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Functional Knee Bracing: Effects and Efficacy

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FUNCTIONAL KNEE BRACING: EFFECTS AND EFFICACY

by

Lisa A. Philion
Bachelor of Science in Physical Therapy
University of North Dakota, 1993

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

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1994
This Independent Study, submitted by Lisa A. Philion in partial fulfillment of the requirements for the Degree of Master of Physical therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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Title Functional Knee Bracing: Effects and Efficacy

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Date 28 March 1994
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ABSTRACT

Functional knee braces are intended to provide stability to the unstable knee joint. The purpose of this literature review is to examine available research on functional knee braces in order to summarize their effects and efficacy.

Research indicates that the most effective brace for controlling abnormal knee motions would be a custom designed shell brace with rigid straps and a polycentric hinge. However, individual characteristics of the wearer must also be considered.

Subjective research indicates that functional knee braces improve function and provide support for the unstable knee. However, these findings do not correlate with objective findings.

Results of biomechanical research show that braces are effective when subjected to low forces, but their effectiveness decreases as the loads increase. Objective functional analysis demonstrates that wearing a knee brace can ultimately impair performance by increasing energy and oxygen consumption and by changing neuromuscular control patterns.

Effects and efficacy of functional knee bracing remains controversial and the choice of whether or not to brace should be up to the individual.
Knee bracing is a relatively recent and controversial phenomenon. Prior to the late 1960s, orthoses were primarily designed to address neuromuscular abnormalities. In the late 1960s, the need for a "derotation" or ACL brace was addressed by James Nicholas when he recognized Joe Namath's chronic knee instability.\textsuperscript{1,2} To combat Namath's knee instability, Nicholas and Castalgia of Lenox Hill Hospital developed what was to be the first of a wide variety of functional knee braces, the Lenox Hill Derotation knee brace.\textsuperscript{1,2,3} The Lenox Hill Brace was essentially alone in the market until the later part of the 1970s.

In June 1984, the American Academy of Orthopedic Surgeons\textsuperscript{4} formed a Committee on Sports Medicine. The committee conducted a seminar on knee bracing in order to obtain data from brace manufacturers, physicians, and bioengineers. The collected data were used to classify the types of knee braces available, to review the existing research, and to stimulate further research.

The AAOS committee defined three classifications of knee braces. (1) Prophylactic: braces which attempt to prevent or reduce the severity of knee injuries; (2) Rehabilitative: braces which allow protected motion of an
injured knee treated operatively or nonoperatively; and (3) Functional: braces which provide functional stability of an unstable knee. These classifications continue to be used by most researchers and health professionals in defining brace types.

The symposium also concluded that, although there were a large number of braces marketed, there was little research validating claims made by the manufacturers. However, since 1984, there have been numerous well-controlled studies performed on the various types of braces.

Most research has centered around the functional knee brace. Existing research on this brace can be divided into four main areas: (1) brace construction, (2) subjective analysis, (3) biomechanical analysis, and (4) functional analysis.

The purpose of this literature review is to examine these four main areas of research in order to summarize the effects and efficacy of functional knee braces. Such knowledge of functional knee braces aids the physical therapist, or another health practitioner, in the decision of whether or not to suggest the use of a functional knee brace for a patient.
CHAPTER II
BRACE CONSTRUCTION

Before examining specific studies, it is helpful to be somewhat familiar with the design of functional knee braces. Brace design includes brace suspension, hinge concerns, brace fabrication, and any accommodations to the wearer. Brace design ultimately affects brace function.

Suspension

In 1984, Paulos\textsuperscript{4} identified the following two basic constructions: hinge/post/strap and hinge/post/shell. Millet and Drez\textsuperscript{5} also came up with the same two categories of construction techniques. The main difference between the two constructions is whether they use thigh and calf straps or shell-type enclosures for suspension of the brace.

The straps employed by the hinge/post-strap construction can be either elastic or rigid. The elastic strap is found by wearers to be more comfortable, but it is less effective than the rigid strap in developing proper leverage.\textsuperscript{6} The elastic strap allows give, resulting in a decreased constraining effect.

