VU Research Portal

Ability and physical condition in relation to injury risk in downhill skiing

Bouter, L.M.; Knipschild, P.G.; Volovics, A.

published in

Skiing trauma and safety: 7th International Symposium
1989

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Bouter, L. M., Knipschild, P. G., & Volovics, A. (1989). Ability and physical condition in relation to injury risk in downhill skiing. In R. J. Johnson, & C. D. Mote (Eds.), *Skiing trauma and safety: 7th International Symposium* (pp. 94-102). ASTM.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

Ability and Physical Condition in Relation to Injury Risk in Downhill Skiing

REFERENCE: Bouter, L. M., Knipschild, P. G., and Volovics, A., "Ability and Physical Condition in Relation to Injury Risk in Downhill Skiing," in *Skiing Trauma and Safety: Seventh International Symposium, ASTM STP 1022*, Robert J. Johnson, C. D. Mote, Jr., and Marc-Hervé Binet, Eds., American Society for Testing and Materials, Philadelphia, 1989, pp. 94-102.

ABSTRACT: A case-control study was performed by way of a postal questionnaire among Dutch downhill skiers insured by a company covering one-third of the market. Cases ($N = 572$) were a sample of those who claimed medical costs because of a ski injury that prevented them from skiing or other activities for one day or longer. Controls ($N = 576$) were a sample of uninjured skiers who claimed for nonmedical reasons. Self-reported beginners appeared to have an elevated injury risk ($OR = 2.1$) compared to intermediate or advanced skiers. Among skiers with only 1 or 2 years of experience ski lessons seemed to have a protective effect. No beneficial effect on injury risk could be demonstrated in this study for training on an artificial ski run, ski gymnastics, a good physical condition, or sports participation.

KEY WORDS: downhill skiing, injury, ability, physical condition, ski gymnastics, artificial ski run, etiology, epidemiology, risk factors

As in most other sports activities, downhill skiing is not without risk. The reported incidence ranges from one to ten ski injuries per 1000 skier days [1-3]. This variation is mainly due to different definitions of injury, different source populations, selective reporting and underreporting [3]. During the last few decades the injury rate has decreased substantially, probably because of improvement of ski bindings and possibly because of better maintenance of ski runs [2,4,5]. The number of lower extremity injuries has especially decreased [2]. A further substantial reduction in the incidence of ski injury might only be expected by changing the prevalence of other risk factors. Such preventive measures should be based on controlled etiologic studies in which relevant risk factors are identified and quantified [3].

This article focuses on the contribution of the risk factors ability and physical condition. Results will be presented from a case-control study conducted among Dutch skiers ($N = 1148$) during the 1984/1985 season [6]. In the literature there is consensus with respect to the higher risk for beginners [1,3,5,7,8]. This holds both for self-reported ability and for the number of seasons of ski experience. It seems reasonable to expect that formal instruction will increase ability and, thus, lower the injury risk. Sound empirical evidence on this point is lacking though. Some authors [7,9] report even an elevated injury risk during ski lessons, but it can be argued that this may be due to differences in ability or number of hours of skiing between the groups of skiers compared [5].

¹Epidemiologists, Department of Epidemiology and Health Care Research, University of Limburg, P.O. Box 616, 6200 MD Maastricht, the Netherlands.

²Department of Medical Informatics and Biostatistics, State University of Limburg, P.O. Box 616, 6200 MD Maastricht, the Netherlands.

It is often suggested that good physical conditioning can prevent fatigue and, thus, lower injury risk [10-13], but there have been no controlled studies in which this effect is quantified. Furthermore, at least in the Netherlands, the commonly heard advice [14] to prepare for skiing by performing a course of ski gymnastics or to prevent accidents by taking lessons on an artificial ski run is not based on adequate empirical evidence.

Valid studies quantifying the effect of putative risk factors are sparse. The inclusion of a comparable control group of uninjured skiers is still not a common practice, and adequate multivariate analysis of the data is almost never performed. Accepted measures of association (for example, odds ratios) between risk factors and risk are usually not given, and often it is impossible for the reader to calculate them. In case-control studies especially the issues of selection bias and information bias deserve more attention than they get in most articles relevant to the subject [15]. In our own study we have tried to avoid these flaws.

