RISK FACTORS FOR INJURIES FROM IN-LINE SKATING AND THE EFFECTIVENESS OF SAFETY GEAR

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ABSTRACT

Background Of the estimated 22.5 million people participating in in-line skating in the United States in 1995, about 100,000 were sufficiently injured to require emergency department care. We investigated the effectiveness of wrist guards, elbow pads, knee pads, and helmets in preventing skating injuries.

Methods We used data from the 91 hospital emergency departments participating in the National Electronic Injury Surveillance System, a national probability sample of randomly selected hospitals with 24-hour emergency departments. Injured in-line skaters who sought medical attention between December 1992 and July 1993 were interviewed by telephone. We conducted a case–control study of skaters who injured their wrists, elbows, knees, or heads as compared with skaters with injuries to other parts of their bodies.

Results Of 206 eligible injured subjects, 161 (78 percent) were interviewed. Wrist injuries were the most common (32 percent); 25 percent of all injuries were wrist fractures. Seven percent of injured skaters wore all the types of safety gear; 46 percent wore none. Forty-five percent wore knee pads, 33 percent wrist guards, 28 percent elbow pads, and 20 percent helmets. The odds ratio for wrist injury, adjusted for age and sex, for those who did not wear wrist guards, as compared with those who did, was 10.4 (95 percent confidence interval, 2.9 to 36.9). The odds ratio for elbow injury, adjusted for the number of lessons skaters had had and whether or not they performed trick skating, was 9.5 (95 percent confidence interval, 2.6 to 34.4) for those who did not wear elbow pads. Nonuse of knee pads was associated with a nonsignificant increase in the risk of knee injury (crude odds ratio, 2.2; 95 percent confidence interval, 0.7 to 7.2). The effectiveness of helmets could not be assessed.

Conclusions Wrist guards and elbow pads are effective in protecting in-line skaters against injuries. (N Engl J Med 1996;335:1630-5.)

IN-LINE skating is a fast-growing recreational sport in the United States. In-line skates, with three, four, or five low-friction wheels set in a single row, afford greater maneuverability and speed than traditional quad skates, which have four wheels arranged in two rows. An estimated 22.5 million people participated in 1995, reflecting a 79 percent increase over the 1993 figure.[1] During the same two-year period, the estimated number of in-line skaters injured badly enough to require emergency department care increased by 169 percent to an annual level of 99,500 (in 1995).[2] The most common site of injury is the wrist, accounting for 37 percent of all skating injuries, and two thirds of wrist injuries are fractures.[3,4] Wrist guards are designed to prevent sudden extreme hyperextension, to absorb shock and dissipate kinetic forces by enabling the skater to slide forward on the guard's hard volar plate, and to prevent gravel burns. Helmets, elbow pads, and knee pads are designed to absorb shock during a fall. The use of all four of these items of safety gear has been recommended,[5-7] but their effectiveness, although suggested,[3-5,8] had been untested. We surveyed a representative sample of injured in-line skaters who received emergency department treatment in order to identify behavioral and environmental risk factors for injury, the mechanism and nature of injury, and the degree of protection afforded by safety gear.

METHODS

Sample Design and Data Acquisition

Subjects were drawn from a sampling frame consisting of all patients injured during the study period who were wearing in-line skates and sought treatment at 1 of the 91 hospital emergency departments participating in the National Electronic Injury Surveillance System (NEISS).[9] NEISS is a national probability sample, stratified into four levels according to the annual number of emergency visits, of randomly selected U.S. hospitals with 24-hour emergency departments. The study period had two parts: December 25, 1992, through April 7, 1993, and July 1 to July 31, 1993.

We developed a list of possible risk factors for injury by conducting focus-group discussions with skaters[10] and by interviewing novice and experienced skaters. We constructed a 20-minute questionnaire to gather information on the characteristics of injured skaters, the circumstances surrounding the injury, and the use of safety gear.

Injured skaters were interviewed by telephone by Dr. Schieber during August 1993 after providing informed consent. If the skater was a minor, consent was obtained from the participant and a parent. Children were interviewed directly (although a parent was present in a few instances); the parent was then interviewed privately to verify the child's reported level of experience, the account of the injury, and the use of safety gear at the time.

