Skiing Injuries

Epidemiologic Study

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THE fundamental question in searches for the etiology of accidents, as well as other causes of morbidity, is how do persons affected differ from those who are not. Despite this, there has heretofore been no scientifically adequate attempt to investigate this question with respect to any type of recreational accident.

This report records the methods, findings, and implications of a controlled epidemiologic investigation of skiing accidents. The study was undertaken as a result of a suggestion by one of the authors (Ellison) who provides emergency care of skiing injuries at a large ski resort. The accompanying report presents a clinical analysis of skiing injuries and their variation with age, sex, and skiing ability. The epidemiologic report carries the investigation back to the population from which the injured were derived and records the characteristics of the skiers and their equipment which were associated with increased risk of injury.

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Methods

The study was conducted at Mount Snow, Vt., a ski resort owned by the Mount Snow Development Corp. The study population was composed of all persons purchasing tickets to ski on the four consecutive Saturdays and Sundays from January 28 through February 19, 1961. The case-subjects were those members of this population who were injured while skiing and who came to the resort's medical facility on the day of injury. It is estimated that at least 95 percent of those injured at the resort who received medical care anywhere on the day of injury were in this group, and that virtually all those seriously injured were included. Members of the resort's ski patrol were excluded

from both the case and the control groups, as were those whose tickets entitled them to only single rides on the lifts.

The population at risk was sampled by interviewing every 50th person obtaining a ski ticket at either of the resort's two ticket booths. Immediately after the ticket was stapled to the skier's clothing, those selected were asked to step aside for the "ski census." For each person who refused, the next 25th person was interviewed. Of 451 persons so selected, only 5 refused, leaving a sample of 446.

The interview included questions on the following: residence, age, marital status, occupation or school year, age when he or she first skied, frequency of skiing, previous skiing at Mount Snow, types of turns performed, history of previous injury, height, weight, hours of sleep during each of the previous 2 nights, ski club membership, self-rating as a skier, ownership of equipment in use, and time and place of last binding adjustment. In addition, the skis were measured, and the type of binding used was recorded.

The injured, on arrival at the resort's medical facility, were asked the same questions by either physicians or medical students. The nature of the injuries, in full clinical detail, was also recorded. Since the skis in use by those injured were sometimes not brought to the medical facility, the majority of the accident sites were visited before the injured were removed. At the site, full particulars of the accident were obtained, the skis were measured, and the binding type was noted. The visits were made by expert skiers who worked with the ski patrol and also circulated continuously on the trails where accidents most often occurred.

Because this research design did not control for possible variations in the amounts and types of skiing by skiers of different characteristics, use of a second design was explored. For 1 day each person interviewed was asked to wear a prominently numbered canvas racing bib of the vest type used for identification of participants in ski races. Bands of intense color painted on these made them visible up to 700 feet. Only 8 percent of those requested to wear the bibs refused, but study of the skiing population late the same afternoon showed that significant numbers must have taken them off. Hence, these bibs were not used further during the investigation. The intention was to have the research workers visiting the accident sites record the numbers of the first bibbed non-accident-involved skiers passing the accident scenes. These skiers would have been used as a site- and time-matched control group for those

Table 1. Injury rates for male and female skiers, by turn group and age, Mount Snow, Vt., 1961

Turn group and age [1]	Males			Females			Both sexes		
	Cases	Controls	Injury rate [2]	Cases	Controls	Injury rate [2]	Cases	Controls	Injury rate [2]
Snow plow:									
Under 20 years	13	11	23.6	14	18	15.6	27	29	18.6
20–29 years	17	14	24.3	18	19	18.9	35	33	21.2
30 years and over	5	11	9.1	5	18	5.6	10	29	6.9
Stem christie:									
Under 20 years	6	22	5.5	4	22	3.6	10	44	4.5
20–29 years	6	26	4.6	6	14	8.6	12	40	6.0
30 years and over	3	35	1.7	3	22	2.7	6	57	2.1
Parallel and wedeln:									
Under 20 years	5	39	2.6	2	9	4.4	7	48	2.9
20–29 years	7	65	2.2	6	19	6.3	13	84	3.1
30 years and over	7	61	2.3	3	13	4.6	10	74	2.7
Total, all ages	[3] 69	[4] 284	4.9	61	154	7.9	[3] 130	[4] [5] 438	5.9

[1] Turn group assignment was based on the most difficult turn each skier stated he could perform.

