REVIEW

Nr 2019;9 (2):282-294

The efficacy of knee orthoses following anterior cruciate ligament injury. Review of literature

M. Karimi

Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
Bone and Joint Diseases Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

CORRESPONDING AUTHOR:
Mohammad Karimi
Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences,Shiraz, Iran
Phone: +98 913 420 6371
E-mail: mt_karimi@sums.ac.ir

DOI:
10.32098/mltj.02.2019.19

LEVEL OF EVIDENCE:
1a

SUMMARY

Background. The anterior cruciate ligament (ACL) plays a significant role in controlling anterior tibial translation and rotation. A variety of treatment approaches, including knee orthoses, are used to restore the performance of subjects with ACL injuries. The aim of this review is to explore the efficiency of knee orthoses on the functional performance (walking, standing, jumping and running) of individuals with ACL injury. **Method.** A literature search was conducted. Key words (knee, orthosis, anterior cruciate ligament, rupture, brace and/or walking, standing, running, jumping and ACL injury) were inputted into selected databases (ISI Web of knowledge, PubMed, Google scholar, Ebsco and Embasco) using Boolean search terms. The quality of obtained studies was evaluated using the PEDro scale. **Results.** Initial search results yielded 250 papers. Following review of titles and abstracts and application of inclusion criteria, 39 papers were selected. Of these, 32 focused on motion analysis of individuals following ACL injury (with /without reconstruction); 3 were biomechanical evaluations conducted on cadavers and 4 on the effect of a knee orthosis on the performance of able-bodied subjects. Overall, the quality of studies was rated between 3 and 7 in the PEDro scale. **Conclusion**. Results showed insufficient evidence to suggest that knee orthoses have a significant effect on standing, walking and running performances of the individuals with ACL injury and those who had reconstruction surgery. However, the use of an orthosis increased energy consumption during walking. Based on the available literature, it is debatable whether the use of an orthosis has a positive effect on the treatment. Future research of appropriate design is required to further explore changes in performance of ACL-injured subjects using different knee orthoses.

KEY WORDS
anterior cruciate ligament; rupture; knee orthosis; walking; running; standing

INTRODUCTION

The anterior cruciate ligament (ACL) plays a significant role in stabilization of the knee joint during daily activities, especially when walking and running (1,2). It mainly restricts the anterior tibial translation, 86% of which is controlled by the ACL (1,3). ACL deficiency not only results in functional instability, but also influences proprioception of the knee joint as the ACL has mechanoreceptors that are sensitive to knee joint's moment and position (4,5).

It is estimated that 35 to 44 million people participate in sporting activities each year in the USA, and that up to 300,000 individuals experience ACL tear which requires treatment (6,7). Any injury to the ACL deteriorates both stability and mobility of the knee joint, which in turn has a negative effect on the knee joint function (2,4,8-10). The altered knee joint performance changes the symmetry of knee motions and load bearing between the affected and unaffected sides, which finally increases the incidence of degenerative joint disease (DJD) at the knee articular surfaces (3,11,12).

Various strategies are used by the ACL-injured individuals to decrease the loads applied to the knee joint, such as increased hip joint extension and decreased knee joint extensor moments (10). Additionally, hamstring and quadriceps work in synergy to protect the knee joint. This is a strategy used involuntarily by subjects to stabilise the knee joint during walking and standing. However, there are some treatment approaches used for individuals with

ACL injuries, including reconstruction surgery (bone-patellar tendon-bone graft, a graft of hamstring and peroneus muscles), rehabilitation including exercise and the use of functional knee braces (13,14).

In the past few decades, sports medicine has been inundated by a plethora of commercially available knee orthoses, the majority of which have been prescribed to stabilise the knee joint in ACL-deficient subjects. It has been demonstrated that knee braces may decrease anterior tibial translation, prevent quadriceps inhabitation, reduce anterior posterior laxity and prevent excessive loads on the injured ACL or the healing graft (15-18). However, effectiveness of orthotic treatment is still controversial and may be influenced by the design of the orthosis, including the shell design, hinge design, type of straps, mechanism of manufacture and mechanism of applied loads (weight bearing and non-weight bearing conditions) (19). Other factors, such as proprioceptive facilitation, comfort of use, and psychological support also influence performance when using an orthosis (20).