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TABLE 1. SELECTED CHARACTERISTICS OF INJURED IN-LINE SKATERS IN THE NATIONAL SAMPLE.*

CHARACTERISTIC	% OF SAMPLE
Ability level	
Novice	10
Beginner	34
Intermediate	37
Expert	18
No. of times in-line skating	
1–5	25
6–12	12
13–99	26
≥100	37
Reasons for participation†	
To get exercise	75
To play roller hockey‡	37
For transportation	35
To perform tricks§	31
No. of lessons taken	
0	50
1–5	37
≥6	11
Ownership of skates	
Owned	72
Rented or borrowed	28
Condition of skates	
Good	85
Fair or poor	14

*The percentages given are calculated for an estimated 6331 persons treated in emergency departments nationally during the study period. They are based on data from 161 injured skaters, weighted according to the hospital in the NEISS sample in which they were treated. These values do not include subjects for whom the following were unknown: ability level (1 percent of the total), number of lessons taken (2 percent), or condition of skates (1 percent).

†Subjects could give more than one reason.

‡Of subjects who gave this reason, 34 percent were injured while playing roller hockey.

§Of subjects who gave this reason, 40 percent were injured while doing tricks.

The study was conducted with approval from the Office of Management and Budget, which authorized the Consumer Product Safety Commission to conduct confidential, selective telephone surveys of persons with product-related injuries to learn of the interactions among the product, the victims, and the environment.

Definitions and Analytic Design

Subjects were assigned to case and control groups for our analyses of the relative benefits of the use of wrist guards, elbow pads, knee pads, and helmets. To enhance precision, we defined four risk groups according to the four anatomical sites shielded by the various types of safety gear: the wrist, elbow, knee, and head (or face). Subjects were classified in a particular risk group if the given anatomical region had been exposed to injury in the subject's fall. For example, subjects were included in the wrist risk group if they fell on one or both outstretched arms or otherwise struck the wrist or lower arm during the fall. Within each risk group, we defined as case patients those skaters who injured the specified anatomical 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. The main exposure variable was the self-reported use (or

TABLE 2. CHARACTERISTICS OF FALLS AND OF INJURIES SUSTAINED BY IN-LINE SKATERS.*

CHARACTERISTIC	% OF SAMPLE
Location of fall	
Sidewalk or driveway	26
Street	22
Park or bike path	19
Indoors	10
Parking lot	9
Other	14
Proximate cause of fall	
Spontaneous loss of balance	41
Striking a stationary hazard†	40
Striking a moving object‡	11
Swerving to avoid hazard or collision	4
Other	4
Special factors§	
Hazardous road condition†	
Cited	53
Cited as key cause	63
Skating out of control	
Cited	25
Cited as key cause	67
Poor visibility (twilight or darkness)	
Cited	17
Cited as key cause	6
Fatigue	
Cited	11
Cited as key cause	37
Anatomical site of primary injury¶	
Wrist	32
Lower leg (including ankle)	13
Face (or chin)	12
Elbow	9
Knee	6
Head	5
Other	23
Type of injury	
Wrist fracture	25
Face or chin laceration	10
Wrist sprain	6
Elbow fracture	5
Lower-leg fracture	5
Ankle sprain	4
Severity of injury‖	
Major	51
Minor	49
Safety gear worn at time of injury	
Wrist guards	33
Elbow pads	28
Knee pads	45
Helmet	20
All the above gear	7
No gear	46

*The values given are calculated for an estimated 6331 persons treated in emergency departments nationally during the study period. They are based on data from 161 injured skaters, weighted according to the hospital in the NEISS sample in which they were treated.

†The hazard was usually a defect or debris in the road.

‡Collisions usually occurred with another skater, and less than 1 percent involved a motor vehicle.

§More than one response was allowed. Percentages given for key-cause citations are of those who cited the factor.

¶Thirteen percent of skaters had more than one injury.

‖Seventy-two percent of wrist injuries, 48 percent of elbow injuries, 38 percent of head injuries, and 34 percent of knee injuries were major. Six percent of patients with major injuries were admitted to the hospital.