Another classical threat to validity is uncontrolled confounding. Confounded measures of association may arise when the levels of other risk factors (for example, ability) are unequally distributed over the different levels of the risk factor under study (for example, taking ski lessons). Control for a few confounders can be accomplished by way of stratified analysis. However, in studies on the etiology of ski injuries there are usually many potential confounders to be taken into account. In that case adjustment must be accomplished by adequate multivariate analysis (for example, logistic regression). Apart from an independent effect (confounding), risk factors might also have an effect depending on the presence or the absence, and in general on the levels of, other risk factors. This means that the effect of a risk factor (for example, physical condition) is modified by the level of one or more other risk factors (for example, experience). In statistical terminology this is called interaction. The interpretation of statistical interaction in terms of effect modification is usually very difficult, and a valid quantification of the risk in subgroups requires large numbers of respondents.

Material and Methods

Both cases and controls during the 1984/1985 winter season were obtained from the records of a large Dutch insurance company. Most Dutch downhill skiers are insured, and this company covers about one third of the market. The cases selected included skiers who had claimed for medical costs as a result of a ski injury that made skiing or other activities impossible for more than 1 day. All casualties suffering a fracture, a dislocation, or a ruptured ligament were selected. Furthermore, a sample was taken of less severe injuries. For every case of injury selected, an equal number of uninjured skiers were chosen by taking the next claim from an uninjured skier received by the insurance company for other reasons (for example, loss or theft). In addition to this, some extra cases were selected who were insured elsewhere for skiing risks but who had been repatriated by the organization selling the insurance. A postal questionnaire was sent shortly after the ski holiday to the population thus defined. Reminders were sent after 10 and 20 days. The questionnaire consisted of about 80 items for the controls and 120 items for the cases. For both groups information was collected on most risk factors mentioned in scientific and popular literature (for example, ability, prior ski experience, alcohol consumption, snow quality, weather, physical condition, equipment, adjustment of bindings, and demographic data). In addition to this, cases were also questioned about the circumstances of the accident and the characteristics of the injury. This article presents only the effects of risk factors related to ability and physical condition, although confounding and effect modification by a number of other risk factors will be taken into account. The separate effects of the other risk factors investigated will be presented elsewhere.

Data analysis was performed with the aid of BMDP and GLIM statistical software [16,17]. Two steps can be distinguished. First, an elementary analysis was performed in which only confounding by age and gender was adjusted for. For continuous variables this was done by way

of analysis of covariance. Differences between adjusted means for cases and controls were tested with student *t*-test [16]. For discrete variables the distribution of risk factors was calculated for both cases and controls, based on direct standardization for age (three categories) and gender. Furthermore, odds ratios (OR) were calculated as a weighted average over six strata for age and gender using the Mantel-Haenszel method [18] with the corresponding test-based confidence intervals (CI) following the method of Miettinen [18].

The second step of data analysis concerned a more precise control for confounding and first order interaction. For this purpose a logistic model was fitted based on a selection of 25 variables [18]. In the final model 20 variables remained and 12 interaction terms were included. From the logistic regression coefficients in this model adjusted odds ratios with their approximate 95% confidence intervals [18] could be calculated.

Results

Response

Response was well over 80% and about the same for cases (84%) and controls (82%). Cases responded slightly faster. The majority (81%) of the 1540 respondents had practiced downhill skiing only; the rest were cross-country skiers and were excluded from the analysis. A number of skiers (103) did claim medical costs but appeared not to have been prevented from skiing or other activities for 1 day or longer. These were also excluded from the analysis. Data on 1148 downhill skiers were analyzed, including 572 cases and 576 controls. The group of cases consisted roughly of one-third fractures and another third with a ruptured ligament or a dislocation. The rest of the cases suffered other kinds of trauma. A number (130) of the cases were not insured by the insurance company that provided the source population but had been repatriated by the organization selling the insurance.

Between cases and controls slight differences in age and a rather strong difference in sex composition was found. Mean age for the cases was 32.0 years and for the controls 32.6 years. This is similar to the mean age (32.1 years) of active skiers among a representative sample of the Dutch population [19]. Forty-six percent of the cases were males compared to 67 percent of the controls. Among a representative sample of the Dutch population [19] females appeared to go on winter sport holiday as often as males. In our opinion the figures in our study population reflect selection bias due to the way the controls have been selected. In the Netherlands males are probably still mentioned more often as the owner of lost or stolen objects because they are considered to be the head of the family. The consequence is that the risks associated with age and gender cannot be estimated in our study. For the same reason every odds ratio calculated is adjusted for confounding by age and gender.

