

# Performance and Return to Sport After Anterior Cruciate Ligament Reconstruction in X-Games Skiers and Snowboarders

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**Background:** Skiing and snowboarding have become increasingly popular since the inception of the winter X-Games in 1997.

**Purpose:** To determine (1) rate of return to sport (RTS) to the winter X-Games following anterior cruciate ligament (ACL) reconstruction and (2) performance upon RTS following ACL reconstruction.

**Hypotheses:** There is a high rate of RTS to the winter X-Games in subjects undergoing ACL reconstruction. There is no difference in performance upon RTS following ACL reconstruction versus preinjury.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** Skiers and snowboarders competing in the winter X-Games who tore their ACL and underwent ACL reconstruction between 1997 and 2012 were evaluated. Athlete data were extracted from winter X-Games media websites, ESPN, injury reports, player profiles/biographies, and press releases. All athlete, knee, and surgical demographic data were analyzed. RTS and performance as it related to the number of gold, silver, and bronze medals won both pre- and postoperatively in the X-Games were analyzed.

**Results:** Fifteen skiers (19 knees) and 10 snowboarders (10 knees) were analyzed. There were 13 males and 12 females, with a mean subject age of  $22.6 \pm 4.45$  years. The rate of RTS in the X-Games following ACL reconstruction was 80% overall (20/25 subjects). The rate of RTS in winter X-Games following ACL reconstruction in skiers was 87% (13/15 subjects) and in snowboarders was 70% (7/10 subjects). The rate of RTS in winter X-Games following ACL reconstruction in males and females was 85% (11/13 subjects) and 75% (9/12 subjects), respectively. The rate of revision ACL reconstruction due to ACL tear following primary ACL reconstruction was 4% (1/25 subjects). There were more left- than right-sided tears (18 vs 11). Skiers and snowboarders competed in the X-Games for  $3.84 \pm 2.73$  and  $3.40 \pm 2.84$  years prior to ACL reconstruction and  $2.56 \pm 2.06$  and  $7.29 \pm 3.30$  years after ACL reconstruction, respectively. Skiers earned 22 medals prior to ACL reconstruction (9 gold, 5 silver, 8 bronze) and 24 medals after ACL reconstruction (16 gold, 2 silver, 6 bronze). Snowboarders earned 7 medals prior to ACL reconstruction (4 gold, 1 silver, 2 bronze) and 19 medals after ACL reconstruction (7 gold, 7 silver, 5 bronze).

**Conclusion:** Winter X-Games skiers and snowboarders have a high rate of RTS after ACL reconstruction. Skiers earned a similar number of medals preinjury and postsurgery, while snowboarders earned more medals following surgery.

**Keywords:** anterior cruciate ligament; X-Games; skiing; snowboarding; return to sport; knee injury

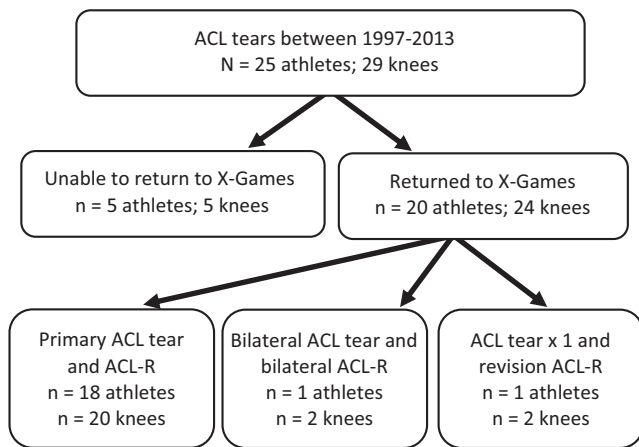
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Skiing and snowboarding have become popular recreational and competitive sports in recent years. According to the SnowSports Industries America (SIA), there were over 22 million Americans who participated in snowboarding as well as alpine and cross-country skiing in the 2011-2012 season, the majority of whom were in the 25- to 34-year age group.<sup>1</sup> With this surge in popularity, ESPN introduced the winter X-Games in 1997 as a way to showcase the talents of some of the most well-recognized skiers, snowboarders, and snowmobilers from around the world.<sup>11</sup> While there are many regional and statewide skiing and

snowboarding competitions, the X-Games features the most talented athletes from around the world and highlights their skills with several days of high-level competition. The competitions include freestyle jumps, superpipes, and big air events, all of which place the athlete at significant risk for injury.