Although a variety of orthoses are used to reduce knee injury, it is debatable whether there is sufficient evidence to suggest that the use of a knee orthosis reduces the risk of further injury. Consequently, the aim of this review is to explore the evidence to support the efficiency of functional knee orthoses on performance activities (walking, standing, jumping and running) of individuals with ACL injuries.

METHOD

A search was implemented in the Embasco, Google Scholar, ISI Web of Knowledge, PubMed, and Ebsco. Key words, including the anterior cruciate ligament (ACL), were used in combination with brace, orthosis, and cast, in the period of 1960 to 2018. Primarily, the papers were selected based on the titles. Then, the abstracts were checked to see if they fulfilled the research questions of interest or not. Only papers published in English were selected.

Type of studies. Although the emphasis of this study was to focus mostly on randomized control trial (RCTs), due to lack of these studies on this topic, we included other type of studies.

Type of participants. We intended to include people with ACL injuries and also cadaveric studies. We ignored the papers which only focused on modeling approach.

Type of interventions. Actually, all types of braces used for the subjects with ACL injuries were included in this review.

Type of outcome measures. The main outcome measures which we have included in this study were functional performance of the subjects during running, walking, jumping and landing, laxity of knee joint, and range of motion of knee joint. Moreover, other parameters such as proprioception, kinetic asymmetry, dynamic stability, pain and muscle strength were selected.

Secondary outcomes. Any adverse effects of bracing reported in the included studies were considered as secondary outcomes.

Selection of the studies. Actually, two researchers determine the suitability of the papers based on the inclusion criteria. This was done mostly based on the abstracts and titles. If there was any sense of disagreement a third researcher was enrolled.

Data extraction and management. Actually, data extraction in this review was based on PICO style (population, intervention, comparison and outcomes).

Quality assessment and determination of the risk of bias. The output of scientific studies depends on parameters such as the methodology used, number of subjects, statistical analysis and method of reporting. Therefore, the quality of the studies was evaluated using of PEDro scale, which is considered as a reliable tool for literature quality assessment (21). The tool consists of 11 questions. Selected studies were categorized as following:

Evaluation of the efficiency of knee orthoses on:

- the performance of subjects following ACL-reconstruction;
- the performance of subjects following ACL injury without reconstruction;
- the performance of subjects following ACL rupture and ACL deficiency;
- controlling anterior tibial translation and tension developed in ACL ligament on cadavers;
- the performance of normal subjects.

Each category was summarized to include type of injury, number of subjects, age range, duration of follow up, type of orthosis and method of evaluation. **Figure 1** shows the procedure used in this review study. It should be emphasized that the selected studies meet the ethical standard of the Muscles, Ligament and Tendons Journal.

RESULTS

A total of 250 papers were found. Based on the titles and abstracts, 39 studies were included in the final analysis and categorized for analysis into five themes.

The first category of studies (n = 20) evaluated the efficiency of orthoses on the performance of ACL-reconstructed subjects, with qualities varied between 3 and 8 based on the PEDro scale. 4 studies addressed effects of knee brace during running and jumping (20,22-24). A total of 13 studies focused on the effects of knee orthoses on knee joint range of motion, stability and joint laxity (15-17,23,25-34). Only

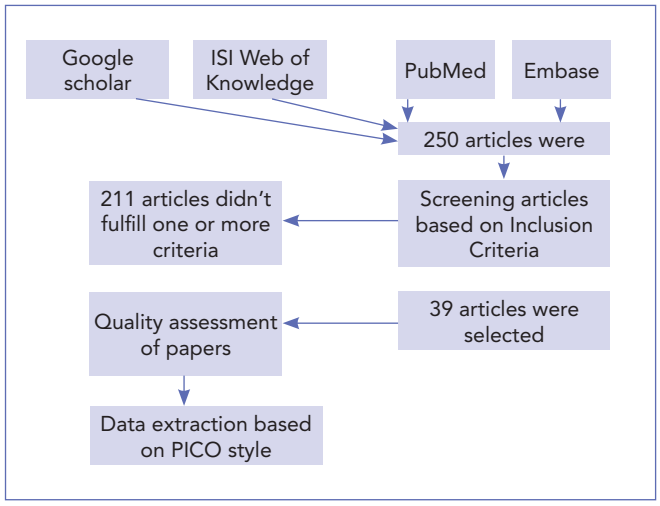

Figure 1 - The diagram of article selection procedure used in this study.

