Foreword

This publication, *Skiing Trauma and Safety: Seventeenth Volume*, was derived from 64 podium presentations given at a congress of the same name which occurred May 13-19, 2007, in Aviemore, Scotland. The meeting was sponsored by the International Society of Skiing Safety and the publication itself was supported by ASTM International Committee F27 on Snow Skiing.

The chairman of the meeting was Mike Langran, BM, BSc, MRCGP, General Practitioner, Aviemore Medical Practice, Aviemore, Scotland, Honorary Research Fellow, Centre for Rural Health, University of Aberdeen, Scotland. Editors of this book included Robert J. Johnson, MD, Emeritus Professor of Orthopaedics, Department of Orthopaedics and Rehabilitation, University of Vermont College of Medicine, Burlington, Vermont, USA; Jasper E. Shealy, PhD, Consultant and Emeritus Professor of Human Factors Engineering, Rochester Institute of Technology, Rochester, New York, USA; and Mike Langran, MD, of Aviemore, Scotland.
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Overview

From the 64 papers, 5 debates and 1 workshop that were presented at the 17th International Conference on Skiing Trauma and Skiing Safety of the International Society of Skiing Safety which was held in Aviemore, Scotland, from May 13-19, 2007, 21 papers successfully made it through the peer-review process and are presented in this book. The ISSS came into being after the 1st World Congress on Skiing Safety which was held in Riksgränsen, Sweden, in 1974. The first meeting of the ISSS occurred primarily because of the efforts of Ejnar Eriksson, MD, of Stockholm, Sweden. The new society had its first official meeting in the Sierra Nevada of Spain in 1977 and has been held biennially ever since then. Subsequent meetings occurred in Queenstown, New Zealand in 1979, Bormio, Italy in 1981, Keystone, Colorado, USA in 1983, Naeba, Japan in 1985, Chamonix, France in 1987, Riksgränsen, Sweden for a second time in 1989, Thredbo, Australia in 1991, Zell am Zee, Austria in 1993, Voss, Norway in 1995, Whistler/Blackcomb, British Columbia, Canada in 1997, Breuil Cervinia, Italy in 1999, Queenstown, New Zealand in 2001, St. Moritz/Pontresina, Switzerland in 2003, Arai, Niigata, Japan in 2005, Aviemore, Scotland in 2007, and will be held in Garmisch-Partenkirchen, Germany, April 26-May 1, 2009. This meeting will be chaired by Veit Senner, of the Technical University of Munich, Faculty of Sports Science, Department of Sports Equipment and Materials, Munich, Germany.

The ongoing mission of the ISSS and its Ski Trauma and Skiing Safety Congresses is to bring together individuals from many different disciplines, all of whom are interested in snow sports safety. While the initial emphasis of the society dealt with alpine and cross-country skiing, the scope has widened as snow sports enthusiasts have developed new disciplines such as freestyle skiing, snowboarding and skiboarding. The goals of the meetings are to present formal talks concerning all aspects of skiing safety with plenty of time for discussion concerning the means of reducing the risk of all snow sports injuries. Subjects such as epidemiology, injury prevention, snow sports equipment and the means of treating snow sports injuries are all important aspects of the discussions waged on these matters. After each of the Skiing Trauma and Skiing Safety symposiums, a publication has been derived from the proceedings of these meetings. Since the meeting in Keystone, Colorado in 1983, those presentations that have successfully completed the peer-review process have been published in an ASTM Special Technical Publication (STP), and more recently in the Journal of ASTM International. The unique relationship between the International Society of Skiing Safety and ASTM International has allowed us to assemble a relevant body of literature dealing with safety and winter sports activities which we believe has become the standard for the world.

Many of the members of the ISSS and others who attend the Ski Trauma and Skiing Safety meetings are involved in the ASTM International Standards process and similar standards organizations on a national or international level. Among those who have attended our meetings include representatives of the skiing industry, engineers from industry, universities and technical institutions, skiing professionals such as ski instructors, patrollers, and physicians, lawyers and ski area managers as well as representatives of organizations from all disciplines of skiing and riding activities. The interchange of ideas, comments and critiques are encouraged from these formal presentations and informal discussions and we believe this has been instrumental in promoting the knowledge necessary to improve skiing safety throughout the world.
Summary of Papers

The 21 papers published in this Special Technical Publication are divided into the following groups: Epidemiology—11 papers, Head Injuries—2 papers, Snow Sports Equipment—3 papers, Miscellaneous Topics—3 papers, and Ski Jumps—2 papers.

