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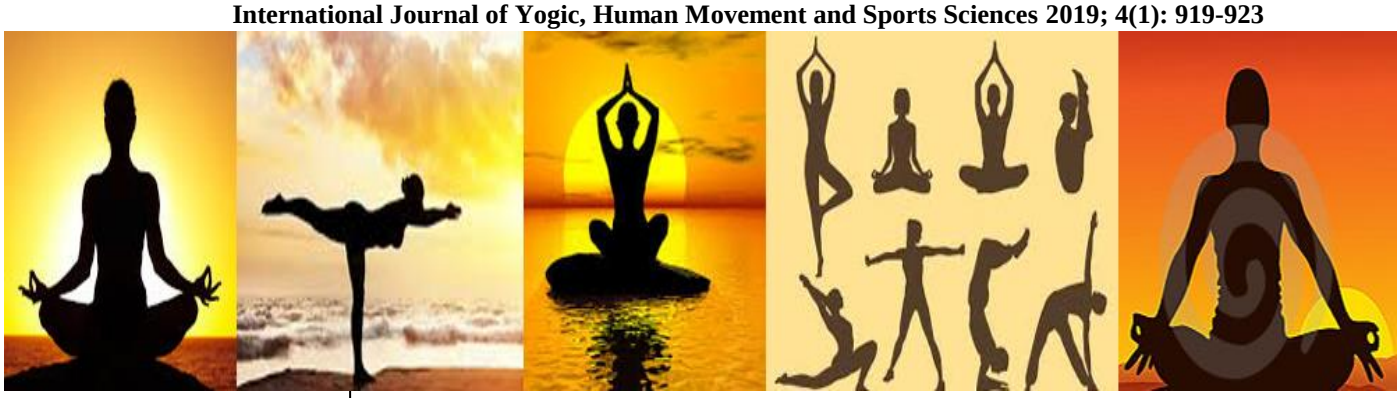

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Alpine skiing injuries: Causes and prevention

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Abstract
Snow skiing is the most popular winter Olympic sport. Skiing is an adventurous sport and has life taking risks associated with it. Proper precautions are a must for safeguarding one's life while skiing. A skier must have a full-fledged knowledge about the injuries, their causes and preventive measures that can keep a skier safe. In this review we have tried to accumulate knowledge about the skiing injuries mainly based on alpine skiing to make the skiers aware of various injuries that can occur during skiing and preventive measures that can be taken to avoid these injuries. In the current review article, the major cause of injuries has been discussed along with their preventive measures. This study may be beneficial for alpine skiers.

Keywords: Yoga, pranayama, aged women, breath holding capacity, vital capacity

Introduction
Snow skiing is a complex, multifactorial sport in which combination of physical, physiological, anthropometric, biomechanical and psychological variables influence the performance of a skier and helps in reducing injuries [1, 6]. If any of these variables is missing, the skier may face injuries. So, it is essential for a skier to keep these variables under consideration. High altitude and low temperature is a challenge faced by the skiers [7]. Skiers are prone to different kinds of injuries like ankle, knee, back, neck, shoulder and head. The current study is based on the findings of the rate of injuries in skiing based on particular events like alpine skiing. Based on these injuries a number of studies undertaken till now related to the rate of injuries have been reviewed. The aim is to assess the effect of protective equipment in the reduction of various kinds of injuries to the skiers. Sulheim *et al.* [8] reported 60% decrease in head injuries of alpine skiers after the usage of helmets. In another study conducted by Burtscher *et al.* [9] It was observed that due to the introduction of carving skis the injury rate decreased by 9%.

Table 1: The annual distribution of ACL injuries (n = 78)

Year (s) of study	Country	Number of Injuries	Reference
1983-1992	USA	24,340	Davidson and Latiotis [10]
1985-1986	Norway	341	Ekeland, Holtmoen and Lystad [11]
1985-86	Norway	339	Sahlin [12]
1988-2006	USA	9,465	Kim *et al.* [13]
1990-1993	Northwest, Wyoming	3451	Kocher and Feagin [14]
1990-1996	USA	238	Sacco *et al.* [15]
1990-1996	Norway	2598	Ueland and Branko [16]
1995-2000,2009-2010	USA	1,196	Coury *et al.* [17]
1996	USA	124	Patrick *et al.* [18]
1997-1998	Austria	17,914	Burtscher *et al.* [9]
1998-99	Canada	32	Macnab *et al.* [19]
1999-2000	Scotland	440	Langran and Selvaraj [20]
2002	Norway	3,277	Sulheim *et al.* [21]
2002-2003	Austria	2433	Burtscher *et al.* [9]
2006-2008	USA	811	Rust *et al.* [22]
2006-2012	Finland	2911	Stenroos and Handolin [23]
2013	USA	112	Patrick *et al.* [18]

Methodology

Research articles were manually searched using relevant subject headings and key words, reference lists, relevant journals in the field. Articles were included if they addressed alpine skiing injuries. Original research articles and reviews published in peer-reviewed journals and in the English language were reviewed. Studies focusing primarily on alpine skiing were included while the ones focusing on snowboarding injuries were excluded.