one article studied the effects of knee orthoses on proprioception (34) and 2 studies dealt with the strength of knee extensor muscles (30,35).

The second category of studies (n = 10) focused on effects of knee orthoses on the performance of the subjects with ACL injuries without reconstruction. The quality of studies varied from 4 to 6. Three of these studies focused on kinematic measures (36-38), 4 on proprioception and knee joint stability (37,39-41), 1 on strength of knee muscles (42), 2 on points of view of the subjects and symptoms (43,44), and only 1 on the performance of the subjects during running (45).

The third category of the studies focused on comparison of the efficiency of functional knee braces used for those with ACL rupture and ACL deficiency**.** Only 2 articles compared the efficiency of the knee orthoses on the performance of subjects with ACL rupture and deficiency (46,47). The quality of the studies varied between 3 and 5. Based on the output of these studies, there was no difference between the subjects with ACL deficiency and rupture.

The fourth category of studies focused on efficiency of functional knee braces on controlling anterior tibial translation and tension developed in ACL ligament on cadavers (n = 3) (48-50).

Finally (fifth category), testing the efficiency of orthoses was also done on normal subjects in some of the studies (n = 4), which mostly dealt with energy consumption during walking and kinematic of the joints (47,51-53). Based on the results, walking with knee orthosis can increase the energy consumption during walking and may influence the knee joint kinematic. **Table 1** (**a** - **j**) summarize the outputs of various studies and their quality assessment results.

DISCUSSION

Evaluation of the efficiency of knee orthoses on the performance of subjects following ACL-reconstruction

A total of 20 studies were identified (**table 1 a**-**c**) with quality varying between 3 and 8. The main reason for low quality is generally due to the limited sample number of subjects, follow up duration and etc. Results of studies on the knee kinematics, anterior tibial translation and knee joint laxity suggest that the use of a knee orthosis did not influence the knee joint range of motion, especially in the sagittal plane.

The ACL ligament is responsible for controlling anterior tibial translation. The findings of research on the efficiency of knee orthoses for controlling tibial translation and joint laxity (15,16,27,28,31,33,34) indicate that orthosis does not control anterior tibial translation and knee joint laxities.

The stability of subjects during standing and walking was another parameter evaluated in some research studies. Three studies explored the effects of use of orthosis on proprioception and static stability (20,24,34). In the study done by Rebel and Paessler (2001), 25 subjects with ACL reconstruction and 30 matched normal subjects, the stability during quiet standing was measured based on the symmetry of weight distribution between the legs (sound side and reconstructed side) following the use of an orthosis. This study reported that symmetry of weight bearing returns to normal condition after use of knee orthosis. However, it should be emphasised that stability during quiet standing is mostly evaluated based on the center of pressure sway (linear and non-linear approaches) (54-56). Although the aforementioned parameters have been used in some studies, this is not a good indicator of standing stability. In another study by Risberg et al. (1999), proprioception of the knee joint in braced and unbraced conditions was evaluated. The results did not support the positive effect of orthosis use on proprioception (34). Moreover, some studies were found which examined the effect of the orthosis on the moments of muscles surrounding the knee joint (17,26). Accordingly, the extensor moments of the knee joint decreased following the use of orthosis. It should be emphasised that decrease in the extensor moment of the knee joint and increase in the extensor moment of the hip joint are compensatory mechanisms used by this group of subjects to decrease the loads applied on the knee joint (11,17,57). It may therefore be concluded that a decrease in the knee joint extensor moment is not an effect of the orthosis use. Most studies evaluating ACL biomechanics only considered walking on level surface, but few studies were conducted to

evaluate running and turning activities (20,22-24). Based on the results of study by Wu et al. (2001), there was no significant difference between running and jumping time while walking with and without knee braces, but that the use of an orthosis could decrease running and jumping speed (22). In contrast, Chang et al. (2012) showed that the brace did not constrain the movement of knee joint (23). The subjects with ACL reconstruction have a jumping height, which is 45% less than that of the normal subjects. Use of an orthosis in this study demonstrated a slightly improved jump height.

