

ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Recreational skiing- and snowboarding-related injuries – a four-year trauma center cohort from Kopaonik mountain ski center

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SUMMARY

Introduction/Objective Skiing and snowboarding are popular winter sports with distinct participant demographics, equipment, and movement patterns. Comparative epidemiological data from Southeast Europe are limited. The aim of this study was to compare injury epidemiology and injury patterns between skiers and snowboarders at the Kopaonik Ski Resort, Serbia.

Methods This retrospective descriptive epidemiological study analyzed ski patrol reports and medical records from the University Clinical Center of Serbia over four winter seasons (2021–2024). Injured participants aged 4–81 years who received on-site ski patrol assistance and were evaluated at the resort-based trauma center were included. Participants were categorized according to sport (skiing or snowboarding). Group differences in demographic, temporal, and environmental characteristics were assessed using χ^2 tests. Injury types and anatomical distribution were compared using χ^2 or Fisher's exact tests, and odds ratios with 95% confidence intervals were calculated.

Results A total of 3368 injured participants were included, of whom 3011 (89.4%) were skiers and 357 (10.6%) snowboarders. Snowboarders were younger and more often male ($p < 0.001$). They were more frequently injured on novice slopes, whereas skiers predominated on advanced slopes ($p = 0.001$). Helmet use was higher among snowboarders ($p = 0.004$). Skiers had higher odds of knee and lower leg injuries, while snowboarders more commonly sustained forearm and hand/wrist injuries. Fractures and dislocations were more frequent among snowboarders, whereas sprains predominated in skiers.

Conclusion Significant sport-specific differences in injury patterns were identified. These findings support the development of targeted injury prevention strategies and optimization of healthcare services for winter sports injuries.

Keywords: snowboarding; skiing; injury

INTRODUCTION

Skiing and snowboarding are popular winter sports, and while they share similar environments, they differ in demographics, movement patterns, equipment, and skill level of participants. Previous studies have shown that snowboarders tend to be younger and more often males compared to skiers [1–5]. Historically, helmet use was higher among snowboarders, but recent reports indicate a similar acceptance level between the two groups [2, 6]. Furthermore, the temporal patterns of injuries vary, with skiers being more frequently injured during weekdays and snowboarders more often on weekends [4, 7]. Available evidence indicates that snowboarders sustain injuries on easier slopes, whereas skiers' injuries are more evenly distributed across intermediate and advanced slopes [2, 8]. Weather conditions have also been identified as an external risk factor for injuries, but data comparing skiers and snowboarders are limited [9, 10, 11].

Additionally, previously published papers showed different injury patterns in those two

groups. Upper extremity injuries were predominant in snowboarders, while lower extremity injuries were more frequent in skiers [1, 2, 4, 12, 13, 14].

Kopaonik Ski Center, which was established in 1964, is the largest ski resort in Southeast Europe, encompassing 48 alpine ski slopes, 30 ski trails, and two beginner training grounds, which can accommodate 12,000–14,000 simultaneous skiers. Delibašić et al. [15] have shown that the capacity of the ski lift transportation system at the Kopaonik Ski Center increased by 58%, and the injury rate nearly doubled from 2005. to 2010. Furthermore, snowboarding experienced a significant boom in the 1990s, when most major ski areas developed separate slopes for snowboarders. Snowboarding developed with delay at Mt Kopaonik, where the first snowboard park opened in 2012. The rapid development of the largest ski resort in Southeastern Europe on one side, and the significantly delayed initial adoption may lead to local differences in epidemiology of those injuries, underscoring the need for specific epidemiological data and comparative analyses. Although numerous international

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studies have investigated demographic, temporal, and environmental factors associated with snow-sport injuries, to the best of our knowledge, no previous research has examined those aspects in the Southeastern European context. This retrospective observational study aimed to address two primary objectives:

to analyze and compare differences between injuries in skiers and snowboarders regarding demographic, environmental, and temporal factors;

to compare injury patterns between the two sports in terms of anatomical location and injury type.

Understanding those factors in the local context is essential for developing targeted injury prevention strategies, guiding slope management policies, and improving skier and snowboarder safety. This study presents an opportunity to contribute valuable insights into the field of winter sports safety, particularly in the Southeastern European context.