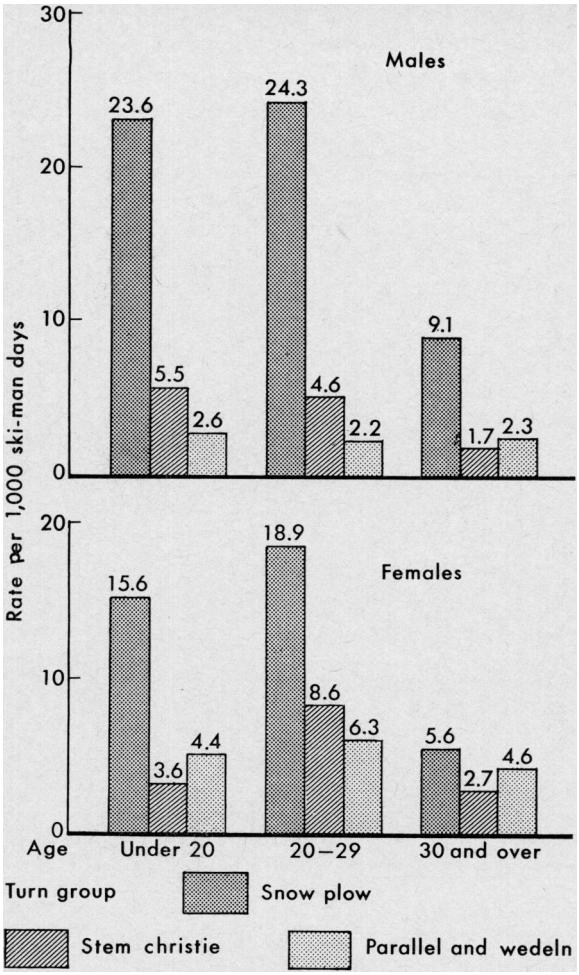
[2] Per 1,000 ski-man-days. Since the controls are a 2 percent systematic sample, injury rate = cases × 20 ÷ controls.

[3] 1 male case was omitted because his turn group was not recorded.

[4] 1 male control was omitted for the same reason.

[5] 7 controls were omitted because their sex was not recorded.

Figure 1. Injury rates of skiers by sex, age, and turn group, Mount Snow, Vt., 1961



injured. Similar tagging has long been used in studies of animal populations. In addition, such site- and time-matched controls have proved exceptionally useful in the study of motor vehicle accidents (*1,2*). This approach should be explored further in studies of recreational accidents because it makes possible comparison of cases and controls equally exposed to risk.

Virtually all the types of weather commonly occurring during skiing were encountered. The temperature ranged from −10° to 67° F. Sleet, rain, and heavy snow fell, but population sampling and case collection continued without interruption.

All the data were analyzed in terms of four variables suspected to be of fundamental importance: age, sex, skiing ability, and type of binding used. The turns which each person said he or she could perform were used as the best measure of skiing ability available in this study. On this basis the skiers were divided into the following three turn groups: snowplow only; snowplow and stem christie only; and snowplow, stem christie, and parallel and wedeln turns. Parallel and wedeln turns were grouped together because of the small number of skiers who could perform these. In the population studied this was almost invariably the sequence in which turns were learned. The skier's turn group could therefore be used as a measure of expertise. However, since some are now learning the turns in a different order, use of turn groups may not be practical in future studies.

In this study it would also have been possible to use the skiers' self-ratings (beginner, novice, intermediate, or expert), since these were highly correlated with the turn group ratings. Self-ratings were not used because we thought it possible that skiers would not give the same assessment of their ability immediately after an accident as they would otherwise.

Multiple injuries were classified in the same manner as in the clinical study, with musculoskeletal injuries given precedence over lesser injuries also present.

Table 2. Use of release bindings by skiers in relation to turn group and age, Mount Snow, Vt., 1961 [1]

Turn group and age	Number using release bindings	Number not using release bindings	Percent using release bindings
Snow plow:			
Under 20 years	20	9	69
20–29 years	22	11	67
30 years and over	21	7	75
Stem christie:			
Under 20 years	34	12	74
20–29 years	29	10	74
30 years and over	46	10	82
Parallel and wedeln:			
Under 20 years	44	7	86
20–29 years	78	7	92
30 years and over	69	5	93
Total, all ages	363	78	82

[1] Based on a 2 percent systematic sample of those obtaining tickets to ski on the 4 consecutive Saturdays and Sundays of the investigation.