The initial attendance at the X-Games was 38,000 people, which has increased nearly 300% over the years, up to its current tally of 114,500 spectators in 2013.<sup>7</sup> Because of this increase in popularity, ESPN recently expanded the competition to 2 events per year instead of 1, with the second event occurring outside of the United States in France.<sup>10</sup>

The incidence of anterior cruciate ligament (ACL) tears has been increasing in skiers and snowboarders.<sup>23</sup> In 1999, Viola et al<sup>22</sup> reported the incidence of ACL tears in



**Figure 1.** X-Games athlete flowchart. ACL-R, anterior cruciate ligament reconstruction.

alpine skiers to be 4.2 and 4.4 per 100,000 skier-days in men and women, respectively. Kim et al<sup>16</sup> demonstrated the most common injury sustained by an alpine skier was an ACL tear, accounting for 17.2% of all skiing injuries, similar to the 17% documented by Warne et al.<sup>23</sup> ACL reconstruction is frequently performed to treat ACL tears in this population, with high success rates.<sup>15,19</sup> Higgins and Steadman<sup>13</sup> reported good success with ACL reconstruction, demonstrating a mean return to skiing time of 5.4 months, with 78% of their patients rating their knees as pain free. To the authors' knowledge, no study exists that reports the rate of return to sport (RTS) and performance upon RTS following ACL reconstruction in elite skiers and snowboarders.

The purposes of this study were to determine the rate of RTS of winter X-Games skiers and snowboarders after an ACL reconstruction and to compare their performance pre-injury to postsurgery. The authors hypothesize there will be at least an 80% rate of RTS to the winter X-Games in subjects undergoing ACL reconstruction and that there will be no difference in performance upon RTS following ACL reconstruction versus preinjury.

## METHODS

Snowboarders and skiers who competed in the winter X-Games and tore their ACLs and underwent ACL

reconstruction between 1997 (the year of the inaugural winter X-Games) and June 1, 2012, were identified for potential inclusion (Figure 1). These participants were discovered through winter X-Games and ESPN websites, publically available Internet-based injury reports, player profiles/biographies, and press releases. This method of participant selection has been used in multiple high-evidence-level studies published in orthopaedic journals.<sup>2,6,9,12,17,18</sup> The search was conducted by an orthopaedic surgery resident and a board-eligible orthopaedic surgeon in sports medicine fellowship training. All players who met the inclusion criteria were included in this study as it related to RTS rate. Certain concomitant knee injuries, when known, were deemed acceptable (articular cartilage injury, meniscal tear, and medial or lateral collateral ligament tear [but not both at same time]). Players were excluded if they sustained a concomitant tibial plateau fracture, a bicruciate (ACL and complete posterior cruciate ligament [PCL]) or combined ACL and bicollateral ligament injury. A player was deemed to have RTS if he or she competed in any winter X-Games event for a given season after surgery. Players did not RTS if they failed to meet any of the aforementioned criteria.

Demographic data (age at injury, sport [skiing vs snowboarding], side of injury [right vs left], number of years played before and after the injury, and if the player returned to the winter X-Games the season following the injury) were extracted. Performance data (number and type [gold, silver, bronze] of medals earned) were also collected and analyzed.

Single-variable analyses for all continuous variables (performance measures) within groups were performed using paired-samples Student *t* tests. One-sample Kolmogorov-Smirnov goodness-of-fit tests for Gaussian data distribution were performed and confirmed normality of all data. All statistical analyses were performed using PASW Statistics Student Version 18.0.0 (IBM, Armonk, New York, USA).

## RESULTS

Fifteen skiers (19 knees) and 10 snowboarders (10 knees) were analyzed. The mean subject age was  $22.6 \pm 4.45$  years. There were 13 males and 12 females analyzed. Five subjects (2 skiers and 3 snowboarders) with at least 1 year of follow-up did not RTS in X-Games since ACL reconstruction (5 knees). The rate of RTS in X-Games following ACL reconstruction was 80% overall (20/25 subjects). The rate

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TABLE 1  
Medal Count for Skiers and Snowboarders  
Prior to Their Anterior Cruciate Ligament (ACL) Tear  
Compared With After Their ACL Tear

Type of Medal	Pre-ACL Tear	Post-ACL Reconstruction
Skiers		
Total	22	24
Gold	9	16
Silver	5	2
Bronze	8	6
Snowboarders		
Total	7	19
Gold	4	7
Silver	1	7
Bronze	2	5

of RTS in winter X-Games following ACL reconstruction in skiers was 87% (13/15 subjects) and in snowboarders was 70% (7/10 subjects). The rate of RTS in winter X-Games following ACL reconstruction in males and females was 85% (11/13 subjects) and 75% (9/12 subjects), respectively. The rate of revision ACL reconstruction due to ACL tear following primary ACL reconstruction was 4% (1/25 subjects). Four subjects (8 knees) had bilateral ACL tears (1 subject had simultaneous bilateral ACL tears; 1 subject had a re-tear; and 2 subjects had sequential, contralateral ACL tears). There were more left- than right-sided tears (18 vs 11).

