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Do Knee Braces Prevent Ski Knee Injuries?

Roberto Negrin,[1,*] Bastian Uribe-Echevarria,[1] and Nicolas Reyes[1]

[1]Department of Orthopaedics and Traumatology, Clinica Las Condes, Santiago, Chile

[*]*Corresponding author*: Roberto Negrin, Lo Fontecilla 441, Santiago, Chile. Tel/Fax: +56-22104000, E-mail: rnegrin@clc.cl

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Abstract

Background: Alpine skiing has high rates of knee injuries. Prophylactic knee braces (PKBs) and functional knee braces (FKBs) are often prescribed by clinicians to reduce injuries or re-injuries in skiers.

Objectives: This literature review evaluates current knowledge on the biomechanical and clinical effectiveness of prophylactic and functional knee braces in preventing knee injuries and their impact on the athletic performance of non-injured and injured individuals.

Methods: A literature review was performed to analyze the efficiency of knee braces concerning the reduction of mechanical stress, influence on muscle control, performance and injury prevention.

Results: Most of the available literature describes research on the use of knee braces in contact sports, specifically American football. In this context, several studies show braces to be more effective in preventing medial collateral ligament injuries than anterior cruciate ligament injuries in both cadaveric and clinical studies. The use of functional braces after anterior cruciate ligament reconstruction has been supported and refuted in both postoperative and long-term studies. Ski-specific studies show a positive effect of knee braces on proprioception; no influence on performance; and a protective effect on previously injured skiers.

Conclusions: Current literature indicates PKBs may have a protective function in healthy patients, while influence on performance is minimal. Functional braces are recommended in ACL-deficient patients and are biomechanically effective under low-loading conditions. They may not be as effective in high-loading conditions, such as athletic activity. There is a protective effect of FKBs of preventing re-rupture of reconstructed ACLs and preventing further knee injuries on ACL-deficient knees in skiers. More research is needed to determine the effectiveness of PKBs snow sports.

Keywords: Knee Injuries, Braces, Skiing, Snow Sports

1. Context

The knee is one of the most frequently injured joints in sports, accounting for up to 60% depending on the evaluated sport, with the anterior cruciate ligament (ACL) representing almost half of these injuries (1).

This is no different for skiers, where recent epidemiological reports show 84 injuries per 100,000 skiers per year (2), with knee injuries accounting for 30-38% of total injuries (2, 3). The most frequently injured structure is the medial collateral ligament (MCL) (38%), followed by the ACL (14%). A different study showed an incidence of 4.2 per 100,000 skier-days for ACL tears in men and 4.4 injuries per 100,000 skier-days for ACL tears in women (4).

ACL injuries often require surgery and long periods of rehabilitation, translating to high healthcare costs, potential long-term consequences and occasional impairment. This fuels the interest of ACL injury prevention research to evaluate intrinsic and extrinsic risk factors and the effectiveness of prevention programs and external aids such as knee braces.

Knee braces have been used for many years to assist ACL deficient (ACLd) or ACL reconstructed (ACLr) knees. Sixty-three percent of orthopedic surgeons prescribe a functional brace after ACL reconstruction (5), translating to 100,000 braces and $60,000,000 USD a year in the United States alone.

Knee braces can be classified into three types: rehabilitation, prophylactic, and functional knee braces. Rehabilitation braces are designed to allow a protected range of motion of injured knees post-operatively. Prophylactic knee braces (PKBs) are designed to prevent or reduce the severity of knee injuries in the uninjured population. These are typically "off-the-shelf" solutions and are not specifically adapted to each individual patient. Their aim is to restrict excessive movement that might be harmful, complementing or reinforcing present ligaments. Functional knee braces (FKBs) are braces designed to provide stability for unstable knees in patients who have already suffered an injury. These are typically custom-made to fit each patient individually and are designed to replace or support the function of a torn ligament. (American Association of Orthopaedic Surgeons. Position paper: the use of knee braces. Rosemont (IL): American Association of Orthopaedic Surgeons, 2004, currently retired) (Figure 1).

Figure 1. Knee Functional Brace in a 17 Years Old Skier from the Chilean Team, Who Recently Had an ACL Reconstruction Surgery, with Bone-Patellar Tendon- Bone Technique

In contrast with broad post-operative use of braces, there is comparatively little use of prophylactic knee braces, and also scant investigation into their effectiveness preventing injuries in the healthy population.

The purpose of this literature review is to evaluate current knowledge on the use of braces in winter sports, specifically the biomechanical and clinical effectiveness of prophylactic and functional knee braces in preventing injuries and their impact on the athletic performance of injured and non-injured individuals.

