Anterior cruciate ligament injury and knee braces – perspectives for prevention and treatment. A review

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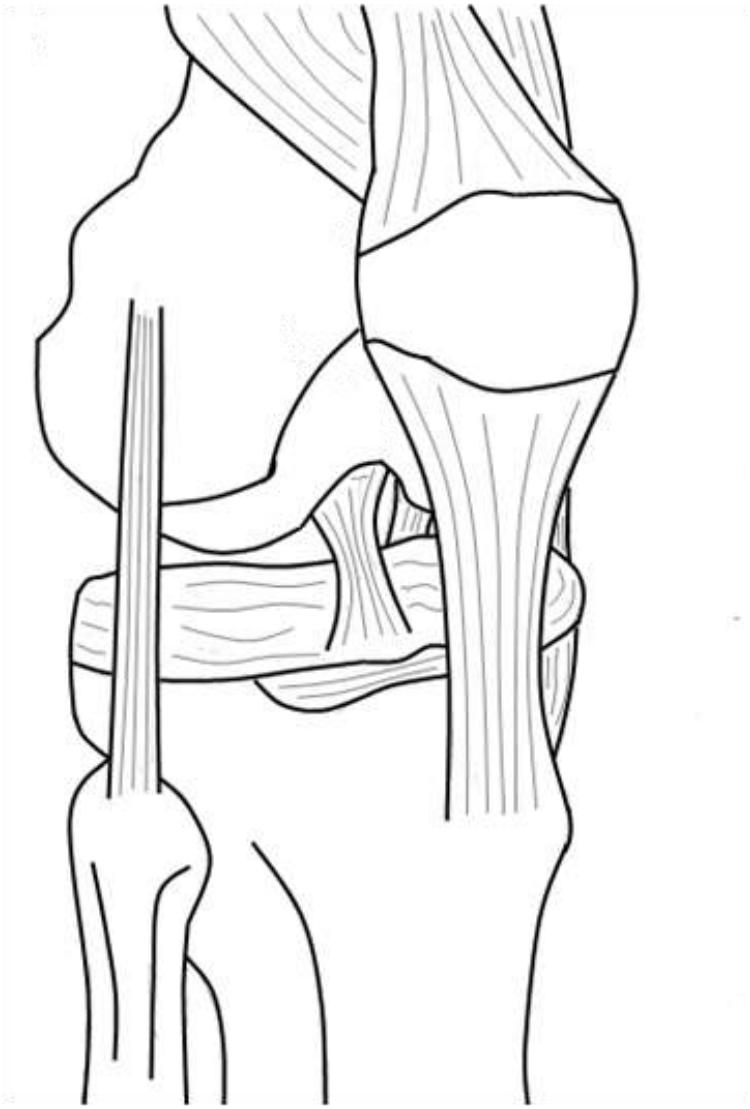

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This paper reviews the research of bracing within the last 15 years in The American Journal of Sports Medicine. The primary focus will be on the role of anterior cruciate ligament (ACL) injuries and ACL reconstruction and braces, both before and after an injury occurs.

ACL injuries are costly and have devastating consequences for the patients' activity level and life quality. In the US approximately 200.000 ACL reconstructions are done annually at a total cost of $4 billion for the surgeries alone (Liu, et al., 2014).
In sports medicine one of the largest tasks are to prevent and minimize knee injuries and therefore many orthotic devices have been developed, such as knee braces (Mortaza, et al., 2012) (Baltaci, Aktas, Camci, Oksuz, & Yildis, 2011).
It has been stated that non-contact movements are responsible for 78% of ACL injuries (Bowerman, Smith, Carlson, & King, 2006).

Conclusion: Rehabilitation braces do what it is made to do but have on long term effect on the outcome. Both in non weight-bearing and weight-bearing situations a FKB reduces the anterior-posterior laxity and shear loading which is positive for athletes with ACL and PCL problems to avoid further injuries. PKB have an overall positive effect by reducing the rate of knee injuries. Some PBK's reduce forward speed and agility. So which brace should be used depends on the specific sport.