Table 3. Use of release bindings among males and females in the matched case-control group,[1] Mount Snow, Vt., 1961

Sex	Release bindings	Non-release bindings	Binding type unknown	Total
Males				
Cases	31	24	8	63
Controls	50	13	0	63
Total	81	37	8	126
Females				
Cases	36	22	0	58
Controls	40	18	0	58
Total	76	40	0	116

[1] Each pair was matched by sex, age, and turn group.

NOTE: For males, $P<0.01$; for females, $P>0.3$, calculated using Cochran's method for comparison of matched samples, pairs containing unknowns omitted (*10*).

Bindings were classified by inspection into release and nonrelease types. A release binding is so designed that it is supposed to disengage from the ski boot under forces exceeding those customarily encountered, thus presumably reducing the likelihood of injury.

Results

Injury rates by sex, age, and turn group observed in the population studied are presented in table 1 and figure 1. Although considerable variation in rate with these characteristics was noted, variations in the type of binding used associated with age and expertise were also found (table 2).

Because of these variations and the stated belief of many persons familiar with skiing that the use of release bindings substantially reduces the risk of accidental injury, a matched case-control group was established in order to deter-

Table 4. Type of injury in relation to sex and use of release bindings, matched case-control group, Mount Snow, Vt., 1961

Sex	Injury group											
	A[1]				B[2]				C[3]			
	Release bindings	Nonrelease bindings	Binding type unknown	Total	Release bindings	Nonrelease bindings	Binding type unknown	Total	Release bindings	Nonrelease bindings	Binding type unknown	Total
Males[4]												
Cases	15	4	2	21	15	17	6	38	0	3	0	3
Controls	17	4	0	21	30	8	0	38	2	1	0	3
Total	32	8	2	42	45	25	6	76	2	4	0	6
Females[4]												
Cases	6	1	0	7	28	16	0	44	2	4	0	6
Controls	5	2	0	7	30	14	0	44	4	2	0	6
Total	11	3	0	14	58	30	0	88	6	6	0	12

[1] All single-site musculoskeletal injuries not affecting the lower extremities and lacerations and contusions of all sites.

[2] All single-site musculoskeletal injuries of the lower extremities.

[3] All multiple-site musculoskeletal injuries. All of these were the syndrome described in the accompanying report, knee sprain associated with sprained or fractured ankle.

[4] One male case and his matched control and one female and her control were omitted because their injuries were not adequately described.

