American Journal of Epidemiology
Vol. 162, No. 2

Printed in U.S.A.
DOI: 10.1093/aje/kwi181

The Effect of Wrist Guard Use on Upper-Extremity Injuries in Snowboarders

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Received for publication December 21, 2004; accepted for publication March 9, 2005.

The objective of this investigation was to determine the effect of wrist guard use on all upper-extremity injuries in snowboarders. This matched case-control study was conducted at 19 ski areas in Quebec, Canada. Cases were 1,066 injured snowboarders who reported upper-extremity injuries to the ski patrol during the 2001–2002 season. Controls were 970 snowboarders with non-upper-extremity injuries who were matched to cases on ski area and the nearest date, age, and sex, in that order. The response rate was 71.8% (73.5% for cases and 70.1% for controls). Cases were compared with controls with regard to wrist guard use. The prevalence of wrist guard use among snowboarders with hand, wrist, or forearm injuries was 1.6%; for those with elbow, upper arm, or shoulder injuries, it was 6.3%; and for controls, it was 3.9%. Thus, wrist guard use reduced the risk of hand, wrist, or forearm injury by 85% (adjusted odds ratio = 0.15, 95% confidence interval: 0.05, 0.45). However, the adjusted odds ratio for elbow, upper arm, or shoulder injury was 2.35 (95% confidence interval: 0.70, 7.81). These results provide evidence that use of wrist guards reduces the risk of hand, wrist, and forearm injuries but may increase the risk of elbow, upper arm, and shoulder injuries.

athletic injuries; case-control studies; risk factors; skiing; snow sports

Abbreviation: CI, confidence interval.

The upper extremity, particularly the wrist and forearm, is one of the most frequently injured body regions in snowboarders (1–6). These injuries can be severe, often resulting in fractures requiring surgical intervention (6).

The few studies that have been conducted on the relation between wrist guard use and wrist injuries in snowboarders have indicated that these devices reduce the risk of wrist and forearm injuries between 52 percent and 87 percent (7–11). However, some results have suggested a link between wrist guards and arm or shoulder injuries (1). Other investigators have suggested no relation but have provided no effect estimates (8–11). Therefore, our goal in this investigation was to determine the effect of wrist guard use on the risks of different types of upper-extremity injuries in snowboarders.

MATERIALS AND METHODS

Twenty of the largest ski areas in Quebec, Canada, were asked to participate during the 2001–2002 ski season. All injured snowboarders who reported injuries to the ski patrol and had an Accident Report Form completed were included. However, one ski area did not provide its Accident Report Forms until long after the season had ended and was therefore excluded.

Subjects for this investigation were drawn from a larger study of helmet effectiveness in skiers and snowboarders (12). In that study, cases were participants with head and neck injuries, with subjects with other types of injuries (i.e., injuries to the upper extremity, lower extremity, or trunk)

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TABLE 1. Types of upper-extremity injuries incurred by 1,066* snowboarders reporting injuries to ski patrols in 19 ski areas, by body part, Quebec, Canada, 2001–2002

	Hand		Wrist		Forearm		Elbow		Upper arm		Shoulder	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Bruise	4	7.1	4	0.8	5	4.2	12	16.9	9	17.7	28	9.9
Dislocation	4	7.1	1	0.2	1	0.8	8	11.3	1	2.0	90	31.7
Fracture	13	23.2	245	46.5	94	79.0	20	28.2	24	47.1	92	32.4
Sprain	28	50.0	239	45.4	10	8.4	17	23.9	7	13.7	47	16.6
Multiple injuries	1	1.8	22	4.2	6	5.0	4	5.6	4	7.8	6	2.1
Other	6	10.7	16	3.0	3	2.5	10	14.1	6	11.8	21	7.4
Total	56	100	527	100	119	100	71	100	51	100	284	100

* Five snowboarders had injuries to three upper-extremity body regions; 32 snowboarders had injuries to two upper-extremity body regions; and 1,029 snowboarders had injuries to only one upper-extremity body region (total = (5 × 3) + (32 × 2) + (1,029 × 1) = 1,108).

serving as controls and being matched to cases on ski area, date of injury, age, and sex.