METHODS

Participants and inclusion criteria

This retrospective descriptive epidemiological study was conducted at Mt Kopaonik Ski Center and included individuals injured while skiing or snowboarding during the period spanning from 2021 to 2024. Included participants were those who received on-site assistance from the Mountaineer Rescue Service of Serbia (ski patrol) and were subsequently medically evaluated at the Trauma Center of the University Clinical Center Serbia, located at the base of the resort. Participants treated only by the ski patrol or those who refused medical evaluation were excluded from the study. Furthermore, only patients with musculoskeletal injuries were included.

Data collection

The study participants were categorized into two distinct cohorts based on their injuries sustained during skiing or snowboarding at the time of injury. Data regarding demographic characteristics and types of injuries were obtained from the hospital database system following a standardized data extraction protocol to ensure consistency. Information regarding helmet usage, environmental, and temporal factors was obtained from ski patrol reports. All participants had a unique ID, which allowed researchers to link them to databases.

Statistical analysis

All analyses were performed in IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., Armonk, NY, USA) with significance set at $p < 0.05$. Means and standard deviations were calculated for continuous variables and percentages for categorical variables. Age was analyzed as a continuous variable and categorized into predefined groups (< 15 , 15–24, 25–44, 45–64, and ≥ 65 years). Comparisons between injured skiers and snowboarders were performed

with the Pearson χ^2 test. Effect sizes (Φ coefficient and Cramér's V) were calculated to determine the strength of associations. To identify cells contributing most to significant χ^2 results the adjusted residuals (AR) were calculated. AR indicated the degree to which the observed frequency differs from the expected frequency. Positive AR values indicated overrepresentation, while negative AR values indicated underrepresentation. An absolute AR value greater than 1.96 was considered statistically significant [16]. AR analyses were considered exploratory, and focused on identifying the largest deviations from expectation. No formal correction for multiple comparisons was applied.

Injury distribution across anatomical regions was compared between sports using the χ^2 /Fisher test as above. For each region, we calculated an odds ratio (OR) with a 95% confidence interval (95% CI) with $OR > 1$ meaning the injury was more common in skiers, and $OR < 1$ meaning it was more common in snowboarders.

Ethics: The study was approved by the Ethics Committee of the University Clinical Center, Number 524/4.

RESULTS

The differences between skiers and snowboarders in terms of demographic characteristics, temporal, environmental factors and helmet usage are summarized in Table 1.

The final sample consisted of 3368 injured participants, including 3011 skiers (89.4%) and 357 snowboarders (10.6%). Among the patients included in the study, 1713 were female (50.9% and 1655 were male (49.1%). The mean age of the patients was 31 ± 14.68 years.

Differences between skiers and snowboarders regarding demographic factors

Compared to skiers, a greater proportion of males was found among snowboarders (58.8% vs. 49.9%, $p = 0.001$). Skiers were older than snowboarders (32.3 ± 15 vs. 26.3 ± 9.7 years, $p < 0.001$). When age was categorized, a significantly higher than expected number of skiers were injured among the 45–64-year group (AR = 8.2) while snowboarders were overrepresented in the 25–44 years group (AR = 4.7) (Table 1).

Differences between skiers and snowboarders regarding environmental factors

Both skiers and snowboarders were most frequently injured on easy slopes. However, there was a significant difference between the two groups with respect to slope difficulty ($p = 0.001$). A significantly higher than expected number of skiers was injured on advanced/expert slopes (AR = 3.4), while this was true for snowboarders on novice slopes (AR = 2.6). Most of the injured skiers (77.2%) and snowboarders used helmets (83.5%), although this proportion was significantly higher in snowboarders ($p = 0.007$) (Table 1)