Content

Anterior cruciate ligament injury and knee braces – perspectives for prevention and treatment. A review

Abstract

This paper reviews the research of bracing, rehabilitation braces, functional knee braces (FKB) and prophylactic knee braces (PKB) within the last 15 years in The American Journal of Sports Medicine. The primary focus will be on the role of anterior cruciate ligament (ACL) injuries and ACL reconstruction and braces, both before and after an injury occurs. The classifications of the braces made by the American Association of Orthopaedics Surgeons were the rehabilitation braces, designed to protect ROM post-surgery. The functional knee braces (FKB) are custom-made and designed to provide stability in an unstable knee joint. The prophylactic knee braces (PKB) which are "off-the-shelf" (OTS) braces are designed to reduce the severity and prevent knee injuries (Rishiraj, Taunton, Lloyd-Smith, Woollard, & Regan, 2009). ACL injuries are costly and have devastating consequences for the patients' activity level and life quality. In the US approximately 200.000 ACL reconstructions are done annually at a total cost of $4 billion for the surgeries alone (Liu, et al., 2014). The use of PKB has increased in sports thereby trying to decrease the severity of the knee injuries and reduce the number of knee injuries (Greene, Hamson, Bay, & Bryce, 2000). In spite of the fact that the use of PKB in sports to prevent or reduce knee injury has been evaluated the conclusions differ and the topic remains controversial (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011).

Conclusion: Rehabilitation braces does what it is made to do which is to prevent flexion during the early healing phases and can be beneficial in the early phases of recovery but have no long term effect on the outcome. Both in non weight-bearing and weight-bearing situations a FKB reduces the anterior-posterior laxity and shear loading which is positive for athletes with ACL and PCL problems to avoid further injuries. PKB have an overall positive effect by reducing the rate of knee injuries. Some PBK's reduce forward speed and agility so which brace should be used depends on the specific sport.

Keywords: knee braces – ACL injury.

Introduction

At the American Association of Orthopaedics Surgeons in 1985 there were established three distinct brace classifications. Knee braces are designed to reduce or prevent the severity of knee injuries (Rishiraj, Taunton, Lloyd-Smith, Woollard, & Regan, 2009). A knee brace should provide support and at the same time it should not impair the performance of the knee joint.

In sports medicine one of the largest tasks are to prevent and minimize knee injuries and therefore many orthotic devices have been developed, such as knee braces (Mortaza, et al., 2012) (Baltaci, Aktas, Camci, Oksuz, & Yildis, 2011). Even though the risk varies between the difference sports. It is estimate that 15-50% of all injuries are related to the knee (Houck, 2003) (deLoes, Dahlstedt, & Thomee, 2000). The biggest part of knee injuries involves the anterior cruciate ligament (ACL) (Houck 2003).

The classifications of the braces are made by the American Association of Orthopaedics Surgeons were; the rehabilitation braces, designed to protect the range of motion (ROM) post-surgery. The functional knee braces (FKB) are custom-made and designed to provide stability in an unstable knee joint. The prophylactic knee braces (PKB) which are "off-the-shelf" (OTS) braces are designed to reduce the severity and prevent knee injuries (Rishiraj, Taunton, Lloyd-Smith, Woollard, & Regan, 2009).

ACL injuries are costly and have devastating consequences for the patients' activity level and life quality. In the US approximately 200.000 ACL reconstruction are done annually at a total cost of $4 billion for the surgeries alone (Liu, et al., 2014). ACL injuries are a major inducer of osteoarthritis even after a successful ACL reconstruction early osteoarthritis in the knee joint is likely. A number for training programs have been designed trying to prevent ACL injuries but these takes 15-90 extra minutes of training time and most of them requires assistance or instructions from professional personnel which is an obstacle for many athletes (Liu, et al., 2014).
The use of PKB has increased in sport thereby trying to decrease the severity of the knee injuries and to reduce the number of knee injuries. It has been stated that a OTS PKB compared to a non-braced condition provides 20-30% greater resistance to a lateral blow in full extension, FKB doubled the protective effect and proved some effect in flexion (Najibi & Albright, 2005), (Greene, Hamson, Bay, & Bryce, 2000). In spite of the fact that the used of PKB use in sport to prevent or reduce knee injury has been evaluated the conclusions differ and the topic remains controversial (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011). A few studies have investigated the effect a knee brace have on the athletes' performance ability. These studies have focused on the effect of a FKB on intramuscular pressure, muscle performance, knee joint kinematics and the associated energy cost. It has been suggested even though the functional performance studies are not consistent, that a preventative knee brace may slow down straight ahead sprinting speed, cause early fatigue, increase energy expenditure, increase blood lactate levels, heart rate and oxygen consumption (Najibi, Albright 2005).