Epidemiology

Using a case-control study design, Greenwald and Laporte hypothesized that age and experience significantly affect injury rates and lower leg injury rates in particular. The overall rate of lower leg fractures in skiboarding was found to be 3-4 times higher than in skiing. However, skiers less than 16 years of age had approximately the same rate of lower leg fracture as skiboarders of similar age. Beginners had a significantly higher injury rate in all their major injury categories. Their results demonstrate that while overall injury rates for a specific injury may be significantly different among individuals participating in various snow sports, controlling for age and ability has significant impact and must be accounted for when comparing injury rates.

In an update of a continuing series of papers concerning injury trends in alpine skiing, Johnson et al presented their latest observations on injury trends in a study that has continued from 1972 through 2006. During this time, 18,696 injuries were evaluated using a case-control study design. The injury rate continued to drop in this latest study with the overall rate down 55%, which is equivalent to 1.9 injuries per 1,000 skier visits. Twist related lower leg injuries improved the most with an 87% reduction. Although the incidence of mild to moderate knee sprains has diminished 77% overall, rupture of the ACL increased by 268% through the early 1990s, but have improved by 37% since then.

Zacharopoulos and colleagues present their two year case-control study of skiing and snowboarding injuries in Greece. They found the overall injury rate to be 6.1 injuries per 1,000 participant days. They noted that despite the high incidence of snow sports injuries in Greece, the patterns and specific rates of injuries were similar to those previously reported in comparable studies. Of all injuries, 19.8% were related to the use of a lift.

In a case-control study by Ekeland and Rodven during a 10-year period ending in 2006, the authors recorded 31,175 injuries among alpine skiers, snowboarders, skiboarders and telemark skiers. Wrist injuries were most common among injured snowboarders, and knee injuries were most common among alpine skiers. Knee injuries were twice as common among females as compared to males. The use of helmets among skiers and snowboarders increased from 11% to 44% during the 10-year period, whereas the head injury prevalence decreased from 19% to 17%. The prevalence of lower leg fracture decreased among injured alpine skiers under 12 years of age.

Shealy and his colleagues evaluated the hypothesis that the use of helmets in winter sports injuries will serve the purpose of reducing the incidence of fatalities. This paper presented results that suggests that while helmets may be effective in preventing minor injuries, they were not shown to reduce the overall incidence of fatality in skiing and snowboarding even though as many as 40% of population at risk are currently using helmets. The results of this paper indicated that the use of a helmet may decrease the number of deaths that are caused by head trauma but apparently will not be able to prevent an individual in a high speed crash from dying of other causes.
In a two-year study during the 2005-2006 winter sports seasons, Ekeland and Rodven evaluated 8,130 injuries based on ski patrol diagnosed injuries occurring to winter sports participants. Of these injuries, 58% occurred to alpine skiers, 35% to snowboarders, 3% to telemark skiers and 4% to those skiboarding. The prevalence for fractures was 34% for skiboarders, 33% for snowboarders, 26% for telemarkers and 22% for alpine skiers. Fracture of the lower leg was uncommon among snowboarders (1%) and telemarkers (3%) compared to alpine skiers (6%) and skiboarders (13%). Twenty percent of the skiers and boarders were injured in terrain parks. They suffered more fractures and head and back injuries than those injured on groomed slopes.

Cooper performed an investigation in an attempt to determine if risk-taking behavior possibly contributes to the explanation for a higher incidence of injury among snow sports participants. In their group of 66 participants, they found that the higher a participant scored in risk-taking behavior, the greater the chance that they would sustain an injury during their snow sports activities. The author suggested that individuals who have high risk-taking scores on a questionnaire such as the one used in this study may warrant special counseling in order to help reduce the risk of injury.