The influence of the orthosis on the performance of ACL-reconstructed subjects appears to be small and does not constrain the movement of knee joint during jumping and turning.

Overall, evidence suggests that the use of an orthosis does not significantly improve the performance of the ACL-reconstructed subjects following surgery, during level walking and standing, jumping or turning.

Evaluation of the efficiency of knee orthoses on the performance of subjects following ACL injury

The quality of papers on this group of subjects was rated between 4 and 6 on the PEDro scale. Most studies suggested that use of a knee orthosis did not improve the performance of subjects during walking and jumping. Moreover, it did not influence the moments and power produced by muscles (38). Although Ramsey et al. showed that brace did not influence anterolateral translation (36), Kannus et al. reported improvement in knee joint stability for cases with partial tear, but not for the complete tear (42). Additionally, Cook et al. showed that use of an orthosis could control the AP shift and lateral shear during straight line running (45). It should also be emphasised that there was a difference in the performance of the orthosis based on the subjects' point of view and functional performance evaluated by motion and stability analysis. Although the experimental results did not support efficiency of the orthosis, the subjects confirmed that sense of instability decreased and they were satisfied in daily activities and sport (43,44).

Evaluation of the efficiency of knee orthoses on controlling anterior tibial translation and tension developed in ACL ligament on cadavers

In the study done by Paulus et al. (1991), 6 different types of prophylactic orthoses were tested on the ACL strain under dynamic load (48). The results showed that these orthoses provide some protection for the ACL under different loading impacts. In another study done by Wojtys et al. about the efficiency of Lenoxhill brace on the anterior tibia translation and external rotation of tibia, it was shown that this orthosis can control anterior tibia translation as well as external rotation of tibia (for maximum moment of 20 Nm) (16). However, it should be emphasized that no vertical load was applied to the limb. In another study, the effect of orthosis use on the valgus force, joint line opening and ligament tension were evaluated (58). They also confirmed that the orthosis was not able to control the mentioned motions. From the above-mentioned studies, it can be concluded that knee orthoses with various designs may be able to control the anterior tibial translation and external rotation under non-weight bearing conditions. However, it should be emphasized that these researches were done on cadavers and the results should be used with caution.

Evaluation of the efficiency of knee orthoses on the performance of normal subjects

Only 4 studies evaluated efficiency of the orthosis on performance of normal subjects while walking (47, 51-53). Beynnon et al. (1977) showed that the tension developed in the anterior tibial strap of the functional knee braces did not differ between low and high setting of the strap force. It means that role of this strap in controlling the anterior tibial translation is negligible (51). Two studies also evaluated the energy consumption of normal subjects while walking with an orthosis (52,53). The results confirmed an increase in energy consumption, which may be due to the weight of orthosis. It should be noted that in the ACL subjects, the orthosis is mainly used to restore the performance of ACL; therefore, the output of studies on normal subjects should be used with caution. Alternation in the neuromuscular performance may be another side effect of orthosis use for normal subjects.

CONCLUSION

Examination of literature in this study suggests a lack of evidence to support the view that knee orthoses influence the kinematics of the knee joint during standing, walking, jumping and running. Orthoses may however restrict the anterior tibia translation and rotation in a non-weight bearing condition. In conclusion, the effectiveness of knee orthoses in treatment of ACL rupture and thus preventing further knee joint injury is debatable. Use of knee braces may be recommended in early stage of recovery after ACL injuries.

Table 1-a - Evaluation the effects of using brace on performance of the subjects with ACL reconstruction.