Table 1. Details of injured skiers and snowboarders

Parameters	Skiers (3011)	AR ^a	Snowboarders (357)	AR ^a	p	Effect size	
Demographic factors							
Gender	Male	1503 (49.9)	-3.2	210 (58.8)	3.2	0.001	$\phi = 0.055$
	Female	1508 (50.1)	3.2	147 (41.2)	-3.2		
Age	Mean age	32.33 ± 15.04		26.33 ± 9.68		0.000 ^b	
	< 15	498 (16.5)	-0.7	64 (17.9)	0.7	0.000	V = 0.150
	15–24	570 (18.9)	-2.5	87 (24.4)	2.5		
	25–44	1230 (40.9)	-4.7	192 (53.8)	4.7		
	45–64	660 (21.9)	8.2	13 (3.9)	-8.2		
65+	53 (1.8)	2.1	1 (0.3)	-2.1			
Environmental factors							
Slope difficulty	Novice	392 (13)	-2.6	64 (17.9)	2.6	0.001	V = 0.069
	Easy	1380 (45.8)	-0.7	171 (47.9)	0.7		
	Intermediate	784 (26)	0.1	92 (25.8)	-0.1		
	Advanced/expert	455 (15.1)	3.4	30 (8.4)	-3.4		
Helmet	Yes	2325 (77.2)	-2.7	298 (83.5)	2.7	0.007	$\phi = 0.050$
	No	686 (22.8)	2.7	59 (16.5)	-2.7		
Temporal factors							
Day of week	Weekday	1925 (63.9)	2.2	207 (58)	-2.2	0.027	$\phi = 0.038$
	Weekend	1086 (36.1)	-2.2	150 (42)	2.2		
Time of injury	Morning (8–10)	130 (4.3)	0.4	14 (3.9)	-0.4	0.143	V = 0.045
	Noon (10–12)	842 (28)	0.0	100 (28)	0.0		
	Afternoon (12–14)	990 (32.9)	1.3	105 (29.4)	-1.3		
	Late afternoon (14–16)	925 (30.8)	-0.5	114 (31.9)	0.5		
	Night (18–22)	121 (4)	-2.4	24 (6.7)	2.4		
Season of injury	2021	1059 (35.2)	1.6	110 (34.7)	-1.6	0.133	V = 0.041
	2022	831 (27.6)	0.1	98 (27.5)	-0.1		
	2023	617 (20.5)	-2.2	91 (25.5)	2.2		
	2024	504 (16.7)	0.2	58 (16.2)	-0.2		
Month of injury	January	1097 (36.4)	1.7	114 (31.9)	-1.7	0.513	V = 0.031
	February	1054 (35)	-0.7	132 (37.2)	0.7		
	March	632 (21)	-0.5	79 (22.1)	0.5		
	April	56 (1.9)	-0.1	7 (2)	0.1		
	December	172 (5.7)	-1.0	25 (7)	1.0		
Off slope	Yes	65 (2.2)	-0.8	10 (2.8)	0.8	0.437	$\phi = 0.013$
	No	2946 (97.8)	0.8	347 (97.2)	-0.8		
Weather conditions	Optimal	1473 (48.9)	-2.3	198 (55.5)	2.3	0.017*	V = 0.049
	Moderate	1292 (42.9)	2.9	125 (35)	-2.9		
	Adverse	246 (8.2)	-0.9	34 (9.5)	0.9		

AR – adjusted residuals; a) statistically significant differences between groups ($p < 0.05$) are denoted by boldface p; AR values > 1.96 or < -1.96 indicate statistically significant differences at $p < 0.05$; b) t-test; ϕ to determine the strength of the association between two variables for 2×2 comparisons; V (Cramer) for multicategory comparisons to determine the strength of the association between two variables

Difference between skiers and snowboarders regarding temporal factors

Skiers had a significantly higher proportion of weekday injuries compared to snowboarders (63.9% vs. 58%), while snowboarders were more likely to be injured on weekends (42% vs. 36.1%, $p = 0.027$) (Table 1).

A significant difference regarding injury risk with respect to weather conditions was observed ($p = 0.017$). Although injuries in both groups most often occurred under optimal weather conditions, a higher-than-expected number of ski injuries were sustained under moderate weather conditions (AR = 2.9) (Table 1).

Time of injury, season of injury, and month of injury did not significantly differ between skiers and snowboarders ($p > 0.05$).

Differences between skiers and snowboarders regarding injuries

The anatomical distribution of injuries differed significantly between skiers and snowboarders (Table 2). Lower-limb injuries were markedly more frequent among skiers, particularly the knee (39.7% vs. 10.1%; OR = 5.87, 95% CI 4.13–8.34, $p < 0.001$) and lower leg (10.2% vs. 3.6%, OR = 3,

95% CI 1.70–5.29, $p < 0.001$). Thigh and ankle injuries did not differ significantly between sports (both $p > 0.05$).