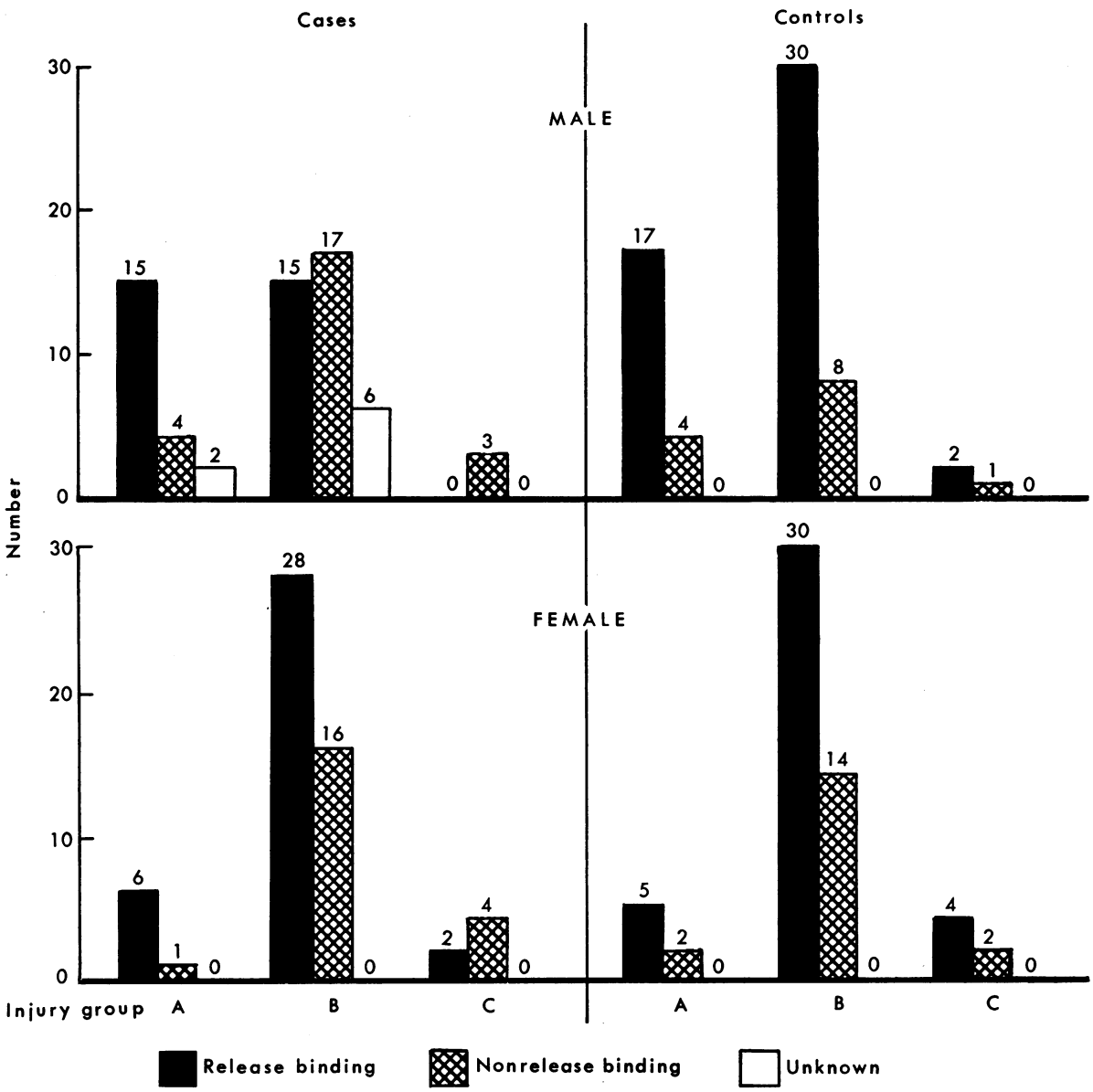
NOTE: For males, group A, $P>0.9$, group B, $P=0.03$; for females, group A, $P>0.5$, group B, $P>0.5$, calculated using Cochran's method for comparison of matched samples, pairs containing unknowns omitted (*10*). Group C data were not tested because of the small numbers.

mine whether users of release bindings actually did have different injury rates from otherwise similar skiers. This group consisted of 121 case-control pairs matched by sex, age (within 3 years), and turn group; 104 were matched within 1 year of age.

In the matched case-control group a statistically significant association ($P<0.01$) between the occurrence of injury and the use of nonrelease bindings was found among the males (table 3). However, no such association ($P>0.3$) was found among the females.

Since the use of release bindings might be expected to have little or no influence on the

Figure 2. Type of injury in relation to use of release bindings among males and females, matched case-control group, Mount Snow, Vt., 1961



Injury groups: A, single-site musculoskeletal injuries not affecting the lower extremities and all lacerations and contusions; B, single-site musculoskeletal injuries of the lower extremities; C, multiple-site musculoskeletal injuries.

incidence of injuries other than musculoskeletal injuries of the lower extremities unless those using such bindings skied differently from those who did not, the matched case-control pairs were next separated by type of injury sustained into three categories (table 4 and fig. 2). Group A included all single-site musculoskeletal lesions not affecting the lower extremities, together with lacerations and contusions of all sites. Group B, which is of principal interest here, included all single-site musculoskeletal injuries of the lower extremities, and group C, all multiple-site musculoskeletal injuries.

No statistically significant differences in the use of release bindings were found between the case and control distributions for either sex with respect to injuries in groups A and C. In the lower extremity-musculoskeletal group B, however, there was a significant ($P=0.03$) difference in the use of such bindings among males, but no significant difference ($P>0.5$) among the females.