Rehabilitation braces are primary used to prevent flexion during the early healing phase. Rehabilitation braces seems to have a positive influence in the early recovery phase after an ACL reconstruction. The use of a rehabilitation brace results in fewer problems concerning swelling, wound drainage and less pain in the rehabilitation compared to rehabilitation without a brace. Over a longer period a rehabilitation brace does not appear to have effect of the ROM, activity level or function (1-legged hop test and thigh muscle strength). (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005).
A study found that FKB did not have an effect on the knee joint regarding ROM, laxity, strength, in functional knee tests, patient satisfaction or pain. They did not find evidence to support that the use of FKB after ACL reconstruction can reduce the risk of a re-injury or evidence to use a FKB after ACL reconstruction (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005).

In spite of the fact that the use of PKB used in sport to prevent or reduce knee injury has been evaluated the conclusions differ and the topic remains controversial (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011). The use of PKB has increased in sport thereby trying to decrease the severity and to reduce the number of knee injuries. It has been stated that a OTS PKB compared to a non-braced condition provides 20-30% greater resistance to a lateral blow in full extension also that FKB doubled the protective effect and proved some effect in flexion (Najibi & Albright, 2005), (Greene, Hamson, Bay, & Bryce, 2000). A study found that it appears using a PKB has a positive effect to prevent and reduce ACL and MCL injuries and reduce the overall rate of knee injuries in off-road motorcycling riders. They believe these findings can be applied on other sports (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011).

A study by Greene (2000) looked into the effect of PKB on the speed and agility for athletes and the braces tendency to migrate. They made a 40-yard dash and a four-cone drill in full gear. Both tests were made with brace on both knees and without braces. Subjects did not have any history of knee injuries or knee

instability. 30 college football players between the ages 18-22 is tested. 6 braces were tested; DonJoy Lenged, Breg Tradition, OMNI-AKS 101W, McDavid Knee Guard, Air Armor knee 1 and 2**.** Result: in the 40-yard dash all braces expect the Air Armor 1 and OMNI were significantly faster then they other braces but significantly slower than without braces. In the four-cone drill the Air Armor 2 and OMNI were significantly faster than the other braces and the Breg was significantly slower than without braces. In both tests the braces showed different migration distances. Data showed that the six tested braces had different effects on speed and agility. Some for the tested PKB reduced the forward speed and agility significantly compared to the non-braces situations and some did not. There is a significant difference in brace migration but it is not known how much the brace needs to migrate before significantly altering the joint kinematics (Greene, Hamson, Bay, & Bryce, 2000).

The debate on the knee braces effect is caused by inconsistencies studies. These inconsistencies can be seen in the next section where different studies show different result on the subject. The aim of this review is to gather and sum up the newest knowledge within the topic. Thereby making a conclusion on whether these braces actually have an effect on the knee joint both positive but also if they have a negative effect. This subject is in continues research and therefore my conclusion is done based on what is known today.

Background

Knee braces were introduced in the 1970's and in the beginning manly used for rehabilitation. The Anderson Knee Stabler became available for professional athletes in 1979 and this brace was made to prevent re-injury after medial cruciate ligament (MCL) injuries (Greene, Hamson, Bay, & Bryce, 2000). After the Anderson Knee Stabler brace was introduced many difference brace types from numerous manufacturers' were designed to prevent MCL and ACL injuries (Rishiraj, Taunton, Lloyd-Smith, Woollard, & Regan, 2009). A knee brace should allow the knee joint to function normal, and make it possible for an athlete to continue participating in sports, instead of reducing their performance level. But when an external device like a knee brace is applied on the joint is might alter the mechanics. Trying to prevent decreasing performance levels there are factors that should be taking into consideration when design a brace; the weight of the brace, hinge friction, completeness of fit, migration, strap tightness and lack of physiologic kinematics (Houston & Goemans, 1982), (Greene, Hamson, Bay, & Bryce, 2000)).

Due to the high rate of knee injuries in sport it is important to see how these can be prevented or their severity reduced. It is estimated that 15-50% of all injuries are related to the knee (Houck, 2003), (deLoes, Dahlstedt, & Thomee, 2000) and the biggest part of knee injuries involves the ACL (Houck 2003). Some claim that contact with another player causes 61% of game injuries (Agel et al. 2007), it is not only in contact sports like handball and basketball, which involve ballistic movements and weight bearing rotations, where the risk of knee injuries are high but also in individual sports like skiing (deLoes, Dahlstedt, & Thomee, 2000), (Lewis, 2000). It has been stated that non-contact movements are responsible for 78% of ACL injuries. These non-contact movements which causes ACL injuries are: straight knee landing, sudden deceleration, pivoting, sudden change in body direction following a foot to ground contact and one-step landings where the knee hyperextend (Lewis, 2000), (Bowerman, Smith, Carlson, & King, 2006).

