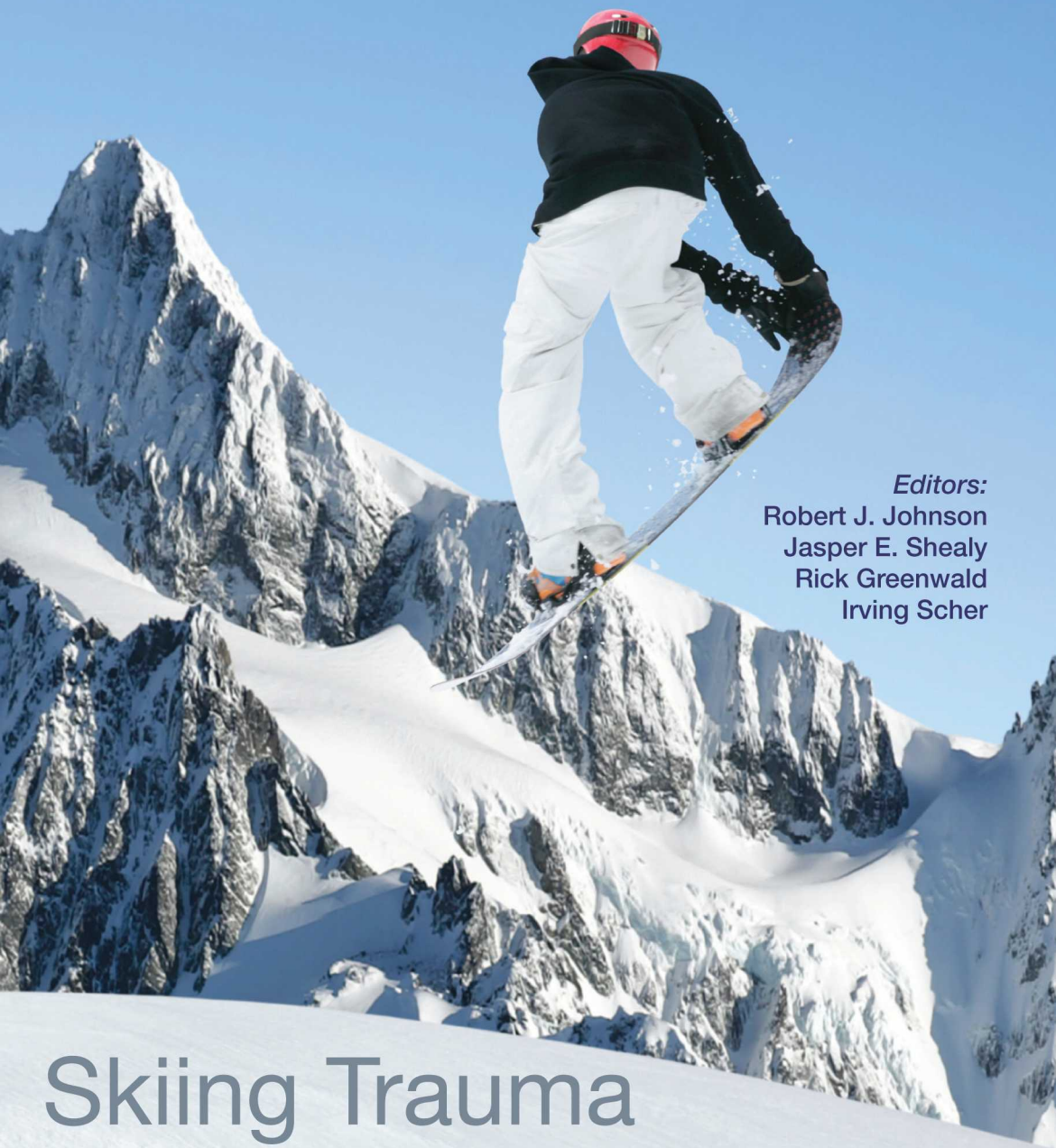
Selected Technical Papers

STP 1553



Editors:
Robert J. Johnson
Jasper E. Shealy
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Irving Scher

Skiing Trauma and Safety: 19th Volume

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Foreword

This compilation of the *Selected Technical Papers*, STP 1553, on *Skiing Trauma and Safety: 19th Volume*, contains 19 peer-reviewed papers that were among the 65 papers presented at the 19th International Society for Skiing Safety (ISSS) Congress in Keystone, Colorado, on May 1–7, 2011. The meeting was sponsored by the ISSS and this publication is supported by ASTM International's Committee F27 on Snow Skiing.