2. Evidence Acquisition

We performed a PubMed, Google Scholar, and Ovid search of the terms "alpine skiing," "winter sports," "ski," "functional knee brace," and "prophylactic knee brace." The search included English-, Spanish-, and German-language articles. Articles were cross-referenced to identify publications that were not located during the original database search.

Due to the paucity of specific studies regarding winter sports, the search was extended to include relevant studies regarding PKBs and FKBs in other sports, previous literature reviews, one systematic review of bracing in collegiate football players, and two books containing the proceedings of the international congress on Science and skiing. Any relevant findings on bracing in sports were summarized. Studies addressing winter sports were highlighted when data was available.

3. Results

3.1. Biomechanical Effects of Bracing

PKBs and FKBs are designed to either reinforce or replicate the function of the ACL or other ligaments. Several studies have confirmed both their effectiveness and their limitations in this regard. The ACL is a primary restrictor of the anterior translation of the tibia and a secondary restrictor of internal rotation and varus-valgus stress.

Biomechanical in vivo studies with transducers attached to the ACL have evaluated the ability of braces to shield the ligament when these forces are applied to a healthy knee, both while bearing weight and not bearing weight. The results show that functional knee braces are able to reduce the strain on the ACL when anterior shear forces up to 130 N are applied in non-weight-bearing and weight-bearing conditions (6). They can also reduce strain on the ACL for internal torques applied to the tibia up to 9 Nm in a non-weight-bearing condition when compared to an unbraced knee, but did not reduce strain values on the ACL when the knee was subjected to external torques (9 Nm) or varus-valgus moments (10 Nm) in weight-bearing and non-weight-bearing conditions (6, 7).

This protection can be put in perspective when compared to forces everyday activities exert on the ACL. Walking on a flat surface produces a strain of 169 N (8). Peak forces on the ACL occur at the beginning of single-leg stance (i.e., contralateral toe-off) achieving 303N, well over the measured shielding ability of evaluated braces (9). Descending stairs can elevate the strain to 455 N (8).

Similarly, functional braces appear to have a corrective role on ACLd knees, but do not fully normalize biomechanics.

One study evaluating activities like stair descending, pivoting, and landing from a platform and subsequent pivoting showed decreased excessive internal rotation in ACLd knees with use of FKB, but the brace did not fully restore values of a normal knee (10).

A similar study evaluating anterior displacement of the tibia showed fabric-based knee braces limiting anterior translation up to 2.8 mm of displacement in ACL deficient knees during low-demand activities, thus replacing the passive mechanical role of the ACL. This strain-shielding effect did not occur at the higher anterior shear loads expected during the high-stress activities common to athletic events (11).

Most biomechanical studies show a positive effect of braces when studying passive loads applied to the knee when wearing a brace, although these effects are limited to low-loading conditions and will not fully normalize knee motion in unstable knees.

A study with an altogether different approach evaluated the effect of a PKB during dynamic activities such as drop-landing in a high risk subject (12). They compared ACL strain in braced and unbraced conditions, showing that wearing the knee brace resulted in a 55% reduction in peak ACL strain. However, according to the authors, the reduction was a result of altered muscle-firing pattern due to the presence of the brace, rather than its mechanical effect, potentially reducing ACL injury risk (12).

This appears to correlate with the demonstrated effect on peripheral proprioceptive input to the knee joint by means of a brace or sleeve, which seems to influence brain activity during knee movement, as measured by functional magnetic resonance imaging (fMRI) of the primary sensorimotor cortex and in the left superior parietal lobule of the brain (13). Additionally, the intensity of brain activation during knee movement can be influenced by the intensity of proprioceptive stimulation at the joint, when comparing a sleeve to a brace.

A study on skiers by Nemth and Lamontagne (14) evaluated electromyographic changes with and without custom functional braces in a group of six expert downhill skiers with various degrees of anterior laxity after ACL injuries during downhill skiing in a slalom course. Synchronized video and EMG recording allowed for evaluation of muscle activity and patterns during different phases of downhill skiing. With use of the brace, there was an increase in electromyographic activity in midphase, a change in firing pattern, and a decrease in electromyographic activity in the contralateral uninjured leg. The authors suggested that there was increased afferent input from proprioceptors, resulting in an adaptation of motor control patterns secondarily modifying electromyographic activity and timing. More clinical instability also correlated with stronger activation of the biceps femoris of the injured leg (14).

