Efficacy of Knee Bracing in Sport Activities: A Preliminary Report

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Team Physicians, trainers and therapists employ knee appliances as a mean of preventing injury to the knee joint in high risk activities, protecting the knee during rehabilitation or to provide support to deficient knee joints. Unfortunately, while there has been a great deal of interest in, and subsequent use of these orthotics the research has remained very confusing. Epidemiological studies designed to evaluate the effectiveness of prophylactic knee bracing in high risk sports have arrived at contradicting conclusions. One side of the argument supports the use of prophylactic braces as a means of decreasing injuries while the other side believe that prophylactic bracing is of little value (Hewson et al., 1986; Rovere et al., 1987). They even venture to suggest that employing braces when there is no injury may give the athlete a false sense of security resulting in reckless behaviour and an increase in injuries. Investigators have also suggested that knee braces can in fact "preload the knee resulting in increasing the risk of injury during contact (Paulos et al., 1987). What is being suggested is that when the knee is placed in a brace, the shape of the brace will cause the knee joint to be positioned at the end of its range of motion. It is primarily when the translational components of the knee joint are involved that the joint ligaments are compromised. A seminar report published by the American Academy of Orthopaedic Surgeons in 1984 stated that the use of braces as prophylactic devices have not proven effective. However they go on to support the use of rehabilitative and functional braces as effective devices in treating knee injuries. Clearly the wide support enjoyed by prophylactic bracing is in part due to aggressive advertising but as well there is some logic to the strategy of protecting the knee with a rigid or semi-rigid orthotic. The problems inherent with developing a brace that will accommodate the intricate dynamics of the knee as well as meet the fit parameters are enormous. Therefore the purpose of this investigation was to evaluate the interaction between three custom fit, double hinged knee braces and the joints.

METHODS

This study involved ten subjects with diagnosed third degree anterior cruciate ligament damaged knees, all unilateral. The subjects reported to the biomechanics laboratory at McGill University where they were tested. The first series of tests involved a functional analysis of the braced knee. The effect the brace had on the range of motion of the knee in flexion, extension, internalrotation and external rotation was recorded followed by on analysis of the influence of the brace on the stiffness and laxity parameters of the knee joint throughout its range of motion (Emery et al., 1989; Oliver and Coughlin, 1987).

FUNCTIONAL TESTS

The subjects' knee braces were evaluated using the following measures: active inward rotation with the knee flexed 90 degrees, active outward rotation with the knee flexed 90 degrees, maximal knee extension during an instep kick and the migration of the brace after running fifteen minutes on a treadmill. The injured knee was measured with and without the brace as well the contralateral knee was measured without a brace. The subject was then evaluated on the Genucom Knee Analyser. The apparatus provides three dimensional stiffness and laxity characterizations of the knee joint (Oliver and Coughlin, 1987). Anterior and posterior laxity, and midrange stiffness values were obtained at 20,30, 40 and 90 degrees of knee flexion under a load range of 130 Newtons. The amount of internal and external rotation expressed by the knee joint under 11 N-m of torque was recorded as was the translation of the lateral tibial plateau during medial rotation of the tibia at 90^{o} of flexion and the medial tibial plateau translation during lateral rotation of the tibia.

BRACES

In this study three commercially available functional knee braces were evaluated. Brace #1 consisted of an extension stopper to prevent full knee extension and a close fitting tibial mold to control internal rotation of the tibia.

A pressure system consisting of a femoral and tibial mold as well as four posterior non-elastic straps help to control anterior translation of the tibia on the femur. A sliding hinge joint provides further control of rotation and extension. Brace #2 had a polycentric joint with an extension stop and a lateral tibial mold to decrease abnormal tibial rotation and lateral tibial subluxation. Brace #3 was made from a plaster cast taken of the leg flexed to approximately 30 degrees and the foot completely dorsiflexed. All orthoses had a 15 degrees extension stop which prevents the knee from extending completely. The plastic pre-tibial shell helped to suspend the orthosis and provides a distribution of pressure over the anterior tibia as the orthosis reaches its extension stop and thus prevents pain from tibial impingement. Rotational control was obtained by the shape and close fit of the plastic pre-tibial shell. The posterior strap maintained the subject's leg inside the orthosis and prevented the joint from extending beyond 10-15 degrees of flexion.

Brace #1 was designed to restrict anterior lateral instability. If there was an increase in translatory or rotatory motion causing the knee axis to shift into an unstable position the brace would act to restrain the shift. Anterior translation of the tibia was restrained in Brace #1 by forces created by the pre-tibial bar, the derotation strap, the distal knee loop and the circumference rubber band. A hyperextension stop prevents movement into the unstable position of full extension. Rotatory instability was restrained by the contour and placement of the lateral leg pads, the medial knee disc, the circumferential rubber band above and below the knee and the derotation strap. The sliding axis of motion corresponded to the axis of movement in the knee and helps control rotatory instabilities.

RESULTS

The anterior mid-range stiffness and anterior end point stiffness values vary throughout the range of knee flexion angles. At 40 degrees of flexion both mid-range and end point stiffness values were the lowest with the values at the other three angles similar (Table 1). As expected the lowest stiffness values were recorded for the injured knee with the intact knee and Brace #1 demonstrating similar stiffness values. The next greatest amount of stiffness was demonstrated by Brace #2 with Brace #3 having the greatest amount of stiffness. The lowest amount of laxity was at 20 degrees of flexion with the other three angles demonstrating similar levels of laxity.