TABLE 3. SELECTED CHARACTERISTICS OF THE IN-LINE SKATERS WITH WRIST OR ELBOW INJURIES AND THEIR CONTROLS.*

CHARACTERISTIC	WRIST RISK GROUP			ELBOW RISK GROUP		
	CASE PATIENTS (N=2471)	CONTROLS (N=2933)	P VALUE	CASE PATIENTS (N=1724)	CONTROLS (N=2984)	P VALUE
	no. (%)			no. (%)		
Age group			0.002			0.83
Elementary school	1357 (55)	696 (24)		765 (44)	1149 (39)	
Junior or senior high school	558 (23)	608 (21)		377 (22)	643 (22)	
Adult	557 (23)	1629 (56)		582 (34)	1192 (40)	
Sex			0.14			0.13
Male	993 (40)	1638 (56)		728 (42)	1783 (60)	
Female	1478 (60)	1295 (44)		996 (58)	1201 (40)	
Dominant hand†			0.08			ND‡
Right	2100 (86)	2711 (95)		1492 (94)	2676 (90)	
Left	337 (14)	137 (5)		87 (6)	291 (10)	
Ability level			0.75			0.82
Novice	317 (13)	310 (11)		188 (11)	249 (8)	
Beginner	978 (40)	891 (30)		574 (33)	1124 (38)	
Intermediate	849 (34)	1181 (40)		687 (40)	950 (32)	
Expert	327 (13)	551 (19)		275 (16)	661 (22)	
No. of times in-line skating			0.35			0.70
1–5	479 (19)	764 (26)		420 (24)	384 (13)	
6–12	196 (8)	421 (14)		179 (10)	361 (12)	
13–99	1013 (41)	573 (20)		678 (39)	849 (28)	
≥100	783 (32)	1176 (40)		447 (26)	1390 (47)	
Cross-training			0.45			ND‡
No other sports	188 (8)	343 (12)		120 (7)	335 (11)	
One or more other sports	2283 (92)	2590 (88)		1605 (93)	2649 (89)	
No. of lessons taken§			0.57			0.03
0	1346 (54)	1355 (47)		496 (29)	1748 (60)	
1–5	799 (32)	1218 (43)		824 (48)	909 (31)	
≥6	327 (13)	283 (10)		404 (23)	249 (9)	
Performed tricks¶			0.60			0.05
Yes	300 (12)	377 (13)		69 (4)	532 (18)	
No	2171 (88)	2513 (87)		1613 (96)	2452 (82)	
Level of perceived exertion at time of fall			0.97			0.93
Warm-up	205 (8)	214 (7)		120 (7)	256 (9)	
Cruise	1949 (79)	2361 (81)		1383 (80)	2308 (77)	
Fatigue	317 (13)	358 (12)		222 (13)	419 (14)	
Fall related to difficulty stopping‖			0.27			0.08
Yes	455 (20)	919 (32)		585 (35)	480 (17)	
No	1784 (80)	1945 (68)		1071 (65)	2315 (83)	

nonuse) of the appropriate safety gear for the specified anatomical site. The outcome variable was the presence or absence of an injury to that anatomical site, as reported by the skater and confirmed by the NEISS record.

Selected characteristics of the skaters were considered as covariates. The subjects were classified according to age into groups: elementary-school children (6 to 12 years), junior or senior high-school youth (13 to 18 years), and adults (19 years or older). Subjects comfortable standing up on skates were classified as novices; beginners were those who could make a simple turn on two skates; intermediates could perform a crossover turn (made with a sequence of short, alternating cross-steps); and experts could do two or more stunts. In-line skating experience was classified according to the number of times the skater had participated in the sport. Ice hockey, ice skating, alpine skiing, roller skating, bicycle racing, and mountain bicycling were defined as cross-training sports. Lessons were defined as prior training with an instructor or accompaniment by a more skilled skater. The levels of perceived exertion at the time of injury, as assessed by the skaters themselves, were warming-up, cruising, and fatigued. Other covariates in the analysis were sex, handedness, and whether the skater performed tricks (as a covariate, considered a proxy for risk-taking behavior). Characteristics of the fall that were considered as covariates included the subject's reported inability to stop just before injury and the severity of injury. A fracture, a dislocation, or an internal injury constituted a major injury; a laceration, abrasion, contusion, sprain, or strain was a minor injury.