Definitions

Cases. Cases were persons who reported sustaining an injury while snowboarding to the ski patrol at one of the 19 ski areas and had an Accident Report Form completed for an upper-extremity injury (the area from the hand to the forearm or the elbow to the shoulder, including the clavicle and scapula), as indicated by the body region recorded on the Accident Report Form. The Accident Report Form allowed the ski patrol to record information on up to three types of injuries (from a list of 18) and three body regions (from a list of 27). When several injuries were recorded and at least one involved the upper extremity, the victim was considered a case.

Controls. Controls were snowboarders with non-upper-extremity injuries who reported an injury to another part of the body to a ski patroller at one of the same 19 ski areas. Control snowboarders were perfectly matched for ski area and the nearest date, age, and sex, in that order. Because the matched sets were formed in the original study of helmet effectiveness, there was a variable case:control ratio.

Data collection

The 19 ski areas were asked to send in their Accident Report Forms every 2–3 weeks, and an employee of the Quebec Secrétariat au loisir et au sport sent photocopies to the project coordinator at the Montreal Children's Hospital. Information was abstracted regarding contact, participation, and injury. Questionnaires were then sent to all cases and injured controls by mail; parents responded for children under age 15 years. Nonresponders received a second questionnaire or up to five follow-up telephone calls from one of four trained research assistants. We asked about wrist guard use and other potential injury determinants: general characteristics (age, sex, ability, experience, lessons, education, and past head or neck injury) and event circumstances (helmet use, participation hours, self-reported speed, participation type, mechanism of injury, other protective equipment, run difficulty, visibility, snow conditions, and temperature).

All risk-factor-related data (including helmet use, age, ability, sex, etc.) used in the analysis were taken from the telephone interview or the mailed questionnaire. However, to avoid missing values in the analysis, we created variables that were derived from both questionnaire and Accident Report Form information. For example, when a participant did not indicate his or her age on the mailed questionnaire, we used the age reported by the ski patrol on the Accident Report Form.

We received ethical approval from the McGill University-Montreal Children's Hospital Research Institute Ethics Committee. We also obtained permission from the Commission d'accès à l'information du Québec to use Accident Report Form contact information.

Analysis

We examined the prevalence of wrist guard use in two case groups: persons with hand-forearm injuries and persons with elbow-shoulder injuries. This information was compared with the prevalence of wrist guard use among persons with non-upper-extremity injuries (controls).

Conditional logistic regression was used for the case-control analysis. For prognostic logistic regression models, the ideal number of potential independent variables should be less than 10 percent of the minimum of the number of cases or the number of controls (13). However, because only discordant sets contribute to estimation of the odds ratio in a matched study, we adapted Harrell et al.'s 10 percent-or-fewer rule of thumb and applied it to the number of discordant matched sets to avoid overfitting the model (14).

We used a forward model selection strategy when the number of independent variables exceeded 10 percent of the number of discordant matched sets. Possible confounders (e.g., age, sex, ability) were added one at a time, and those that had the largest influence on the point estimate of the wrist guard effect were retained in an iterative process until no additional variables changed the natural logarithm of

TABLE 2. Odds ratios for upper-extremity injury among 2,036* snowboarders reporting injuries to ski patrols in 19 ski areas, by body region and sociodemographic characteristics, Quebec, Canada, 2001–2002

