

Review Article

Difference in Injury Risk between Male and Female Alpine Skiers: Review of the Literature

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Abstract

Alpine skiing is popular at varying levels of competitiveness with many skiers participating recreationally and elite skiers competing in downhill, super-G, giant slalom, slalom, and combined events in the World Cup and in the Winter Olympic Games. The rate of injury in alpine skiing is high both recreationally and competitively and methods to reduce injury rates are needed. Additionally, it is well-established in other sports that the risk of injury for an athlete varies based on gender. The purpose of this review is to determine how injury risk differs for each gender of alpine skier. Injury rates vary throughout the literature but point towards males being at a higher risk for overall injury and upper body injuries while females are at a higher risk for knee injuries. Even the specific knee injuries for which each gender is at risk varies with medial collateral ligament (MCL) injuries more common in males and anterior cruciate ligament (ACL) injuries more common in females. More studies are needed to confirm the differences in injury risks and how these risks may differ across levels of competition, thus allowing regulations and injury prevention methods that may be tailored specifically to the injuries an alpine skier is most susceptible to.

Introduction

Since its inclusion in the Winter Olympic Games in 1936, alpine skiing has evolved into a worldwide phenomenon, composed of the events downhill, super-G, giant slalom, slalom, and combined competitions [1]. Additionally, recreational skiing takes place in approximately 80 countries worldwide with the total number of skiers currently around 115 million and possibly growing [2,3]. The risk of injury in alpine skiing is well-documented. Although advances in equipment, such as the introduction of carving skis and newly adjusted bindings, have decreased the overall risk of injury, it is still quite high [4,5]. Some studies have even found that the risk of severe injury events has increased in elite skiers [6].

Distinct differences exist between male and female alpine skiers, encompassing both their physiological attributes and the characteristics of the courses in which they compete. Recreational alpine female skiers have a lower body height, weight, body mass index (BMI), and higher relative fat mass when compared to their male counterparts with males engaging in more vigorous intensity activity as well [7-9]. Moreover, in the World Cup, males compete at a higher skiing speed and experience longer and higher vertical drops compared to females [10].

Understanding the specific injuries an athlete is at risk for can impact the intervention needed. For example, balance training has been shown to be effective in reducing the risk of lower extremity injuries [11]. Furthermore, gender plays an important role in both susceptibility to injury and treatment outcomes [12,13]. However, more information is needed on how these risks are expressed in alpine skiing and, therefore, how injuries can be prevented in the sport. The purpose of this review is to explore the current literature regarding the sex differences in injury risk between male and female alpine skiers.

Injury rates

The overall rate of injury in alpine skiing is high for many types of injuries. One study, following elite competitive alpine skiers, found the rate of injury to be as high as 184.1 injuries per 100 athletes per season with 75% of athletes suffering a traumatic injury, and 52.3% suffering an overuse injury [14]. Other estimates yield more conservative values such as 36.7 injuries per 100 athletes per season or 9.8 injuries per 1000 runs. Several studies have investigated the makeup of these injuries, finding that most injuries are time loss injuries, and the highest incidence of injury is in downhill skiing, followed by super-G, giant slalom, and slalom with the lowest rate of

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injury [15]. Recreationally, the most common cause of injury is falling, and in young elite skiers, traumatic injuries occur more often than overuse injuries [14,16]. In World Cup skiers, injuries occur most frequently from turning or landing [17].

While many factors contributing to injury between both genders are the same, the context of the injury can differ by gender. Females are more likely to sustain traumatic injuries during the preparation part of the season and overuse injuries during the competitive season while males experience the reverse with a higher risk of overuse injuries during the preparation part of the season and a higher rate of traumatic injuries during the competitive season [14]. Overuse injuries are likely due to both training load and previous traumatic injuries [18]. Thus, there are distinct differences between the context and timing of injury between male and female alpine skiers, and more than just the overall rate of injury should be analyzed.

When comparing the overall injury rates in alpine skiers based on gender, there are many other important components to consider. One study, looking at World Cup skiers, found a larger chance of injury and time loss injury in training and in competitions in men compared to women [15]. Additional studies have found a larger rate of injury in recreational skiing and downhill skiing in male alpine skiers compared to females [10,16]. Several factors could be contributing to the higher rates seen in males such as increasing speed and risky behaviors [19]. Additionally, one study found that female alpine skiers had better stability and sensory scores [20]. While most studies found men to have a higher risk of injury, when controlling for age, severe injury is more common in women. Additionally, elite junior female alpine skiers have three times the risk of injury than their male counterparts [6]. The earlier the first injury occurs, the higher the risk of a skier experiencing reinjury or new injury [21]. Therefore, it is important to implement regulations to prevent these early injuries in young females. The International Ski and Snowboard Federation (FIS) has introduced new regulations in the World Cup, including increasing the side cut radius and length of skis in several disciplines, to provide more stability to skiers and try to reduce the rate of injury [22,23]. One study found the regulations had no significant reduction in injuries while another analyzed the number of injuries before and after regulations and found they reduced the rate of injury for males but not for females, again pointing to the need for regulations to specifically reduce injuries in female alpine skiers [24,25].

