Helmet use and risk of head injuries in alpine skiers and snowboarders: changes after an interval of one decade

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ABSTRACT

Background In a previous study, we concluded that a safety helmet can reduce the risk for head injury by 60%. Other studies reported similar effects, resulting in a general recommendation to wear a helmet while skiing or snowboarding.

Aim To determine the effect of the expected increased helmet wear on the risk of head injury one decade after the recommendation.

Methods Ski patrols reported injury cases in major Norwegian alpine ski resorts. Injury type, helmet use and other risk factors were recorded. A multiple logistic regression analysis was used to assess the relation between individual risk factors and the risk of head injuries by comparing head injured skiers (cases) with skiers and snowboarders who reported other injuries (controls).

Results Helmet use was associated with improved odds for head injuries (OR: 0.45, 95% CI 0.34 to 0.60; p<0.001) in 2002; this effect was attenuated in 2010 (OR: 0.79, 95% CI 0.63 to 0.98; p=0.02), and not significant in 2011 (OR: 0.80, 95% CI 0.60 to 1.06; p=0.12). For potentially severe head injuries, the protective effect of using a helmet was better sustained over the observation period, from an OR of 0.44 (95% CI 0.28 to 0.68, p<0.001) in 2002 to an OR of 0.74 (95% CI 0.57 to 0.97, p=0.02) in 2010 and 0.67 (95% CI 0.47 to 0.96; p=0.03) in 2011.

Conclusions We observed an unexpected reduction in the protective effect of a skiing helmet. This may be due to new skiing trends in the alpine resorts.

INTRODUCTION

Helmet use in alpine skiing and snowboarding has been a contentious issue for many years. Haid first introduced the issue of wearing a safety helmet while skiing in 1955.[1] Mandatory helmet use for children up to 17 years was first advocated in 1983.[2] Still, helmet use among adults did not become common until the current decade, after several studies had led to the same conclusion that head injury risk among skiers and snowboarders is reduced by wearing a helmet and with no evidence of increased risk of neck injury.[3–8]

In 2005, Hagel *et al*[4] reported a 29% reduction in head injury risk for skiers and snowboarders wearing a helmet at 19 ski areas in Quebec, Canada. On the basis of a case–control study in eight major Norwegian alpine resorts during the 2002 winter season, comparing 3277 injured skiers and snowboarders with 2992 non-injured controls, we concluded that using a helmet was associated with a 60% reduction in the risk for head injury (57% for severe head injuries).[3] In 2008, Mueller *et al*[9] reported a 15% reduction in head injuries with helmet use. Another study looked at head, face and neck injuries among children, and found an increased risk among those who did not wear a helmet.[5] A retrospective cohort study by Greve *et al*[10] showed a 5.8-fold decreased incidence in loss of consciousness when hitting the head when using a skiing helmet. Rhugani *et al*,[11] in a retrospective study of skiers with skull fractures, reported that the risk of a skull fracture was 10.5-fold higher among those not wearing a helmet compared with helmet users. On the basis of self-reported injury data from 2986 neck injured skiers and snowboarders in Quebec covering the period from 1995–1996 to 2004–2005, Hagel *et al*[12] concluded that helmets did not increase the risk of neck injuries or cervical spine fractures in skiers and snowboarders. On the basis of the above studies, recent reviews have also concluded that safety helmets decrease the risk and severity of head injuries in alpine skiing and snowboarding by roughly 40%, without increasing the risk of neck injuries or risk-taking behaviour.[6 7 13]

According to the 2012/2013 National Ski Areas Association (NSAA) National Demographic Study, 70% of skiers and snowboarders wore helmets, a dramatic increase from the 2002/2003 season, when only 25% wore helmets.[14] We therefore wanted to repeat our study on Norwegian skiers and snowboarders,[3] expecting to find a similar increase in the proportion of helmet users and hypothesising that, as a consequence, there would be a substantial reduction in head injuries.

METHODS

Ski patrols at major Norwegian ski resorts registered injuries during the 2002, 2010 and 2011 winter seasons. This study was based on anonymised data from the Norwegian Ski Lift Association injury and marketing research databases.