The shell braces employ semi-rigid or rigid plastic thigh and calf shells in an attempt to create better suspension, stiffness, and rigidity; they provide a larger contact area with soft tissue.\textsuperscript{7} In a study on the response of eight knee
orthoses to valgus, varus, and rotation loads, Lunsford et al\textsuperscript{6} concluded that the more rigid the knee brace, the more resistant it was to deforming forces. The rigidity of the brace depends on design, use of metal sidebars, and overall length (leverage).

The shell braces have greater biomechanical constraining effects than the strap brace.\textsuperscript{9} Beck et al\textsuperscript{10} tested several functional knee braces using clinically available knee laxity testers on ACL deficient knees. They found that the hinge/post/shell type braces performed better than the hinge/post/strap braces in regard to controlling anterior tibial displacement. Millet and Drez\textsuperscript{5} found the same results in their study. In addition, the shell braces are also more durable than the strap braces.\textsuperscript{6}

Hinge Concerns

Brace design includes hinge design considerations. Braces have either a fixed or polycentric axis.\textsuperscript{9,11} The optimum design is one which closely matches the kinematics of a normal knee,\textsuperscript{9} thus reducing pistoning, discomfort, and slippage.\textsuperscript{11} The polycentric hinge meets these demands.\textsuperscript{11}

More important than hinge design is hinge position.\textsuperscript{9} Slipping of the brace on the wearer’s leg, as well as inconsistencies in donning and doffing of the brace, can cause malalignment of the brace hinge and knee joint.\textsuperscript{7} This malalignment creates alterations in moments and forces at the hinge.\textsuperscript{9} A misplacement of the hinge axis as small as 5 millimeters can result in changes in ligamentous length.\textsuperscript{7}
Brace Fabrication

The braces can also differ in individual fabrication. Functional knee braces can be "off-the-shelf," adjustable, or of a customized design.

The "off-the-shelf" braces are prefabricated and are sized according to circumferential measurements taken above and below the knee. They are made in various sizes and are designed to fit the majority of the population. One author suggests that the wearer's overall build and the valgus/varus alignment of the limb will become determining factors when deciding between an "off-the-shelf" brace and a custom brace. Advantages of the former include: a decreased cost compared to custom-made braces and the brace can be readily purchased over the counter rather than being constructed. The "off-the-shelf" brace is readily available.

A less common concept is the adjustable (postoperative ACL) brace. It is an "off-the-shelf" brace with some custom-fitting features adjusted in the therapy office. This style of brace has the advantage of decreased cost. It can be used first as a rehabilitative brace and then later adjusted into a functional brace, allowing the wearer to avoid buying two braces.

Custom braces are designed according to the patient's individual dimensions. Dimensions are taken through tape measurements, paper tracings, or cast molding. Since custom braces are fabricated according to the wearer's individual dimensions, they fit better than the "off-the-shelf" braces.
Regardless of the design, the brace must fit properly and not migrate up and down the leg. Braces that are contour fit, such as custom braces, tend to migrate less than those braces which are not constructed according to the wearer's dimensions. In addition, a more rigidly and tightly applied brace is a better match of knee motion. These findings would suggest that a custom-made shell brace is best for decreasing migration of the brace.

Individual Characteristics

When choosing a brace design, it is also important to look at the individual characteristics of the wearer. Individuals who are heavier, are very active, and present with significant functional instability will be the better candidates for the more durable, custom fit, rigid shell brace. The athletes who are lighter, less active, and present with minimal instability will benefit just as well with an "off-the-shelf" strap brace.

Prior to choosing a functional knee brace for a patient, it is important for the therapist to take into consideration brace suspension, hinge type, and fabrication factors. Research indicates that the most effective brace for controlling abnormal knee motions would be a custom designed shell brace with rigid straps and a polycentric hinge. However, the most important consideration is the individual characteristics of the wearer, such as the activity level, body type, and amount of knee instability.
It is also important to inquire about the wearer's perceived effects of the brace during use. It is important to get the wearer's input on such things as comfort and stability through subjective analysis.
CHAPTER III

SUBJECTIVE ANALYSIS

Subjective analysis is the wearer's perception of the brace on stability and athletic performance. Essentially, all functional braces offer some perceived benefit to the patient with an unstable knee. Most patients report fewer episodes of the involved knee 'giving out,' less pain with activity, and a return to a higher level of activity.