The Congress co-chairmen were Richard M. Greenwald, Ph.D., President, Simbex, Lebanon, New Hampshire, USA, and Adjunct Associate Professor, Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, USA; and Irving S. Scher, Ph.D., Principal, Guidance Engineering and Affiliate Scientist, Applied Biomechanics Laboratory, University of Washington, Seattle, Washington, USA. The STP editors were Robert J. Johnson, MD, Emeritus Professor of Orthopaedic Surgery, Department of Orthopaedics and Rehabilitation, University of Vermont College of Medicine, Burlington, Vermont, USA; Jasper E. Shealy, Ph.D., Consultant and Emeritus Professor of Human Factors Engineering, Rochester Institute of Technology, Rochester, New York, USA; Richard M. Greenwald, Ph.D., and Irving S. Scher, Ph.D.

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Overview

The 19 papers published in this Special Technical Publication (STP) underwent a rigorous peer-review process before being accepted for publication. Since 1983, there has been a very cooperative relationship between the ISSS and ASTM International, working together to publish the proceedings of the ISSS Congress.

The ISSS was founded under the enlightened leadership of Ejnar Eriksson, MD, of Stockholm, Sweden. After the first World Congress on Skiing Trauma and Safety that occurred in Riksgränsen, Sweden, in 1974, the ISSS was organized. The first official ISSS congress was held three years later in 1977 in the Sierra Nevada of Spain. The chairman of that initial meeting was Jose Figueras of Barcelona, Spain, who I am sad to report passed away shortly before the writing of this overview. After the 1977 meeting, the ISSS has held its congress every other year at or near a ski resort in many parts of the world. The congress has been held at the following sites: Queenstown, New Zealand in 1979; Bormio, Italy in 1981; Keystone, Colorado, USA in 1983; Naeba, Japan in 1985; Chamonix, France in 1987; Riksgränsen, Sweden 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; Garmisch-Partenkirchen, Germany, in 2009; and Keystone, Colorado, USA in 2011. The next congress will be held in San Carlos de Bariloche, Argentina, from August 4–10, 2013. Roman Chioconni will be the chair of the conference.

Since its inception, the objective of the ISSS has been to gather together individuals from many professions for the purpose of identifying, evaluating and discussing all aspects of safety concerning outdoor winter sports activities. Among those attending the congresses have been representatives of the skiing industry, equipment manufacturers, engineers from industry, universities and technical institutions, skiing professionals, including instructors and patrollers, competitors, physicians, lawyers, the general public, and representatives of organizations from all disciplines of outdoor winter sports. Many of the individuals active in the ISSS and other participants that attend our meetings are members of ASTM International and other similar organizations from around the world.

Since the very beginning, the focus of the ISSS has been on the problems associated with alpine skiers, cross-country skiers, and ski jumpers. However, as time has passed new endeavors such as freestyle skiing, snowboarding, and skiboarding have been added to our areas of interest. The ISSS meetings are held

over a five-day period that includes keynote addresses, podium papers, panel discussions, debates, posters and demonstrations. In recent years there have been between 60-80 formal presentations at each of our meetings. A good deal of time has always been allowed for discussion so that varying views and interpretations of the many aspects of winter sports participant safety can be heard.

After each congress, since the organizing meeting in 1974, a book has been published. Since 1983, there has been a very close relationship between ASTM International and the ISSS which has resulted in the publication of a Special Technical Publication (STP). To date, 15 STPs have been produced and provided free of charge to each active member of the ISSS. These include STPs 860, 938, 1022, 1104, 1182, 1266, 1289, 1345, 1397, 1440, 1464, 1474, 1510, 1525 and 1553. All previous STPs are still available for purchase by contacting ASTM.