Upper-limb injuries were more frequent among snowboarders (62.7% vs. 26.7%, $p < 0.001$) with the largest differences in the forearm (OR = 0.14, 95% CI 0.11–0.188, $p < 0.001$) and hand/wrist (OR = 0.49, 95% CI 0.342–0.713, $p < 0.001$). Trunk injuries were less common in skiers than snowboarders (OR = 0.64, 95% CI 0.43–0.95, $p = 0.027$). This difference was mainly due to lower back-pelvis injuries (OR 0.42, 95% CI 0.25–0.70, $p = 0.001$)

Types of injury

Injury type differed between sports (Table 3). Compared with snowboarders, skiers had higher odds of sprain (27.5% vs. 9.8%; OR = 3.48, 95% CI 2.41–4.93, $p < 0.001$), whereas

fracture (20.7% vs. 36.0%; OR = 0.47, 95% CI 0.37–0.59, $p < 0.001$) and dislocation (5.2% vs. 10.6%; OR = 0.47, 95% CI 0.32–0.68, $p < 0.001$) were more frequent among snowboarders. Differences for contusion, laceration, and concussion were not statistically significant (all $p > 0.05$).

DISCUSSION

Almost 90% percent of injuries in our cohort were sustained by skiers. Recent studies reported the incidence of ski injuries being between 62–69.7%, indicating that skiing still maintains greater popularity compared to snowboarding [2, 4]. Results from our study demonstrated demographic differences and confirmed globally observed patterns between skiers and snowboarders in the local setting. A higher

proportion of younger population and males was found among snowboarders compared to skiers. This is in accordance with data from previous studies suggesting that snowboarding tends to be more popular among younger demographics, particularly males [1–5, 8].

Most injuries in both groups were sustained on easy slopes. Our results align with limited results reported in literature showing that most injuries from both sports occur on easy to intermediate slopes, where the most participants spend the majority of their time [2, 17]. However, our results showed a higher proportion of snowboard related injuries on novice slopes, and a higher proportion of ski related injuries on advanced/expert slopes in skiers. This finding suggests that injured snowboarders are beginners compared to skiers who were more experienced. Lower ability is a clearly recognized risk factor for injury [18, 19, 20]. Promotion of responsible skiing and snowboarding within one's limits and abilities with a special focus on novice snowboarders should be considered an important educational task.

A significantly higher helmet usage among snowboarders compared to skiers found in our study is in line with results from the 2000s [21, 22, 23] but different from recent years results, suggesting similar helmet use between the two groups, and a dramatical increase in helmet adoption for both skiing and snowboarding [2, 6]. The pattern observed in our cohort suggests the need to create more focused helmet adoption safety initiatives for both groups, with a special focus on skiers.

Skiers had a higher proportion of injuries during the weekdays compared to snowboarders (63.9%

Table 2. The anatomical distribution of injuries in skiers and snowboarders common in skiers