All athletes participating in a study by Cook et al reported fewer episodes of subluxation and better athletic performance while wearing a custom fit C.Ti. brace (Innovation Sports, Irvine, CA). In a subjective data review by Cawley and associates, it was determined that 90% of the subjects in the studies reviewed had fewer episodes of giving way and were functionally improved. In another study, 91% of the patients reported being satisfied with their braces and felt it was beneficial for them during athletic activities. If problems with bracing were reported, the problems were present during more challenging sports, such as basketball, soccer, or racquetball.

Participants in a study by Mishra, Daniel, and Stone reported improved subjective ratings on knee pain and swelling during sport activities with brace wear. Fourteen of the 42 subjects reported pain and swelling during sporting
activities when unbraced. Both symptoms were decreased with brace use, with only six subjects reporting pain and seven swelling.

The effects of brace wear on specific task performance was also studied using subjective analysis. Participants were asked to evaluate their performances while wearing and not wearing a brace during prolonged standing, walking, walking on uneven terrain, climbing an incline, ascending and descending stairs, kneeling or squatting, jogging, running fast, stopping fast, jumping, twisting or pivoting, and cutting. The majority of the patient's performances were rated highest (good, fair, or poor) while wearing a brace. However, during the one-legged hop and 40-year shuttle run, the mean values were not significantly changed by brace usage. The hop test also showed that those subjects with severe disability benefitted most from brace usage, while those with minimal disability were basically unaffected.

Participants in the study by Mishra, Daniel, and Stone did report negative responses. The most common complaint was slipping or migration of the brace during functional activities. Other complaints were related to brace bulk and heat retention.

Subjective analysis of braces, whether custom fitted, off-the-shelf, shell or strap type, indicate that functional braces improve function and support the unstable knee. However, the majority of subjective findings do not correlate with the results of biomechanical research.
CHAPTER IV

BIOMECHANICAL ANALYSIS

Biomechanical analysis focuses on how well the brace stabilizes the knee joint. Most of the research is on the brace’s ability to control tibial translation and rotation at the knee joint.

Several review papers have been written regarding the biomechanical effects of functional knee braces. The review and support articles conclude that functional knee braces are effective at reducing anterior tibial displacement at low loads. As the loads increase, however, the effectiveness of the brace decreases.

Markoff and associates identify the level of translational forces needed to obtain accurate measurements of absolute laxity. Translational forces need to exceed 200 Newtons (N) in order to determine the joint laxity beyond the inherent stiffness of the soft tissue of the knee joint. Noyes states that at least 400 N of anterior force is needed to simulate forces placed on the knee during athletic play. The majority of the studies reviewed do not test the braces at such forces.

Beck et al tested the ability of seven functional knee braces to control anterior tibial displacement using the KT 1000 (San Diego, CA) and the Stryker
Knee Laxity tester (KLT) (Kalamazoo, MI). Measurements for the KT 1000 were 20 pound anterior, 20 pound total, maximum anterior drawer and active anterior drawer. Measurements for the KLT were 20 pound. All forces used were below the translational forces recommended by Markoff et associates and Noyes, and yet the brace was ineffective in controlling anterior tibial translation.

Jonsson et al\(^{18}\) tested anterior/posterior and rotatory laxities for braced and unbraced conditions using 150-180 N tractions, 8 Newton-meter (Nm) torques, or a combination of traction and torque at 30° and 60° of flexion. The use of a brace reduced but did not normalize the anterior laxity compared to the intact knee. External rotation laxity was slightly reduced by the orthoses, whereas internal rotation laxity did not change. When the tibia was displaced anteriorly and rotated, the braces altered neither internal nor external rotation laxity.

Wojtys and colleagues\(^ {19} \) studied the control of tibial translation and rotation for 14 braces using manual clinical testing procedures on fresh frozen cadavers. Forces of 125 N (28 pounds) for translation and 12 Nm (88 ft. lbs.) for internal and external rotation were used with the knee at 30-60° of flexion. Results showed that anterior/posterior displacements were not kept within normal limits by any of the braces studied, but a few braces did restrict the rotational displacements to less than normal range. The braces were also more effective at decreasing displacements at 60° rather than 30° of knee flexion, with a mean decrease of 19% compared to 13%. This finding could be
irrelevant when considering the brace's effects during functional activities, as an angle of 60° of knee flexion rarely occurs during functional activities. It would be more important to have greater stability at 30° of knee flexion.