Reference	Method			Results	Pedro scale	
	subjects	type of orthosis	procedure		score	satisfied criteria
(22)	number, 31; age, 26 ± 6.7; time after injury, 5 months	Donjoy Legend No brace supportive knee brace	the subjects were asked to run on 22 meter figure 8 tract, and run and jump on semicircular path; the subjects did under three conditions, with Donjoy, with no supportive knee brace, and without brace	regarding total time for running 10 lops, there was a significant difference between the conditions; no significant difference between running, jumping and landing time amongst three conditions; brace decreased running and turning speed; there was no difference in jumping and running performance amongst three test conditions	5	1, 4, 8, 10, 11
(59)	number, 73; age, 16-60; time after injury, 6 weeks	hard brace and water filled soft brace	they divided into two groups; 36 wore a hard brace for 6 weeks after surgery, 37 wore a water filled soft brace	compared to standard hard brace, water filled soft brace was superior regarding effusion, and swelling; it was concluded that soft brace has several advantages over classic brace	7	2, 3, 4, 8, 10, 11
(23)	number, 7; age, 26.4 ± 6.9; time after injury, 6 months	Donjoy Legend brace	the motion of the knee joint was recorded in this study; moreover, vertical jump was evaluated in this study	the results of this study confirmed that in athletes with ACL reconstruction, brace did not have any significant effects on constraining movement of vertical jump especially during landing; in high impact activities brace did not constrain the motions of knee joint; moreover, it did not influence the kinematic of knee joint	5	1, 4, 8, 10, 11
(25)	number, 36; age, 27.6 - 29, time after injury, 6 - 12.3 months	functional knee orthosis	the subjects were divided into two groups; in the first group the brace locked from 0 to 90, the second group received braces locked in extension	the results showed that locking the knee in extension, increased knee extension range of motion; KT 1000 arthrometric scores showed no difference between two groups; it was recommended that rehabilitation brace with full extension immobilization be used for these subjects	5	1, 4, 8, 10, 11
(26)	number, 62; age, ; time after injury, 6-10 months	functional knee brace	the subjects were divided into two groups, those treated with surgery and brace and those treated with surgery without brace; isokinetic peak flexion/extension moments were measured at angular velocity of 90 and 180 degree/second; laxities, range of motion of the knee joint were also evaluated in this study	the results of this study did not indicate any positive effects of using this brace for subjects with ACL reconstruction; there was no beneficial effect of this brace on either subjective or objective knee functions 2 years after surgery	6	1, 2, 4, 8, 10, 11

Reference	Method			Results	Pedro scale	
	subjects	type of orthosis	procedure		score	satisfied criteria
(27)	number, 40; age, ; time after injury, 3 weeks	functional knee brace	the subjects were divided into two groups, none brace and braced; the anterior laxity of knee joint was tested by applying anterior directed force	the brace did not appear to have effects on knee joint laxity and range of motion	6	1, 2, 4, 8, 10, 11
(16)	number, 5; age, 32.3; time after injury: ---	functional knee brace	the patients used their brace several weeks before testing; anterior tibial translation and fit of orthosis were evaluated	anterior tibial translation was controlled at low level of force (30 pounds); the performance of orthosis should be evaluated at higher functional level	3	4, 8, 10

Table 1-b - Evaluation the effects of using brace on performance of the subjects with ACL reconstruction.