There are many different methods to test how a brace affects the knee joint. Some look at the performance level of the athletes while others focus on the clinical changes in the knee joint. Even after many years of testing both clinical outcomes, biomechanical protection and on-the-field performances, there are still no

final conclusion on how these braces effect the knee joint (Greene, Hamson, Bay, & Bryce, 2000). Studies which have been looking on the athletic performance levels have been focusing on how the brace effect intramuscular pressure, muscle performance, knee joint kinematics and the associated energy cost. Even though inconsistent results, it have been suggested that knee braces may decrease an athlete's straight ahead sprint speed, increase energy expenditure, blood lactate, heart rate, oxygen consumption and cause early fatigue (Najibi, Albright 2005). A study observed a change during the stance phase when running in the knee joint position while wearing a PKB compared to a non-braced situation. It was also observed that at the ROM of the hip and ankle significantly altered which indicates that wearing a knee brace might affect the kinematics of adjacent joints (Najibi, Albright 2005). Not all studies can confirm that change in the performance level due to the use of a knee brace. A study by Mortaza et al. (2004) did both isokinetic and functional tests of one PKB and two neoprene sleeves on healthy athletes and found no significant difference between the four conditions (PKB, two neoprene sleeves, non-braced). The tests used was jump height, cross-over hop distance, peak torque to body weight ratio and the average power (Mortaza et al. 2012).

Knee joint

The knee joint is a synovial joint and is the most complicated joint and the largest in the body. It is the space between the articulating bones that characterize this joint and the synovial cavity allows the knee joint to move more freely. Accompanied with the synovial knee joint is ligament, which lies both on the inside and outside of the articular capsule. This ligament known, in the joint, as the LCL (Lateral Cruciate Ligament, on the fibular) and the MCL (Medial Cruciate Ligament, on the tibial) lies outside the articular capsule and gives strength and stability to the knee medial and lateral. Inside the articular capsule lie the ACL and posterior cruciate ligament (PCL) (see figure 1). The ACL is either torn or stretched in 70% of all knee injuries. ACL and PCL limit the movement of the femur both anterior and posterior and keep the alignment of the femur with the tibia (Tortora & Derrickson, 2007).

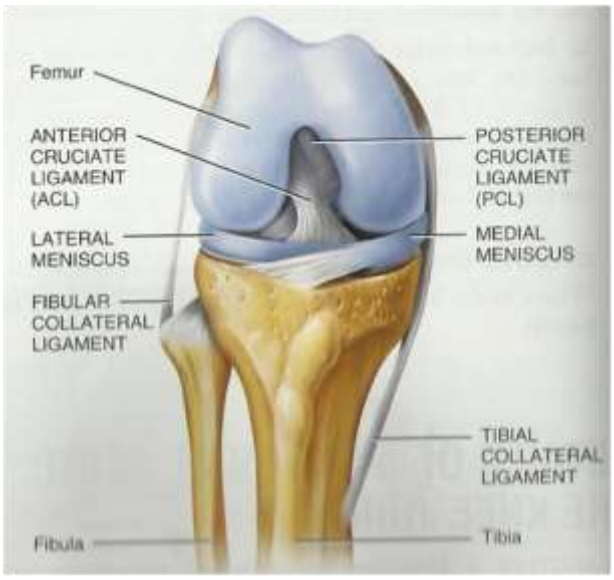

Figure 1 shows a knee joint and where ACL, PCL, MCL and LCL are placed (Tortora & Derrickson, 2007).

Anterior Cruciate Ligament reconstruction

Due to conflicting conclusions regarding the effect of braces after an ACL reconstruction a study by McDevitt et al. (2004) wanted to determine the effect of a FKB after an ACL reconstruction. They tested 100 subjects who had received surgically treatment within 8 weeks after an ACL tear. The subjects were randomized into a braced and a non-braced group. The only difference between the groups were that the braced group were instructed to use an OTF FKB the first year after surgery for all activities involving cutting, pivoting and jumping. Data showed no significant difference between the two groups in the tests; knee stability, single-legged hop test, strength and ROM. Two subjects in the braced group and three subjects in the non-braced group had re-injuries. McDevitt et al. concluded that postoperative bracing after ACL reconstruction does not appear to have any effect (McDevitt, et al., 2004).