Ability

The skill of the skier is supposed to be an important risk factor for ski injuries. In our questionnaire it was operationalized in terms of ability, experience, number of falls, and the exposure to formal instruction. Elementary analysis revealed that skiers who had classified themselves as intermediate or advanced had a lower accident risk compared to beginners (Table 1). This association is summarized as the cross-product or odds ratio (OR).

Given some assumptions, the odds ratio may be interpreted as relative risk. This is the absolute risk (incidence) in the presence of a factor divided by the absolute risk in the absence of that factor. More generally, in an odds ratio two levels of a risk factor are compared. In doing this the choice of the reference level ($OR = 1$) is arbitrary. An odds ratio of 0.6 for intermediate skiers compared to beginners is equivalent to an odds ratio of $1/0.6 = 1.6$ of beginners compared to intermediate skiers. The higher risk for beginners is even more pronounced when adjusted for a number of confounders. The logistic model shows that beginners have twice ($OR =$

TABLE 1—Adjusted percentages^a and odds ratios^b from elementary analysis for ability, instruction on an artificial slope, physical condition, ski gymnastics, and warming-up.

	Cases, %	Controls, %	OR _{MH}	CI
Ability:				
Beginner (L) ^c	39	28	1.0	
Intermediate (A) ^c	55	65	0.6	0.5-0.8
Advanced (S) ^c	6	7	0.6	0.3-1.1
Instruction on artificial slope before holiday:				
No	94	96	1.0	
Yes	6	4	1.5	0.8-2.8
Physical condition before holiday:				
Good	71	64	1.0	
Intermediate or bad	29	36	0.7	0.5-0.9
Course in ski gymnastics before holiday:				
No	79	81	1.0	
Yes	21	19	1.1	0.7-1.6
Warming-up during holiday:				
Never	56	62	1.0	
Sometimes	36	34	1.2	0.9-1.5
After breaks	8	4	2.0	1.2-3.4

^aAfter direct standardization for age and gender.

^bWeighted average (Mantel-Haenszel) over six strata for age and gender followed by test-based 95% confidence intervals (Miettinen) [18].

^cL = learner, A = all-round skier, and S = skilled skier.

2.0) the injury risk of intermediate or advanced skiers. In both the elementary analysis and the logistic regression 95% confidence intervals (CI) of the odds ratios are calculated. These are the boundaries between which the "real" value of the odds ratio is assumed with 95% confidence to lie, given the point estimate found in the study. The confidence interval gives an impression of the imprecision of the point estimate and makes further statistical testing unnecessary. A 95% confidence interval not including the null-value (OR = 1) is equivalent to a *p*-value smaller than 0.05 in a two-sided significance test. Both Table 1 and the confidence interval calculated from the logistic model (1.5 to 2.9) show that the risk of being a beginner is statistically significant indeed.

It seems reasonable to expect that the skill of the skier increases with growing experience. The questionnaire included items on the total number of times the respondent had gone on winter sports holiday and on the total number of days skiing. Table 2 shows the adjusted means for these variables for both the cases and the controls. These figures reveal that the cases went less often on winter sports holiday and had fewer days of ski experience. The means presented in Table 2 are adjusted for differences in age and gender by way of analysis of covariance.

The total number of times that the respondents went on winter sports holiday is also included in the logistic model. Overall, the effect of this variable on the injury risk seems small. Probably, this is because ability is also included in the model. When ability is adjusted for, the effect of the number of winter sports holidays decreases and vice versa. This holds especially for the majority of respondents (359 cases and 449 controls) who knew which type of skis they had used and what the age of the bindings and the skis were. The minority of skiers who did not have this knowledge appeared to have a higher injury risk.

In Fig. 1 this (statistical) interaction is illustrated. Among the skiers with inadequate knowledge of their equipment the injury risk increases in proportion to the growing number of winter sports holidays. This association, however, should be interpreted with some caution, because the number of respondents without adequate knowledge who went frequently on a winter sports

TABLE 2—Adjusted means from elementary analysis for a number of continuous variables.

	Cases ^a	Controls ^a	p-Value ^b
Number of winter sports holidays	5.6	6.0	0.07
Total number of days skiing	48.4	55.4	0.03
Falls a day during this holiday	2.8	2.6	0.17
Total number of days of instruction	19.6	19.8	0.85
Hours of group instruction this holiday	5.9	7.7	0.003
Hours of private instruction this holiday	0.4	0.4	0.84
Hours of sport a week before holiday	3.8	3.4	0.07

^aAdjusted mean based on analysis of covariance with age and gender as covariates.