Characteristic	Injured cases								Injured controls (n = 970)	
	Hand to forearm (n = 681)				Elbow to shoulder (n = 397)					
	No.	%	OR†,‡	95% CI†	No.	%	OR‡	95% CI	No.	%
Age (years)										
<15	318	46.7	1.83	1.22, 2.74	146	36.8	0.78	0.52, 1.18	397	40.9
15–25	323	47.4	1.52	1.02, 2.28	209	52.6	0.92	0.61, 1.37	484	49.9
>25	39	5.7	1.00§		42	10.6	1.00§		89	9.2
Missing data	1	0.2								
Sex										
Male	417	61.2	0.89	0.72, 1.09	306	77.1	1.88	1.44, 2.46	622	64.1
Female	263	38.6	1.00§		91	22.9	1.00§		348	35.9
Missing data	1	0.2								
Self-reported ability										
Beginner–intermediate	337	49.5	1.65	1.29, 2.11	146	36.8	0.86	0.65, 1.14	381	39.3
Intermediate	195	28.6	1.16	0.89, 1.52	128	32.2	0.92	0.68, 1.23	313	32.3
Intermediate–expert	148	21.7	1.00§		123	31.0	1.00§		276	28.5
Missing data	1	0.2								
Snowboarding experience										
No. of seasons of participation										
1	90	13.2	1.31	0.89, 1.92	52	13.1	0.85	0.55, 1.32	129	13.3
2–5	400	58.7	1.25	0.92, 1.69	245	61.7	0.86	0.62, 1.19	601	62.0
≥6	77	11.3	1.00§		68	17.1	1.00§		144	14.9
Missing data	114	16.7			32	8.1			96	9.9
No. of days of participation during current season										
1	210	30.8	2.08	1.53, 2.83	78	19.7	0.82	0.58, 1.18	208	21.4
2–10	353	51.8	1.39	1.06, 1.84	215	54.2	0.90	0.68, 1.21	522	53.8
≥11	99	14.5	1.00§		93	23.4	1.00§		204	21.0
Missing data	19	2.8			11	2.8			36	3.7
Receipt of lessons										
No	279	41.0	1.00§		180	45.3	1.00§		340	35.1
Yes	401	58.9	0.78	0.64, 0.96	217	54.7	0.66	0.52, 0.83	625	64.4
Missing data	1	0.2							5	0.5
Level of education										
High school or less	189	27.8	1.16	0.90, 1.49	111	28.0	1.09	0.82, 1.47	253	26.1
College or professional diploma	222	32.6	1.17	0.92, 1.49	117	29.5	0.99	0.74, 1.32	294	30.3
University or graduate school	235	34.5	1.00§		146	36.8	1.00§		364	37.5
Missing data	35	5.1			23	5.8			59	6.1
Past upper-extremity injury										
No	624	91.6	1.00§		362	91.2	1.00§		878	90.5
Yes	51	7.5	0.88	0.61, 1.26	33	8.3	0.98	0.64, 1.49	82	8.5
Missing data	6	0.9			2	0.5			10	1.0

* Twelve snowboarders had both hand-forearm and elbow-shoulder injuries (total = 681 + 397 + 970 − 12 = 2,036).
† OR, odds ratio; CI, confidence interval.
‡ Odds ratio for injury in comparison with injured controls.
§ Reference category.

TABLE 3. Odds ratios for upper-extremity injury among 2,036* snowboarders reporting injuries to ski patrols in 19 ski areas, by body region and characteristics of the injury event, Quebec, Canada, 2001–2002

Characteristic	Injured cases								Injured controls (n = 970)	
	Hand to forearm (n = 681)				Elbow to shoulder (n = 397)					
	No.	%	OR†,‡	95% CI†	No.	%	OR‡	95% CI	No.	%
Wrist guard use										
No	670	98.4	1.00§		372	93.7	1.00§		932	96.1
Yes	11	1.6	0.40	0.20, 0.79	25	6.3	1.65	0.98, 2.77	38	3.9
Missing data										
Hours of participation before injury event										
<2	282	41.4	1.00§		146	36.8			349	36.0
2–5	337	49.5	0.78	0.64, 0.96	199	50.1	0.89	0.69, 1.15	533	55.0
≥6	62	9.1	0.88	0.61, 1.27	52	13.1	1.43	0.96, 2.12	87	9.0
Missing data									1	0.1
Non-wrist-guard equipment damage										
No	628	92.2	1.00§		354	89.2	1.00§		831	85.7
Yes	37	5.4	0.42	0.29, 0.61	35	8.8	0.70	0.47, 1.05	117	12.1
Missing data	16	2.4			8	2.0			22	2.3
Self-reported speed										
Slow	238	35.0	1.00§		78	19.7	1.00§		257	26.5
Average	211	31.0	0.73	0.57, 0.93	127	32.0	1.33	0.96, 1.85	314	32.4
Fast	106	15.6	0.44	0.33, 0.59	116	29.2	1.48	1.06, 2.06	259	26.7
Missing data (and other¶)	126	18.5			76	19.1			140	14.4
Participation at time of injury										
Lesson or school outing	134	19.7	1.00§		53	13.4	1.00§		183	18.9
Recreation	534	78.4	0.96	0.74, 1.22	332	83.6	1.50	1.08, 2.09	764	78.8
Missing data (and other¶)	13	1.9			12	3.0			23	2.4
Mechanism of injury										
Collision or jump	282	41.4	0.68	0.56, 0.83	185	46.6	0.83	0.66, 1.05	494	50.9
Fall	396	58.2	1.00§		212	53.4	1.00§		470	48.5
Missing data (and other¶)	3	0.5							6	0.6

