# Effect of Functional Bracing on Knee Injury in Skiers With Anterior Cruciate Ligament Reconstruction

## A Prospective Cohort Study

William I. Sterett,*† MD, Karen K. Briggs,† MPH, Timothy Farley,‡ MD, and J. Richard Steadman,† MD
*From the †Steadman Hawkins Research Foundation, Vail, Colorado, and ‡Orthopedic Sports Medicine, Inc, St Louis, Missouri*

**Background:** The role of knee bracing in anterior cruciate ligament reconstructions is controversial.

**Hypothesis:** Functional bracing will have an effect on subsequent knee injury in skiers with anterior cruciate ligament reconstruction.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** From 1991 to 1997, 11606 skiers at a major destination ski resort underwent preseason knee screening. The anterior cruciate ligament–reconstructed group consisted of 820 skiers who had had an anterior cruciate ligament reconstruction 2 years or more earlier. Of these, 257 skiers selected the use of functional knee brace during skiing. The dependent variable was subsequent knee injury, identified via workers' compensation records. Covariates included age, gender, ski occupation, Lachman grade, pivot-shift grade, KT-1000 arthrometer manual maximum displacement, and use of a functional brace. Univariate and multivariate risk factors for subsequent knee injury were determined.

**Results:** In this study, 257 skier-employees with anterior cruciate ligament reconstruction wore braces and 563 skier-employees with anterior cruciate ligament reconstruction did not. Braced skiers had significantly higher preseason rates of grade II or higher Lachman and pivot-shift tests (braced, 29% and 22%, respectively; nonbraced, 11% and 10%, respectively; $P < .05$). Sixty-one subsequent knee injuries were identified, 51 (8.9 injuries/100 knees/ski season) in the nonbraced group and 10 (4.0 injuries/100 knees/ski season) in the braced group ($P = .009$). Nonbraced skiers were 2.74 times more likely to suffer subsequent injury than were braced skiers (odds ratio, 2.74 [confidence interval, 1.2-4.9]). Logistic regression modeling identified nonbracing as a significant independent multivariate risk factor for subsequent knee injury in the high-demand skiers with anterior cruciate ligament reconstruction.

**Conclusion:** Because of the increased risk of subsequent knee injury in nonbraced skiers, the authors recommend functional bracing for skiers with anterior cruciate ligament reconstruction. Whether the protective effect of functional bracing can be extrapolated to other high-demand patients is yet to be determined.

**Keywords:** functional bracing; anterior cruciate ligament (ACL) reconstruction; knee; injury

The role of knee bracing in ACL injury is controversial.[1,15,18,24,29,33] In a 1985 report, the American Academy of Orthopaedic Surgeons Committee on Sports Medicine defined 3 categories of bracing: prophylactic, rehabilitative, and functional.[2] Biomechanical studies of functional ACL bracing suggest that some functional knee orthoses do increase mechanical stability under low loading conditions.[§] However, the effect of bracing on mechanical stability under physiologic conditions is not established.[10] Clinical evidence of efficacy for functional bracing in the ACL-reconstructed (ACLr) knee is lacking.

*Address correspondence to William I. Sterett, MD, The Steadman Hawkins Research Foundation, Attn: Clinical Research, 181 West Meadow Drive, Suite 1000, Vail, CO 81657 (e-mail: karen.briggs@shsmf.org).

Presented at the interim meeting of the AOSSM, San Francisco, California, March 2004.

One or more of the authors have declared a potential conflict of interest: Innovation Sports provides research support to the Steadman Hawkins Research Foundation. Dr Steadman is a consultant and shareholder in Innovation Sports.

The American Journal of Sports Medicine, Vol. 34, No. 10
DOI: 10.1177/0363546506289883


§References 3, 4, 8-13, 18, 19, 21-23, 25, 27, 28, 30-32.

The purpose of this study was to determine the effect of functional bracing on subsequent knee injury in ACLr skiers.