Reference	Method			Results	Pedro scale	
	subjects	type of orthosis	procedure		score	satisfied criteria
(28)	number, 54; age, 24-28; time after injury, 3 months	straight post-operative brace; brace was set at 5 degrees of extension	knee joint laxity was measured before and 3 months after surgery; the subjects were divided into two groups based on brace used conditions	there was no significant difference in knee joint laxity between the groups; no difference between the groups regarding post-operative pain; it was concluded that use of hyper extension brace prevent extension deficient of knee joint	4	4, 8, 10, 11
(29)	number, 60 age; time after injury, 2-12 weeks	Donjoy	the subjects were divided into two groups, braced and non braced; the knee joint laxity was measured in this study	there was no difference between both groups, therefore, no benefits can be demonstrated with the use of brace; full weight bearing, unlimited range of motion and exercise should be recommended for these subjects	5	2, 4, 8, 10, 11
(34)	number, 20; age, 35; time after injury, 4.6 months	Donjoy	patient's perception of knee function was evaluated with the KOOS and Cincinnati knee score; proprioception was tested in this study	there was no significant difference between ACL reconstructed and contralateral knee (sound side); the difference between braced and unbraced conditions was not significant	5	1, 4, 8, 10, 11
(20)	number, 25 acl reconstructed and 30 normal; age, 29.5 ± 8.8; time after injury, 7.4 ± 1.9 weeks	hypex knee brace (air cast Europa, Neubeuern Germany)	two legged drop jump test and static balance test were done in this study	in the ACL reconstruction subjects, mean jumping height was 45% less than that of control; bracing improved jumping performance rather slightly; bracing also improved the coordination during standing and dynamic stability	4	4, 8, 10, 11

Reference	Method			Results	Pedro scale	
	subjects	type of orthosis	procedure		score	satisfied criteria
(17)	number, 7 with acl injury and 11 normal; age, 20.3; time after injury, 4-5 weeks	functional knee brace	powers, moment, kinetic and kinematic were evaluated in this study	subjects put their knees in an extended position in brace; extensor angular impulse decreased 41% at knee with brace; reduced extensor moment at knee in brace condition indicates decrease in load applied on knee which protects the knee during stance phase	4	4, 8, 10, 11
(34)	number, 60; age, ; time after injury, 6 weeks to 2 years	functional knee brace	the subjects were divided into two groups, brace group and none-brace group; Cincinnati knee score and goniometry were done; moreover, muscles strength and VAS were evaluated	there were no significant differences between two groups with regards to knee joint laxity, range of motion, muscle strength, functional knee test and pain; Cincinnati score showed an improvement in knee joint function in braced group	5	1, 4, 8, 10, 11
(35)	number, 27; age, 28 ± 11; time after injury, 6-48 months	functional knee brace	strength test was done by using a computerized isokinetic dynamometer	functional knee brace did not affect knee extension strength of the subjects of this study; moreover, the flexion moment of the knee joint was significantly lower than that with knee brace	4	4, 8, 10, 11
(15)	number, 27; age, 28 ± 11; time after injury, ;	functional knee orthosis	the subjects with chronic ACL tears were studied with and without braces; AP and compressive loads were applied on the knee; translation of tibia relative to femur in weight bearing, none weight bearing and transformation phase were evaluated in this study	bracing of knee reduces abnormal AP laxity during weight bearing and none- weight bearing conditions; however, it did not influence translation phase	5	1, 4, 8, 10, 11

Table 1-c - Evaluation the influence of orthosis on the performance of the subjects with ACL reconstruction.

Reference	Method			Results	Pedro Score	
	subjects	type of orthosis	procedure		score	satisfied criteria
(30)	number, 60; age, ; time after injury, 1-5 years	Donjoy	the subjects were divided into two groups, braced group and non-braced group; laxity test and isokinetic muscles torque measurement were performed	the use or not use of the brace does not influence the end results, not even in the long term; other surgical related parameters, such as placing the graft in anatomical position, firm initial fixation and injuries to ligaments and meniscus seem to play a much important role in stability and clinical outcomes	4	4, 8, 10, 11
(31)	number, 50; age: --; time after injury: 12.5 - 13.5 months	functional knee orthosis and plaster cast	the subjects were divided into two groups, those immobilize with brace and those immobilize with plaster cast in 10 degrees of knee flexion; range of motion of knee joint, total sagittal knee laxity and thigh muscles strength were evaluated in this study	there was no difference in total sagittal laxity between plaster and brace groups	6	1, 2, 4, 8, 10, 11
(32)	number, 42; age: --; time after injury,	Donjoy, RYS, Lenoxhill and CTI	four different types of knee orthose were evaluated; onstrument laxity testing with KT-1000 artrometer was done with a passive anterior displacement of 89N	34 out of 42 patients reported no giving way during brace usage; brace usage decreased anterior displacement of all knees; however, with one legged hop and 40 yard shut turn no change can be seen	4	4, 8, 10, 11
(24)	number, 36; age, --; time after injury, 12 months	functional knee brace and compression sleeve	the subjects perform a 10 cm standing drop jump from an elevated platform to a force plate and stand on one leg for 25 second; the tasks were repeated for both orthoses; the impact of loading, path length, and RMS of COP were calculated	drop loading with bandage decreased significantly; it was concluded that compressive sleeve improved the integration of balance control and muscles coordination	4	4, 8, 10, 11
(33)	number, 4; age, 21 ± 2.4; time after injury: --	Donjoy Legend	motion analysis, ground reaction force and EMG performance of muscles evaluated under two conditions, with and without orthosis	no subjects experienced significant difference, but muscles activities were altered by use of orthosis; the activities of biceps, semitendinosus decreased; in contrast, quadriceps showed increased performance; it was concluded that joint stability increased follow the use of orthosis	4	4, 8, 10, 11