Table continues

the odds ratio estimate by more than 10 percent, or before exceeding 10 percent of the number of discordant matched sets.

We also broke the matching and analyzed the data with regular logistic regression, controlling for all covariates, because of concern that there would be too few discordant sets contributing to the analysis. We used a generalized estimating equations implementation of logistic regression to account for clustering of outcomes by ski area. All analyses were conducted with Stata statistical software (15).

To examine the reliability of the data on wrist guard use, we compared the responses on the Accident Report Form with the responses given on the mailed questionnaire or in the telephone interview. We used the kappa statistic for our concordance analysis (16, 17).

RESULTS

We sent a questionnaire or scheduled a telephone call to 1,451 cases with upper-extremity injuries and 1,384 controls with non-upper-extremity injuries. The response rate was 73.5 percent (n = 1,066) for cases and 70.1 percent (n = 970) for controls.

All of the case-control sets were perfectly matched with regard to ski area. For the hand-forearm case-control sets, 152 (39.5 percent) of 385 sets were perfectly matched for

TABLE 3. Continued

Characteristic	Injured cases								Injured controls (n = 970)	
	Hand to forearm (n = 681)				Elbow to shoulder (n = 397)					
	No.	%	OR‡	95% CI	No.	%	OR‡	95% CI	No.	%
Run difficulty										
Easy	267	39.2	1.00§		115	29.0	1.00§		283	29.2
Difficult	330	48.5	0.67	0.53, 0.85	222	55.9	1.05	0.79, 1.41	527	54.3
Very difficult/ extremely difficult	65	9.5	0.66	0.51, 0.84	42	10.6	1.01	0.74, 1.37	103	10.6
Missing data (and other¶)	19	2.8			18	4.5			57	5.9
Other protective equipment										
No	442	64.9	1.00§		251	63.2	1.00§		593	61.1
Yes#	229	33.6	0.83	0.68, 1.02	143	36.0	0.91	0.72, 1.16	370	38.1
Missing data	10	1.5			3	0.8			7	0.7
Visibility										
Good	563	82.7	1.00§		330	83.1	1.00§		824	85.0
Average–fair	93	13.7	1.13	0.85, 1.52	52	13.1	1.08	0.76, 1.54	120	12.4
Missing data	25	3.7			15	3.8			26	2.7
Snow conditions										
Groomed-hard-pack/ice	504	74.0	1.32	1.05, 1.65	306	77.1	1.48	1.12, 1.95	673	69.4
Powder/wet/corn/crud	161	23.6	1.00§		87	21.9	1.00§		283	29.2
Missing data	16	2.4			4	1.0			14	1.4
Temperature										
0°C or above	87	12.8	1.00§		66	16.6	1.00§		153	15.8
−1°C to −10°C	502	73.7	1.33	0.99, 1.77	264	66.5	0.92	0.67, 1.27	666	68.7
Below −10°C	71	10.4	0.98	0.66, 1.44	51	12.9	0.92	0.60, 1.43	128	13.2
Missing data	21	3.1			16	4.0			23	2.4