There was also a substantial difference in the proportions of males and females in each injury group. While 64 percent (38/59) of the males in groups A and B sustained group B injuries, the corresponding figure for females was 86 percent (44/51).

No significant association ($P>0.3$) between the occurrence of ankle sprains as opposed to fractures and the type of binding was found among members of the entire case series (table 5). Actually, the ratio of fractures to sprains was greater among those with release bindings (14/11) than among those with nonrelease bindings (9/13).

Many additional analyses were performed, using chiefly variance analysis and the chi-square test. Without exception no statisically significant or suggestive differences were found between cases and controls with respect to any of the following variables: weight, height, ski length (none of the skis were the very short ones now becoming popular), amount of skiing during the present and previous seasons, previous skiing at the same resort, ski club membership, use of own as opposed to rented or borrowed skis, interval since binding adjustment, distance traveled to the resort, years of skiing experience and age when person first skied, marital status, and history of previous skiing injury. The comparisons with respect to marital status and previous injury shown in tables 6 and 7 illustrate the typically negative findings obtained in these analyses.

Table 5. Relationship between sprains and fractures of the ankle and use of release bindings, Mount Snow, Vt., 1961 [1]

Injury	Release bindings	Nonrelease bindings	Total
Sprains	11	13	24
Fractures	14	9	23
Total	25	22	47

[1] Of 51 such ankle injuries in the entire case series, 2 fractures and 2 sprains were omitted here because the binding type was unknown.

NOTE: $P>0.3$, by chi-square test.

Table 6. Marital status of males and females in the matched case-control group, Mount Snow, Vt., 1961

Sex	Married	Widowed	Separated	Divorced	Never married	Marital status unknown	Total
Males							
Cases	13	1	0	0	48	1	63
Controls	8	1	0	1	52	1	63
Total	21	2	0	1	100	2	126
Females							
Cases	18	1	0	0	39	0	58
Controls	16	0	0	1	39	2	58
Total	34	1	0	1	78	2	116

Table 7. History of previous injury among males and females of the matched case-control group, Mount Snow, Vt., 1961

Sex	Previous injury	Fracture		No previous injury	History unknown	Total
		Yes	No			
Males						
Cases	7	1	6	56	0	63
Controls	4	1	3	59	0	63
Total	11	2	9	115	0	126
Females						
Cases	6	4	2	52	0	58
Controls	7	0	7	50	1	58
Total	13	4	9	102	1	116

Discussion

One of the fascinations of epidemiology is that the afflictions of man show characteristic ecologic patterns, and skiing injuries are no exception. The gross distribution of such injuries, however, unlike those of certain chronic diseases now under investigation, is easily predicted. These injuries reflect the times and places in which the sport is practiced, and, as a result, they occur largely in discrete foci in mountainous areas. They also vary in time, as is well known, with the availability of snow, and at least in New England increase in incidence on weekends and holidays with the increase in the numbers of persons skiing.

Skiing accidents have also increased during recent years as the number of skiers has grown. In the United States skiing has progressed rapidly since the 1932 Winter Olympics at Lake Placid, and the techniques and the equipment used are still evolving. This is reflected in the considerable variety of equipment seen in this investigation and in the youthfulness of most of the skiers. For example, 26 was both the median and the mean age of the population studied. In addition, 94 percent (421/446) were between 10 and 45 years of age.

It is likely that skiing populations will tend to become older as the sport reaches and passes its period of most rapid growth. When this happens, the injury pattern may be expected to shift to include relatively more of the lesions which tend to occur among older skiers, as documented in the accompanying report. An association between age and type of injury has been noted also by Boder (*3*), who reported that all of the femoral fractures in his series occurred in persons over 60 years of age. This age group was not found in the population described here; the oldest person in the case and control groups was 53 years of age. In this context it should be borne in mind that the present findings, particularly as they relate to the efficacy of release bindings, should not be indiscriminately extrapolated to substantially older, or younger, populations, since injury thresholds probably shift substantially with age (*4*), as has been documented for adult pedestrians struck by motor vehicles (*1*).

The overall injury rate in the population at Mount Snow was 5.9 per 1,000 ski-man-days. This is consistent with the recent statement of Earle and co-workers (*5*), based on their experience at Sun Valley, Idaho, that "it seems likely that the overall ski-accident rate approaches 1 percent per day." Although such crude rates are useful for estimating caseloads, they obscure the major variations in rates with age, sex, and skiing ability revealed by more detailed analyses.

