study, a higher risk of injury due to falls resulting from imbalance and failed jumps or tricks was observed for snowboarding than for skiing. In this regard, Kim et al. (2012) indicated that many injuries in snowboarding occur as a result of jumping and losing control. However, Nakaguchi and Tsutsumi (2002) reported that because of the opposite-edge phenomenon on a gentle slope, snowboarding carries a high risk of serious head injury, even after a simple fall which suggests that neglecting a simple fall is extremely dangerous.

Regarding injury severity, snowboarding led to more injuries than did skiing, regardless of the degree of injury; in particular, many injuries with moderate or higher severity occurred. In addition, a total of 68 fatal injuries occurred in skiing and snowboarding during the six seasons. Uchida and Kato (2016) conducted a comprehensive study of serious accidents in skiing and snowboarding and reported that 296 fatal accidents occurred over a 15-year period in Japan, with an average of 19.7 cases per year. In this study, 11.3 fatal injuries occurred per year, which is fewer compared with that study; however, the high number of fatalities in snow sports remains a serious problem, and safety measures to help prevent fatalities further are still urgently needed.

Regarding the location of the injury and the slope conditions, most injuries in both skiing and snowboarding occurred on mild to moderate groomed slopes, which is consistent with previous studies (Bergstrøm & Ekeland, 2004; Ekeland et al., 2017). Bergstrøm and Ekeland (2004) indicated that the IRs and numbers of injuries increased as the number of grooming hours decreased. However, we did not investigate the slope grooming conditions at the ski resorts surveyed in this study, so this association remains unclear. In addition, more injuries occurred in the jump area in snowboarding compared with skiing. Goulet et al. (2007) reported that both skiing and snowboarding increase the risk of serious injuries in snow parks involving acrobatics and jumps. Fukuda, Takaba, Saito, and Endo (2001) pointed out that snowboarding carries a higher risk of severe head injury than does skiing, especially among beginners, who should not attempt jumps or airborne tricks. A relationship has been reported between injuries and slope and course design (Bergstrøm & Ekeland, 2004); therefore, as difficult slopes and courses tend to be attractive to skiers and snowboarders, it is necessary to consider the effects of slope and course design on injuries.

Younger people in their teens to 30s experienced more injuries in snowboarding than in skiing, whereas middle-age people aged 40 years and older had more injuries in skiing than in snowboarding. A previous study reported that snowboarding leads to more injuries than does skiing in younger people (aged 10–24 years), whereas skiing leads to more injuries in people aged 30 years and older (Xiang et al., 2005); this tendency is similar to the results of the present study. These age characteristics are related to the snow sports situation in Japan (Ministry of Land, Infrastructure, Transport and Tourism, 2017). The skiing population is highest among men in their 20s to 40s, while the snowboarding population is highest for men in their 20s to 30s and women in their 20s. These trends are thought to have affected the characteristics of age- and gender-related injuries. In recent years, the number of older skiers (aged 60 years and older) at Japanese ski resorts has been increasing. An epidemiological study in the United States reported that the IR in skiing was highest among those aged 55–64 years, followed by those aged over 65 years (Xiang et al., 2005). These results were similar to those in this study, suggesting that skiers over the age of 60 years are at higher risk of injury.

In this study, snowboarding led to more injuries among novices to beginners than did skiing, whereas skiing led to more injuries among advanced skiers than did snowboarding. This result was considered to be influenced by the skill levels of novices and beginners, because most of the injuries in snowboarding occurred on mild to moderate slopes, and the most frequent injuries were due to falls resulting from imbalance. As reported in a previous study (Goulet et al., 2007), advanced skiers typically ski at high speeds, and skiing injuries often occurred on unsmooth slopes and moguls.