* Twelve snowboarders had both hand-forearm and elbow-shoulder injuries (total = 681 + 397 + 970 − 12 = 2,036).
† OR, odds ratio; CI, confidence interval.
‡ Odds ratio for injury in comparison with injured controls.
§ Reference category.
¶ For example, being injured on the lift.
# Excludes all "yes" answers with only "goggles" or "sunglasses" specified.

date of injury, 137 (35.6 percent) for age category, and 134 (34.8 percent) for sex. For the elbow-shoulder case-control sets, 94 (35.9 percent) of 262 sets were perfectly matched for date of injury, 101 (38.6 percent) for age category, and 87 (33.2 percent) for sex.

Table 1 illustrates the types of upper-extremity injuries recorded. Fracture was the most common injury for all upper-extremity regions except the hand, where sprains represented half of the total.

Table 2 shows the distribution of case and control characteristics. Snowboarders with hand-forearm injuries were younger, reported lower ability and fewer days of participation, and less often had lessons than injured controls. A greater proportion of males had elbow-shoulder injuries than controls. Those with elbow-shoulder injuries were also less likely to have taken lessons compared with injured controls.

Table 3 shows the distribution of injury event circumstances. Snowboarders with hand-forearm injuries reported less wrist guard use, fewer hours of participation, less non-wrist-guard equipment damage, and slower speed at the time of injury than injured controls. They were also injured more often as a result of a fall and on easier runs. Snowboarders with elbow-shoulder injuries were more likely to be injured during recreational participation and on groomed-hard-pack/ice snow conditions than controls.

Table 4 demonstrates the effect of wrist guard use on risk of injury to the hand-forearm and elbow-shoulder. There were only 32 matched sets with discordant wrist guard use between snowboarders with hand-forearm injuries and controls. Therefore, we only considered models with, at most, three variables (32 × 10 percent). After adding variables one at a time and retaining those that had the greatest influence on the wrist guard estimate, only self-reported speed (two indicator variables) at the time of injury and the receipt of lessons (one indicator variable) were retained. Inclusion of these two variables in the conditional logistic regression model

TABLE 4. Effectiveness of wrist guard use among 2,036 snowboarders reporting upper-extremity injuries to ski patrols in 19 ski areas, by body region, Quebec, Canada, 2001–2002*

Body region	Unadjusted OR†	95% CI†	Mantel-Haenszel adjusted‡ OR	95% CI	Unadjusted CLR† OR	95% CI	Adjusted CLR OR	95% CI
Hand to forearm	0.40	0.20, 0.79	0.31	0.15, 0.67	0.26	0.11, 0.63	0.15§	0.05, 0.45
Elbow to shoulder	1.65	0.98, 2.77	2.50	0.99, 6.32	2.46	1.0, 6.08	2.35¶	0.70, 7.81

* Odds ratio for upper-extremity injury among cases using wrist guards in comparison with injured controls without upper-extremity injury.
† OR, odds ratio; CI, confidence interval; CLR, conditional logistic regression.
‡ Adjusted for matched set.
§ Adjusted for self-reported speed (fast, average, or slow) and receipt of lessons (yes vs. no).
¶ Adjusted for self-reported speed (fast, average, or slow) and run difficulty (very difficult/extremely difficult, difficult, or easy).

produced a final wrist guard estimate of 0.15 (95 percent confidence interval (CI): 0.05, 0.45), indicating an 85 percent reduction in hand-forearm injury risk with wrist guard use.

In comparisons between cases with elbow-shoulder injuries and controls, there were 24 matched sets with discordant wrist guard use. Therefore, only two (24×10 percent) additional variables were considered for the final model. Using the forward selection procedure, the two variables that had the most influence on the relation were self-reported speed and run difficulty. After inclusion of these two variables, the effect estimate was 2.35 (95 percent CI: 0.70, 7.81), which suggests that wrist guards may increase the risk of these injuries more than twofold, although the effect was not statistically significant (two-sided $p = 0.17$). (Because the variables for self-reported speed and run difficulty had more than two levels, the precision of the estimate suffered.)