A study by Beynnon et al. reached the conclusion that rehabilitation braces seems to have a positive effect in the early recovery phase after ACL reconstruction, giving fewer problems concerning swelling, wound drainage and less pain in the rehabilitation compared to rehabilitation without a brace. They reached the conclusion that there was no evidence to support the use of FKB after an ACL reconstruction. (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005).

A study including 820 skiers with an ACL reconstruction (257 using FKB after injury) by Sterett et al found that the group of skiers who did not use an FKB had an 8.9% risk of getting a re-injury. The risk for getting a re-injury was 4% for the group of skiers who used a FKB. The non-braced group was 2.74 times more likely to get a re-injury. On the background of this study Sterett et al. recommended skiers with an ACL reconstruction to use an FKB in trying to prevent a re-injury (Sterett, Briggs, Farley, & Steadman, 2006).

A study by Birmingham et al. compared rehabilitation braces to sleeves in a randomized controlled trial for post op knee surgery. The patients wore either a brace (62) or neoprene sleeve (65) in 6 weeks after an ACL reconstruction and the patients were assessed 12 and 24 months post op. The outcomes showed no significant difference between conditions comparing the outcomes after 12 months and 24 months. They reached the conclusion that braces do not result in a superior outcome compared to a neoprene sleeve after ACL reconstruction (Birmingham, et al., 2008).

Another study focusing on subjects after an ACL reconstruction concluded that the asymmetry between the knees rises concern regarding reinjuring the graft or the contra lateral knee after returning to sport. Dai et al. tested 23 adolescent patients 6 months after an ACL reconstruction. They used a FKB with extension–resistant to see if it would decrease the limb asymmetry during a 35° side-cutting task both preformed with and without FKB. Kinematic and kinetic data were obtained on both the effect knee and the healthy knee. The data showed that the effected knee had a significant decrease both non-braced and braced when comparing to the healthy knee. When braced, the data showed an increase in the effected knee in the initial knee flexion velocity and a decrease in the effect knee in the initial knee flexion angle (see table 1).

Both non-braced and braced, effected knee vs. healthy:			
	Effected knee	Healthy knee	Statistical power
peak impact vertical ground-reaction force	2.55 BW	2.8 BW	P < .01
peak propulsion vertical ground-reaction force	2.15 BW	2.3 BW	P <.01
peak knee extension moment	0.13 BW 3 BH	0.17 BW 3 BH	P <.01
knee flexion angle at peak knee flexion velocity	27.8°	30.0°	P = .01
peak knee flexion angle	44.1°	48.5°	P<.01
peak knee flexion velocity	571.3 deg/sec	640.1 deg/sec	P <.01
Effected knee when knee braced:			
initial knee flexion velocity	42.4 deg/sec	240.2 deg/sec	P = .01
knee flexion angle	13.1°	15.7°	P<.01

Table 1 shows the results from a study by Dai et al. BW stands for Body Weight and BH stands for Body Height (Dai, Butler, Garrett, & Queen, 2012).

The FKB did not decrease the asymmetry between the effected knee and the healthy knee. Kinematics where affected on both knees. Dai et al. concluded that there were a significant kinematic and kinetic asymmetry between the effect knee and the healthy knee in adolescent 6 months post op after ACL reconstruction. This asymmetry was persistent while wearing a FKB. In the effected knee there were kinematic changes with and without the FKB, particularly just before ground contact. (Dai, Butler, Garrett, & Queen, 2012)

Anterior Cruciate Ligament injuries

Another study evaluated ACL strain response in braced/non-braced in both with and without external loads. This study by Fleming et.al tested 11 subjects with a knee flexion at 20° and the external load applied on the tibia in three test; 1. Anterior-posterior shear force. 2. Internal-external torques. 3. Varus-valgus moments. Their results showed that the brace reduced significantly strain values for anterior shear loads up to 130 N compared to non-braced both in weight-bearing and non weight-bearing. For the internal torques strain was significantly less in the braced condition compared to non-braced condition in the non weight-bearing tests. Strain was not reduced when the knee were subjected to external torque or varus-valgus moment. Fleming et.al concluded that they data indicate that a FKB can protect ACL during anterior-posterior shear loading in both weight-bearing and non weight-bearing and during internal torques in non weight-bearing knee (Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000).