Summary of Papers

The 19 papers published in this Special Technical Publication were divided into six categories: Wrist Guards—5 papers, Jumping—4 papers, Resort Safety—3 papers, Epidemiology—3 papers, Helmets: Head/Neck—3 papers, and Hip Injuries—1 paper.

Wrist Guards

In the first paper in this section on wrist guards, Engel and Langran did a retrospective case study, the goal of which was to describe the relationships between wearing wrist guards and whether or not a wrist injury occurred among a group of pediatric snowboarders. Data was gathered from a national incident database over a five-year period (2006-2010) from a single medical clinic in New Zealand. They identified 174 wrist injuries occurring to 171 pediatric patients who were snowboarding. Seventy percent of the wrist injuries in this study were fractures. Thirty individuals (18%) were wearing a wrist guard at the time of the injury. Several of the most common factors seen in individuals with pediatric wrist injuries were teenage years (14-17), male gender, a falling injury and hard snow. A slightly higher percentage of fractures compared to sprains were seen in children who did wear wrist guards.

In the second investigation in this group, Binet and Rowlands designed their study to determine if protection differs between wrist guard designs. They found that the use of all types of wrist guards was 20.2% of the injured group who sustained wrist, forearm or elbow injuries; and 27% for injured patients who did not sustain upper extremity injuries. The difference was significant. Short wrist guards accounted for 83% of all guards used by injured snowboarders and 76.5% of the guards used by controls. However, 100% of the snowboarders who had distal radius fractures despite using wrist guards used short guards. Wrist guards that were situated on the palmar side of the forearm and wrist, were used by 55.6% of the injured wrist guard wearers and by 47.1% of control wrist guard wearers. They concluded that wrist guards can reduce the prevalence of wrist injury and suggested that some wrist guards may offer better protection than others. Short wrist guards and possibly those worn on the palmar side of the wrist do not protect against distal radius fractures adequately. Further work is needed to determine the wrist guard design which offers the greatest protection against wrist injuries.

Dickson and her co-workers examined the use of wrist guards in snow sports participants who suffered an upper limb injury and presented to one of two Australian resorts during July, 2010. They identified 40 wrist fractures and measured the distance of the fracture site from the joint. They were looking for differences

in the average distance of the fracture site from the wrist between those wearing a guard and those not wearing a guard. No significant difference in the anatomic site of upper limb fractures was found for those wearing wrist guards compared to those not wearing wrist guards. This study did not support the suggestion that wrist guard use shifts the site of fractures more proximally in the upper limb than when a wrist guard is not used.

In a Swiss study, Bianchi and co-investigators analyzed attitudes of snowboarders regarding the use of wrist guards. Their goal was to determine the best way to persuade snowboarders to wear wrist guards. Their analysis involved 3,791 snowboarders who were interviewed by questionnaire over six winter seasons from 2003-2010. Between 2002 and 2007, use of wrist guards was highest with about 40% of those snowboarders evaluated in their study wearing wrist guards. However, in the final season of this study, usage of wrist guards decreased to 27%. Those who wore wrist guards did so primarily for safety (68%). The three most common reasons for not wearing wrist guards were lack of safety consciousness (35%), dissatisfaction with the design of the wrist guards (25%), and the perception that wrist guards did not provide sufficient protection (19%). Many riders felt that wrist guards were uncomfortable. The authors felt that safety requirements and related performance criteria need to be identified, defined and implemented.

In the final paper in this section, Schmitt and co-authors investigated whether the standards specified for safety gear in roller sports can be applied to snowboarding equipment. The dampening characteristics of wrist guards were investigated by drop tests and wrist extension properties were studied using bending tests. They felt that the tests indicated that roller sports standards for wrist protection was also applicable to snowboarding products. However, they did find that dampening test conditions need to be modified since most products failed during the testing. In addition, higher upper threshold values in the bending tests seem to be more efficacious for falls observed during snowboarding than for roller sports.

Jumping

In the first paper in this section on terrain park jumping, Hubbard and Swedberg state that "it has been shown that the severity of impact risk can be characterized by equivalent fall height (EFH), a measure of jumper impact velocity normal to the slope and that design algorithms exist to calculate landing surface shapes that limit EFH to arbitrarily low values." Although proposals have been made recently to introduce design, the skiing industry and others have objected that analysis, design and standards are impossible because of various uncontrollable factors. The authors considered the list of uncontrollable factors and showed that to the contrary each is either 1) irrelevant to the design; 2) has negligible effects; or 3) can be directly incorporated into the design process.