We also refitted both the hand-forearm model and the elbow-shoulder model using simple logistic regression (i.e., ignoring the matching) and included all covariates listed in tables 2 and 3. The odds ratio for the effect of wrist guard use on hand-forearm injuries was 0.50 (95 percent CI: 0.21, 1.21). For elbow-shoulder injury, the odds ratio was 2.0 (95 percent CI: 0.95, 4.10). The generalized estimating equations results suggested that clustering by ski area had little influence.

The kappa value relating the information on wrist guard use from the mailed questionnaire or telephone interview to that from the Accident Report Form for persons with upper-extremity injuries was 0.42 (95 percent CI: 0.36, 0.47), and for the controls it was 0.40 (95 percent CI: 0.34, 0.46). For both cases and controls, most discrepancies occurred as a result of wrist guard use being reported on the questionnaire or in the interview but not indicated on the Accident Report Form (93 percent and 87 percent of discrepancies, respectively).

DISCUSSION

This study provides evidence that wrist guards reduce the risk of hand, wrist, or forearm injuries in snowboarders by up to 85 percent. This result is consistent with the findings of other biomechanical (18) and epidemiologic (7–9, 11) studies, particularly the 87 percent reduction found in the randomized controlled trial by Machold et al. (9). However, a disturbing finding was the over twofold (albeit non-statistically-significant) risk of an elbow, upper arm, or shoulder injury. Other studies have not found this effect, but few have directly examined the relation between wrist guard use and injuries proximal to the forearm. Those that have attempted to examine the relation between wrist guards and upper arm/shoulder injuries used a prospective design resulting in few or no injuries of this kind, precluding comprehensive analysis (9, 10).

Cheng et al. (19) examined forearm fractures associated with the use of wrist guards or wrist splints among in-line skaters. They noted open forearm fractures at the proximal border of the splints and suggested, “The splint and distal forearm may act as a single unit to convert the impact from the level of the wrist to a torque moment, with the fulcrum located at the proximal border of the splint” (19, p. 1194). However, these investigators did not examine injuries proximal to the forearm, making it unclear from their work how, if at all, the elbow, upper arm, and shoulder may be affected. Surface characteristics (asphalt or concrete vs. powder or hard-pack snow) also limit the comparisons between our findings and the work of Cheng et al.

Limitations

Selection bias. A perfect comparison for assessing the effect of wrist guards in preventing upper-extremity injuries would involve two people, identical in every respect, who crashed and fell on their arms with the same force, under the same conditions, with one wearing wrist guards and the other not wearing them. However, such a comparison is impossible short of a randomized controlled trial, which would almost certainly be judged unethical. In nonexperimental research, we are well removed from this “ideal,” and instead we used as a control series persons with the same probability of upper-extremity injury as the cases (i.e., those who had an injury but did not sustain an upper-extremity injury).

The challenge was to select controls independently of wrist-guard-use status so the controls would be representative of the wrist guard “experience” in the source population that produced the cases (20). It is a tenuous argument, at best, to suggest that the occurrence of ankle injuries, knee injuries, etc. among snowboarders is related to wrist guard use.

A second argument for selecting a control group with body-region-specific injuries is the example provided by other studies. This approach has been used to provide evidence for the effectiveness of helmet use in cycling (21–23), wrist guard use in in-line skating (24), and binding release in skiing (25).

Injury specificity with respect to determinants of upper-extremity injury is the crux of the argument for the use of injured controls. This efficient and logical approach was used by researchers from Seattle, Washington, in their studies of the effect of bicycle helmets on head injuries (21–23). The first of their investigations demonstrated surprisingly similar results using both a non-head-injured group of bicyclists and an uninjured group of bicyclists as denominators for the head-injured cyclists (the prevalence of helmet use was reported to be 7.2 percent among head-injured cases, 23.8 percent among emergency room controls with other injuries, and 23.3 percent among uninjured controls) (21).

