

Overview

The papers published in this text are divided into eleven sections of related information. The first presents nine papers concerning epidemiology of injuries sustained by skiers. The second presents information on skier behavior, ability, and conditioning. The third section includes five papers dealing with specific injuries resulting from skiing accidents and their treatment. Seventeen papers related to ski boot and binding mechanics, the biomechanics of the lower extremity, and the biomechanics of thumb injuries are included in the fourth through the eighth portions of the volume. The final three sections include five papers investigating skiing safety, biomedical testing of competitors, and ski clothing. All papers published within this text were presented at the 7th International Symposium of Skiing Trauma and Safety held in Chamonix, France in May of 1987 in response to a call for papers sent to individuals throughout the world known to be interested in skiing traumatology and safety.

Epidemiology of Skier Injuries

Knipschild and Bouter present the basics for the development of epidemiologic methods necessary to develop an effective means for studying skiing injuries in the first paper of this volume. Hauser demonstrates in an excellent fashion the application of sound epidemiological practices in presenting his work concerning the population of skiers in Germany. This important prospective controlled investigation, including two experimental intervention studies, demonstrated once again that ski equipment which is set and functioning properly can help to reduce the risk of injury to the lower extremity and that a ski pole grip of a specific design can reduce the incidence of thumb injuries compared to those poles which use grips of conventional design. In their ongoing investigation of the epidemiology of skiing injuries over a 15-year period, Johnson, Ettlinger, and Shealy demonstrated that the overall risk of injury in skiing has continued to decline. This was especially true of injuries to structures below the knee. Little change in incidence of upper body injuries was observed, but severe knee sprains have notably increased over the recent seven years of their study. Lystad presented an epidemiological investigation of injuries resulting from ski accidents over a five-year period at a large Norwegian ski area. He observed that 30% of the injuries resulted when the binding did not release and that skiers who performed self binding release tests had a reduced risk of injury. Ekeland, Holtmoen, and Lystad shared their findings with the reader concerning injuries sustained by alpine recreational skiers in Norway. They studied 328 injuries of which 41% resulted when no binding release occurred, 17% during collisions, 30% were fractures, and 24% involved the knee. Beginning skiers were four times more likely to be injured as the average skier and ski instruction and self-release checks appear to reduce the risk of injury. In a Swiss investigation Bally and Bonjour shared their experiences in studying many phases of skiing safety, including the general investigation of ski injuries at four large resorts during the 1983–1984 season and specific case studies from 1985–1986. They also outlined their investigative methods. Berghold presented an investigation on 268 skiing related fatalities occurring in Austria between 1983 and 1986. Nearly two thirds of these deaths resulted from trauma and the rest from cardiac arrest. The single most common cause of deaths resulted from a collision with a tree. Lystad reported that 18% of all injuries in his study in Norway resulted from collisions. Beginners and children had disproportionately high collision injury rates. His findings suggest that crowding and trail design may be

important factors in the risk of collision. In the final paper of the epidemiology section of this text Shealy and Sundman share their results concerning injuries occurring to snowboarders.

Skier Behavior, Ability, and Conditioning

Ekeland et al. found that only 38% of alpine skiers in Norway had received formal skiing instruction and that 29% of the randomly selected non-injured skiers had never had their bindings functionally tested. Of the 789 skiers they surveyed, 16% had previously sustained an injury while skiing. Bouter and Knipschild presented an excellent controlled study of injury likelihood among Dutch alpine skiers. Beginners had an elevated risk of injury, and of the factors investigated, only skiing lessons reduced the risk of injury for the inexperienced skiers. The observations were disappointing that such variables as training on an artificial ski run, ski gymnastics, good physical conditioning, or previous sports participation did not reduce the risk of injury.

Specific Skier Injuries

Ellman and his coinvestigators studied a group of alpine racers to determine if female participants had a higher incidence of injury to the anterior cruciate ligament (ACL) than their male counterparts. They found that females were six times more likely than males to sustain severe ACL injury. In a second article concerning anterior cruciate ligament injuries, Figueras and his coauthors concluded that women are more likely to sustain this injury than men, backward falls can produce this injury, in certain circumstances bindings could possibly prevent some of the injuries, and boots with reduced stiffness in the posterior shell may assist in reducing the risk of ACL tears. They do not believe that knee braces can help protect the ACL from injury.

Yamagishi and Yahashi presented three patients who sustained injuries to the posterior bony elements of the lumbar spine by the mechanism of hyperextension with compression in skiing falls. The clinical course of these injuries was uncomplicated. Their study stressed the need to investigate carefully individuals who sustain trauma to the low back. A relatively uncommon injury sustained in skiing accidents has been investigated by Piziali. He observed that only 18 relatively minor eye injuries resulting from contact with eye wear are reported in the United States annually. Eye injuries resulting from broken glass are almost nonexistent. In the final paper in this section Essinger alerts the reader to the unusual circumstance of the development of an arterial occlusion in the distal leg. Repeated micro trauma resulting from compression by the ski boot top resulted in this lesion which fortunately responded satisfactorily to the treatment discussed in this article.