^bBased on student t-test for adjusted means.

FIG. 1—Odds ratios from the logistic model for interaction between the number of winter sports holidays and knowledge about equipment.

holiday is small. In that case the confidence intervals tend to become very wide (for example, for ten holidays OR = 4.5 [1.9 to 10.1]).

After self-reported ability and experience, the third operationalization of skill in our study was the mean number of falls a day during this holiday. As shown in Table 2, cases fall as often as controls do (2.8 versus 2.6), so the mean number of falls a day does not appear to be a substantial risk factor in itself.

Ski lessons are supposed to improve the skill of the skier and might thus reduce the injury risk. Table 2 indicates that there is no apparent difference between cases and controls as far as the total number of days of instruction (private or in groups) is concerned. In our data there is no evidence of any risk reduction for those who had trained on an artificial ski run before the holiday (Table 1). However, there is a pronounced difference in the number of hours of group instruction during the holiday (Table 2), but this is probably due to the fact that cases missed a part of their planned ski lessons because of their injury.

To elucidate this problem, a study was made of the dichotomous answer to the question whether any formal instruction was taken during this holiday. It appeared that instruction was

associated with a lower injury risk ($OR = 0.4$) only among the skiers who had gone skiing for the first or second time (Table 3). In the logistic model the absence of an overall effect of instruction is confirmed ($OR = 1.0$ [0.8 to 1.4]).

Physical Condition

Most skiers reported they were in good physical condition (Table 1). Rather surprisingly respondents who reported an intermediate or bad physical condition before their holiday appeared to have a lower injury risk ($OR = 0.7$). This finding was supported by the difference in the weekly number of hours of sports participation (Table 2) between cases (3.8 h) and controls (3.4 h). For the majority of skiers who had refrained from ski gymnastics before holiday, the logistic model also showed a preventive effect of an intermediate or bad physical condition (Table 4).

Roughly one fifth of the respondents prepared by way of a course in ski gymnastics before their holiday. No reduction of accident risk was found for this group (Table 1). The same holds in the logistic model (Table 4), but there is some difficulty interpreting the statistical interaction found with the reported physical condition (Table 4). This interaction is not very strong though and might well be a chance phenomenon in our study.

Besides sports participation and ski gymnastics, warming-up during holiday was considered as a factor with a possible influence on physical condition. We found no evidence in favor of a preventive effect of warming-up (Table 1). There was even a tendency in the other direction. Skiers who reported to have performed warming-up exercises sometimes or after every break seemed to have an elevated risk compared to those who refrained from this.

TABLE 3—Adjusted percentages^a and odds ratios^b from elementary analysis for instruction during this holiday stratified for experience.

	Cases, %	Controls, %		
<i>One or two times winter sports</i>	(<i>N</i> = 157)	(<i>N</i> = 132)		
No instruction	22	9	1.0	
Instruction	78	91	0.4	0.2-0.9
<i>Three times or more</i>	(<i>N</i> = 366)	(<i>N</i> = 432)		
No instruction	64	65	1.0	
Instruction	36	35	1.1	0.7-1.6

^aAfter direct standardization for age and gender.

^bWeighted average (Mantel-Haenszel) over six strata for age and gender followed by test-based confidence intervals (Miettinen).

TABLE 4—Odds ratios and 95% confidence intervals from the logistic model for interaction between physical condition and ski gymnastics.

	Physical Condition			
	Good		Intermediate/Bad	
No ski gymnastics	1.0		0.6	0.4-0.8
Ski gymnastics	0.7	0.5-1.1	1.0	0.5-1.9

Discussion

Before discussing the interpretation of the results, the internal validity and reliability of our study deserves attention. Validity can be impaired by selection bias, information bias, and uncontrolled confounding. The central issue in selection bias is whether the group of cases and the group of controls are comparable with respect to the relevant factors. This is different from representativeness. Because of the restricted nature of the source of our respondents (an insurance company associated with an organization of road-users), the skiers in our study are not a random sample of all Dutch alpine skiers. Furthermore, the study was biased in favor of the more severe cases, because medical costs must have been made and repatriated cases insured elsewhere were added to the study population. This introduces selection bias only when there is reason to doubt that the effect of the risk factors investigated in our study population is the same as among Dutch skiers in general. We think there is no reason for such doubt.