An injury was recorded when a skier or snowboarder was treated by or consulted the ski patrol or first aid room staff after an injury in the skiing/snowboarding area during skiing/snowboarding or lift transport. To qualify for the ski patrol, the personnel are required to go through a structured programme of first aid education. A standard form was used to record personal data (age, gender, nationality), as well as information about equipment used (alpine skis, telemark skis (turning with free heel lift), snowboard, sleigh or other), the use of helmet (yes/no), rented or own equipment (yes/no), previous ski school attendance (yes/no) and skiing

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ability. Skiing ability was classified into four categories (beginner, intermediate, good or expert) based on self-reported performance of turns.[1]

In addition, recordings were made of whether the injury occurred on the prepared piste, in park areas (terrain parks, areas within the ski resort with jumps, rails, obstacles), off-piste (outside groomed runs) or while taking the ski lift. The anatomical location (ranked from highest to lowest: head, neck, back, chest/tummy, shoulder, arm, wrist, hand, thigh, knee, leg, ankle, foot) and injury type (fracture, sprain, contusion, skin wound, illness) was recorded, as well as whether the patient needed further evaluation and treatment by physician or at a hospital, as assessed by the ski patrol. We defined such patients as potentially severe cases. Facial injuries were included among head injuries, while neck injuries represented a separate category. In cases with multiple injuries to the same person, only the highest ranked injury was recorded. In head injury cases with multiple injuries, we always ranked the head injury as the most severe.

Cases were skiers with injuries to the head, while as controls we used skiers and snowboarders who reported other injuries than head injuries (ie, arm, leg, trunk) at the same ski area in the same year. Fisher's exact tests were used to compare characteristics between groups. We used logistic regression analysis to estimate the relationship between helmet use and head injuries. To select potential confounders, we performed univariate analyses of the relationships to both head injuries and helmet use. Factors with $p<0.20$ were used as adjustment factors for potential confounding in the logistic models. Owing to the large number of outcomes, it was not necessary to limit the number of variables in the model. A test of interaction between helmet use and study year was performed by adding a cross product term between the two variables together with the two linear terms, adjusting for the other covariates. In addition, we performed individual logistic regression analyses with and without each individual potential confounder to estimate the effect on the helmet use estimate on head injury risk, and we included confounders where the coefficient was 10% or more. A Wald test was used for significance testing. We used SPSS (V.22.0. Armonk, New York, USA) for the analyses. ORs are presented with their 95% CIs. A two-sided α level of 0.05 was considered statistically significant.

RESULTS

We recorded 11 108 injured persons, 3276 in 2002, 4396 in 2010 and 3436 in 2011. In 2002, 17.6% of these were head injuries and we observed a 13.1% relative reduction in the proportion of head injuries to 15.3% in 2010 ($p<0.01$ vs 2002) and 15.4% in 2011 ($p<0.05$ vs 2002) (table 1). During the same decade, helmet use increased substantially among injured skiers and snowboarders, from 23.8% in 2002 to 68.1% in 2010 ($p<0.001$ vs 2002) and 77.1% in 2011 ($p<0.001$ vs 2002).

Table 1 shows the distribution of injuries in relation to other candidate risk factors in 2002, 2010 and 2011. The proportion of injured skiers and snowboarders who defined themselves as experts increased from 2002 to 2010 ($p<0.01$ vs 2002) and 2011 ($p<0.01$ vs 2002). In addition, a greater proportion of injuries occurred in park areas in 2010 ($p<0.001$ vs 2002) and 2011 ($p<0.001$ vs 2002). There were also changes in the equipment used with a greater proportion of injured alpine skiers in 2010 ($p<0.01$ vs 2002) and 2011 ($p<0.01$ vs 2002). In the same period, the proportion of injured snowboarders was reduced ($p<0.001$ vs 2002 in 2010, $p<0.001$ vs 2002 in 2011), as was that of injured telemark skiers ($p<0.01$ vs 2002 in 2010, $p<0.01$ vs 2002 in 2011). Apart from these changes, only minor differences were observed over the years in the distribution of other characteristics (table 1).