Upper and lower body injuries

It is well-established that the most common site of injury for the alpine skier, both recreationally and competitively, is the knee [5,10,26,27]. In World Cup skiers, 36% of injuries are knee injuries [10]. In recreational skiers, the rate of injury to the knee was found to be 39.5% in women, and 22.8% in men [16]. The data with regards to whether females are at

a higher risk for knee injuries is mixed with some studies showing females have a higher risk and others showing no sex difference [4,15]. Within the female alpine skiing population, the knee injury rates are highest in females aged 15-59 compared to those younger or older [4]. One possible reason for this is that female sex hormones increase knee laxity. Females even experience different knee laxity throughout their menstrual cycle [28]. Another interesting finding is that females experience left-sided lower extremity injuries more often than right-sided [21].

As lower body injuries are more common in alpine skiing, there is less data about upper body injuries. For most upper body injuries, males are generally found to be at a higher risk, with 11% of injuries to male alpine skiers being shoulder injuries compared to 6% of injuries for women [16]. Additionally, males are more likely to experience injuries to the hand, finger, and thumb [21]. Of interest, upper body injuries occur more often from crashing while lower body injuries occur more often while the skier is skiing [17].

Anterior cruciate ligament injuries

The most frequent diagnoses for World Cup alpine skiers are anterior cruciate ligament (ACL) injuries and concussions, with ACL injuries being the more common of the two [10]. Additionally, ACL injuries tend to be more severe, making up 48.6% of severe injuries in alpine skiing and 70.8% of severe knee injuries [29]. Studies have found varying results on whether gender plays an important role in the risk of ACL injury. One study on World Cup alpine skiers found there was no difference in male and female ACL injury risk [10]. However, another study found female skiers are 1.65 times more likely to experience an ACL injury than their male counterparts [29]. Looking more specifically into ACL injuries, one study analyzed combined ACL and MCL (medial collateral ligament) injuries. ACL and MCL were the most common combined injury in both genders. However, men more commonly had multiple knee ligament injuries. Overall, in women, ACL injury was more common, while, in men, MCL was more common [7]. Even within the subset of knee injuries, the severity and specific injury differs between male and female alpine skiers.

In alpine skiing, there is a high risk of ACL tear due to the landing and maneuvers performed throughout. Particularly, the first 50 milliseconds after landing are when peak ACL forces are experienced by the skier [30]. In alpine skiing, ACL injury in the left knee is more common than in the right knee. Though the exact reason for this is unknown, it is possibly due to the difference in explosive power and dynamic balance between the two sides since those with unequal performances in each leg on a one-legged hop test for distance were more likely to experience ACL injuries [31,32]. A few different factors reduce the risk of ACL injury. The first relates to the experience of the skier. Those who have skied for more than 13 years are at a reduced risk [31]. However, another study found those with a higher FIS rank were more at risk



for ACL injury, suggesting that the relationship between experience and ACL injury risk may be complicated [33]. The second factor involves the landing technique of the skier. A skier activating their hip flexors, ankle plantar flexors, and hamstrings experiences lower peak ACL forces. Additionally, landing in a flexed position with a backward lean reduces the ACL injury risk during the early impact phase when peak ACL forces are experienced [30]. Finally, for a skier to remain in a safe landing position they must increase the flexion of their knee and hip, engage in dynamic movement, and coordinate the correct muscle firing pattern. As there are many factors contributing to ACL injury risk, the differences in ACL injuries between male and female alpine skiers are likely due to multiple factors including anatomical, mechanical, and hormonal differences [34-38]. There has been some success in reducing the risk of ACL injury. In young elite skiers, an ACL injury prevention program, focusing on neuromuscular control and core strength, was shown to reduce the risk of ACL injury [39,40].

Conclusion

While it is not possible to draw definitive conclusions, current research points to the overall injury risk and upper body injury risk being higher in male alpine skiers and knee and ACL injury risks being higher in female alpine skiers. It is important to note that the data regarding injury rates by gender yields mixed results for almost every category discussed. This review began to uncover some factors that may contribute to the mixed results. There remain limitations with the currently available data. One aspect to note is that this review mentions varying levels of competitiveness of alpine skiers. Due to the small number of competitive alpine skiers, it is challenging to draw conclusions from this population alone. In this review, studies were included from all levels ranging from recreational to World Cup skiers. Although many of the components of alpine skiing are similar at all levels, there are likely to be subtle differences in injury profiles depending on the level of competition.

In this review, some predictors for ACL injury risk were discussed. However, more studies are needed to uncover how predictors of injury differ by gender and determine what factors the athlete can modify to reduce their risk of an injury. The profile of the injured alpine skier differs greatly depending on the gender of the athlete. Male and female alpine skiers' injuries differ by location, specific diagnosis, and when and how the injury occurs. The risk factors contributing to injury vary greatly by gender. In addition to different methods of injury prevention, males and females need different regulations to reduce injury rates in alpine skiing.

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