We have already mentioned that there is probably some selection bias with respect to age and gender due to the way the controls were selected. This bias, however, is adjusted for in the data analysis. There seems to be no reason to postulate other selection bias in relation to the risk factors presented in this article. The same holds for selection bias due to differential nonresponse. Response was high and in no observable way selective.

Information bias is concerned with the question whether the information gathered is comparable between cases and controls. An inherent limitation is that all the information gathered was based on self-assessment. Therefore, our study lacked precise and objective information on, for instance, physical condition and ability. Respondents were approached within three weeks after the end of their holiday to lessen the likelihood of incomplete recall of relevant facts. This, however, does not exclude bias. Our study is retrospective and, as a consequence of the known outcome of the holiday, the assessment of certain risk factors might be influenced. Perceived ability and physical condition especially might have been underestimated among the cases and/or overestimated among the controls for this reason. Probably less subjective items, such as the total number of days skiing and the number of hours of sports participation, are less susceptible to this type of bias.

Uncontrolled confounding is the third and last issue of validity. In the logistic regression every important confounder on which we collected information was adjusted for. This does not exclude bias due to unmeasured confounders nor confounding due to imprecise measurement. In general, the effects as estimated in the elementary analysis are quite similar to those based on the logistic model.

Reliability or precision of the estimated odds ratios is a function of random measurement error in our study. The variability in the data is rather large, which might stem from the fact that the questionnaire provides rather global indicators and respondents might give imprecise answers due to incomplete recall of the relevant items. Due to the fairly large variances of most variables, interpretation of *p*-values and confidence intervals calculated becomes difficult. Also the issues of multiple testing and interdependency of the calculated confidence intervals for variables within the logistic model must be taken into account. Taken together, it is doubtful whether a strict interpretation in terms of significance is justified.

For the interpretation of the association between putative risk factors and injury risk we found in our data, credibility is at least as important as statistical significance. Thus, the results of our study must also be interpreted in the context of earlier investigations and (biological) plausibility. The observed higher risk for beginners is both plausible and accords with earlier work [1,3,5,7,8]. This does not exclude information bias though, because all the studies cited were also retrospective. The decreasing risk with growing experience, as expressed in the total number of days skiing and number of winter sports holidays, is also consistent with other studies [7,8]. The fact that the effect of the total number of winter sports holidays is smaller may be because not all reported holidays involved alpine skiing. In logistic regression the effect of experience is less pronounced, probably due to the fact that ability is adjusted for. Absence of knowl-

edge about the equipment used was associated with a higher risk, especially among experienced skiers. This has not been reported before, but certainly does not seem implausible. The same holds for the absence of any effect of training on an artificial slope. It is doubtful whether the mean daily number of falls is a valid indicator of skill. Velocity and difficulty of the pistes presumably have a strong influence on this variable. Furthermore, most falls do not lead to injury. Although cases did not report more falls, it cannot be excluded that at least some of their falls were more severe. A preventive effect of formal instruction is found only among skiers who had gone on winter sports holiday for the first or second time. We found no evidence of the higher risk associated with the taking of ski lessons reported by some authors [7,9,15]. The absence of an overall effect of ski lessons was confirmed in the logistic model.

No evidence could be demonstrated for a preventive effect of good physical condition. This is postulated in the literature [10,13] but never adequately quantified. Our study indicates that good physical condition may even be a risk factor. This is supported by the difference in sports participation between cases and controls before holiday. However, some caution is indicated in interpreting this finding. It is difficult to imagine how a bad physical condition can protect skiers against injury. Furthermore, information bias may play some role in these findings, especially because our measures of physical condition are indirect and probably imprecise. The same holds for the observation that absence of doing warming-up exercises seems to be associated with a lower accident risk.

Conclusion

It is now established beyond reasonable doubt that beginners have an elevated injury risk. For skiers with one or two years of experience, ski lessons seem to have a preventive effect. Whether ski lessons can actually lower the injury risk among inexperienced skiers who do not yet take lessons should be investigated in a preventive trial. A preventive effect of training on an artificial slope, ski gymnastics, a good physical condition, and sport participation could not be demonstrated.

Again, it is stressed that our results are not yet to be interpreted causally. Further studies, preferably with a prospective design and more direct and objective measurements of putative risk factors, are first needed to replicate our findings. Finally, preventive trials should be undertaken to elucidate whether manipulating putative risk factors related to ability and physical condition actually lowers injury risk in downhill skiing.