Table 1 Distribution of characteristics associated with injured skiers and snowboarders in 2002, 2010 and 2011

	2002 (n=3276)		2010 (n=4396)		2011 (n=3436)	
	n	Per cent	n	Per cent	n	Per cent
Helmet use						
Yes	780	23.8	2992	68.1	2650	77.1
No	2443	74.6	1000	22.7	647	18.9
Unknown	53	1.6	404	9.2	139	4.0
Age						
<13	453	13.8	682	15.5	565	16.5
13–20	1392	42.5	1540	35.0	1430	41.7
>20	1393	42.5	1839	41.8	1305	38.1
Unknown	38	1.2	335	7.6	128	3.7
Gender						
Male	1965	60.0	2626	59.7	2140	62.4
Female	1281	39.1	1654	37.6	1273	37.1
Unknown	30	0.9	116	2.6	15	0.4
Nationality						
Norwegian	1717	52.4	2248	51.1	1926	56.5
Swedish	634	19.4	675	15.4	472	13.9
Danish	661	20.2	908	20.7	685	20.1
Other	260	7.9	418	9.5	324	9.5
Unknown	4	0.1	147	3.3	29	0.8
Ability						
Expert	448	13.3	723	16.4	553	16.1
Good	946	28.9	1166	26.5	1076	31.4
Intermediate	963	29.4	1284	29.2	979	28.6
Beginner	846	25.8	829	18.9	671	19.6
Unknown	73	2.2	394	9.0	149	4.3
Location						
On piste	2468	75.3	2557	58.2	2063	60.2
Off-piste	312	9.5	429	9.8	316	9.2
Park area	262	8.0	911	20.7	841	24.5
Lift	142	4.4	140	3.2	113	3.2
Unknown	92	2.8	298	6.8		2.0
Equipment						
Alpine	1607	49.1	2753	62.6	2330	68.8
Snowboard	1391	42.5	1183	26.9	948	27.7
Telemark	179	5.5	97	2.2	60	1.8
Unknown	93	2.8	288	6.6	28	0.8

Table 2 shows the univariate relationship between head injuries and each of the candidate risk factors in 2002, 2010 and 2011. Head injuries were less common among those wearing a helmet than those not wearing a helmet in 2002 (OR: 0.57, 95% CI 0.45 to 0.73, $p<0.001$); this difference was less pronounced in 2010 (OR: 0.82, 95% CI 0.68 to 0.99, $p<0.05$) and 2011 (OR: 0.90, 95% CI 0.77 to 1.11, $p=0.21$). There was a continuing gender difference with favourable odds for females (OR: 0.70 in 2002, 95% CI 0.58 to 0.85, $p<0.001$; OR: 0.82 in 2010, 95% CI 0.68 to 0.98, $p=0.03$; OR: 0.80 in 2011, 95% CI 0.66 to 0.98, $p=0.03$). Experienced skiers and snowboarders had greater odds of being head injured in 2002 (OR: 1.43, 95% CI 1.18 to 1.72, $p<0.001$), 2010 (OR: 1.22, 95% CI 1.03 to 1.47, $p=0.03$) and 2011 (OR: 1.25, 95% CI 1.02 to 1.52, $p=0.03$). Previous skiing instruction was not associated with the proportion of head injuries at any time.

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Table 2 Univariate comparison of relationship between candidate risk factors and head injuries