A study using artificial limbs to compare functional knee braces for control of anterior tibial displacement demonstrated an inability of ten different braces to reduce anterior translation at forces greater than 300 N. None of the braces in the study were effective at forces associated with strenuous activity.

Only one study reported that brace use decreased the measured pathologic anterior displacement on all tests used. All of the braces tested were also found to decrease the grade of pivot shift. The tests used included instrumented laxity testing with the KT-1000 with an 89 N passive anterior displacement, high load passive anterior displacement, and a quadriceps contraction active displacement. The authors recognized Karkoff et al's statement that forces in an excess of 200 N are required to produce an accurate absolute laxity measurement. However, they felt that using a maximum passive test and a more physiological test (active quadriceps contraction), in addition to the 89 N anterior displacement test was sufficient. The authors state that although the ability to prevent displacement was statistically significant, it may not be functionally significant. At low loads, the braces were more effective in reducing anterior displacement than at higher
loads. Reduction was possible at higher loads, but very few returned to normal stability.

The above articles support the findings of the 1984 AAOS Committee on Sports Medicine. The 1984 AAOS Committee concluded that functional knee braces controlled anterior motion if external forces were low, but at higher functional forces there was little control.

It is believed by some researchers that the functional knee brace is intended to enhance athletic performance by allowing the ligament deficient athlete to aggressively compete without pathological subluxation. Does the brace enhance athletic performance, have no effect, or ultimately impair it? Previously mentioned subjective data indicate that the majority of brace users feel performance is enhanced when wearing the brace, but objective functional analysis does not support improved performance.
CHAPTER V
FUNCTIONAL ANALYSIS

Functional analysis examines the brace’s effects on performance during a functional task. Analysis factors include the effects of added weight and rigidity on energy expenditure, task performance, neuromuscular recruitment.

A functional knee brace can weigh up to two pounds. This added weight can cost the wearer excess energy and strength, which ultimately affects performance. Zetterlund et al. studied the effects of wearing the Lenox Hill Derotation Brace on energy expenditure during horizontal treadmill running at six miles per hour (mph). Results showed that wearing the brace caused significantly higher values for oxygen consumption ($V_{O_2}$) and heart rate. The brace produced a 4.58% increase in oxygen ($O_2$) consumption and caused a 5.10% increase in heart rate compared to the no brace condition. This increase in energy expenditure results in a decrease in energy reserves. Decreased energy reserves would ultimately affect the wearer’s performance, as well as put the knee at risk for reinjury. These effects would be most evident during a prolonged sporting event.

Highgenboten and associates expanded Zetterlund et al’s study by increasing the running speeds, examining four commercially available braces
and recording perceptual responses. The subjects were tested at horizontal treadmill speeds of six, seven, and eight mph. Compared to the no brace condition, the braced condition caused increases in O₂ consumption, heart rate, and ventilation of three to eight percent. The wearer's ratings of perceived exertion also elevated between 9 to 13 percent. The authors theorized that the weight of the brace caused the increase in energy expenditure.

Houston et al²³ demonstrated that the benefits from functional knee braces come at the expense of impaired performance. The effects of wearing and not wearing the prescribed knee brace on muscle performance during Cybex testing, stair running, and a 15-minute stationary bike ride were compared.

Isometric and dynamic strength during knee extension were measured on the Cybex II isokinetic dynamometer (Cybex Division of Lumex, Inc., Bayshore, NY 11706). Mean maximum torque outputs during isokinetic knee extension were significantly lower (12 to 30%) when the subject wore the brace; the differences were more prominent with faster contractions.

Vertical velocity and maximal power output were used to measure performance during a brief all-out stair run. Results of both measurements showed better performance when the subject was not wearing a support brace.

After the 15-minute endurance ride on a stationary bike, blood lactate concentrations were 41% higher in subjects who wore braces. The increase in
lactate acid suggests that braces could interfere with blood flow and hence $O_2$ delivery.\textsuperscript{23}

Cook et al\textsuperscript{13} examined the effects of wearing and not wearing a custom-fitted C.Ti. brace (Innovative Sports, Irvine, CA) on running and cutting maneuvers. They used a foot switch, high speed photography, and force plate analysis to record forces in the coronal plane, sagittal plane, and vertical direction. The authors suggest that "better running" performance could be interpreted as a faster velocity while running a straight path with less ground shear forces. Therefore, increased shear in the medial or lateral planes would indicate wasted energy not being used for forward propulsion.