Skiers and snowboarders competed in the X-Games for  $3.84 \pm 2.73$  and  $3.40 \pm 2.84$  years prior to ACL reconstruction, respectively. Following ACL reconstruction, skiers and snowboarders competed in the winter X-Games for  $2.56 \pm 2.06$  and  $7.29 \pm 3.30$  years, respectively. Skiers earned 22 medals prior to ACL reconstruction (9 gold, 5 silver, 8 bronze) and 24 medals after ACL reconstruction (16 gold, 2 silver, 6 bronze). Snowboarders earned 7 medals prior to ACL reconstruction (4 gold, 1 silver, 2 bronze) and 19 medals after ACL reconstruction (7 gold, 7 silver, 5 bronze) (Table 1).

## DISCUSSION

The purpose of this study was to determine the rate of RTS of winter X-Games skiers and snowboarders after an ACL reconstruction and to compare their performance preinjury to postsurgery. The authors hypothesized that there would be at least an 80% rate of RTS, with no significant difference in performance preinjury to postsurgery. The first hypothesis was confirmed, as the athletes demonstrated an 80% rate of RTS (87% in skiers, 70% in snowboarders). The second hypothesis was proven to be incorrect, as there was an increase in the total number of medals earned preinjury to postsurgery for snowboarders.

Our study demonstrated an 80% overall rate of RTS; however, there were 2 athletes who returned to competitive skiing and snowboarding for their respective countries but have not competed in the X-Games yet. There was also

1 athlete who plans to return this upcoming season, as she was only 1 year out from her reconstruction during the 2013 X-Games. Of the other 2 athletes, 1 athlete switched careers to become a musician during the rehabilitation process and 1 retired. The purpose of this study was to determine the RTS to the X-Games, and so this strict criterion was upheld. However, taking into account the nature of the 5 players who did not RTS, one could argue that 2 have RTS and 1 most likely will, making the overall RTS 92%.

Although literature on the incidence of injuries in both skiers and snowboarders is abundant, there is a paucity concerning the outcomes after ACL reconstruction in this population. Higgins and Steadman<sup>13</sup> reported on 27 skiers (30 knees) who were either current or past members of the US Ski Team or professional skiers and underwent primary ACL reconstruction. They found an 89% RTS, with a re-tear rate requiring revision ACL reconstruction of 7.4%. These results are similar to the cases presented in the current study. Nordahl et al<sup>19</sup> reported on 5 elite alpine skiers who underwent ACL reconstruction and found that the 2 male skiers returned to their preinjury level while the 3 female skiers did not. Pujol et al<sup>20</sup> reported on 157 ACL tears sustained by the French Alpine Ski Team over 25 years; while they did not comment on the RTS rate, their study demonstrated a significantly higher reoperation rate at 14% compared with our 4%, and a similar overall career length of 7.5 years compared with our 6.3 and 10.5 years for skiers and snowboarders, respectively. Their study<sup>20</sup> also showed a mean age at the time of ACL tear of  $21 \pm 3.8$  years, similar to the  $22.6 \pm 4.45$  years from the current study. We could not find any studies that analyzed the RTS rate of snowboarders following ACL reconstruction to compare with the results of the current study.

It has been reported that ACL tears are significantly more common in skiers versus snowboarders—especially female skiers.<sup>16,21</sup> The mechanism of injury for ACL tears in skiers and snowboarders is very different. While there are several proposed mechanisms for ACL tears in skiers, there are significantly fewer in snowboarders. According to Järvinen et al,<sup>14</sup> skiers tear their ACLs by a valgus-external rotation, flexion-internal rotation, or hyperextension-internal rotation mechanism. Bere et al<sup>4</sup> elaborated on these forces and introduced 3 types of mechanisms using systematic video analysis: landing back-weighted, where the athlete is leaning too far backward at the takeoff of a jump and attempts to correct this by landing on their ski tails with essentially straight knees; dynamic snowplow, where the knee is forced into internal rotation and valgus due to inappropriate weight distribution and ski edging angle; and slip-catch. However, the most common mechanism that leads to ACL tears in skiers is the slip-catch mechanism, which has been well studied via video from World Cup alpine skiing events. Bere et al<sup>5</sup> recently elaborated on the slip-catch mechanism that seems to play a large role in ACL tears in skiers. According to this study, the inner edge of the outer ski catches the snow surface while the skier is turning, forcing the knee into valgus and tibial internal rotation. A component of abduction and knee compression is also involved.