	2002 (578/3276)				2010 (673/4396)				2011 (530/3436)			
	Head injured (n)	Controls (n)	Per cent	p Value	Head injured (n)	Controls (n)	Per cent	p Value	Head injured (n)	Controls (n)	Per cent	p Value
Helmet use				<0.001				0.03				0.21
Yes	96 (17)	684 (26)	12.3		455 (72)	2487 (76)	15.5		400 (79)	2206 (87)	15.3	
No	476	1967	19.5		179	806	18.2		107	534	16.7	
Age				0.85				0.72				0.65
<13	78 (67)	375 (70)	17.2		112 (90)	552 (95)	16.9		90 (91)	468 (96)	16.1	
13–20	249 (12)	1143 (22)	17.9		234 (73)	1273 (75)	15.5		219 (87)	1195 (84)	15.5	
>20	237 (5)	1156 (15)	17.0		291 (53)	1509 (66)	16.2		196 (60)	1088 (66)	15.3	
Gender				<0.001				0.03				0.01
Male	385 (19)	1580 (29)	19.6		437 (72)	2139 (75)	17.0		356 (73)	1759 (78)	16.6	
Female	187 (12)	1094 (21)	14.6		233 (68)	1377 (72)	14.5		174 (72)	1084 (76)	13.8	
Nationality				<0.001				<0.001				0.05
Norwegian	345 (18)	1372 (25)	20.1		391 (70)	1815 (75)	17.7		320 (75)	1580 (79)	16.8	
Swedish	79 (16)	555 (33)	12.5		104 (71)	556 (74)	15.8		76 (75)	391 (80)	16.3	
Danish	105 (12)	556 (22)	15.9		101 (70)	789 (73)	11.3		84 (74)	587 (78)	12.5	
Other	45 (14)	215 (17)	17.3		72 (65)	333 (68)	17.8		46 (65)	270 (66)	14.6	
Skiing ability				<0.001				0.04				0.02
Expert	108 (20)	340 (29)	24.1		123 (76)	591 (79)	17.2		94 (82)	451 (85)	17.2	
Good	184 (11)	762 (28)	19.5		195 (71)	956 (75)	16.9		174 (74)	891 (79)	16.3	
Interm	147 (16)	816 (22)	15.3		199 (67)	1059 (73)	15.8		132 (67)	833 (77)	13.7	
Beginner	121 (21)	725 (24)	14.3		111 (69)	700 (72)	13.7		89 (85)	572 (77)	13.5	
Location				<0.001				0.007				0.023
On piste	395 (16	2073 (24)	16.0		365 (69)	2147 (72)	14.5		295 (78)	1740 (76)	14.5	
Off-piste	52 (17)	260 (31)	16.7		82 (82)	373 (82)	18.0		41 (69)	283 (83)	12.7	
Park area	70 (11)	192 (35)	26.7		155 (70)	772 (80)	16.7		155 (76)	687 (81)	18.4	
Lift	38 (22)	104 (34)	23.0		35 (80)	104 (75)	25.1		26 (72)	92 (81)	21.6	
Equipment				0.49				0.97				0.03
Alpine	287 (20)	1320 (26)	17.9		432 (75)	2278 (77)	15.9		381 ((79)	1916 (84)	16.6	
Snowboard	245 (12)	1146 (25)	17.6		184 (65)	981 (70)	15.8		122 (70)	817 (75)	13.0	
Telemark	32 (3)	147 (17)	17.9		14 (71)	80 (72)	14.9		11 (40)	49 (82)	18.3	
Rented equipment				0.02				0.13				0.26
Yes	162 (18)	896 (24)	15.3		171 (72)	1009 (74)	14.5		140 (82)	835 (80)	14.4	
No	400 (15)	1743 (26)	18.7		443 (73)	2250 (75)	16.5		352 (80)	1851 (81)	16.0	
Skiing instruction				1.00				0.14				0.65
Yes	180 (17)	838 (29)	17.7		151 (75)	912 (82)	14.2		134 (89)	720 (87)	15.7	
No	362 (15)	1691 (23)	17.6		402 (73)	2081 (71)	16.2		303 (75)	1718 (77)	15.0	

*p Values are shown for Fisher's exact test between the head injured and control groups.
†Numbers in parentheses represent the percentage with a helmet in the case and control groups, respectively. The column percentages represent the proportion of total cases (sum of controls and cases) with known helmet use that suffered a head injury.

In table 3, we compare potential risk factors for potentially severe head injuries. Of the 1781 head injuries recorded, 925 were classified as potentially severe, 262 in 2002 (45.3%), 387 in 2010 (56.2%) and 276 in 2011 (52.1%). In 2002, wearing a helmet improved the odds for potentially severe head injuries (OR: 0.50, 95% CI 0.35 to.70, p<0.001); this effect was attenuated in 2010 (OR: 0.70, 95% CI 0.62 to 0.85, p<0.001), and 2011 (OR: 0.77, 95% CI 0.56 to 1.00, p=0.06). There was a higher proportion of potentially severe head injuries in injured older skiers and snowboarders (>13 years) compared to younger (OR: 1.57 in 2002, 95% CI 1.01 to 0.2.45, p=0.04; OR: 1.77 in 2010, 95% CI 1.27 to 2.46, p<0.001; OR: 1.20 in 2011, 95% CI 0.97 to 1.64, p=0.32). Also, skiing ability seems to be associated with the odds for potentially severe head injuries, with good and expert skiers and snowboarders consistently having worse odds (OR: 1.38 in 2002, 95% CI 0.1.07 to 0.1.79, p<0.01); in 2010: 1.25, 95% CI 1.01 to 1.54, p<0.05; (OR: 1.66 in 2011, 95% CI 1.09 to 2.56. p=0.01).