## METHODS

The study design was a prospective cohort study. There were 11 606 skiers employed at a major destination ski resort who underwent required preseason knee screening from 1991 to 1997. This group was composed of ski instructors (74%), lift operators (8%), ski patrol (8%), and employees such as mountain hosts who provided on-mountain skier services, and miscellaneous other employees (10%). All screened employees skied as part of their jobs. A preemployment questionnaire was completed by each ski resort employee. This included age, gender, height, weight, job description, years of skiing experience, number of days skied during the previous season, medical and surgical history, and knee injury history. Preemployment screening also included Lachman and pivot-shift tests performed by an orthopaedic sports medicine fellow that were graded per International Knee Documentation Committee criteria.[20]

The ACLr group was operationally defined as individuals who had undergone ACL reconstruction with patellar tendon or hamstring autograft or allograft at least 2 years before the current ski season for which they were being screened. Each screening year, ACLr individuals were identified and were considered at risk of injury for 1 ski season. Individuals did participate in multiple years of screening. All ACLr individuals were referred to one of the staff surgeons for advice on functional bracing. The ACLr skiers were counseled and self-selected the use of a functional knee brace during skiing based on a shared decision-making process taking into account time since surgery, any complaints of instability, and laxity profile. If functional bracing was recommended, a CTi2 brace (Innovation Sports, Irvine, Calif) was provided by the ski resort corporation free of charge. There was no formal protocol to evaluate patient compliance in wearing the functional brace during work-related skiing after its provision. Knee injuries during the ski season were operationally defined as an injury to the knee that prevented the employee from working for any period of time, thus generating a workers' compensation claim. Knee injuries were identified via workers' compensation records, regardless of whether these injuries required further surgery.

The dependent variable was subsequent knee injury. Covariates included age, gender, Lachman grade, pivot-shift grade, and use of a functional brace. Univariate and multivariate risk factors for subsequent knee injury were determined. Statistical analysis was performed using SPSS (version 11, SPSS Inc, Chicago, Ill).

## RESULTS

There were 159 individuals who participated in the screening for 1 year and 187 who participated in the screening for multiple years (range, 2-6 years). The study population comprised 820 ACLr employee-skiers at risk of injury for 1 ski season. The mean age at screening was 36 years (range, 18-72 years). The gender distribution was 64% male and 36% female. Bracing was selected in 31% (n = 257) of skiers. Characteristics of the bracing group and the nonbracing group are shown in Table 1.

TABLE 1
Characteristics of Braced and Nonbraced Groups

| | Braced | Nonbraced | *P* |
|---|---|---|---|
| n | 257 | 563 | |
| Mean age, y | 35 | 37 | .02 |
| Gender, % (male:female) | 63:37 | 66:34 | .391 |
| >+1 Lachman, % | 29 | 11 | .000 |
| >+1 pivot shift, % | 22 | 10 | .000 |
| Job distribution, % | | | .223 |
| Ski school | 79 | 72 | |
| Ski patrol | 6 | 9 | |
| Lift operator | 6 | 9 | |
| Skier services and others | 10 | 10 | |
| 1 screening year, % | 42 | 47 | .427 |
| Multiple screening years, % | 57 | 53 | |

TABLE 2
Characteristics of Injured and Noninjured Groups

| | Injured | Noninjured | *P* |
|---|---|---|---|
| n | 61 | 766 | |
| Age, y | 35.2 | 36.3 | .288 |
| Gender, % (male:female) | 52:48 | 66:34 | .035 |
| >+1 Lachman, % | 25 | 16 | .098 |
| >+1 pivot shift, % | 12 | 14 | .589 |

There were 61 subsequent injuries for an incidence of 7.4 injuries per 100 ACLr skiers per ski season. The mean age of the injured skiers was 35.2 years. There was no difference in Lachman or pivot-shift tests between injured and noninjured ACLr skiers (Table 2). Of the 61 subsequent injuries, 28 required knee surgery (3.4 injuries requiring surgery per 100 ACLr skiers per ski season). Of these, 11 individuals (all in the nonbraced group) required revision ACLr.