A controlled laboratory study (Beynnon, Fleming, Churchill, & Brown, 2003)tested the anteropsterior shear and compressive loads applied to the knee and tested the translations of the tibia relative at the femur. It concluded that subjects with ACL deficient's can obtain some control of pathologic anteroposterior laxity but might still experience abnormal translations during physical activity while wearing a brace. They tested subjects with chronic ACL tears in non weight-bearing also throughout the transition to weight-bearing, and during weight-bearing both with and without braces. The data showed significant reduced laxity values of the anteroposterior when bracing an ACL deficient knee joint. The reduction of the laxity values came within the limits of what is expected for a healthy knee joint during non weight- bearing and weight-bearing postures. During transitioned from non weight-bearing and weight-bearing they found at bracing did not

reduce the anterior translation of the tibia relative to the femur. Instead their data showed at the anterior translation of the tibia relative to the femur were 3.5 times greater in an ACL deficient knee joint then in a healthy knee joint. They also reached a conclusion that bracing was effective in reducing anteroposterior laxity values both in non weight-bearing and weight-bearing situations for a knee joint with ACL deficiency. Bracing however did not reduce the anterior translations (Beynnon, Fleming, Churchill, & Brown, 2003).

Sanders et al. tested 2115 off-road motorcycle riders using a commercially PKB in off-road motorcycling. Data was collected during a time period for 1 year where 39.611 riding hours were recorded. Data showed a significantly higher rate of overall knee injuries 3.675 vs. 1.587 per 1000 rider hours, P<.001 with the group of non-braced riders compared to the braced group. Among the non-braced riders data showed higher incidence rate of ACL ruptures (1.518 vs. 0.701 per 1000 rider hours, P = .0274) and MCL injury (0.799 vs. 0.111 per 1000 rider hours, P = .002) compared to the braced riders (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011) (see figure 2).

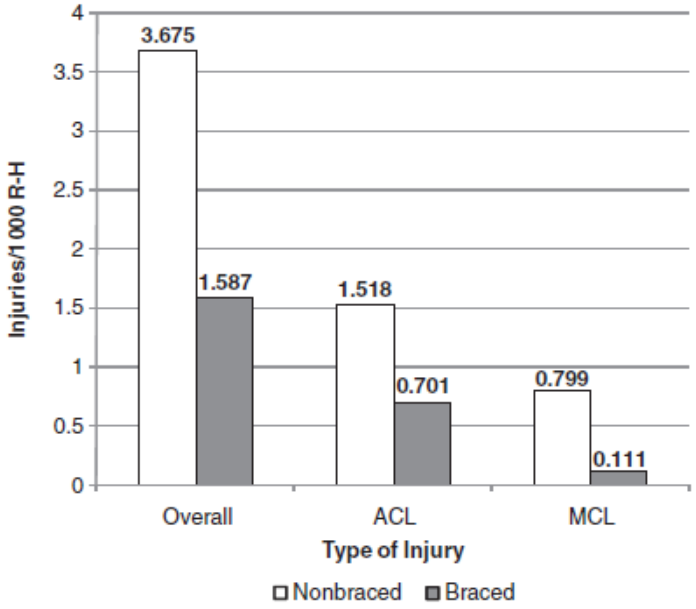

Figure 2 shows the overall, ACL and MCL injury rate pr. riding hours within the two groups. (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011)

Sanders et al. concluded that use of a PKB has a positive effect to prevent and reduce ACL and MCL injuries and reduce the overall rate of knee injuries. The findings might be applicable to other sports (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011).

Overview

Table 2 below shows an overview over the articles conclusion and whether the subject used were healthy or not and whether the subjects were use to wearing a brace or not. As it can be seen most of the positive results have involved subjects who have been use to wearing a brace. The results differ but it might have an influence whether the subjects were use to wearing braces before testing or if it was the subjects first time wearing a brace.