As shown in table 1 and figure 1, the snowplow turn group, composed largely of beginners, had the highest injury rate. Although they constituted only 21 percent of those skiing, members of this group contributed 55 percent of the injuries. Their injury rate was 16.0 per 1,000 ski-man-days, compared with rates of 4.1 and 2.9 in the stem christie and parallel and wedeln groups. Females also contributed a disproportionate share of the injuries. Although only 35 percent of those skiing were females, they accounted for 47 percent of those injured. The injury rate for females was 7.9 per 1,000 ski-man-days in comparison with a male rate of 4.9. The markedly higher injury rates of these two groups suggest that preventive measures should be directed particularly toward them.

It would be easy to jump to conclusions concerning the reasons for the age-, sex-, and experience-associated differences in these rates. For example, it might be postulated that they

result from inexperience, poorer neuromuscular coordination, poorer physical condition, lower injury thresholds, or inappropriate equipment. They might also result from beginners' slopes of too great difficulty or use of advanced slopes by the unqualified. Remarkable speeds can be reached on relatively gentle slopes (see Technical Note). In view of these, perhaps at least beginners' slopes should be made less steep since this group has the highest injury rate. Another possibility is that attrition from the skiing population of beginners with high accident rates results in lower rates among those progressing to the stem christie and parallel and wedeln groups.

Investigations concerned with these and similar variables will require considerable sophistication of design and data analysis. Although this is the rule in controlled studies, it is particularly necessary here because the various characteristics of skiers tend to be statistically highly associated. For example, use of release bindings among skiers at Mount Snow increased with age and expertise (table 2). The investigation of the efficacy of release bindings was therefore approached through the use of a case-control group matched by age, sex, and turn classification, which made possible the comparison of the injury experience of otherwise similar skiers.

This comparison revealed significantly fewer injuries among males using such bindings but not among females so equipped (table 3). Without further analyses these findings could have been considered consistent with at least two hypotheses:

1. That the release bindings per se were significantly effective for the males, but not for the females; or

2. That the release bindings per se were not significantly effective, but that there were pertinent differences in the ways in which males using them skied.

Because of the central importance of this point, the equivalent of questions raised in connection with smoking and lung cancer, for example, analyses were made to determine whether the reduction in injury occurrence with the use of release bindings was specifically related to the injuries which they were purportedly designed to prevent, or whether there was also a similar reduction in other types of injuries (table 4 and fig. 2). Finding of the latter would have strongly supported the second hypothesis.

The data, particularly as presented in figure 2, show for each injury group and its matched controls the numbers of skiers with release as opposed to nonrelease bindings. Among females no difference in any of the injury groups was found in the proportions of cases and controls using each type of binding. However, among males there was a large and statistically significant case-control difference in the use of nonrelease bindings among those sustaining lower extremity musculoskeletal injuries (B), but not among those with other types of injuries (A and C). In other words, the decrease in injury rates among males using release bindings (or, conversely, the increase in injuries with the use of nonrelease bindings) was specifically limited to those injuries which would be expected to be influenced.

These findings indicate that release bindings, as adjusted and used by the population studied, are a specific preventive device, significantly effective in the partial prevention of injuries among males, but not among females. The most reasonable interpretation of this difference is that the forces required to disengage ski boots from these bindings tended to exceed the injury thresholds of females, but not those of males. This is consistent with the lighter musculoskeletal structure of females and with the fact well known to those concerned with skiing injuries that such bindings often fail to disengage before injury is sustained. However, although we favor the attribution of this sex-associated difference in efficacy to lower female injury thresholds, it is also possible that it was the result of pertinent sex differences in the adjustment of the bindings themselves or in the specific types of release bindings employed.

Whichever interpretation is correct, these results do not suggest that release bindings should not be used by females or that they may not occasionally be of value. Rather, they indicate that an attempt should be made through the lowering of the binding release thresholds to extend to females at least the partial protection they now afford males. In addition, a similar attempt should be made to

improve their efficacy for males. These attempts must consider the highly varied musculoskeletal characteristics of skiers within each age, sex, and experience group. While release bindings as a whole have been shown to be of some value, it is likely that among these highly varied devices there is considerable variation in release thresholds and efficacy, both of which should be investigated in future research. When this is done, it would be desirable to study release bindings in relation to each of the many types of injuries in the B group. This was not possible here because of the relatively small number of cases.