The injury rate in nonbraced skiers was 9% (51/563). In the nonbraced ACLr group, the injured skiers had a significantly higher proportion of >+1 Lachman than did the noninjured ($P$ = .013) (Table 3). The injury rate in braced skiers was 4.0% (10/257) (Table 4). There was a significantly higher proportion of knee injuries in nonbraced skiers than in braced skiers ($P$ = .009) (Table 5). The ACLr skiers without a brace were at increased risk of knee injury (odds ratio, 2.74; 95% confidence interval, 1.2-4.9). For injuries requiring surgery, the injury rate in nonbraced skiers was 4% (25/563), and the injury rate in braced skiers was 1% (3/257). The ACLr skiers without a brace were at increased risk of knee injury requiring surgery (odds ratio, 3.9; 95% confidence interval, 1.2-12.3).

TABLE 3
Characteristics of Nonbraced Skiers

| | Injured | Noninjured | *P* |
|---|---|---|---|
| n | 51 | 512 | |
| Age, y | 35.5 | 36.8 | .264 |
| Gender, % (male:female) | 51:49 | 68:32 | .019 |
| >+1 Lachman, % | 22 | 10 | .013 |
| >+1 pivot shift | 12 | 8 | .597 |

TABLE 4
Characteristics of Braced Skiers

| | Injured | Noninjured | *P* |
|---|---|---|---|
| n | 10 | 247 | |
| Age, y | 33.5 | 35.1 | .444 |
| Gender, % (male:female) | 60:10 | 63:37 | .855 |
| >+1 Lachman, % | 40 | 29 | .488 |
| >+1 pivot shift, % | 10 | 20 | .462 |

TABLE 5
Characteristics of Injured Braced and Nonbraced Skiers

| | Brace Injured | Nonbraced Injured | *P* |
|---|---|---|---|
| n | 10 | 51 | |
| Age, y | 33.5 | 35.5 | .444 |
| Gender, % (male:female) | 60:10 | 51:49 | .735 |
| >+1 Lachman, % | 40 | 22 | .243 |
| >+1 pivot shift, % | 10 | 12 | .676 |
| Required surgery, % | 30 | 49 | .226 |
| Required ACL reconstruction, % | 0 | 22 | .114 |

Controlling for Lachman, pivot shift, and age, logistic regression modeling identified nonbracing as a significant independent multivariate risk factor for subsequent knee injury (Table 6).

## DISCUSSION

The role of functional knee bracing in the ACLr knee has been poorly studied. However, in a survey of members of the American Orthopaedic Society for Sports Medicine, 87% of respondents always or sometimes brace the ACLr knee.[14] The current study showed that functional bracing after ACL reconstruction in skiers resulted in a lower injury rate. Although use of a brace lowered the injury rate, the brace did not lower the rate to that of a skier without previous ACL injury. In our previous study, we found that skiers with no previous ACL injury had an injury rate of 2.1%, and skiers with an ACL reconstruction had an injury rate of 6.6%.[26] In the current study, we found skiers with an ACL reconstruction who were braced had an injury rate of 4%. The skiers with ACL reconstruction, even when braced, had a higher injury rate than did the skiers without previous ACL injury.

TABLE 6
Multivariate Analysis: Binary Logistic Regression Model[a]

| Variable | (B) | 95% Confidence Interval | *P* |
|---|---|---|---|
| Age | 0.99 | 0.97–1.0 | .74 |
| Lachman | 1.5 | 1.0–2.4 | .05 |
| Pivot shift | 0.837 | 0.50–1.407 | .50 |
| Nonbraced group | 2.5 | 1.2–5.2 | .016 |

[a]Dependent variable was knee injury (yes/no). Statistical analysis was performed with SPSS (version 11.0, SPSS Inc, Chicago, Ill) software package.