This indicates that knee braces could not only have a mechanical role in shielding the ACL from strain and possibly from injuries, but could also have a positive impact on proprioception and neuromuscular control, something that has been demonstrated by several different studies (14-18).

3.2. Influence on Performance

Findings regarding the influence of knee braces (PKBs and FKBs) on athletic performance are contradictory. Current literature appears to indicate that knee bracing has the potential to impact performance via several mechanisms, including changes in proprioception and neuromuscular control as in the Nemth and Lamontagne study (14) in addition to mechanical effects like restriction of movement and muscle compression. Much of the current data is contradictory, perhaps due in part to differences in brace design and construction.

Negative effects have been reported, such as increased oxygen consumption, increased heart rate and respiratory rate (19), and reduced speed and agility in the instance of brace slippage (20). Straps can increase compartmental pressure, reducing muscle perfusion and increasing fatigue (21). Regarding strength, there are conflicting results, showing both increase and decrease in strength even within the same study, with different results for different braces (22).

Athlete adjustment to the brace seems to be possible in terms of reaction, fatigue, and performance (23, 24). After 14 hours of brace use, no differences in braced and non-braced groups were found, suggesting the need for an adaptation phase before engaging in full sport activity (24, 25).

Specifically regarding skiers, Spitzenpfeil presented a study evaluating the influence of a custom knee brace in professional downhill skiers in the Fifth international congress on Science and skiing in 2013 (Erich Muller, Meyer and Meyer Verlag, Science and Skiing Volume V, 2012). Three skiers completed several runs with and without a custom knee brace on a slalom course. Racing times were recorded. The skiers did a total of 9 runs. The first 3 were completed while wearing a brace, and showed a decrease in racing times, potentially due to the learning effect of repeating runs. Runs 4 - 6 were completed without a brace, and showed a leveling of racing times. Runs 7 - 8 were completed again with a brace, demonstrating an insignificant increase in racing times. Run 9 was completed without a brace and no changes were observed.

The skiers reported a subjective negative influence on agility and speed of movement, uncomfortable pressure of the hard material of the brace at fixing points, and a subjective feeling that an injury might be prevented.

This study has a very small sample and not all the subjects completed all runs. Nevertheless, it demonstrates that professional skiers' racing times with and without a brace can be similar.

Based on this study and the subjective negative influence reported by the skiers, the same group is currently developing a preventative knee brace specifically for alpine ski racing in an attempt to optimize the brace's contact and fixation points. This is based on their own study of surfaces that do not extend or contract with knee flexion-extension movements and areas of no or minimal volumetric changes during runs. The developed brace, still in the testing period, showed comparable values for jumping, concentric, and eccentric isokinetic testing with and without knee bracing in skiers (Erich Muller, Science and skiing VI, Meyer and Meyer Sport, 2014).

3.3. Clinical Studies

There is a dearth of clinical studies relevant to the potential efficacy of either functional or prophylactic knee bracing in skiers. Most of the clinical literature regarding the use of PKBs or braces in sports come from American football. Results are again conflicting regarding their efficacy in preventing knee injuries.

There are two major studies in favor of PKB use. One level I randomized controlled trial on 1396 military cadets participating in intramural tackle football (26) showed significant differences between braced and unbraced groups. This supports the use of PKB in American football players, reducing medial collateral ligament injuries and overall knee injuries ($P < 0.05$). It did not, however, show a significant reduction in ACL injuries or the severity of the knee injuries. Most of the mechanisms described involved lateral knee contact, making the results less applicable to winter sports.

The other study, a non-randomized level 2 prospective cohort study on protection against medial collateral ligament sprains in 987 collegiate football players, showed a non-significant trend towards lower injury rate in braced players (27).

Three prospective cohort studies showed no significant differences between braced and unbraced groups (28, 29) and three level 2 prospective cohort studies showed the following results when using a PKB: an increased injury rate (30-32), increased ACL injuries (6.1/7.5 injuries per 100 players, no P value provided) (30), and increased ipsilateral foot and ankle injuries ($P < 0.01$) (32). Additionally, the use of braces was associated with increased episodes of muscle cramping and called for coaches and trainers to remind the players to wear the braces and to apply them correctly (30).

Several systematic reviews have tried to evaluate the effectiveness of PKB. They arrive to similar conclusions: there are some data suggesting that bracing may be effective preventing and reducing severity of MCL injuries, but there is no conclusive evidence for PKB decreasing the rate or severity of ACL injuries in football players (1, 33, 34).