Similarly, in an investigation concerning the evaluation of protective equipment in in-line skating, Schieber et al. defined as cases "those skaters who injured the specified anatomic site seriously enough to require medical attention. The controls were skaters in the risk group who did not injure the specified site, although they did injure another part of their body" (24, p. 1631). That study used no uninjured controls. The adjusted odds ratio for the comparison of rates of wrist injury in those who wore wrist guards and those who did not was 10.4 (95 percent CI: 2.9, 36.9).

Finally, this type of control group was used to examine binding function in skiing in a study by Bouter et al. (25). These investigators used persons with non-lower-extremity injuries as the control group for lower-extremity injuries to assess the effect of binding release. The age-adjusted rate ratio for lower-extremity injury was 3.2 (95 percent CI: 1.6, 6.5) when bindings failed to release. This finding is very similar to the lower-extremity equipment-related injury rate ratio of 3.4 found by Hauser (26) in a randomized controlled trial comparing an experimental group (binding adjustment at beginning of season) with a control group (not offered binding adjustment).

We contend that the use of injured controls is essential for a proper evaluation of the effect of wrist guard use. Nevertheless, there may still have been ways that bias could have played a role in the comparisons using the injured control group.

Not all injuries are reported to the ski patrol (27–31). However, in order for this to bias the results, reporting of certain injuries would have to be related to both wrist guard use and outcome (hand-forearm injury; elbow-shoulder injury). This seems unlikely, and even if this were the case, the relation between wrist guard use and the outcomes would have to hold only within strata of the covariates that we adjusted for.

Confounding. We adjusted for a number of covariates through matching and regression analyses. Regardless of the number of variables included or the analysis strategy, the results were consistent in showing that wrist guards were protective for hand-forearm injuries but possibly harmful for elbow-shoulder injuries.

Misclassification bias. Other investigators have noted that injury classification by the ski patrol may be imperfect for distinguishing between types of injuries—between fractures and sprains, for example—but that the body region of injury is reported accurately (32). Although there is potential for misclassification of the precise nature of the injury, it is unlikely that the body region would be recorded in error. Further research is required on the severity of elbow-shoulder injuries, particularly in relation to wrist guard use.

Although the kappa values for wrist guard use were low for cases and controls, they were similar, which suggests nondifferential misclassification of use. This bias would be expected to move the estimated odds ratios toward the null (i.e., no effect); this could, in part, account for the elbow-shoulder results but not for the hand-forearm results, as the confidence limits for the hand-forearm estimate excluded the null.

We used data obtained from the telephone interview or the mailed questionnaire when they were available (99.1 percent of controls and 98.6 percent of cases) to classify someone as using or not using wrist guards. The ski patrol may not have had an opportunity to see the use of wrist guards or may have only recorded it for injuries they felt were relevant (e.g., for an upper-extremity injury). Therefore, even though the kappa values were low, it is quite likely that few persons were truly misclassified if we treat the responses given on the mailed questionnaire as the "gold standard."

Type of wrist guard used. Recent research suggests that different wrist guards have different biomechanical properties at the level of the distal radius and below (18). Because we did not collect information on the make of the wrist guards used, our results must be considered an average effect of a variety of wrist guards.

Conclusions

Although our results confirm the protective effect of wrist guards on hand-forearm injuries, the point estimate suggests an increased risk of elbow-shoulder injuries. Better biomechanical data are required for careful examination of the forces acting from the elbow to the shoulder region. This will further our understanding of why wrist guards might adversely affect this region and whether the effect can be mitigated through design changes to more adequately address mechanisms of snowboarding injury.

ACKNOWLEDGMENTS

Funding for this project was provided by the Canadian Institutes of Health Research and the Québec Secrétariat au loisir et au sport. Dr. Brent Hagel's personal funding was provided by the Alberta Heritage Foundation for Medical Research.

The authors thank research assistants Genevieve Gore, Liam Gore, Helen Magdalinos, Gail Martin, Anna Sampogna, and Nicole Marchand of the Quebec Secretariat au loisir et au sport for copying and sending the ski patrol Accident Report Forms in a timely manner. The cooperation of the Quebec Ski Areas Association and of the participating ski areas is gratefully acknowledged.

Conflict of interest: none declared.

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