Table 4 shows the relationship between participant characteristics and odds for head injuries in 2001, 2010 and 2011 analysed using multiple logistic regression analyses. Helmet use was associated with favourable odds for head injuries (OR: 0.45, 95% CI 0.34 to 0.60; p<0.001) in 2002; this effect was attenuated in 2010 (OR: 0.79, 95% CI 0.63 to 0.98; p=0.02), and not significant in 2011 (OR: 0.80, 95% CI 0.60 to 1.06; p=0.12), when adjusted for potential confounders (age, sex, nationality, skiing ability, location and equipment). The test of interaction between helmet use and study year was statistically significant (p=0.001). The associations with age, gender and ability were also weakened.

For potentially severe head injuries, the protective effect of using a helmet was better sustained over the observation period,

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Table 3 Univariate comparison of relationship between candidate risk factor and cases with potentially severe head injuries

	2002 (262/3276)			2010 (387/4396)			2011 (276/3436)		
	Cases (n)	Per cent	p Value	Cases (n)	Per cent	p Value	Cases (n)	Per cent	p Value
Helmet use			<0.001			<0.001			0.06
Yes	37 (14)	4.7		247 (63)	8.3		201 (73)	7.7	
No	223	9.1		124	12.6		64	10.0	
Age			0.09			<0.001			0.68
<13	25 (72)	5.5		46 (97)	6.9		43 (95)	7.7	
13–20	116 (9)	8.3		118 (82)	7.8		105 (81)	7.4	
>20	117 (7)	8.4		209 (54)	11.6		117 (60)	9.1	
Gender			<0.001			0.13			0.05
Male	187 (16)	9.5		247 (68)	9.5		186 (72)	8.8	
Female	75 (10)	5.9		137 (72)	8.5		90 (60)	7.2	
Nationality			0.003			<0.001			0.008
Norwegian	161 (16)	9.4		216 (65)	9.8		157 (75)	8.3	
Swedish	35 (8)	5.5		70 (69)	10.6		48 (73)	10.3	
Danish	41 (7)	6.2		50 (64)	5.6		(44/65)	6.6	
Other	25 (24)	9.6		50 (76)	12.3		27 (62)	8.5	
Skiing ability			0.004			0.20			0.002
Expert	48 (21)	10.7		72 (84)	10.1		53 (80)	9.7	
Good	90 (10)	9.5		111 (79)	9.6		100 (73)	9.4	
Intermediate	69 (11)	7.2		116 (60)	9.2		65 (72)	6.7	
Beginner	50 (18)	5.9		67 (46)	8.2		40 (65)	6.1	
Equipment			0.55			0.73			0.07
Alpine	120 (15)	7.5		250 (68)	9.2		200 (72)	8.7	
Snowboard	121 (13)	8.7		102 (73)	8.8		61 (71)	6.5	
Telemark	15 (0)	8.4		11 (70)	11.8		8 (65)	13.3	
Location			<0.005			0.02			<0.001
On piste	189 (13)	7.6		210 (62)	8.4		142 (67)	5.3	
Park area	33 (6)	12.6		92 (85)	9.9		97 (78)	11.5	
Off-piste	18 (17)	5.7		52 (75)	11.4		22 (74)	6.8	
Lift	16 (0)	11.3		16 (75)	11.5		11 (72)	9.3	
Rented equipment			0.08			0.11			0.04
Yes	72 (17)	6.8		98 (71)	8.3		64 (81)	6.6	
No	185 (12)	8.6		258 (77)	9.6		192 (81)	8.7	
Skiing instruction			0.13			0.01			0.21
Yes	70 (14)	6.9		77 (73)	7.2		74 (85)	8.7	
No	173 (12)	8.4		241 (72)	9.7		156 (78)	7.7	

*p Values are from Fisher's exact tests comparing skiers with and without each of the factors.
†Numbers in parentheses represent the percentage with a helmet in the case and control groups, respectively. The column percentages represent the proportion of total cases (sum of controls and cases) with known helmet use that suffered a potentially severe head injury.