References

- [1] Jaffin, B., "An Epidemiologic Study of Ski Injuries: Vail, Colorado," *The Mount Sinai Journal of Medicine*, Vol. 48, No. 4, July-August 1981, pp. 353-359.
- [2] Johnson, R. J., Ettlinger, G. F., Campbell, R. J., and Pope, M. H., "Trends in Skiing Injuries," *The American Journal of Sports Medicine*, Vol. 8, No. 2, 1980, pp. 106-113.
- [3] Bouter, L. M. and Knipschild, P. G., "Risk Factors of Ski Injury" (in Dutch), *Tijdschrift voor Sociale Gezondheidszorg*, Vol. 63, No. 20, 1985, pp. 846-851.
- [4] Tapper, E. A., "Ski Injuries from 1939 to 1976: The Sun Valley Experience," *The American Journal of Sports Medicine*, Vol. 6, No. 3, 1978, pp. 114-121.
- [5] Shealy, J. E., "Overall Analysis of NSAA/ASTM Data on Skiing Injuries for 1978 through 1981," in *Skiing Trauma and Safety: Fifth International Symposium, ASTM STP 860*, R. J. Johnson and C. D. Mote, Eds., American Society for Testing and Materials, Philadelphia, 1985, pp. 302-313.
- [6] Bouter, L. M. and Knipschild, P. G., *Ski Risks* (in Dutch), Rijksuniversiteit Limburg/ANWB, Maastricht, 1985.
- [7] Shealy, J. E., Geyer, L. H., and Hayden, R., "Epidemiology of Ski Injuries: Effect of Method of Skill Acquisition and Release Binding Accident Rates," *Human Factors*, Vol. 16, No. 5, pp. 459-473.
- [8] Young, L. R., Oman, C. M., Crane, H., Emerton, A., and Heide, R., "The Etiology of Ski Injuries: An Eight Year Study of the Skier and His Equipment," *Orthopedic Clinics of North America*, Vol. 7, No. 1, January 1976, pp. 13-29.

- [9] Garrick, J. G. and Requa, R., "The Role of Instruction in Preventing Ski Injuries," *The Physician and Sportsmedicine*, Vol. 5, No. 12, December 1977, pp. 57-59.
- [10] Eriksson, E., "Physiological Demands in Downhill Skiing," *The Physician and Sportsmedicine*, Vol. 5, No. 12, December 1977, pp. 28-35.
- [11] Buck, P. G., Sophocles, A. M., and Beckenbaugh, R. D., "Unique Aspects of Downhill Ski Injuries," *Orthopedics*, Vol. 5, No. 3, March 1982, pp. 317-324.
- [12] Brouns, F., Saris, W. H. M., and Ten Hoor, F., "Nutrition as a Factor in the Prevention of Injuries in Recreational and Competitive Downhill Skiing," *The Journal of Sports Medicine*, Vol. 26, 1986, pp. 85-90.
- [13] Nygaard, E., Andersen, P., Nilsson, P., Eriksson, E., Kjessel, T., and Saltin, B., "Glycogen Depletion Pattern and Lactate Accumulating in Leg Muscles during Recreational Downhill Skiing," *The European Journal of Applied Physiology*, Vol. 38, 1978, pp. 261-269.
- [14] Luyten, J., "Ski Training" (in Dutch), *Geneeskunde en Sport*, No. 6, 1976, pp. 7-11.
- [15] Knipschild, P. G. and Bouter, L. M., "Risk Factors for Ski Injuries: A Crash Course of Epidemiologic Methods with Emphasis on Comparability in Experiments and Case-Control Studies," in this volume, pp. 9-17.
- [16] Dixon, W. J., *BMDP Statistical Software*, University of California Press, Berkeley, 1983.
- [17] Baker, R. J. and Nelder, J. A., *The Glim System. Release 3*, NAG, Oxford, 1978.
- [18] Kleinbaum, D. G., Kupper, L. L., and Morgenstern, H., *Epidemiologic Research: Principles and Quantitative Methods*, Lifetime Learning Publications, Belmont, CA, 1982, pp. 331-338 and 419-446.
- [19] Central Bureau voor de Statistiek, *Holiday Survey 1984* (in Dutch), Staatsuitgeverij/CBS-publicaties, 's Gravenhage, 1986.