We do not know, except in gross terms, the nature or magnitude of the forces to which the ski-binding-boot-foot-leg-thigh-torso linkage is subjected in either normal skiing or under injury-producing conditions, and this information is needed for better design of safety equipment. Some of this missing information could come from laboratory research, for example, the instrumentation of the several portions of this linkage while subjected to various force conditions. However, results of such work would tend to be of indeterminate relevance to the prevention of skiing accidents unless buttressed substantially with data from studies conducted under actual skiing conditions. In addition, while either laboratory or field experiments might lead to understanding of the forces produced under non-injury-producing circumstances, they would not be likely to lead to determination of those which result in injury, since injuries cannot be deliberately induced in human subjects. Lower animals could not be used because of the differences in the structure of their lower extremities. For these reasons, progress in the understanding of skiing accidents will depend largely on further epidemiologic study of the natural experiments posed by skiers engaged in their sport.

Serious consideration should also be given to the study of ways in which group A injuries might be prevented, since the release bindings appear to contribute little to their prevention. Some of these, for example, injuries to the head and shins, might be reduced through the use of protective devices, but whether this will prove practical remains to be determined.

We had expected to find a decrease in the fracture-to-sprain ratio associated with the use of release bindings on the theory that such bindings in comparison with nonrelease types might disengage before the forces applied reached fracture thresholds even after those for sprains had been exceeded. No such decrease was found (table 5), but in view of the small numbers available for this comparison and the inclusion of 26 females, the results are not conclusive. This point should be studied further, particularly since a reduction in severity of injury should be one of the objectives of preventive measures.

It was also not possible to settle the question of whether or not there was a shift in accident rate with age—binding type, turn group, and sex being held constant. No statistically significant shift was found, but again the numbers available for analysis precluded a firm conclusion. This point should also be explored further.

Many skiers feel that preseason conditioning, that is, some form of preparatory exercise, contributes greatly to their safety. For this reason, those interviewed were asked whether they had engaged in any such activity, but responses were so varied and vague as to be unsuitable for analysis. What constituted "conditioning" to one did not to another. If physical condition is studied in the future in relation to skiing or other recreational accidents, it is suggested that ergometric and other objective measurements be used rather than interviews alone.

Other variables analyzed in this study failed to discriminate between cases and controls. Marital status was included not only as a common social parameter, but also because the unmarried have recently been shown to be significantly more often involved in fatal motor vehicle accidents than the married similarly exposed (*2*). Our data show that skiing, at least at Mount Snow, is overwhelmingly a sport of the unmarried, as were, as a result, the injuries (table 6). In addition, while there was no difference between cases and controls in the amount of sleep obtained during each of the previous nights, among adults of each sex the married had had considerably more sleep than the unmarried.

The negative findings with respect to previous injury were of particular interest (table 7).

Though the small numbers of such injuries may have obscured case-control differences, the important point is that a history of prior injury was absent in 89 percent (108/121) of the cases and 90 percent (109/121) of the controls. Therefore, whether or not there is an increased risk with such history, its rarity indicates it to be of no importance in the causation of the overwhelming majority of such injuries.

Many additional variables, not among those formally considered, deserve attention. For example, surface and weather conditions are undoubtedly important. Increased numbers of accidents seemed to occur, for example, with the sudden freezing of wet slopes. Fatigue has often been mentioned, chiefly because accidents in some series have increased in numbers in the afternoon. Evidence has not yet been presented, however, that the numbers of persons skiing do not show parallel increases, and the point consequently remains undecided. Alcohol might be expected, from its effects and its demonstrated importance in accidents of other types (*1*, *2*, *6*), to play a role in at least occasional skiing accidents, but this appeared likely in only two accidents known to us. No firm conclusions about alcohol could be reached, since no objective determination of its presence—through the use, for example, of the breath and blood tests employed in other accident research—was made.