from an OR of 0.44 (95% CI 0.28 to 0.68, p<0.001) in 2002 to an OR of 0.74 (95% CI 0.57 to 0.97, p=0.02) in 2010 and 0.67 (95% CI 0.47 to 0.96; p=0.03) in 2011, adjusted for the same potential confounders (table 5). The test of interaction between helmet use and study year was statistically significant (p=0.038). The gender difference was attenuated during the same period. The location of the incident seemed to matter, with worse odds for potentially severe head injuries in park areas compared to groomed slopes (table 5).

DISCUSSION

The main finding of this study was that helmet use among injured skiers and snowboarders has increased more than three-fold from 2002 (23.8%) to 2011 (77.1%), but that the relative reduction in the proportion of head injuries over the same period was smaller than anticipated (from 17.6% to 15.4%). Also, the results show that the helmet effect was attenuated over the decade in question; the OR for head injury when the skier or snowboarder wore a helmet was reduced by 55% in 2002 compared to only 21% and 20% in 2010 and 2011.

Recent decades have seen dramatic changes in alpine skiing equipment, especially with the carving skis and twin-tip skis, opening new possibilities for acrobatic skiing moves, possibly with increased injury risk.[15] The park areas have gone through an extreme development over the past decade, high jumps and other obstacles raising concerns about the potential for severe injuries from high-impact crashes. Our data document an increase in the number and proportion of injured persons in park areas from 8% in 2002 to 21% and 25% in 2010 and 2011. In the same period, the proportion of expert and good skiers has increased. Therefore, it is possible that an increased number of skilled skiers performing more risky moves has led to an increased injury risk in snow parks over the observed decade.

The study shows that the likelihood of potentially severe head injuries by location was greater in snow parks relative to other areas, and does not appear to have changed much over the

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Table 4 Multiple logistic regression analyses of relationship between head injuries and potential risk factors in 2002, 2010 and 2011

	2002 (578/3276)		2010 (673/4396)		2011 (530/3436)	
	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value
Helmet use		<0.001		0.02		0.13
No	1		1		1	
Yes	0.45 (0.34 to 0.60)		0.79 (0.63 to 0.98)		0.80 (0.60 to 1.06)	
Age		0.002		0.03		0.78
<13	1		1		1	
13–20	0.69 (0.49 to 0.96)		0.80 (0.61 to 1.06)		0.89 (0.65 to 1.23)	
>20	0.55 (0.39 to 0.78)		0.90 (0.68 to 1.20)		0.93 (0.66 to 1.29)	
Gender		0.003		0.02		0.10
Male	1		1		1	
Female	0.72 (0.59 to 0.90)		0.78 (0.64 to 0.95)		0.89 (0.65 to 1.22)	
Nationality		0.002		0.006		0.02
Norwegian	1		1		1	
Swedish	0.58 (0.44 to 0.77)		0.90 (0.70 to 1.17)		0.98 (0.72 to 1.35)	
Danish	0.80 (0.61 to 1.06)		0.62 (0.47 to 0.81)		0.70 (0.49 to 0.99)	
Other	0.78 (0.53 to 1.14)		0.95 (0.69 to 1.13)		0.82 (0.65 to 1.04)	
Ability		<0.001		0.77		0.32
Expert	1		1		1	
Good	0.78 (0.58 to 1.03)		1.13 (0.80 to 1.37)		1.01 (0.74 to 1.37)	
Intermediate	0.55 (0.41 to 0.75)		1.02 (0.77 to 1.34)		0.73 (0.56 to 0.94)	
Beginner	0.55 (0.39 to 0.76)		0.91 (0.65 to 1.25)		0.92 (0.61 to 1.37)	
Location		<0.005		0.03		0.17
On piste	1		1		1	
Off-piste	0.96 (0.69 to 1.34)		0.95 (0.74 to 1.24)		0.77 (0.53 to 1.13)	
Park area	1.80 (1.30 to 2.48)		1.18 (0.88 to 1.58)		1.16 (0.90 to 1.50)	
Lift	1.94 (1.04 to 3.65)		2.35 (1.06 to 5.26)		1.47 (0.63 to 3.42)	
Equipment		0.12		0.12		0.04
Alpine	1		1		1	
Snowboard	0.79 (0.63 to 0.98)		0.90 (0.73 to 1.14)		0.72 (0.56 to 0.94)	
Telemark	0.61 (0.45 to 1.06)		0.75 (0.39 to 1.42)		0.90 (0.41 to 1.98)	