Whelan and Coates used video analysis of individuals exiting from an eight passenger chair lift because of a concern of increased risk of collision, falling and possibly sustaining an injury while unloading such a chair lift. Over a two-day weekend, the authors evaluated 7,293 passengers exiting from 1,103 chairs. Sixty-two percent of the passengers were skiers and 38% were snowboarders. Twelve percent of the passengers (877) fell while exiting the chair lift. Fifteen percent of the falls involved skiers and 85% involved snowboarders. Although no injuries were recorded, the high fall rate, particularly of snowboarders, was of concern for the potential for suffering an injury during the exit from the chair. The fall rate was much higher on the first day of the weekend than on the second day, indicating that practice over a single weekend was associated with a significant reduction in the risk of falling.

Tracy Dickson developed an exploratory study using an online survey to better understand the behaviors and attitudes of snow sport participants concerning safety. The results suggested that additional efforts are needed to inform snow sport participants on the level of risk they face while performing their chosen sport. Her results suggested that beginners, alpine skiers and females are at particular risk and might benefit from positive safety campaigns. She felt that further work is needed to identify the influences that risk-taking behavior has on the production of injuries and how to best mitigate them.

In an Austrian study, Burtscher and his colleagues proposed a set of potential risk factors for knee injuries in female skiers. They found that female skiers with knee injuries were older, reported less regular physical activities, had more injuries in the morning hours and on cold days, and were less frequently using newly adjusted bindings in comparison to female skiers with non-knee injuries.

In a case-control study design, Laporte et al hypothesized that lower leg injuries in alpine skiing could be reduced by lower binding release values, especially for women. They defined lower leg injuries to include all lesions of the leg, ankle and knee, including all sprains. The knee sprain category included all types of sprains and degrees of severity, without regard to specific ligaments or injury mechanism. The control group was not matched to the injury group in terms of gender, age or ability. They found an inadvertent release rate of 4.6% for the injured group and 5.6% in the control group. When comparing their study group to their control group they found significantly higher binding release values for the majority of all lower leg injuries, as well as all knee injuries (when considered as a single group). They acknowledged that they found no proof of causation in their work.
Head Injuries

Scher and his coworkers used an instrumented HYBRID-III anthropometric test device which simulated a 10-year old to determine head accelerations, neck loads and chest deflections associated with impacts into a rigid barrier or direct head contact and neck loading during a skier-to-pole or skier-to-skier impact. Speeds used matched the average of the speed of pediatric skiers and snowboarders obtained by direct measurement of speeds throughout the entire ski area. They found no evidence that helmets increased the likelihood of severe neck injury. The helmet use did reduce substantially the likelihood of severe brain injury in the skier-to-pole (by 47%) and skier-to-skier (by 69%) impacts by decreasing the linear accelerations, angular accelerations and head injury criteria.

In a second study by the same research team, this time lead by Richards, an anthropometric testing device was used to define the fall kinematics and quantified head velocity in order to evaluate helmet energy management requirements associated with an opposite-edge-phenomenon fall. Although the speed of the anthropometric models center of gravity decreased during the fall, the test data showed that the absolute speed of the head increased to as much as 178% of the initial velocity as a result of the induced angular rotation. The data obtained from this study may be useful for assessing drop height requirements for snow helmet evaluations.

Snow Sports Equipment

A review of the literature pertinent to the possibility of predicting the effects of a releasable snowboard binding was undertaken by Shealy et al. No scientific studies performed to demonstrate whether releasable snowboard bindings would have any effect on injuries in snowboarding were found. It was assumed that the release function of the snowboard binding would be the same for snowboarders as those of alpine skiing bindings is for skiers; (i.e., protection of the midshaft of the tibia.) It was found that the risk of tibia fracture was significantly higher for skiers than for snowboarders even though skiers use a releasable binding, and snowboard bindings have no releasable feature. The results of this study imply that releasable snowboard bindings would not decrease injury rates, but appropriate scientific studies are required to demonstrate their potential effectiveness.

A computer model was developed to simulate consecutive ski turns by Mössner and his colleagues. Using the model, the trajectory of the skier was simulated over four and a half turns. Simulation of the influence of edge angle and backward/forward lean was assessed while performing parameter studies. Increased edge angle caused smaller turn radii. The authors felt that it was surprising that forward lean caused larger and backward lean smaller turn radii. They felt that this phenomena could be explained by the turn moment of the skier.