Injured body region	n (%)	Skiers n (%)	Snowboarders n (%)	p ^b	OR ^a	CI
Head and neck	332(9.9%)	304 (10.1%)	28 (7.8%)	0.177	1.32	0.88–1.97
Head	228 (6.6%)	204 (6.8%)	24 (6.7%)	0.970	1.00	0.65–1.56
Face	59 (1.8%)	59 (2%)	0 (0%)	0.002 ^c	14.4 d	NC
Neck	45 (1.3%)	41(1.4%)	4 (1.1%)	1.00 ^c	1.21	0.43–3.42
Trunk	211 (6.3%)	179 (5.9%)	32 (9%)	0.026 [*]	0.64	0.43–0.95
Chest	103(2.9%)	93 (3.1%)	10 (2.8%)	0.765	1.10	0.57–2.14
Back	4 (0.1%)	3 (0.1%)	1 (0.3%)	0.361 ^c	0.35	0.04–3.42
Abdomen	11 (0.3%)	10 (0.3%)	1 (0.3%)	1.000 ^c	1.18	0.15–9.29
Lower back and pelvis	93 (2.8%)	73 (2.4%)	20 (5.6%)	0.001	0.41	0.25–0.69
Upper limb	1027 (30.5%)	803 (26.7%)	224 (62.7%)	0.000	0.21	0.17–0.27
Shoulder	429 (12.7%)	362 (12%)	67 (18.8%)	0.000	0.59	0.44–0.78
Upper arm	79 (2.3%)	73 (2.4%)	6 (1.7%)	0.380	1.45	0.63–3.36
Elbow	41 (1.2%)	32 (1.1%)	9 (2.5%)	0.035 [*] c	0.41	0.19–0.87
Forearm	267 (7.9%)	164 (5.4%)	103 (28.9%)	0.000	0.14	0.11–0.18
Hand/wrist	211 (6.3%)	172(5.7%)	39 (10.9%)	0.000	0.49	0.34–0.71
Lower limb	1766 (52.4%)	1700 (56.5%)	66(18.5%)	0.000	5.71	4.34–7.54
Thigh	106 (3.1%)	99 (3.3%)	7 (2%)	0.174	1.75	0.81–3.81
Knee	1231 (36.5%)	1195 (39.7%)	36 (10.1%)	0.000	5.86	4.13–8.34
Lower leg	320 (9.5%)	307 (10.2%)	13 (3.6%)	0.000	3.00	1.71–5.29
Ankle	96 (2.9%)	89 (3%)	7 (2%)	0.285	1.52	0.70–3.31
Foot	13 (0.4%)	10 (0.3%)	3 (0.8%)	0.152 ^c	0.39	0.11–1.43
Other	32 (1%)	25 (0.8%)	7 (2%)	0.073 ^c	0.41	0.18–0.97

^aOR – odds ratio for injury in skiers relative to snowboarders; OR > 1 indicate injuries more; OR < 1 indicate injuries more common in snowboarders;

^bps refer to χ^2 or Fishers exact test as appropriate; statistically significant differences between groups ($p < 0.05$) are denoted by boldface p;

^cFishers exact test;

^dOR calculated using a continuity correction of 0.5 due to zero cases among snowboarders

Table 3. Comparison of injury types between skiers and snowboarders

Type of injury	n (%)	Skiing	Snowboarding	p	OR ^a	CI
Dislocation	193 (5.8%)	156 (5.2%)	37 (10.6%)	0.000	0.46	0.32–0.68
Contusion	1249 (37.1%)	1128 (37.8%)	121 (34.6%)	0.241	1.14	0.91–1.45
Fracture	745 (22.1%)	619 (20.7%)	126 (36%)	0.000	0.46	0.36–0.58
Laceration	156 (4.7%)	140 (4.7%)	16 (4.6%)	0.922	1.02	0.61–1.74
Sprain	864 (25.7%)	829 (27.5%)	35 (9.8%)	0.000	3.49	2.44–4.99
Concussion	129 (3.8%)	114 (3.8%)	15 (4.2%)	0.662	0.89	0.52–1.55
Other	32 (1%)	25 (0.8%)	7 (2%)	0.037	0.41	0.19–0.97

^aOR = odds ratio for injury in skiers relative to snowboarders;

^{*}Statistically significant differences between groups ($p < 0.05$) are denoted by boldface p

vs. 58%), while snowboarders were more likely to be injured on weekends (42% vs. 36.1%, $p = 0.027$). This is in contrast with previously published works by Chen et al. [7] and Subaşı et al. [4], who reported only minor or non-significant differences between sports. Our results show a clear temporal difference, suggesting that injury timing may be sport-specific and that targeted preventive strategies during peak weekend periods may be particularly relevant for snowboarders. The higher injury counts on weekends in snowboarders can possibly be explained by the fact that snowboarders are younger and less experienced than skiers, and primarily snowboard only on weekends, which is consistent with results observed in this study.

While most injuries in both groups occurred under optimal weather conditions, skiers sustained injuries more often under moderate weather conditions compared to snowboarders. To the best of our knowledge, prior studies have not compared weather-related injury risk by sport but showed that injuries concentrate in favorable or warmer conditions, and that temperature/visibility influence risk in both groups [9, 11]. Our results may reflect specific differences in risk-taking behavior, with snowboarders being more active only during favorable conditions, potentially increasing their exposure to injury only under these conditions. It could also be assumed that skiers are more experienced, thus skiing also when weather conditions are not optimal.