Given that the incidence of ACL tears in snowboarders is not as high as skiers, the mechanism of ACL tears in snowboarders has not been as well studied.<sup>16</sup> What has been studied in snowboarders is whether the snowboarder had 1 or both feet attached to the board at the time of injury and in what venue the injuries occur. Kim et al<sup>16</sup> demonstrated that 32% of knee injuries in snowboarders occurred with 1 foot detached from the snowboard, secondary to torsional forces experienced by the knee whose foot is attached to the snowboard, and that 60% of ACL tears occur in terrain parks. Davies et al<sup>8</sup> described a mechanism of ACL tears in snowboarders in which the snowboarder lands on a flat surface from a big jump, experiencing significant knee flexion and compression. In this study, the injury occurred in the front knee in 31 of 35 knees; the front knee in the snowboarding position sits in internal rotation, causing preloading of the ACL, which may predispose to injury. Davies et al<sup>8</sup> postulated the ACL tear was due to excessive eccentric quadriceps contraction of the leg in a knee that is preloaded.

It is well documented that ACL tears occur more frequently in women as compared to men.<sup>3</sup> Our study did not show a significantly greater number of ACL tears in women versus men, with a gender distribution favoring men (12 women to 13 men), similar to Pujol et al,<sup>20</sup> who showed no difference in ACL tear rates between men and women skiers. This is in contrast to several studies that have demonstrated the rate of ACL injury in female skiers and snowboarders to be greater than their male counterparts. Viola et al<sup>22</sup> reported the incidence of ACL tears in alpine skiers to be 4.2 and 4.4 per 100,000 skier-days in men and women, respectively, while Järvinen et al<sup>14</sup> reported on 78 skiers who sustained ACL injuries, 76% of whom were female. Stevenson et al<sup>21</sup> reported that females were 3.1 times more likely to sustain an ACL injuries than males. Currently, there is no evidence that definitively accounts for this discrepancy.

### Limitations

There may have been some winter X-Games skiers and snowboarders whose ACL injuries were not discovered with the search methodology. Although both an orthopaedic surgery resident and a board-eligible orthopaedic surgeon in sports medicine fellowship training conducted separate searches to look for all winter X-Games skiers and snowboarders between 1997 and 2012 who tore their ACLs, some may have been missed. To the best of the authors' knowledge, there is no database where this information is kept. However, this method of subject selection has been utilized in multiple high-evidence-level studies in sports medicine journals.<sup>2,6,9,12,17,18</sup> The number of athletes analyzed was also very small, introducing the possibility of type II error in comparison of groups within the study, failing to reject a null hypothesis when a true difference actually exists. There was no control group of winter X-Games skiers and snowboarders for comparison. It was determined that it would be subjective to match the cases with controls, so this was not attempted. Additionally, the authors were unable to identify and report any validated clinical outcome scores

in these players, and patient satisfaction, personal perception of knee pain, function, and stability were unable to be assessed versus preinjury. These factors may influence RTS performance. Surgical technique information (single- vs double-bundle, 1- vs 2-incision, bone-patellar tendon-bone vs hamstring, autograft vs allograft, transtibial vs accessory anteromedial femoral tunnel drilling, meniscal and articular cartilage concomitant injury) was unobtainable from publically available sources. Similarly, post-operative physical examination (eg, Lachman, pivot-shift), instrumented laxity (KT-1000 and KT-2000 arthrometer), and imaging (radiographic assessment of degenerative changes, magnetic resonance imaging assessment of meniscal and/or chondral damage) outcomes were unavailable. Additionally, the rehabilitation program utilized post-operatively was unavailable.

### CONCLUSION

Winter X-Games skiers and snowboarders have a high rate of RTS after ACL reconstruction. Skiers earned a similar number of medals preinjury and postsurgery, while snowboarders earned more medals following surgery.

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