One study evaluating the use of prophylactic knee bracing in off-road motorcycling showed a higher rate of overall injury, ACL injury, and MCL injury in the non-braced group (35). Because of the specific traumatic mechanisms of off-road motorcycling, it may not be possible to extrapolate the results to other sports, such as skiing.

A prospective randomized multicenter study in a captive population (3 US service academies), evaluated efficacy of FKBs after anterior cruciate ligament reconstruction (36). The braced group was instructed to wear an off-the-shelf functional knee brace for all cutting, pivoting, or jumping activities for the first year after surgery. Ninety-five ACLr patients were randomized for use of brace. The results showed no change in clinical outcomes or stability with similar re-injury rates (4.3% in the braced group vs. 6.3% in the non-braced group), showing similar clinical and functional results after a 2-year follow up regarding knee stability, functional testing with the single-legged hop test, IKDC scores, Lysholm scores, knee range of motion, and isokinetic strength testing.

There are, to our knowledge, two clinical studies evaluating FKB in skiers. A study by Kocher, Sterett et al. in 2003 showed the effect of FKBs in a cohort of 180 ACLd professional skiers identified by both physical and instrumented exams (positive pivot-shift or Lachman tests and positive manual maximum KT-1000 $\geq$ 5 mm) (37). The study was non-randomized and use of the brace was determined by shared doctor/patient decision-making after a counseling session. Subsequent knee injuries were identified through workers' compensation claims and included meniscus tears, ligamentous sprains, and tears that required time off work.

In the Kocher study, 101 subjects decided to wear a FKB. Two of them (2%) suffered a subsequent knee injury, compared with 10 out 79 patients in the non-braced group. This difference was shown to be significant (P = 0.006), with an OR of 6, 4. The authors noted that patients with a higher degree of knee laxity, as measured with manual maximum KT-1000 going into the study, had a higher tendency to choose the use of a brace, suggesting a bias towards bracing in more lax knees. When knee laxity and other covariates in the multivariate analysis are controlled for, bracing retains its independent association with less risk of subsequent knee injury and OR increases to 8.0.

One limitation of this study was the lack of image confirmation of ACLd patients and the fact that only 11% of patients had symptoms of giving-way, suggesting the cohort of ACLd skiers was comprised predominantly by copers (37). The subset of functionally unstable patients did not show an increased proportion of subsequent knee injuries, according to the authors.

The second clinical investigation evaluating FKB in skiers is a prospective cohort study of the effects of functional bracing in skiers with ACL reconstruction. In this study, Sterret followed a group of 820 ACLr professional skiers (38). The skiers were employees at a major ski resort and had undergone an ACLr at least two years before enrolling in the study. Re-injuries were also defined as any new knee injury that required time off work and generated a workers' compensation claim.

As in the previous study, patients were not randomly assigned. Two-hundred fifty-seven chose to use a brace, while the remaining 563 preferred not to use one. Sixty-one new injuries were recorded. The non-braced group showed a higher risk of recurrent knee injuries with an incidence 8.9 vs. 4.0/100 knees per ski season (OR 2.7). This group also showed an increased need for a subsequent knee surgery with an incidence of 4.0 vs. 1.0/100 knees per ski season (OR 3.9, P = 0.009). Brace use did not lower the injury rate to that of a skier without previous ACL injury (2.1% vs. 4%) (38).

The Kocher and Sterett studies show a decreased knee injury rate with FKBs in ACLd and ACLr patients. These studies were non-randomized and the decision to wear a brace could be influenced not only by the presence or absence of clinically significant knee instability, but also by other factors that are more difficult to control for, such as skiing behavior. It is possible that that the non-braced group featured a higher percentage of risk-takers, which may have led to the decision to not wear a brace, and could have also increased the likelihood of exposure to situations making this group more prone to knee injury.

The current knowledge of FKBs cannot be directly extrapolated to PKBs in uninjured skiers, due to the lack of clinical studies regarding this specific issue.

4. Conclusion

The current literature indicates that much more is known about functional bracing than prophylactic bracing, likely due to the widespread use of functional knee bracing in post-operative care.

Functional braces are recommended in ACL-deficient patients and are biomechanically effective under low-loading conditions. They may not be as effective in high-loading conditions, such as athletic activity.

For skiers, there is a protective effect of FKBs in preventing re-rupture of reconstructed ACLs and preventing further knee injuries on ACL-deficient knees.

There is need for additional biomechanical and clinical research into the efficacy of prophylactic bracing. However, the available research does indicate that PKBs may have a protective function in healthy patients. Influence on performance appears to be minimal.

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