Anterior cruciate ligament injury in recreational alpine skiers: analysis of mechanisms and strategy for prevention

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Abstract Between 1995 and 1997, a retrospective survey was conducted in Japan to classify the types of injuries sustained by recreational alpine skiers. The purpose of this study was to investigate the causes and mechanisms of lower-extremity equipment-related (LEER) anterior cruciate ligament (ACL) injury in this population. Seventy-seven (96%) of the 80 respondents reported that their ski bindings did not release their ski boots at the time of their accident, and 30 respondents (38%) reported functional failure of their ski bindings, or that the ski boots came off. By presenting this investigation, we hope to give sports medicine clinicians a better understanding of LEER injuries and insights into how to prevent such injuries.

Key words Recreational alpine skiers · LEER injury · ACL injury · Injury prevention

Introduction

The nature of skiing has changed dramatically over the years, evolving from a sport of finesse to its current designation as a high-risk, free-style sport. The contemporary skiing style emphasizes the speed and technique of the skier. Even at the recreational level, skiers participate on longer slopes, for a greater number of minutes per slope, and for a longer season than was the case previously. Consequently, both the frequency and the intensity of contemporary skiing expose participants to potentially injurious forces across the 5-month Northern hemisphere skiing season.

Empirically and anecdotally, lower-extremity injury is the most common trauma suffered by all levels of skiers. Of these injuries, 25% to 30% are lower-extremity equipment-related (LEER) anterior cruciate ligament (ACL) injuries. In addition, mechanical failure of ski equipment occurs unexpectedly, and has become a major risk factor in serious lower-extremity injuries.

Today, the number of LEER injuries in recreational skiers is gradually increasing. According to previous studies, most ACL complete tears seen in recreational skiers were LEER injuries. Most ACL injuries, however, were caused by a combination of passive and active loads arising from the ski equipment. Speer et al. reported that the patient’s overall recall of the circumstances of the LEER injury was inconsistent, and they suggested the need for an accurate analysis of the causes of LEER injuries. Against this background, we carried out this study to present a normative overview of LEER injuries and to investigate the rate of LEER injuries sustained by recreational skiers. The purpose of our investigation was two fold. First, we wanted to collect accurate data on the accident patterns of LEER injuries. The second purpose was to assess correlations between the accident patterns and the severity of the LEER injuries.

Methods

Subjects

From 1995 through 1997, we collected descriptive statistics for LEER ACL injuries and conducted a frequency analysis of these injuries. A total of 80 alpine skiers who sustained LEER ACL injuries (43 men and 37 women; mean age, 28.0 ± 8.5 years) volunteered for this study. All skiers had visited the Hiroshima University Hospital within 2 weeks after their ski accidents. A survey questionnaire was distributed to these skiers, asking about several matters regarding their injury episode. A
“Guide to reporting”, which described the administrative aspects of this injury surveillance program, and supplied definitions of terms, was distributed to each subject. Informed consent was obtained from all respondents prior to the commencement of this research.

**Questionnaire**

A 19-item questionnaire was developed for the purpose of identifying the characteristics of the LEER injury. The questionnaire consisted of four demographic sections: subject profile, injury profile, accident location profile, and details of ski equipment. All information was linked to the injury database for analysis.

**Subject profile.** The subject profile included the following demographic information: (a) age, (b) height, (c) weight, (d) sex, (e) number of years of skiing experience, and (f) the subject’s skill level. In determining the skier’s skill level, we used three classes to categorize the skiers: those skiers who reported having the ability to control their skis on any slope under any conditions were classified as advanced (18%). Skiers who had the ability to ski only on properly conditioned slopes, while having difficulty in maintaining ski control under irregular slope conditions were classified as intermediate (59%). Skiers who could ski only on a well-maintained, mild slope were classified as novices (24%). The average number of years of skiing experience of the cohort was 8.6 (SD, 7.7 years).

**Injury profile.** The injury profile included the following information: (1) the date of the injury, (2) the difficulty of the slope where the accident occurred (categorized as beginner, intermediate, or advanced), (3) the condition of the slope, (4) the weather conditions, (5) the degree of incline of the slope where the accident occurred, (6) the direction of the turn at the time of the accident, and (7) the subject’s physical condition at the time of the accident (scored as one of five levels on the Likert scale: very good, good, average, poor, very poor).

**Accident location profile.** All slopes were categorized into three classes according to the degree of the incline. The incline of a slope was classified as follows: (1) mild (slope incline less than 15°), (2) slightly steep (slope incline between 16° and 25°), and (3) steep (slope incline greater than 25°).

**Ski equipment.** The following information was collected regarding the specifications of the ski equipment: (1) the length of the skis, (2) whether or not the skis were rented, and (3) whether the equipment was properly adjusted and checked for safety (if ski binding was adjusted, the ISO 80613 level was to be reported). All subjects were also asked whether the ski bindings had released the ski boots at the time of the accident.

**Results**

Table 1 presents the frequency distribution of the number of LEER ACL injuries and the course difficulty. According to the data, 56% of the accidents occurred on intermediate courses, 28% on advanced courses, and 16% on beginner courses. The $\chi^2$ test revealed a significant association between the level of expertise and the course incline ($P < 0.05$).

Sixty-three percent of the population sample had injured the left knee, and 37% had injured the right knee. The data revealed that 44% of the skiers fell while executing a right turn, 41% while executing a left turn, and 15% while going straight. Sixty-three percent of the respondents reported sustaining injuries on the outside knee in terms of the direction of a turn and 37% reported that the injury was sustained on the inside knee. There was a significant correlation between the direction of the turn and the side of the injured knee (i.e., whether inside or outside) ($P < 0.05$) (Table 2).

Table 3 shows the frequency distribution of the risk factors in relation to the 80 LEER ACL injuries in this study. Technical factors accounted for 40% of the injuries; equipment factors for 35%, and environmental factors for 25%. Sixty-three percent of the respondents reported being in a physically good condition at the time of the accident, while 37% sustained the injuries while being in a poor physical condition. Further analysis revealed that the major causes of poor physical con-

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$\chi^2$, $P = 0.0366$, Level of expertise vs. course difficulty (i.e., course incline)