On the premise that the risk of falls and injuries increases when snowboarders remove the rear foot from the binding, Böehm and co-investigators explain their investigation of an anti-slip pad which is placed on the top of the snowboard just behind the front binding. They evaluated three different rim positions and one anti-slip pad with no rim. They found that experts were not consistent in picking the setup that they felt was most appropriate, but beginners and advanced snowboarders felt that the anti-slip pad enhanced the perceived steering abilities during backside turns.
Urabe and colleagues devised a three-part study to evaluate the premise that ACL injury in alpine skiing more frequently occurs to the left side than the right. They also evaluated through kinematic analysis with a high speed camera the hip and trunk angles during trunk turning tests to see if there was asymmetry that might explain the predominance of left side ACL injuries. They found in their investigation of alpine skiers that the left ACL injury occurred 33% more frequently than to the right side. Although they were unable to find a difference in knee flexion angle during the trunk turning test, the height of the left shoulder appeared to be higher than the right shoulder during this test.

Stradijot and Ligiard believed that periodic monitoring of functional abilities of individuals recovering from acute and chronic knee injuries should be performed to assess the status of the functional recovery among alpine skiers. They evaluated 30 skiers who had sustained knee injuries that required significant surgical interventions or other forms of treatment and who felt they were no longer disabled. They found a diminished ability to produce force at the knee isokinetically, increased force plate sway during proprioception analysis and a decrease in jump height when performing these tests with the injured leg. They advocated the use of these tests at several times during rehabilitation to more thoroughly evaluate skiers who were recovering from injury even when the skier feels that they no longer have any disability.

Krause et al applied the principles of visual perception, light and optics to quantify the influence of ambient sunlight on the ability of skiers and snowboarders to perceive ground contours on a ski slope. The subjective visibility rating for various weather/lighting conditions were compared to quantify the on-slope visibility measurements. Their results support objective measurement as a tool to quantify on-slope visibility and suggested additional cues that skiers and snowboarders may use in assessing visibility. It was their hope that resorts could use this data to develop methods of enhancing visibility on poorly-lit runs before injury occurs.

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Ski Jumps

Böhm and Senner used computer simulations based on takeoff velocity measured during 11 jumps of skiers and snowboarders. These measurements were used to calculate the impact energy during landing on different table lengths combined with different landing slopes. If the jumper fails to adjust takeoff velocity to account for the shorter deck length, the sum of the impact energies with simulated jumps increased dramatically as table lengths smaller than 15 meters combined with a landing steepness of greater than 20 degrees were encountered. The authors were able to suggest guidelines for a design of the kicker used in these jumps.

Hubbard proposed a theoretical mathematical model for the design of the surface of the landing area for a terrain park jump. The intent of the model was to limit the normal velocity at first contact with the landing surface for a jumper using a jump. Hubbard proposed that the injury potential due to first contact for landing a jump can be limited by designing the landing surface at the moment of first contact to be as parallel to the landing trajectory as possible, thus limiting the velocity normal to the landing area surface. The model used ordinary differential equations to match the theoretical trajectory of the jumper to the landing surface contour and ordinary ballistic equations to predict the path of the jumpers center of mass at a distance of one leg length above the landing surface. It only considered the vertical velocity of the jumpers center of mass while in flight and up to the point of first contact but not beyond. Thus, the model did not consider the shock-absorbing capacity of the jumpers legs in reducing the effects of the normal...
velocity following the initial contact of the jumper with the landing surface. Hubbard proposed that this theoretical design methodology could be used to limit exposure to excessive equivalent fall heights in the design of any landing slope in a ski resort terrain park or for a Nordic jumping hill.

**Concluding Remarks**

The interrelationship between the International Society of Skiing Safety and the American Society for Testing and Materials International has resulting in a unique method for providing a forum for the discussion of problems of winter sports safety and the publication of state-of-the-art books such as this Special Technical Publication. Our primary goal remains the identification of the risks and the means of reducing the risks encountered in winter sports. We encourage all who are interested in these snow sports to join us in the future as we seek to improve quality and safety of these activities.

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