Ski Boot Mechanics

Schaff et al. used a capacitive electronic measuring system to determine pressures between the sole of the foot and the insole of the ski boot. Shealy and Miller believe in the interest of safety that the allowable forward flexion of the ski boot should be restricted so that ankle dorsiflexion will be limited in a forward fall. They observed that the dorsiflexion angle in 63 volunteers was 42.7° (5th percentile value was 28.5° and the 95th percentile was 56.7°). They concluded that a dorsiflexion limit of 30° might be more safe than the current practice which allows up to 45°. Binet and associates demonstrated that removal of a prosthetic, articulated foot from a "top entry" ski boot could be done with minimal extraction forces and without changing the ankle flexion-dorsiflexion angle. Extraction of the prosthetic foot from a "rear entry" boot required much higher extraction forces and frequently necessitated alteration of the ankle flexion-dorsiflexion angle. The development of a lower leg prosthesis for testing ski boot design and skier-ski boot-ski binding interactions is discussed in an article by Menke and coinvestigators. Bonjour and Delouche presented their findings concerning ski boot stiffness. They concluded

that only the paired stiffness of the ski boot on the human foot should be considered when evaluating boot stiffness effects.

Binding Mechanics

In a continuation of ongoing research in the development of an electronic binding, Wunderly, Hull, and Maxwell discuss their new general purpose microprocessor-based data acquisition and release control module. In a second article by Wunderly and Hull, a mechanical ski binding that eliminates the downward force from affecting release in forward bending and has a reduced sensitivity to frictional forces that are problematic in heel-toe type bindings is presented. Bahniuk et al. used an anthropometric dummy to simulate skier impacts to determine the effect of the amount of ankle plantar-dorsiflexion motion on the moments passed from the dummy to the ski binding. Young confirmed that two groups of recreational ski racers set their bindings higher than binding manufacturers and ASTM/IAS recommendations for expert skiers. In a case study analysis of 13 "inadvertent releases" high release settings were incapable of preventing some toe and heel releases during standard ski race maneuvers.

Biomechanics of the Lower Extremity in Skiing

Maxwell and Hull used an electromyograph, a goniometer, and loading of a ski binding-dynamometer to deduce the strength and loading of the knee of three test skiers skiing on a slalom run. In an investigation by Mote and Quinn, the average laxity of the primary (linear) region of the axial moment versus internal-external rotation of human knees was found to be 36% greater when the ankle was constrained in a buckled ski boot than when the ankle is taped or in a standard shoe. Bally and coinvestigators modeled the load sustained by the anterior cruciate ligament during "boot-induced ACL injuries" and found that the steeper the ski slope and the stiffer the ski boot in backward lean the higher were the loads sustained by the ACL. In the final two papers in this section Hull and Johnson present data concerning the axial rotation of the lower extremity under torsional loading.

Biomechanics of Thumb Injuries

Lamont provided further analysis based on his previous work concerning the mechanism of thumb injuries in skiing. He concluded that the ski pole rarely acts as a lever to rupture the ulnar collateral ligament of the metacarpophalangeal joint (skier's thumb), but the ski pole still grasped in the hand as it strikes the snow directs the thumb into the snow allowing it to be abducted and extended. Four different mechanisms of injury to the thumb metacarpophalangeal joint were described by Ledoux et al. They showed that the ski pole strap and ski pole handle design were important factors in the production of these injuries.

Miscellaneous Mechanical Subjects

Brown and Outwater observed that the complex physical and mechanical properties of the snow responsible for its skiability can be related to its machinability. It was revealed that the critical angle (40 to 70°) of the ski edge should be a function of the shear strength to hardness ratio of the snow.

Skiing Safety

In the first paper in this section, Figueras discussed a series of television programs on topics concerning skiing safety broadcast during two ski seasons in northern Spain. In the second article, Ekeland and his associates revealed the means by which an Alpine Ski Safety Council

was established by several skiing related organizations and state authorities in Norway. The goal of this group was to promote and coordinate skiing safety activities in five target areas (skiing equipment, skiing injuries, skiing ability and behavior, ski slopes, and rescue service).

Biomedical Testing

Zucco and coauthors evaluated competitors in a winter endurance competition and found that significant increases in muscular enzymes and the hematocrit occurred, but lactic acid levels did not elevate. They concluded that in these fit athletes the lactogenic mechanism was not involved.

Clothing

The final section of this book presents two papers dealing with the thermal characteristics of ski clothing. Roberts discussed his method of evaluating the thermal resistance of ski gloves using a heated, inflatable bladder and an infrared imager. Hester and Laine presented the considerations necessary for the development of functional and fashionable ski wear for a male alpine instructor, including fabrics, insulation, and design features.

Conclusion

The papers in this book undoubtedly add further to our knowledge concerning skiing safety. Epidemiologic studies from many nations demonstrate that the major problems of skiing injury are similar throughout the world. The overall injury rate based on the population at risk appears to have decreased slightly during the past few years. However, the disturbing rate of severe knee sprains appears to be a problem for which present technology offers no certain solution. The number of studies addressing knee injuries in this text indicates the great effort devoted to reduction of these injuries.

Further contributions to the literature concerning ski boots and bindings are present in this book. Efforts to identify the loads and torques responsible for injuries to the lower extremity, and especially the knee ligaments, are stressed in several articles. It appears that present skiing equipment, styles, slopes, and methods are largely responsible for the significant reduction in injury rates to the leg, ankle, and foot, but are inadvertently responsible for the epidemic of knee injuries continuing to be reported. The slow progress in determining the key to reduction of the rate of injury to the knee is the single biggest challenge in the skiing safety field. The editors hope the information provided in this book will challenge new and experienced investigators to intensify their efforts to decrease the severity of the knee injury problem.

The ongoing work of national standards organizations such as ASTM and similar groups elsewhere in the world continue to develop. The efforts of the International Standards Organization (ISO) stresses the better communication and cooperation between these organizations. The ISSS is proud of its role of providing a forum for presentation, discussion, and publication of material on skiing safety in cooperation with ASTM. We look forward to others joining us in our efforts to reduce the risk of skiing injury.

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