Article	Subjects	Conclusion	Outcome
		Rehabilitation Braces	
Birmingham et al. 2008	Post op subjects Not used to wearing a brace	Rehabilitation braces have no effect on the outcome after ACL surgery	-
Beynnon et al. 2005	Post op subjects Not used to wearing a brace	Rehabilitation braces have some beneficial effect in early recovery But no effect on the outcome.	- (+)
		Prophylactic Knee Braces	
Greene et al. 2000	Healthy subjects Not used to wearing a brace	PKB gives 20-30% greater resistances to a lateral blow How the braces effect the knee joint differs between the difference brace types	+
Sanders et al. 2011	Active athletes Use to wearing a brace	PKB prevent and reduce ACL injuries	+
Mortaza et al. 2012	Healthy subjects Not used to wearing a brace	PKB have no effect	-
		Functional Knee Braces	
Sterett et al. 2006	Post op subjects Use to wearing a brace	FKB Reduce ACL re-injuries	+
Fleming et al. 2000	Healthy subjects Not used to wearing a brace	FKB protect ACL during shear-loading	+
Beynnon et al. 2003	Post op subjects Use to wearing a brace	FKB reduce laxity values in a knee with ACL deficiency	+
Najibi et al. 2005	Healthy subjects Not used to wearing a brace	FKB gives protection in extension and some in flexion	+
McDevitt et al. 2004	Healthy subjects Not used to wearing a brace	FKB have no effect	-
Dai et al. 2012	Post op subjects Not used to wearing a brace	FKB due not decrease asymmetric between the effected knee and the healthy knee	-

Table 2 shows an overview of the articles conclusion.

Discussion

Prevention

Which effects do FKB and PKB have on the knee joint? A question many want an answer for. A study by Beynnon et al. from 2003 reached the conclusion that the brace significantly reduced the anteroposterior laxity values in the knee joint after ACL injuries (Beynnon, Fleming, Churchill, & Brown, 2003). Another study by Beynnon et al. from 2005 concluded that an FKB do not have any effect on laxity (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005). Two studies where one has positive results and one has negative results. The conflicting data might be explained by the fact that one is measuring the general laxity and the other focusing on the anterioposterior laxity but is it unsolved.

There have been found significant kinematic and kinetic asymmetry in the knee joint when comparing a healthy knee to a knee with an ACL reconstruction (Dai, Butler, Garrett, & Queen, 2012). Even though the brace might not decrease this asymmetry it do decrease the anterior-posterior shear load in the knee after ACL reconstruction (Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000). Both in non weight-bearing and weight-bearing situations a FKB reduces the anterior-posterior laxity (Beynnon, Fleming, Churchill, & Brown, 2003) and shear loading (Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000). There might be asymmetric between the knees but the effected knee is helped by the a FKB with reducing laxity and shear load anterior and posterior which is positive for athletes with ACL and PCL problems to avoid further injuries. This is supported by a study done on skiers which showed that non-braced skiers were 2.74 times more likely to get a re-injury (Sterett, Briggs, Farley, & Steadman, 2006). A FKB have beneficial factors after an ACL injury and it provides a greater resistance 20-30% (Najibi & Albright, 2005), (Greene, Hamson, Bay, & Bryce, 2000) to a lateral blow. Choosing a brace depends on the individual athlete and the individual sport. Different PKB have different effects on the athletes speed, agility and brace migration (Greene, Hamson, Bay, & Bryce, 2000). Therefore choosing a brace is difficult and might take time to find the optimal brace to each athlete.

OTS PKB is designed to reduce the severity and prevent knee injuries (Rishiraj, Taunton, Lloyd-Smith, Woollard, & Regan, 2009). A study by Sanders et al. showed that PKB have an overall positive effect by reducing the rate of knee injuries in off-road motorcycling riders and appears to prevent and reduce ACL and MCL injuries (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011). These are positive findings for all off-road motorcycling riders since it is OTS PKB's they are fairly easy to purchase and available also for the amateur riders. If these findings can be applied to other types of sport is not known at this moment. It might be able to apply these findings to sports involving some kind of bikers where the demands to the knee joint are similar. When the demands change it is not a given that the same result will be obtained. It is known that braces tend to migrate (Greene, Hamson, Bay, & Bryce, 2000) and migration of the braces might have an influence on the results if the subjects pattern of movement changes. The motorcycling riders have a primarily sitting posture compared to a handball players more upright position.
The PKB's should not only provide protecting of the knee joint but also allow the athlete to perform at the same level. Is has been shown that how the performance is effected differs between the difference models of PBK's, some for them reduce forward speed and agility significantly compared to a non-braces situations and some did not (Greene, Hamson, Bay, & Bryce, 2000). So which brace should be used depends on the specific sport. The PKB's also migrate significantly different (Greene, Hamson, Bay, & Bryce, 2000) depending on the model. Therefore choosing the correct brace can be very difficult and should not be

chosen lightly. Even though the braces migrate it has not been proven how much migration is too much. It is not known when the joint kinematics is altering due to brace migration (Greene, Hamson, Bay, & Bryce, 2000) and therefore some PKB might still protect the knee even though they have migrated.