ORs are shown with 95% CIs.

years. So, despite the trend for higher relative injury risks in park areas, the risk of head injury cases compared to controls over the actual period decreased. We observed a similar trend with an increased proportion of injured alpine skiers, while the proportion of alpine skiers with head injury was relatively stable over the same period. In other words, park areas appear to have become safer in terms of head injuries, while they are getting less safe generally. This apparent disassociation may be the result of the large increase in the proportion of helmeted skiers and snowboarders. However, it should be noted that all these changes are relative within the injured population. Further studies are necessary to classify injury patterns in the parks, and continuous preventive efforts are needed to limit injury severity.

More injured skiers and snowboarders classified themselves as good or expert in 2010 and 2011 than in 2002. In our previous study,[3] we asked control skiers and snowboarders about risk-taking behaviour, and compared it with helmet wear. We saw that expert skiers and risk-takers were more likely to wear a helmet. A study by Buller *et al*[16] found that the highest proportion with helmets was among expert skiers and snowboarders. Ružić and Tudor[17] also made similar observations, while others have found no evidence of risk compensation among helmet wearers.[18 19] Mueller *et al*[9] found a poor helmet correlation among head-injured grown female skiers, indicating that helmeted skiers continue to take risks, while unhelmeted skiers gradually ski less risky. If this were a factor in our study, it could help explain the results, as it would lead to a higher injury rate among helmet users and even the attenuated gender difference in injury risk observed over the decade.

In our study, we observed a trend that severe head injuries occurred more frequently in adult skiers and snowboarders. In 2010 and 2011, potentially severe head injuries occurred more often among Norwegian and Swedish skiers than Danish skiers, possibly because the latter are less skilled and ski more cautiously. Thus, skiing ability also seems to be associated with risk of potential severe head injuries, with the good and expert skiers and snowboarders at highest risk.

We have conducted the study in the same skiing areas, and the ski patrol registration system remains the same, as well as the injury registration form used. Recall bias is not likely, since the ski patrol made the injury interviews on the spot, typically only a few minutes after the injury occurred. Nevertheless, except for skiing ability,[20] we have not carried out any reliability studies, so we do not know the degree of misclassification errors. Although we do not know how a stressful injury situation may have affected how skiers reported their skiing ability or skiing instruction, most other factors (including helmet status) could be observed directly by the ski patrol.

Still, there are some issues that should be borne in mind when interpreting the results of the current study. One limitation is that we used skiers and snowboarders with other injuries as controls, as was done in most previous studies to estimate the

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Table 5 Multiple logistic regression analyses of relationship between potentially severe head injuries and potential risk factors in 2002, 2010 and 2011