Table 1-d - Evaluation the effects of orthosis on performance of subjects with ACL injury (treated with orthosis).

Reference	Method			Results	Pedro Scale	
	subjects	type of orthosis	procedure		score	satisfied criteria
(36)	number, 6; age, time after injury, months		the kinematic of subjects during walking was evaluated with and without orthosis	bracing resulted in only minor kinematic changes in tibiofemoral joint motion; it did not influence the anterior tibia translation	4	4, 8, 10, 11
(37)	number, 18; age, 12.8	long leg cast, then functional knee brace	the subjects allowed partial then full weight bearing after 6 weeks of injury	the output of treatment was not acceptable for most of the subjects; it did not influence the instability and progressive deterioration of the knee	1	11
(43)	number, 72 with complete tear, and 35 with partial tear; age, ; time after injury, 38	functional knee brace	the symptoms of ACL injury were evaluated	overall results include 11% excellent, 20% good, 15% fair, and 54% poor; the results of this study confirmed unsatisfactory results of using brace in adults with high physical activities; the result of partial seems to be better than total tear	5	1, 4, 8, 10, 11
(39)	number, 36; age, time after injury:	Lenox Hill brace	anterolateral rotatory instability of knee joint	of the 20% patients with anterolateral rotatory instability, 89% of those with grade 1 and 45% of those with grade 2 instability improved; generally, antromedial instability improved in all subjects, but anterolateral instability improved only in 69% of them	5	1, 4, 8, 10, 11
(40)	number, 42; age, 18-50; time after injury, 38	functional knee brace	the subjects were divided into two groups, those treated with brace and without brace; VAS, knee OA outcome scores, clinical knee score and muscles peak force were analyzed in this study	the results of this study showed that subjects in brace group experience less sense of instability; however, bracing did not influence any other variables; although the subjects experience a positive sense, the outcome did not support it	4	4, 8, 10, 11
(44)	number, 79; age, 26; time after injury, 52 months	functional knee brace	the subjects received monitoring rehabilitation, functional brace and activity modification	8% underwent ligament reconstruction; 11% reported excellent, 32% good, 22% fair and 35% poor results; 97% were satisfied with their knee for daily living activities, 49% satisfied with their knee for sports	4	4, 8, 10, 11

Reference	Method			Results	Pedro Scale	
	subjects	type of orthosis	procedure		score	satisfied criteria
(41)	number, 25 with acl injury reconstruction and 30 normal subjects; age, time after injury	knee bandage	the proprioception of the subjects was tested by angle reproduction test	there was a significantly decrease in proprioception in these patients; knee bandage improves proprioception; patients with ACL reconstruction had no better proprioception sense	5	1, 4, 8, 10, 11
(38)	number, 5 with acl injury reconstruction and 5 normal subjects; age, ; time after injury,	functional knee brace	moments and power of the joints were evaluated during running with and without orthosis	the results confirmed no significant difference between brace and none braced conditions in ACL injury subjects	4	4, 8, 10, 12
(42)	number, 49 with complete acl injury and 41 with partial tear of acl; age, ; time after injury,	functional knee brace	evaluation of isokinetic and isometric strength were made	the long term results of treatment with conservative approach were poor, due to chronic instability; for partial tear the use of orthosis was good, but the stability of knee had not improved; it was concluded to not recommend this method for complete tear	4	4, 8, 10, 11
(45)	number, 14 with acl injury reconstruction; age, ; time after injury,	C.T.I knee brace	the subjects were asked to perform running and cutting maneuvers with and without brace; Cybex testing, KT 1000 evaluation were collected for each subject	brace control AP shifting and lateral shear force during straight line running; it was concluded that running and walking performance of athletic improved follow the use of brace; use of the brace is recommended for those without 80% quadriceps strength	5	1, 4, 8, 10, 11