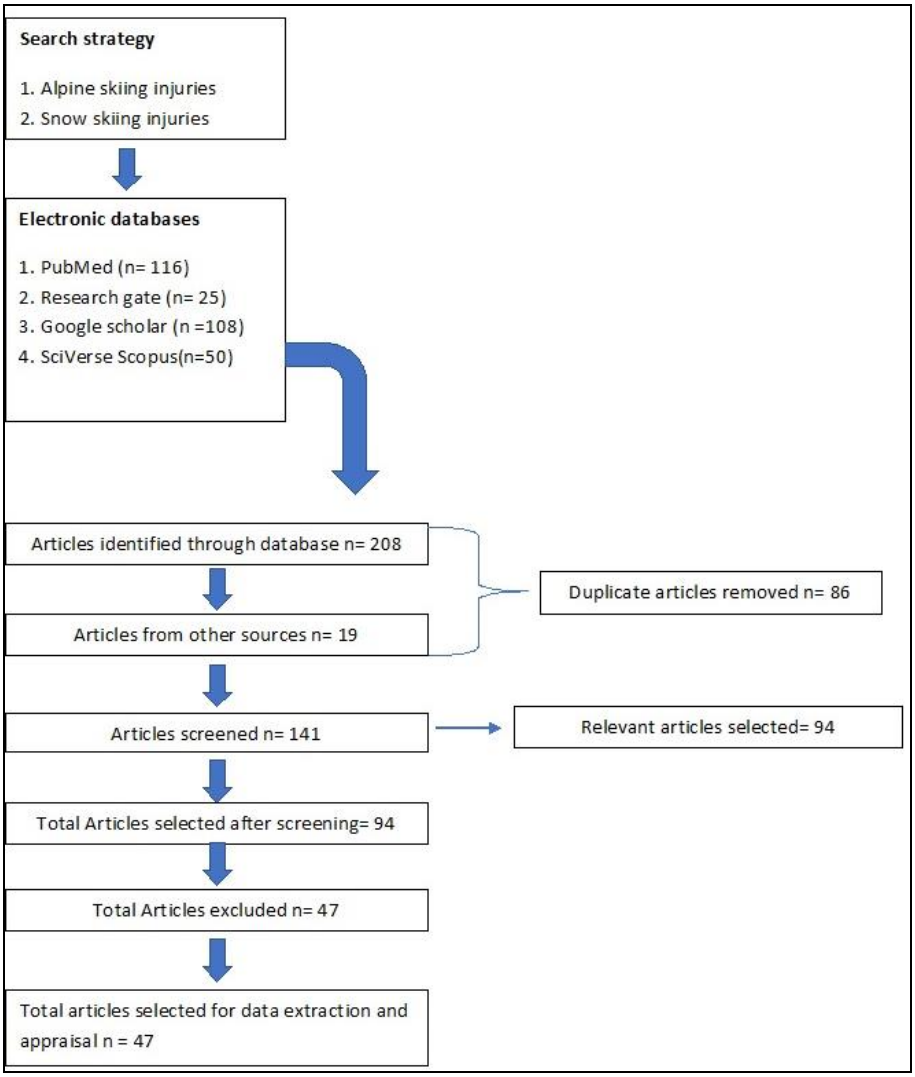

Fig 1: Flow Chart of Data Search

A number of studies have been reviewed to find out the injury rate. All the studies have focused on various injuries that take place during skiing from time to time. Since the skiing has become a competitive sport for the last five decades, there have been noticeable and surprising changes in injury statistics. During 1930's injuries in skiing were estimated to be 5 to 8 skiers per thousand days of skiing [24, 25]. But this rate of injuries started to reduce in the early part of the following decade and came down to about 3 to 6 skiers per thousand days of skiing [26]. With the passage of time the rate of injuries kept on decreasing, 2 to 3 injuries per thousand days of skiing [26, 27]. Warme *et al*. [26] did a retrospective study at Jackson Hole Ski Resort from 1982 and 1993 and reported that 50% reduction in injuries. In this study they made a comparison of lower extremity injuries and upper extremity injuries and concluded that the rate of injuries decreased from 4:1 in 1982 to 2:1 in 1993. [26] Another prospective study done by Deibert *et al*. [28] shows that there has been 43% of decrease in injuries from 1972 to 1994 [28]. During this period there was 89% reduction in adult tibias fractures, but ACL injuries increased to 28% [28]. Another two studies were conducted in England in which questioners were provided to the skiers (in 1985 and 1995) and following details were asked i) nature of the injuries, ii) training system and iii) their treatment. After evaluation of the questionnaires the results showed 3 to 6-fold higher rate of ACL injuries [29, 30]. Viola *et al*. [31] In a study on ski patrollers and ski instructors examined 7155 skiers over 7 years in Vail, Colorado. This study reported that the injury ratio of ACL was 4.5 per 200000 days of skiing. Foot and ankle injuries have shown a decreasing trend since 1970s with the installation of new ski binding.