The characteristics of ski boots should also be studied. Except for their ownership (rented, borrowed, or owned), which correlated highly with that of the skis and which was not associated with risk of injury, no characteristics of the boots were studied. Since the dynamic relationships between foot and ski must be mediated through the boot, it is extremely likely that its characteristics, including the tightness of the straps and laces, influence injury rates.

Finally, it is appropriate to consider four strategies which may be employed in reducing the occurrence of skiing injuries and mitigating their consequences. These have close parallels in the prevention of motor vehicle accidents (*7*) and correspond in general to the levels of prevention long discussed by public health workers (*8*). They also correspond to interference at four levels in the causal sequence, the end results of which are of concern here. These four strategies are: (*a*) prevention of skiing accidents per se, for example, through better training and use of gentler slopes by the unqualified; (*b*) prevention of skiing injuries per se, for example, through development of more effective release bindings and other protective devices; (*c*) amelioration of the immediate effects of injuries through provision of the best possible emergency orthopedic and general medical care; and (*d*) provision of the best possible followup medical care and rehabilitation. It is hoped that recognition of these strategies and the work reported here will favor development of the knowledge and means by which the incidence of these injuries will be greatly reduced or perhaps even eventually eliminated.

Summary

This report describes the first adequately controlled investigation of any type of recreational accident. The population at risk, those skiing at a large New England resort on four consecutive weekends, was sampled by interviewing and inspecting the equipment of every 50th person obtaining a ticket to ski. The case series consisted of the injured from the same population.

The overall injury rate was 5.9 per 1,000 ski-man-days, but major variations in rates with age, sex, and skiing ability were found. There was a significant association between the occurrence of injury and the use of nonrelease bindings among males. That this was true only for musculoskeletal injuries of the lower extremities suggests that the differences resulted from the bindings per se, rather than from associated differences in skiing. Among females no significant differences in any of the injury groups were found in relation to the use of release bindings. The most reasonable interpretation of this sex difference is that the forces required to disengage ski boots from these bindings tended to exceed the injury thresholds of females, but not those of males. This suggests that an attempt should be made through the lowering of release-binding thresholds to extend to females at least the partial protection such bindings now afford males. In addition, a similar attempt should be made to improve their efficacy for males.

No differences were found between cases and

controls with respect to a number of other variables, including age when person first skied, history of previous injury, height, weight, ski length, sleep during each of the previous 2 nights, and marital status.

The directions which further research might take are discussed, and strategies for prevention are outlined.

TECHNICAL NOTE

Physical forces applied to the body in skiing are the immediate and necessary cause of the injuries sustained. These in turn result from forces secondary to the characteristics of (*a*) the skier and his actions, (*b*) his equipment, and (*c*) the environment in which he skis. While this has long been recognized informally, it is only very recently that Sprague has treated the physical parameters of these three aspects of the system analytically (*9*). On the basis of this work, he has derived the following equation for the velocities which can be reached on given slopes. These agree closely with velocities observed under racing conditions (personal communication).

$$v = K\left(\frac{W\ (\sin\theta - K_s\cos\theta)}{A \times K_w}\right)^{1/2}$$

v=maximum attainable velocity (the "terminal velocity" at equilibrium, i.e., the speed at which wind resistance and friction of the skis balance the force of gravity), in miles per hour.
K=0.68 (with this term=1.0 the equation gives v in feet per second).
W=weight of skier, in pounds.
θ=slope angle in degrees.
K_s=coefficient of friction.
A=frontal area of skier, in square feet.
K_w=coefficient of wind resistance.

According to Sprague, for a 190-pound skier in a medium crouch (A=5.6 ft.^{2}), with well-waxed skis and under optimum skiing conditions, K_s=0.02 and K_w=0.0009. v then varies with θ as follows:

Slope angle (degrees)	*Velocity (mph)*
3	24
5	34
10	52
20	75
30	92
45	110

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Clinical Study

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SKIING is one of the most rapidly growing participant sports in the world, and the rising numbers of injured skiers have become a concern both to the medical profession and to the ski industry itself. Reports of the nature of such injuries are appearing frequently in the medical literature (*1–4*). However, as far as we can determine, none of these have given both detailed descriptions of the injuries observed and their variation with such characteristics as age, sex, and skiing experience.

To increase understanding of the pertinence of these variables, we are reporting in this paper a study of 684 consecutive injuries which oc-