A reason why the results vary can be the difference between the subject's familiarization with using a brace and the test preformed. A study by Moir et al. found that to avoid learning effects in the results at familiarization attempt, was not needed to get reliable measurements (Moir, Button, Glaister, & Stone, 2004). However another study found that to obtain a reliable outcome, when subjects were unfamiliar with the test, at least two familiarization attempts are needed (Glaister, Stone, Stewart, Huges, & Moir, 2003). These findings shows that the need for familiarization attempts to avoid learning effects depend on the physical status of subjects, the different tests and if the subject is familiar with the movements included in the tests. Glaister et al. showed that if unfamiliar tests were performed it can be speculated whether a test with a brace can be categorized as an unfamiliar test and therefore have influence on the outcome. Sanders et al. showed that PKB have an overall positive effect by reducing the rate of knee injuries in off-road motorcycling riders and appears to prevent and reduce ACL and MCL injuries (Sanders, Cates, Baker, Barber-Westin, Gladin, & Levy, 2011). Strerett et al. showed that non-braced skiers were 2.74 times more likely to get a re-injury compared to skiers using FKB (Sterett, Briggs, Farley, & Steadman, 2006). These two studies both have positive results and both compare athletes who are used to wearing a brace to athletes who are not. Due to the fact that the subjects are use to wearing braces might be influenced. The use of rehabilitation braces shows on long term effect and the brace do not give a superior outcome compared to Neoprene sleeves (Birmingham, et al., 2008). All the subjects used in the study by Birmingham et al. were not familiar with using a brace. This might indicate that athletes need a period to get familiar with a brace before it is possible to see whether the brace have an effect for the individual athlete.

Treatment

After an ACL reconstruction the braces used is a rehabilitation brace designed to protect ROM post-surgery (Rishiraj, Taunton, Lloyd-Smith, Woollard, & Regan, 2009) (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005). A study by Beynnon et al. showed that the long term outcome is not affected, but a rehabilitation brace do put some restricting on the ROM, which can be beneficial in the early phases of recovery. Rehabilitation braces do what they are made for which is to prevent flexion during the early healing phases (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005). If comparing rehabilitation with and without the use of rehabilitation braces they do not have any effect. The rehabilitation braces can reduce swelling and wound drainage and thereby reducing the pain in the knee joint (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005). The rehabilitation braces might not give any clinical measurable effect but if it can relieve the subject for pain in the early phases. Thereby it can be very relevant for subjects to us.

In addition to rehabilitation braces a neoprene sleeve can be used after ACL reconstruction. The neoprene sleeves are simpler and easy to use, due to the fact there is not any possibility to adjust it like there is on a rehabilitation brace. It has not been proven that the rehabilitation braces gives a superior outcome compared to a neoprene sleeve (Birmingham, et al., 2008). The neoprene sleeves might have an advantage because it is difficult for a patient to use it wrong. Where a rehabilitation brace placed or adjusted wrong might have a negative effect. The rehabilitation braces also sets a higher demand to the hospital staff in adjustments of the brace and the instructions giving to the patient.

The effects for using a brace are controversial and even if a brace supports the ACL it might have a negative effect on speed and agility. For some of the time between injury and treatment it might have an influence. A study by Hirschmann et al. showed that athletes treated within 40 days of their injury had better outcome. 19 out of 24 athletes returned to sport but only 8 out of 24 reached their former sports activity level (Hirschmann, Iranpour, Mu, & Friederich, 2010). Early treatment can mean returning to sport without the use of a brace but for others a brace might be their only possibility for returning to sport after an ACL injury in order to provide stability to an unstable knee joint. Therefore a FKB or PKB might be a necessary evil for some athletes. Furthermore a brace might give an athlete a physiological comfort but this have not yet, to my knowledge, been investigated but could be something of an interesting factor to look further into.

Conclusion

Rehabilitation braces does what it is made to do which is to prevent flexion during the early healing phases and can be beneficial in the early phases of recovery but have on long term effect on the outcome.
Both in non weight-bearing and weight-bearing situations a FKB reduces the anterior-posterior laxity and shear loading which is positive for athletes with ACL and PCL problems to avoid further injuries.
PKB have an overall positive effect by reducing the rate of knee injuries. Some PBK's reduce forward speed and agility. So which brace should be used depends on the specific sport. When comparing the results from the articles a tendency to give positive results depend on the athletes and how practised they are in wearing a brace this might have an influence on the outcome.

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