We evaluated the possibility that selection bias might result from the use of controls who also were injured while skating. For example, many subjects treated as case patients in the analysis of wrist injury were used as controls for the analysis of elbow injury. If nonuse of wrist guards was highly correlated with nonuse of elbow pads, then these subjects might be less likely than the general population to wear gear and have protection. Therefore, separate covariates were defined for each type of gear used as well as for a composite variable indicating the use or nonuse of any additional safety gear not related to the injury site.

Statistical Analysis

All data reported have been weighted according to the probability of hospital selection from the four levels based on hospital size in the total NEISS sample. All analyses were conducted with SUDAAN statistical software to account for complex sampling.[11]

TABLE 3. CONTINUED.

CHARACTERISTIC	WRIST RISK GROUP			ELBOW RISK GROUP		
	CASE PATIENTS (N = 2471)	CONTROLS (N = 2933)	P VALUE	CASE PATIENTS (N = 1724)	CONTROLS (N = 2984)	P VALUE
	no. (%)			no. (%)		
Wrist guards worn at time of fall			<0.001			0.96
Yes	154 (6)	1356 (46)		446 (26)	755 (25)	
No	2317 (94)	1577 (54)		1278 (74)	2229 (75)	
Elbow pads worn at time of fall**			0.03			0.003
Yes	360 (15)	1058 (36)		111 (6)	1056 (36)	
No	2094 (85)	1875 (64)		1613 (94)	1910 (64)	
Knee pads worn at time of fall††			0.05			0.66
Yes	780 (32)	1495 (51)		652 (39)	1305 (44)	
No	1657 (68)	1438 (49)		1038 (61)	1679 (56)	
Helmet worn at time of fall			0.93			0.56
Yes	403 (16)	499 (17)		336 (19)	420 (14)	
No	2069 (84)	2434 (83)		1388 (81)	2564 (86)	
Additional gear worn at time of fall‡‡			0.06			0.66
Yes	865 (35)	1563 (53)		720 (42)	1399 (47)	
No	1606 (65)	1370 (47)		1004 (58)	1585 (53)	

*The values given are calculated for two subgroups of the estimated national sample of 6331 injured in-line skaters: 5404 case patients and controls in the wrist risk group and 4708 case patients and controls in the elbow risk group. Values are based on weighted data from 141 interviewed subjects in the wrist risk group and 122 interviewed subjects in the elbow risk group. The values shown do not include subjects for whom data on a given variable were missing. For categories within each variable, the values may not add up to the totals in the estimated national samples (N values) because of rounding involved in the estimating process or missing data (see below). P values are for the comparisons of case patients and controls by the log-linear chi-square test. Because of rounding, percentages may not total 100. ND denotes not determinable.

†An additional 85 subjects in the wrist risk group and 85 in the elbow risk group were ambidextrous, and data on handedness were missing for an additional 34 in the wrist risk group and 77 in the elbow risk group. The subjects were not included in the analysis of handedness.

‡The small number of left-handed subjects precluded chi-square analysis.

§Data were missing for an additional 77 subjects in the wrist risk group and 77 in the elbow risk group; they were not included in this analysis.

¶Data were missing for an additional 43 subjects in the wrist risk group and 43 in the elbow risk group; they were not included in this analysis.

‖Data were missing for an additional 301 subjects in the wrist risk group and 258 in the elbow risk group; they were not included in this analysis.

**Data were missing for an additional 17 subjects in the wrist risk group and 18 in the elbow risk group; they were not included in this analysis.

††Data were missing for an additional 34 subjects in the wrist risk group and 34 in the elbow risk group; they were not included in this analysis.

‡‡"Additional gear" refers to safety gear intended to protect anatomical sites other than the site by which the risk group was defined (e.g., the use of both wrist guards and elbow pads in the wrist risk group).

Log-linear chi-square tests were used to test for association between groups and for significant differences in proportions.[11,12] Association was assessed with unadjusted odds ratios and 95 percent confidence intervals. Logistic regression was used to compute adjusted odds ratios with control for confounding factors. Population-attributable risks were calculated with established methods.[13] A P value of less than 0.05 (two-tailed) was considered to indicate statistical significance, with the use of variances derived from the weighted sample.