Results

When we talk of anatomical structure, lower limb injuries occur among skiers, and mostly knee injuries. Saddle joint injuries occur among skiers due to the ski poles, while as wrist, ankle and spinal injuries occur to the snowboarders [32, 35]. The anterior cruciate ligament (ACL) is the injury which occurs in both downhill and cross-country skiers [36, 41]. Johnson and colleagues [38, 45] found that there has been a drastic change in the type and severity of knee injuries during the last 20 years. Another study was conducted in 1980-1989 by Jarvin *et al*. [37] and in this study 59 female and 19 male injured skiers were selected for the study and it was reported

that 48 patients were injured during downhill skiing and 30 patients were injured during cross country skiing. The researchers concluded that there was an increase downhill skiing injury while cross country skiing injury rate was found to decrease. In 1980-1982 only one injury was recorded during downhill skiing and the number of injuries rose to 30 in the year 1987-1989 [43].

A lot of changes have taken place in lower leg injuries since last 50 years [39, 37, 44, 31]. It was reported that in 1942, there were 46% of skiing injuries involving ankle and foot, but the rate of injuries has dropped by 1976 to only 7% [37]. While as the fractures of tibia increased in 1942 it was 3% and in 1964 it raised to 16% but again the rate of tibial fractures again decreased in 1976 to 6% due to some alterations in ski binding. In alpine skiing the knee injury has remained almost same throughout all the years [37] but ACL injuries has raised [45].

Causes

In the ancient times the ski binding was not expertly made, it was too tough to be released at the time of fall or any untoward incident [46]. Skiers inexperience is one of the factors of injuries in skiing. Many studies have mentioned that the less trained and less expert skiers were more liable to injuries [47, 48]. There are three chances of muscle tearing among skiers such as, the edge of the ski collapse in the snow which makes the skier to fall forward (valgus-external rotation). Second, the skier leans backward and falls backward and strikes with the backside edge of skies (flexion-internal rotation). Third one, when the skier lands on the heels of skies but the boots go forward leading to an injury (transient anterior dislocation) [18]. Most of the lacerations occur due to the edges of the skies [49]. The saddle joint injury or "Skiers thumb" is caused by the ski poles [50, 44]. Arm injuries are caused due to falling. Another four-year study done Davidson *et al*. [51] states that most of the injuries among skiers occur due to human error and reports that 58% injuries occur among alpine skiers. Many other injuries occur due to the equipment and over speed. It has been observed that alpine skiers were more prone to injuries in jumping events. Striking with objects like trees, rocks and other things were main cause of injuries among alpine skiers [51]. There are many other causes of skiing injuries as stated by Bouter *et al*. [52] in their study as depicted in the following table.

Table 2: Main Causes of Injuries

Personal characteristics	Skill level	Physical Condition	Behaviour	Environment	Equipment
Age	Self-rated Ability	Fitness Level	Fear	Snow Quality	Binding
Gender	Experience	Sports participation	Risk Taking	Visibility	Boots
Height	Lessons	Ski gymnastics	Alcohol Consumption	Weather Condition	Poles
Weight		Warm-up	Nutrition	Difficulty of Ski Run	Brakes
Education		Sleep		Time of Day	
		Menstruation		Duration of Exposure	

Adapted from Bouter *et al*. [52]

Prevention

Newer designs have incorporated better construction and multiple release mechanisms. Concurrently, as in early times leather boots were used for skiing but with the passage of time they have been replaced by hard plastic boots which helps in preventing the ankle and lower leg injuries. [46] Two studies evaluating the role of educational instructions regarding skiing injuries have shown a measurable reduction in injuries. A special training programme based on video analysis, flip charts and workbook has been found to be productive in developing special awareness about injury prevention [27]. The video analysis provides instructions and safety tips on injury prevention like testing and adjustment of ski binding. These videos provide advice on injury prevention and the significance, testing and adjustment of ski bindings. [53, 56] Weakness of muscles is also a cause of ACL injuries which can be overcome by strengthening the muscles [55, 56] In order to get rid of injuries skiers should not perform at the time of fatigue [53] Warming up is the best precaution to avoid injuries in skiing [55]. Other risk factors can be overcome by improving skill level, physical condition, behavior, equipment and environment. Beginners have more chance of injuries unless they take advices regarding skiing. Good adjustment of ski binding, ski boots and poles can also reduce chances of injuries. [53] Through many injury prevention programs efforts have been made to modify risk factors that lead to injuries in case of alpine skiing. A 34-year study conducted in 2006, reports that there was a 55% decrease in the overall injury rate [56, 57].

Conclusion

Skiing, the most famous winter sport has more probability of causing intense injuries. These include ACL sprains, Thoracic, Lumber, upper limb and lower limb injuries. It has been reported that most of the injuries decreased while a few of them showed an increasing trend. Due to refinement of ski boots and binding the ankle injuries reduced but the ACL injuries increased.

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