Results showed that during cutting maneuvers the braced limb generated significantly increased shear forces compared to the same limb unbraced. During straight line running, braced limbs generated significantly less lateral and aft ground shear forces compared to the same limb unbraced; the reduction in shear was greatest in those athletes who were weakest. The weaker athletes also achieved faster running velocity. The authors conclude that wearing the brace allowed significantly better running and cutting performances for athletes with torn ACLs, especially for those who have not achieved quadriceps torque greater than 80% of the sound limb. The authors also state the results should not be interpreted as a recommendation for bracing unstable knees since braces do not prevent abnormal anterior tibial translation and the long term effects of brace wear are unknown.
It has been suggested by some authors\(^1\) that the brace may disrupt neuromuscular control patterns. The wearer is not used to wearing the brace at first, which may cause a disruption of normal neuromuscular control patterns and impaired performance. There is a relearning process for accommodation to the brace. During this accommodation period, the wearer is at increased risk of injury.\(^1\) The authors did not indicate a time frame in which accommodation occurs.

Branch et al\(^1\) researched the possibility of braces working through a proprioceptive effect. They studied the electromyography (EMG) activity of the quadriceps, hamstrings, and gastrocnemius while wearing a brace. The results showed no change in patterns of activity while wearing the brace as compared to not wearing the brace. This led the authors to conclude that braces do not have a proprioceptive effect. They did find, though, that the braced limb showed a decrease in peak quadriceps and hamstring activity. The authors feel that bracing has a direct mechanical effect rather than a proprioceptive one. The direct mechanical effect would result in a decreased need for stabilization of the joint because of the co-contraction of muscles that act across the knee joint. This theory correlates well with the findings of previously mentioned studies,\(^{13,14}\) whereby weaker subjects performed better on certain tasks when wearing a brace. The subjects were able to perform well with braces where there was not the stabilizing co-contraction of muscles acting
knee joint. It must be remembered that this is only a theory and the mechanism of the direct mechanical effect is unknown, if there is, in fact, one.

It appears that like the biomechanical research, the findings of functional research do not correlate with subjective reports. The majority of the results show that wearing a functional knee brace impairs performance, especially during prolonged activities. Most of the effects are physiological in nature and occur due to added weight and lack of familiarity with wearing the brace. Is it worth it to brace if performance is impaired, especially when there is confusion regarding the biomechanical effects of bracing?
CHAPTER VI

CONCLUSION

There are four main areas of research on functional knee braces. They include (1) brace construction, (2) subjective analysis, (3) biomechanical analysis, and (4) functional analysis.

Research on brace construction indicates that the most effective brace for controlling knee instability would be a custom designed shell brace with rigid straps and polycentric hinge. However, whether even the most effective knee brace should be used remains to be answered.

Wearers of knee braces report fewer episodes of the involved knee "giving-out," less pain and swelling with activity, and improved performance with functional tasks. Therefore, subjective reports suggest that braces improve function and provide stability to the unstable knee. However, these data are not supported by objective research.

Biomechanical research on tibial translation and rotation at the knee joint shows that braces are effective at controlling these motions at low loads. However, as loads increase the effectiveness of the brace decreases. Braces would be ineffective at loads encountered with vigorous athletic activity, the time when the brace is needed most.
Functional analysis of performance also indicates that wearing a functional knee brace may not be beneficial. A brace increases $O_2$ consumption and heart rate, resulting in decreased energy reserves. These effects can ultimately impair performance, especially during prolonged activities.

Functional analysis also suggests the brace may impair performance by disrupting normal neuromuscular control patterns. The wearer would need to adapt to wearing the brace. Prior to adaptation, the wearer is at risk for further injury.

The effect and efficacy of functional knee bracing remains controversial. The question lies in why the subjective results conflict with scientific objective data. One author suggests that either the wrong biomechanical tests are being applied to evaluate brace function or the subjective evaluation judges comfort rather than function. Two factors which may contribute to the functional effectiveness of the brace are proprioceptive and psychological effects. Both are difficult to measure and are areas in which research is lacking.

Until further objective research results correlate with subjective research, it appears that the decision of whether to brace or not to brace is up to the individual. The individual must decide if he or she benefits from wearing the brace.
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