RESULTS

Demographic Characteristics of the Skaters and Circumstances of the Injuries

We interviewed 161 of 206 eligible subjects (for a 78 percent response rate[14]); their data were weighted, on the basis of hospital selection, so as to represent the distribution of characteristics of the estimated 6331 in-line skating injuries treated in emergency departments nationally during the study period. The skaters ranged from 6 to 59 years of age (mean, 20.8; median, 15). Forty-eight percent were male, and 89 percent were right-handed (other characteristics of the skaters are provided in Table 1; data on their falls and consequent trauma are provided in Table 2). The most typical fall involved young novice or beginner skaters wearing little or no safety gear, who either spontaneously lost their balance while skating outdoors or fell after striking a road defect or debris. The falls typically occurred on outstretched arms without any attempt to stop. The wrist was the most common site of primary injury (32 percent); 25 per-

TABLE 4. ODDS RATIOS FOR INJURIES TO IN-LINE SKATERS NOT WEARING APPROPRIATE SAFETY GEAR.*

SITE OF INJURY	CRUDE ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)†
Wrist: wrist guards not worn	12.9 (4.5–37.1)	10.4 (2.9–36.9)
Elbow: elbow pads not worn	8.0 (2.1–30.1)	9.5 (2.6–34.4)

*Odds ratios are for subjects not wearing appropriate gear as compared with those who were wearing it. CI denotes confidence interval.

†Odds ratios for wrist injury have been adjusted for age group and sex. Odds ratios for elbow injury have been adjusted for the number of lessons taken and whether or not the subject performed tricks.

cent of all injuries were wrist fractures. Seven percent of the injured skaters wore all four types of safety gear; 46 percent wore none. Of the total, 45 percent wore knee pads, 33 percent wrist guards, 28 percent elbow pads, and 20 percent helmets.

The Case–Control Study

Case patients and controls in the wrist risk group and in the elbow risk group are compared in Table 3. The projected national total in the wrist risk group (5404 persons) was estimated on the basis of weighted data on 141 interviewed subjects; the projected total in the elbow risk group (4708) was estimated on the basis of 122 subjects. Case patients and controls in the wrist group differed significantly in age distribution (case patients tended to be younger) and in their use of wrist guards and elbow pads. Case patients and controls in the elbow group differed only in their use of elbow pads, the number of lessons taken (case patients tended to have taken more lessons), and history of trick skating (controls had more frequently performed tricks).

Analysis of crude odds ratios indicated that among those at risk for wrist injury, skaters who did not wear wrist guards had a likelihood of actually sustaining a wrist injury that was 12.9 times that among those who did wear wrist guards (95 percent confidence interval, 4.5 to 37.1) (Table 4). Among skaters at risk for injury to the elbow, those not wearing elbow pads had a risk of sustaining an elbow injury that was 8.0 times that among skaters who did wear such gear (95 percent confidence interval, 2.1 to 30.1). Nonuse of knee pads was associated with an increase, but not a significant increase, in the risk of knee injury (crude odds ratio, 2.2; 95 percent confidence interval, 0.7 to 7.2). The association between not using a helmet and sustaining a head or facial injury was also not significant (odds ratio, 0.9; 95 percent confidence interval, 0.1 to 6.8).

Bivariate analysis showed a significant association between the likelihood of wrist injury and both the use of wrist guards and age and an association between the likelihood of elbow injury and the use of elbow pads, the taking of lessons, and a history of doing tricks (for all associations, $P<0.05$). The relation between wrist injury and the use of wrist guards was confounded by age and sex; the relation between elbow injury and the use of elbow pads was confounded by having taken lessons and a history of performing tricks. When we controlled for these confounders, the multivariate analysis indicated that the nonuse of wrist guards was associated with a risk of sustaining a wrist injury that was 10.4 times that among skaters who did wear wrist guards (95 percent confidence interval, 2.9 to 36.9), and nonuse of elbow pads was associated with an odds ratio of 9.5 for sustaining an elbow injury (95 percent confidence interval, 2.6 to 34.4) (Table 4). The use of wrist guards was not significantly associated with injury to the elbow (data not shown).