Regarding behavior before the injury event, injuries during self-sliding occurred more frequently in snowboarding than in skiing. In recent years, snowboarding has gained recognition as a leisure sport that can be easily started by young people in their teens to 20s. For this reason, snowboarding is often started without entering a snowboarding school or receiving any professional instruction (Dohjima, Sumi, Ohno, Sumi, & Shimizu, 2001). A previous study comparing 1996 and 2013 reported that the number of injuries had increased among skiers and snowboarders who had never received professional instructions (Patrick et al., 2015). Therefore, it is necessary to recognize that although snow sports are a leisure sport, they carry a high risk of serious or fatal injuries. Especially, snowboarding should not be started before entering school and receiving professional instruction.

In this study, many injured skiers and snowboarders had not been wearing a helmet, and this tendency was particularly high in snowboarding. This result may have been influenced by the fact that few skiers and snowboarders (3.6%) wear helmets at ski resorts in Japan (Ogawa, Sumi, Sumi, & Shimizu, 2010). In Norway, the use of helmets has recently increased from 11% to 81%, leading to a reduction in the rate of head injuries, from 19% to 16% (Ekeland et al., 2017). In New Zealand, on the other hand, even though helmet use increased from 42% in 2010 to 83% in 2015 (84% for skiers and 79% for snowboarders), a 26% increased risk of head injuries in skiers wearing helmets and a 36% increased risk of head injuries in snowboarders wearing helmets have been reported (Costa-Scorse et al., 2017). In previous studies (Ackery, Hagel, Provvidenza, & Tator, 2007; Russell, Christie, & Hagel, 2010), helmet use was found to have reduced the risk of head injuries by 22–60%, suggesting the importance of following rules and responsibility codes at ski resorts to prevent injuries. Taken together, these findings suggest that, in addition to increasing their helmet use at ski resorts in Japan, safety education for skiers and snowboarders should be enhanced to help ensure compliance with rules and conduct codes at ski slopes.

This study did have some limitations. First, not all ski resorts surveyed in this study had installed an integrated circuit gate system, so the number of lift transportations was estimated instead of summed up; this may have slightly affected the SDs. Second, in the injury survey, the injury data were basically recorded by ski patrols at each ski resort. For injuries with a high degree of severity, the reliability of the data is considered to be high when the injuries are recorded after being diagnosed at a clinic in the ski area. However, if no medical facility is located within the ski area, overestimation or underestimation of injury severity is possible. Third, with regard to mild or moderate injuries, there may have been cases in which only first aid treatment was performed in a patrol room at a ski resort, with no diagnosis made by a medical doctor, and thus, the injury may not have been properly diagnosed; therefore, it is possible that the number of injuries recorded was overestimated.

Conclusions

The results of this study revealed that snowboarding has a higher IR than does skiing. The most frequent injury site in skiing was the lower limb (especially the knee), and those in snowboarding were the upper limb (especially the shoulder and the wrist) and the head and neck. Sprains were the most frequent in skiing, and fractures and contusions were the most frequent in snowboarding. Snowboarding injuries were more common than skiing injuries regardless of the severity. A total of 68 fatal injuries occurred to skiers and snowboarders during the six seasons. Simple falls and jump or trick failure were more common mechanism in snowboarding than in skiing. More snowboarding than skiing injuries occurred on groomed mild and moderate slopes, and in particular, more snowboarding injuries occurred in the jump area.

In addition, compared with skiing, snowboarding resulted in more injuries among young people (especially aged 20-29 years), on the other hand, skiing resulted in more injuries among middle-age people (40 years and older) than did snowboarding. Snowboarding more often led to injuries among novices to beginners, while skiing more often led to injuries among advanced skiers. Injuries during self-sliding occurred more frequently in snowboarding than in skiing. Many injured skiers and snowboarders had not been wearing a helmet, especially non-helmet injuries were more common in snowboarding than in skiing.

These findings suggest the importance of recognizing that as opposed to being easy leisurely sports, skiing and snowboarding are high-risk sports in which serious or fatal injuries frequently occur. Therefore, it is essential for skiers and snowboarders not only to take appropriate safety measures at ski resorts, but also to engage in snow sports only after receiving adequate skill instruction and safety education.

Conflicts of interest - There is no conflict of interest.

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