	2002 (262/3276)		2010 (387/4396)		2011 (276/3436)	
	OR (95% CI)	p value	OR (95% CI)	p Value	OR (95% CI)	p Value
Helmet use		<0.001		0.03		0.03
No	1		1		1	
Yes	0.44 (0.28 to 0.68)		0.74 (0.57 to 0.97)		0.67 (0.47 to 0.96)	
Age		0.58		0.003		0.73
<13	1		1		1	
13–20	1.26 (0.71 to 2.24)		1.02 (0.69 to 1.49)		0.91 (0.59 to 1.40)	
>20	1.11 (0.62 to 1.98)		1.16 (1.07 to 2.29)		1.04 (0.66 to 1.64)	
Gender		0.003		0.45		0.30
Male	1		1		1	
Female	0.63 (0.46 to 0.86)		0.83 (0.65 to 1.06)		0.85 (0.62 to 1.15)	
Nationality		0.03		0.001		0.59
Norwegian	1		1		1	
Swedish	0.54 (0.35 to 0.83)		1.1 (0.74 to 1.38)		1.18 (0.80 to 1.76)	
Danish	0.77 (0.50 to 1.21)		0.49 (0.34 to 0.71)		0.82 (0.51 to 1.13)	
Other	1.00 (0.60 to 1.70)		1.05 (0.68 to 1.52)		0.94 (0.53 to 1.63)	
Ability		0.12		0.99		0.29
Expert	1		1		1	
Good	0.93 (0.62 to 1.38)		1.04 (0.75 to 1.44)		1.17 (0.78 to 1.73)	
Intermediate	0.68 (0.44 to 1.05)		1.04 (0.74 to 1.46)		0.82 (0.52 to 1.28)	
Beginner	0.62 (0.38 to 1.03)		1.02 (0.68 to 1.52)		0.88 (0.51 to 1.53)	
Location		0.002		0.05		0.04
On piste	1		1		1	
Off-piste	0.65 (0.38 to 1.10)		1.24 (0.90 to 1.69)		0.85 (0.52 to 1.42)	
Park area	1.41 (0.92 to 2.16)		1.42 (1.00 to 2.05)		1.58 (1.15 to 2.18)	
Lift	2.50 (1.58 to 5.12)		1.76 (0.34 to 3.97)		1.21 (0.45 to 2.01)	
Equipment		0.62		0.59		0.13
Alpine	1		1		1	
Snowboard	0.88 (0.64 to 1.22)		0.85 (0.66 to 1.11)		0.69 (0.49 to 0.92)	
Telemark	0.67 (0.36 to 1.24)		0.92 (0.46 to 1.86)		1.40 (0.60 to 3.25)	

ORs are shown with 95% CIs.

protective effect of cycling helmets,[21] The assumption is that whether a fall causes injury to the head or to another body part is influenced by helmet status, and these injured groups can therefore be compared to assess the protective effect of the helmet. However, this estimate can be confounded by a number of other factors. In our previous study,[3] we therefore also included an uninjured control group from the same skiing areas. When we compared the results between the injured and the uninjured control groups, the helmet effect was essentially the same. This lends support to the current risk estimates reported.

Head injuries combined with other injuries were rare (2–3% of cases), but as these could potentially bias the helmet effect estimates, we also performed sensitivity analyses excluding these cases. There was essentially no change in the risk estimates reported (data not shown).

It would have been preferable to include data from all ski seasons between 2002 through 2011. Unfortunately, data for 2003 through 2009 were not available.

Another issue is the helmet quality. We have not tested or evaluated the helmets of the skiers or snowboarders in this study. Nevertheless, all helmets rented out or sold in Norway are CE-certified.

The large change in helmet use among injured people in the slopes was age-related. We observed an increase in helmet wear in our injured control group among skiers and snowboarders under the age of 13 from 70% to 96% over the decade, compared to from 22% to 84% for age 13 to 20 and from 15% to 66% for those over 20 years. We have adjusted for ability and age in our regression analyses, but it may be important to note that helmet wear was already high among children.

Research methods to assess the effect of protective equipment could be improved. Using exposure-adjusted injury rates would be valuable. Better quality medical injury data are desirable. This could be achieved by better medical education of ski patrol, as well as better cooperation with local hospitals for medical data exchange. Injury forms should be adapted to capture new trends in skiing and snowboarding, as well as information on new injury patterns. Hypotheses around behavioural change and helmet impact performance represent potential areas for future research. Capturing injury-free accidents could also provide important information.

In conclusion, even if the reduction in the proportion of head injuries was smaller than expected, there was a reduction. Also, the results show that, although less pronounced than in 2002, the risk of head injuries, at least of potentially severe head injuries, was still reduced among helmet users in 2011. Therefore, wearing a helmet should be strongly recommended.

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What are the findings?

This study demonstrated an attenuated association between helmet use and risk of head injury among injured skiers and snowboarders after a decade when the vast majority had begun wearing helmets.

How might it impact on clinical practice in the future?

Clinicians as well as the skiing resorts and ski rentals should inform skiers and snowboarders that current helmets have a limited capacity to protect the head. Skiers and snowboarders must remain aware of the risks of head injury associated with the decisions they make while skiing, thus skiing according to their capacity and skill as well as the piste challenges they encounter.

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Competing interests None declared.

Ethics approval The study was based on anonymised data from the Norwegian Ski Lift Association injury and marketing research databases, and the Regional Committee for Medical Research Ethics did not require ethical approval.

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