Different anatomical localization in both disciplines of injuries in our cohort also underline their diversity. The most frequently affected area in snowboarders was the upper extremity, with fractures being the most frequent type of injury. On the contrary, skiers sustained significantly more lower extremity injuries, particularly involving the knee, where sprains occurred with notably higher odds. The results of our study confirmed the previously well-established differences in anatomical localization and types of injuries in both disciplines, which can be explained by different mechanisms of injuries [1–4, 13, 14, 24, 25]. Snowboarders whose feet are fixed attempt to fall with reflex arms outstretching, leading to force of injury transition to the upper limb. On the other hand, skiers are more prone to torsional forces on their stationary lower limbs during falls [14]. Evidence-based equipment related injury prevention measures of knee and wrist injuries should be promoted. Wearing wrist guards, especially during the learning phase

when fall risk is higher for snowboarders, and lower binding settings for easier release of skis have been scientifically demonstrated to be effective [14, 26, 27, 28].

Strengths and limitations

The major strength of our study is the large sample of injuries collected over four years at Mt Kopaonik Ski Center, the largest ski resort in Southeast Europe. In addition, the analysis of both ski patrol and Trauma Center databases allowed comprehensive analysis and deeper understanding of our cohort.

The first limitation of our study is its retrospective nature. Second, the present study assessed data obtained from a single center. Furthermore, available medical records did not encompass all significant variables, such as mechanism of injury, pre-existing conditions, self-reported skill levels, etc. The most important missing variables are specific injury diagnosis, which was due to imprecise medical documentation. Ski patrol reports may not have captured the full spectrum of injuries, especially those that did not require medical treatment. Hence, it was not possible to provide incidence and prevalence data. Also, the sample size for snowboarders was significantly smaller than for skiers, which may have limited statistical power to detect differences between the two groups.

Future research should incorporate prospective data collection, encompass more precise diagnosis and a broader spectrum of variables.

CONCLUSIONS

Despite the increasing popularity of snowboarding in recent years, skiing remains significantly more popular. Snowboarders are mostly less experienced younger male, who commonly sustain injuries on novice slopes on weekends. Targeted prevention strategies should be focused on promotion of evidence-based equipment related injury prevention, responsible skiing and snowboarding within one's capabilities. Special attention should be focused on more precise diagnostics of injuries and defining a standardized approach for uniform data collection in all ski centers.

Conflict of interest: None declared.

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Повреде у рекреативном скијању и сноубордingu – четворогодишња кохортна студија траума центра у ски-центру Копаноник

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САЖЕТАК

Увод/Циљ Скијање и сноубордиг су популарни зимски спортови који се разликују по демографским карактеристикама учесника, опреми и обрасцима кретања. Компаративни епидемиолошки подаци о повредама у овим спортовима у југоисточној Европи су ограничени. Циљ ове студије био је да се упореде епидемиологија и обрасци повређивања код скијаша и сноубордера на Скијалишту Копаноник у Србији.

Метод Спроведена је ретроспективна дескриптивна епидемиолошка студија заснована на анализи извештаја ски-патроле и медицинске документације Универзитетског клиничког центра Србије током четири зимске сезоне (2021–2024). Укључени су повређени учесници узраста од 4 до 81 године који су збринуте на терену и прегледани у траума центру на скијалишту. Испитаници су подељени према врсти спорта. Разлике у демографским, временским и амбијенталним карактеристикама анализирани су χ^2 тестом. Тип и

анатомска локализација повреда упоређивани су применом χ^2 или Фишеровог егзактног теста, уз израчунавање односа шанси (OR) са 95% интервалом поузданости.

Резултати Анализирано је 3368 повређених учесника, од којих су 3011 (89,4%) били скијаша, а 357 (10,6%) сноубордери. Сноубордери су били млађи и чешће мушког пола ($p < 0,001$). Повреде код сноубордера чешће су се јављале на лакшим стазама, док су скијаша доминирали на тежим стазама ($p = 0,001$). Скијаша су имали веће изгледе за повреде колена и потколенице, док су сноубордери чешће задобијали повреде подлактице и шаке/зглоба. Преломи и луксације били су чешћи код сноубордера, а уганућа код скијаша.

Закључак Утврђене су значајне разлике, специфичне за спортове, у обрасцима повређивања, што указује на потребу за циљаном превенцијом повреда и унапређењем здравствене заштите у зимским спортовима.

Кључне речи: сноубордиг; скијање; повреде