In calculations of population-attributable risk, the nonuse of wrist guards accounted for 87 percent (95 percent confidence interval, 84 to 96 percent) of all wrist injuries. Failure to use elbow pads accounted for 82 percent (95 percent confidence interval, 78 to 95 percent) of all elbow injuries. Failure to use knee pads accounted for 32 percent (95 percent confidence interval, 27 to 79 percent) of all knee injuries.

DISCUSSION

Our analysis of several environmental and behavioral risk factors for in-line skating injuries in a nationally representative sample of skaters found that wrist guards and elbow pads afforded skaters a high level of protection, but that their rate of use among injured patients was relatively low. The degree of protection afforded by wrist guards and elbow pads is similar to the degree of protection afforded the head by bicycle helmets (85 percent) in a study of bicycle crashes.[15]

The NEISS data set permits the estimation of the national incidence of an injury with known variance.[9] Even using unweighted data (thereby converting the probability sample to a sample of convenience), we found that the adjusted odds ratio for wrist injuries associated with the failure to use wrist guards was 5.9 (95 percent confidence interval, 1.8 to 18.8), and that for elbow injuries associated with the failure to use elbow pads, 7.9 (95 percent confidence interval, 2.2 to 27.5). To bolster the strength of our analysis, we used a single interviewer and multiple lines of inquiry, sought parental confirmation for important data, controlled the analysis for many potential confounders, sampled a wide age range, sought (and achieved) a high response rate, and increased precision by restricting the selection of case and control patients to those exposed to the risk of injury to a specific anatomical site.

Our study, however, has several potential limita-

tions. Selection bias may have resulted from our use of emergency department patients as controls, rather than skaters drawn from the general population. Controls who have sustained a skating injury may be more similar to case patients than population-based controls would be, which would have biased our results toward the null hypothesis. However, any potential bias of this type would not have altered the public health consequences of our findings because the point estimates of the odds ratios are so large.

On the other hand, had a significant correlation existed among the use of different kinds of safety gear, our results might have been biased away from the null hypothesis. The use of more than one type of gear was not a significant confounder, either when use of a given type was examined individually or when we assessed a composite indicator (data not shown). Forcing these variables for use of more than one type of gear into the final model decreased the point estimate of the odds ratio for wrist injury minimally and increased the odds ratio for elbow injury substantially, but it did not change the significance of these ratios. However, the level of precision was reduced considerably (data not shown). To recruit geographically matched, population-based controls would have been prohibitively costly; controls from a single area only might not have had attributes (e.g., skill level) that properly matched those of the case patients; and seeking to select controls from a random national telephone survey might not have, in 1993, yielded many in-line skaters.

Information bias may be present because these data were reported by the skaters themselves. The recall period ranged from several weeks to eight months, and some respondents may not have remembered details well. Some variables, such as skating frequency, were difficult for the youngest children to quantify. Lifetime person-hours of skating experience, the ideal measure of exposure to possible injury, was crudely approximated by the number of times a subject remembered having skated. This number may not have been recalled accurately. The study lacked sufficient power to detect a significant association between knee injury and the use of knee pads (the point estimate, however, was elevated) as well as between head injury and the use of a helmet. Some potential confounders could not be assessed, including skating speed, crash forces on impact, cross-training experience with cross-country skiing, the use of poorly fitting safety gear, and household income.

The nature of in-line skating has some practical implications for the use of safety gear. The widespread availability of gear in child and adult sizes and its relatively low cost should facilitate use. Automatic braking devices, which slow the wheels or apply a heel brake without dorsiflexion of the foot, may reduce the injury rate; such devices became available after the conclusion of the study. Currently, wrist guards may not be practical for participants in roller hockey because the wrist guards interfere with the player's ability to hold the hockey stick firmly or make a wrist shot. This limitation warrants further attention on the part of product designers, given the popularity of roller hockey and the large proportion of the skaters in our study who were injured while playing hockey.

In conclusion, we recommend that in-line skaters wear wrist guards, elbow pads, knee pads, and helmets. Although the small number of skaters who sustained a head injury did not allow us to determine the degree of protection afforded by helmets, other studies[15,16] indicate that helmets that meet existing standards for bicycle helmets[17] are strongly protective against head injuries in physical environments quite similar to that of skaters.

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