McNeil used data from field studies conducted by Shealy, et al., to refine his previous theoretical modeling of jumping using Newtonian ballistic equations of motion. Where previously the author had assumed the jumper to be an inert point mass, he has now established a range of speed variations due to jumper actions, also known as "popping" the jump. He estimated that a jumper can alter the effective jump speed from -2.48 to +1.12 m/s.

Swedberg and Hubbard present a general expression of equivalent fall height (EFH) experienced by a jumper when landing at any possible point on any landing surface. This general expression was then particularized to demonstrate the effects of EFH on the four physical features of a generic tabletop jump. Numerical results of their analysis showed that for tabletop jumps, EFHs have increasing and possible large values near the ends of both the tabletop and the linear landing downslope portions of the jump. They concluded, "that tabletop jumps do not exhibit a low impulse on landing everywhere, which increases the likelihood of jumper injuries compared to those jumps for which the EFH is small everywhere."

In the final paper in this section, McNeil points out that one especially hazardous situation occurs when a ski jumper lands in an inverted position. While jumpers can execute inverted jumps intentionally, curvature in takeoff can lead to involuntary inversion. In this work, the author analyzed the situation, assuming that the human body is rigid, which simulates a stiff-legged jumper. For a jump trajectory, with a landing just past the 'knuckle', the resulting net angle of inverting rotation is found to be about 60 degrees, large enough to pose a potential injury risk. A mitigating takeoff design criterion adopted by the U.S. Terrain Park Council, based on human response times, is also discussed and compared to FIS standards for Nordic jumps.

Resort Safety

In the first article in the section on resort safety, Petrone presents his study concerning the effectiveness of safety barriers which are mandatory during alpine ski racing. A standard method for evaluating crash-worthiness of such equipment has not been established. The aim of the author's work was to develop a full-scale impact test method suitable for safety barriers commonly installed during World Cup ski events. The author used a dummy during impact studies with various types of barriers evaluating peak decelerations and penetration values. Fiberglass poles were found to be most effective in containing the dummy during these tests. The method utilized allowed analysis of the behavior of various mattresses and "quantitative indications to manufacturers and to ski safety operators for the appropriate selection of safety barriers during competitions at ski resorts."

Penniman conducted a detailed survey of safety practices used on trails and slopes at 25 California mountain resorts. During the field survey, data was collected from observations of impact protection, trail design and maintenance practices. These observations were scored and presented in a report using bar charts for resort comparisons. The report showed that the consistency of trail and slope

safety measures utilized at various resorts varied greatly from one to another. Mitigating methodology within resorts was analyzed as well.

In the final paper in this section, Dickson and associates sought to understand the actual and perceived distances and speeds traveled by a variety of snow sports participants during the entire day's participation and while performing their sport on terrain designated as a slow zone. Data was collected over 102 sessions for alpine skiers, snowboarders and telemarkers of varying skill levels. The age ranges were from 9 to 80 years. Maximum speeds recorded ranged from 20.2 and 100.8 kph. All but two of individuals tested attained maximum speeds of 23 kph. The participants were generally unaware of the distance that they traveled and the maximum speeds achieved, with most traveling in slow zones at speeds greater than their own recommendations for that activity.

Epidemiology

Laporte and colleagues, in the first paper in the epidemiology section, evaluated trends and overall incidence of injuries for both skiers and snowboarders at 32 ski resorts between 1992 and 2010. They found that the overall injury rate changed very little over the interval investigated. There was a small elevation of overall injury risk from 1992 until 2005. An ACL injury is the most common injury suffered by skiers. There was an increase in its incidence from 1992 until 2005 but no change since that time. Lower leg fractures and ankle fractures have significantly increased in incidence during recent years. Snowboarders most commonly suffer wrist fractures and the incidence of this injury has remained unchanged since 1999.