Functional bracing is designed to protect the abnormal knee, typically either ACL deficient or ACLr. It has been studied extensively in ACL-deficient knees.[||] Beck et al[4] studied 7 different braces on instrumented laxity in ACL-deficient knees with variable results. Branch et al[8] looked at cutting with and without a brace in 10 subjects with ACL deficiency. A marked decrease in hamstring muscle firing during cutting was seen in the braced limbs, indicating more normalization of function with a functional brace on the ACL-deficient knee during cutting activity. Devita et al[17] found that in subjects with ACL deficiency, a greater proportion of the work performed during running was absorbed by the hip and ankle, thus protecting the knee. Although braces show equivocal ability to normalize the ACL-deficient knee examination, functional knee bracing seems to improve the ability to normalize kinematics of functional activities. Kocher et al,[24] in a study on the ability of functional knee braces to prevent further knee injury in the ACL-deficient knee, found a 6-fold increase in the risk of injury in athletes with ACL deficiency who were not wearing a brace.

Several studies have been done on functional bracing of the ACLr knee.[1,6,7,14,15,33] Beynnon et al[5] looked at the ability of a brace to normalize proprioception after ACL injury and reconstruction. At 2 years after ACL reconstruction, the ability to detect a threshold of passive knee motion had normalized, with or without a functional knee brace.

Functional bracing of the fully rehabilitated knee after ACL reconstruction may have an effect on functional performance. Wu et al[33] studied 31 subjects, 5 months after ACL reconstruction, performing figure-of-8 turns and running, jumping, and landing on a semicircular path. Subjects wore a functional knee brace, a placebo brace, or no brace. Speeds of running and turning were slower in both braced groups compared with the nonbraced group. Birmingham et al[7] studied isokinetic knee flexion strength with and without a custom-fit brace after ACL reconstruction. Overall isokinetic strength at 90 deg/s decreased 7.3% with use of a brace but with high variability. They concluded that a brace may

[||]References 4, 5, 8, 11, 16, 17, 22, 24, 25, 28, 30.

inhibit flexion strength in stronger patients, yet result in improvement in strength of weaker patients.

A limitation of this study was the decision-making scheme of brace use. Because the requirement of a functional knee brace was not based on absolute objective criteria, there may have been characteristics of the 2 groups other than brace use that resulted in different rates of subsequent injury. It is possible that the nonbraced group was more risk takers and that the braced group was more risk adverse. Also, some of the skiers returned for more than 1 year. Although each year was considered 1 ski season "at risk" for injury, some employees did return for multiple years. This may have also allowed for risk characteristics to change over the years. Ideally, in a randomized clinical trial study design, these potential confounders would be distributed evenly between groups owing to randomization. However, this study allowed for information to be collected on a large group of individuals before the at-risk activity and allowed for monitoring of injuries during the at-risk activity.

A second limitation was the identification of subsequent injuries through the resort workers' compensation records. Although the employees had incentive to report potential work-related knee injuries, it is possible that some minor injuries that did not require time off from work resulted in underreporting of injuries. We intentionally did not include injuries to knees that occurred when the individual was skiing while not at work. Not all of these injuries would be reported, and lower compliance of required brace use may be present during nonwork skiing.

A final limitation was an inability to closely monitor brace use during a high-risk sport such as skiing. Although brace use was required if purchased by the employer, there was no interval assessment of compliance with brace use. Despite these limitations, few studies have tracked a high volume of athletes returning to high-risk sports after ACL reconstruction with and without a brace.

This study did not look at the effect of rehabilitative or postoperative bracing in the first 2 years on subsequent laxity or knee function. Rather, we sought to answer the question of whether bracing the fully rehabilitated knee would help lower reinjury rates. In addition, we did not study the effect of bracing on the ability to perform elite-level competitive sports after ACL reconstruction.

In this cohort of ACLr skiers, absence of functional ACL bracing was identified as a univariate risk factor for subsequent knee injury. It is interesting that the braced group actually had looser knees at the beginning of the ski season but had a lower knee injury rate during the course of the ski season. Controlling for age, gender, Lachman, and pivot shift, absence of bracing remained an independent risk factor for knee injury. The ACLr skiers without a brace were estimated to be almost 3 times more likely to sustain a subsequent knee injury. Because of the markedly lower risk of subsequent knee injury, we recommend functional bracing for ACLr skiers with evidence of increased laxity.

## ACKNOWLEDGMENT

Support for this project was provided by Vail Resorts, Inc, and Innovation Sports.

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