Table 1-e - Comparison between the effects of orthosis on Anterior Cruciate Reconstruction (ACLR) and Anterior cruciate deficient performance.

Reference	Method			Results	Pedro Scale	
	subjects	type of orthosis	procedure		scale	satisfied criteria
(46)	number, 30; age, 28 ± 8.7	functional knee brace	the subjects were asked to walk with and without brace on 10 meter walkaway	bracing influenced the asymmetry in ACLR in sagittal plane; functional brace increased adductor moment and decreased bilateral kinetic asymmetry in coronal plane for both groups; it also influenced the asymmetry in ACLR in sagittal plane	4	4, 8, 10, 11
(47)	number, 11; age, 28 ± 8.7	Donjoy Legend, BledSoe brace and placebo device	the strength of knee muscles was tested with Biodex dynamometer	there was no difference between two orthoses and placebo device; there was no correlation between the use of brace and joint laxity	5	1, 4, 8, 10, 11

Table 1-f - The results of the study done on cadavers.

Reference	Method			Results
	subjects	type of orthosis	procedure	
(48)	cadaveric specimens	6 different type of prophylactive knee brace	6 different types of orthosis were tested on ACL strain under dynamic loads	the results of this study showed that most of the braces tested appear to provide some degrees of protection to ACL under direct lateral impact
(49)	4 fresh cadaveric specimens	Lenox Hill brace	anterior tibial translation and external rotation of tibia in reference to femur was evaluated in this study; an anterior directed force was applied on knee in various knee flexion	the orthosis was able to decrease the anterior tibia translation from 10 mm to 5.7 mm at 30 knee flexion with no vertical force applied; external rotation was also limited when 20 NM moments applied on knee joint with no vertical force
(50)	18 fresh cadaveric specimens	MacDavid knee Guard, knee stapler Omni	valgus force, joint line opening and ligamentus tension were evaluated	no significant protection could be seen with these orthoses

Table 1-j - Evaluation the effects of brace on the performance of normal subjects.

Reference	Method			Results	Pedro scale	
	subjects	type of orthosis	procedure		score	satisfied criteria
(51)	number, 5; age, ;	Donjoy	a tensile load sensor was attached on proximal, anterior tibial tuberosity strap of the brace; the loads applied on the strap were measured in this study	the results of this study showed that adjustment of strap tension between low and high setting did not modulate the protective effect of the brace on the ligament	5	1, 4, 8, 10, 11
(52)	number, ; age,	generation II poli-axial knee cage, orthotech performer, CTi brace, Lenox Hill derotation brace	the energy consumption of the subjects was analyzed during walking with and without orthosis	results indicated that the energy consumption increased by 3 to 8% in walking with orthoses, which is mostly due to weight of the orthosis	5	1, 4, 8, 10, 11
(53)	number, 10; age, 23.9 ± 28 months	functional knee orthosis	Vo2 max and heart rate were evaluated in this study	the results of this study showed that heart rate and energy consumption increased by 4.58% in walking with orthosis	6	1, 2, 4, 8, 10, 11
(47)	number, 6; age:	functional knee orthosis	the subjects were asked to walk under 6 conditions, fast, slow walking speed, with and without orthosis, with and without weigh tend west	ankle, hip and knee position altered significantly in walking with orthosis; the results showed neuromuscular control was altered when an orthosis was used	5	1, 4, 8, 10, 11