Ekeland and Rødven continued their analysis of alpine skiing, telemarking, snowboarding and skiboarding injuries during the winter seasons of 2008/2009 and 2009/2010. The overall injury rate was 1.9 injured per 1000 skier/boarder days. Sixty-seven percent of the injuries occurred to alpine skiers, 29% to snowboarders, 2% to telemarkers, and 2% to skiboarders. The injured alpine skiers were most prone to knee injuries, and snowboarders to wrist injuries. The prevalence of knee injuries among females was twice as high as that of males, whereas the reverse was observed for shoulder injuries. These gender differences were observed in all ability groups. The most serious injuries were suffered by expert rather than beginner skiers.

An analysis of cross country skiing injuries in the Czech Republic during the years 2003-2010 was presented by Rokyta and Chlad. They monitored injuries treated by their mountain rescue service in seven mountain ranges where there are over 10 million participants each season. The injury rate for cross country skiers was 0.01 per 1000 participants per day. They found that in comparison with alpine skiing the prevalence of serious injuries was lower among the snowboarders. They noted that in spite of this, cross country skiers who were injured far from the available rescue services frequently made a safe and timely rescue difficult.

Helmets: Head/Neck

The initial paper in the helmets: head/neck section was provided by Dressler et al. The objective of this study was to assess the potential for serious neck injury in head-first impacts into snow surfaces with and without helmets. Drop tests were done from an equivalent fall height of 0.82 m using an anthropomorphic test device. Drop tests were done on snow which varied from soft to hard. They found that head accelerations were low in soft snow impacts both with and without helmets. However, they also noted that helmets were not an effective countermeasure to high neck loads. All tests resulted in neck loads that exceeded the injury assessment reference values for the neck. They concluded that due to the susceptibility of the neck to injury at relatively low drop heights, efforts to prevent neck injuries should focus on education and training to avoid head-first impact.

Kendall and Hoshizaki compared differences between Hybrid III headforms by linear and angular dynamic impact response characteristics. Significant differences in terms of dynamic impact response were found between the two head forms across impact conditions. Their studies showed that the Hybrid III headforms produced similar mean peak linear acceleration for front center impacts; however, differed significantly for mean peak angular response. They felt that future research should look at developing a more precise validation procedure that may help reduce some of the differences described in their study.

In the final study of this section, Post and co-investigators evaluated the influence of headform characteristics on alpine ski helmet performance. The purpose of their investigation was to evaluate the influence of head mass and geometry on the impact performance of alpine ski helmets in laboratory conditions. "To accomplish this, two different sized helmets were tested on a monorail system with different mass and geometry conditions. The results indicate that the helmets tested with a heavier mass headform yielded lower linear accelerations than the other conditions. The geometry condition indicated that the helmets tested with smaller headforms yielded lower accelerations, which implies that materials respond depending on impact footprint." They interpreted this to indicate that the mass difference and geometry of the headform are important factors in the performance of helmet liners under laboratory conditions.

Hip Injuries

Philippon and associates presented an investigation on the mechanisms of hip injury and associated hip pathology in professional skiers and snowboarders who underwent hip arthroscopy between 2005 and 2010 for debilitating hip pain. The specific injury mechanism could not be reliably ascertained by their methodology. A high speed crash resulting in hip pain was the most common mechanism of injury occurring in 14 of 36 hips included in the study. All five

Nordic skiers reported a gradual onset of hip pain with no specific injury. At surgery, all hips were found to have labral pathology and femoral acetabular impingement at the time of the index operation. At the time of arthroscopy, 5 hips (14%) were treated for a chondral defect with arthroscopic microfracture and 17 hips (47%) were treated with capsular plication for hip instability.

Concluding Remarks

The cooperation between the International Society of Skiing Safety (ISSS) and the American Society of Testing and Materials International (ASTM) has provided a forum for presenting, discussing and eventually publishing timely articles on the subject of snow sports safety. We intend to continue this association of the ISSS and ASTM and plan to continue to provide publications which will contribute to safer participation for winter sports enthusiasts throughout the world. We extend an invitation to all those concerned about the problems of safety in winter sports to join us as we attempt to understand, document and eventually reduce the risk of injury based on the proceedings of our two organizations.

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