However each brace demonstrated a unique laxity profile with Brace #3 demonstrating very low laxity values (Table 1). Mid-range and end point stiffness values for internal and external rotation revealed similar effects under the bracing conditions (Table 2). As expected the involved knee did not exhibit increased laxity or decreased stiffness when compared to the intact knee condition. However the brace conditions resulted in an increase in stiffness with a subsequent decrease in laxity. One exception involved medial and lateral tibia plateau translation. Both Braces #1 and #2 demonstrated an increase in tibial plateau translation beyond that occurring in the unbraced intact knee (Table 2).

Active range of motion allowed under the three brace conditions revealed that each brace demonstrated its own movement control profile. Brace #2 allowed the least amount of flexion and external rotation yet the most internal rotation. Brace #3 allowed the greatest amount of knee flexion, extension and external rotation (Table 3). When the angle of the Brace and knee were compared for extension during an instep soccer kick it was revealed that only Brace #3 was different. It followed the knee more closely (Table 4). After jogging on treadmill for ten minutes brace #1 displaced vertically 1.85 cm, Brace #2, 0.33; while Brace #3 did not move (Table 5).

Table 1

Anterior Stiffness (N/mm) and Laxity (mm) Values for Four Knee Flexion Angles (Means and Standard Deviations)

	Degrees of Knee Flexion	Brace #1		Brace #2		Brace #3	
AMRS (N/mm)	90	15.67	(3.68)	31.19	(32.57)	51.94	(34.41)
	40	9.07	(4.75)	9.03	(3.44)	43.02	(22.80)
	30	13.18	(11.72)	11.02	(4.90)	62.75	(28.08)
	20	11.98	(7.74)	16.07	(9.19)	81.74	(30.84)
AEPS (mm)	90	15.10	(5.87)	32.57	(41.10)	31.45	(15.61)
	40	8.22	(2.71)	7.04	(0.87)	24.16	(14.47)
	30	1855	(25.28)	21.35	(25.47)	24.65	(15.37)
	20	14.85	(1556)	23.21	(39.30)	30.02	(23.54)
ALAX (N/mm)	90	8.68	(2.20)	8.12	(3.96)	3.88	(2.72)
	40	8.05	(6.45)	13.57	(3.79)	3.88	(2.72)
	30	6.14	(5.22)	12.09	(3.14)	2.76	(2.80)
	20	6.27	(3.88)	7.11	(5.96)	2.69	(3.48)
		Involved (N =1)		INTACT (N=13)			
AMRS (N/mm)	90	12.21	(4.53)	19.91	(16.42)		
	40	6.67	(1.88)	8.89	(4.52)		
	30	7.46	(254)	10.77	(4.23)		
	20	11.57	(5.63)	25.28	(19.59)		
AEPS (N/mm)	90	19.30	(17.45)	19.76	(12.37)		
	40	9.42	(358)	16.94	(17.13)		
	30	16.49	(14.18)	13.69	(5.31)		
	20	18.63	(11.12)	33.14	(18.95)		
ALAX (mm)	90	10.09	(2.26)	8.16	(3.59)		
	40	12.22	(555)	13.01	(4.57)		
	30	13.79	(3.87)	11.16	(4.79)		
	20	9.43	(4.49)	6.17	(3.84)		

AMRS - anterior mid range stiffness
AEPS - anterior end point stiffness
ALAX - anterior laxity

TABLE 2

Internal and External Rotation Stiffness (Nm/Degrees) and Laxity (degrees and mm) at 90 degrees of knee flexion (Means and Standard Deviations)

	INT	INV	Brace 1	Brace 2	Brace 3
IMRS	.478	.583	.925	1.400*	.613
(Nmldegrees)	(.106)	(.261)	(.728)	(.711)	(.262)
IEPS	.822	.868	.773	1.047	.765
(Nm/degrees)	(.409)	(.594)	(.312)	(.112)	(.281)
EMRS	.468	.472	.798	1.210*	.630
(Nm/degrees)	(.092)	(.120)	(.479)	(.736)	(.260)
EEPS	.642	.779	.802	.987	1.200
(Nm/degrees)	(.301)	(.304)	(.539)	(.538)	(.309)
MTRANS	.648	.761	1.070	3.467	.282
(mm)	(.796)	(.909)	(.616)	(3.536)	(.464)
LTRANS	1.458	.810	3.233	3.347	.775
(mm)	(1.325)	(2.008)	(4.670)	(9.376)	(.896)
INTLAX	16.70	17.38	10.32	11.91	12.92
(mm)	(6.29)	(5.20)	(8.44)	(1.89)	(4.37)
EXLAX	19.08	17.88	11.55	15.07	11.14
(mm)	(4.51)	(5.84)	(7.60)	(.91)	(2.25)

IMRS - internal rotation mid range stiffness
IEPS - internal rotation end point stiffness
EMRS - external rotation mid range stiffness
EEPS - external rotation end point stiffness
MTRANS - medial plateau translation
LTRANS - lateral plateau translation
INTLAX - internal rotation laxity
EXLAX - external rotation laxity

TABLE 3

Active Range of Motion of the ACL Deficient Knee - Braced ACL Deficient Knee (Mean, SD [degrees])

	Brace 2		Brace 1		Brace 3	
Flexion	20.7	(9.8)	10.0	(5.6)	23.3	(4.3)
EXT	3.2	(5.1)	8.0	(5.6)	15.4	(3.6)
IR	1.5	(3.3)	4.0	(4.3)	1.8	(3.4)
ER	3.0	(2.7)	2.3	(.47)	4.4	(2.6)

TABLE 4

Congruency of Brace Angle and Knee Angle During Kicking (Mean, SD [degrees])

	BRACE ANGLE - KNEE ANGLE	
BRACE 2	5.0	(3.5)
BRACE 1	5.0	(2.0)
BRACE 3	2.0	(1.2)

TABLE 5

Total Displacement of Brace After Running (Mean, SD [*cms*])

BRACE 2	1.85	(1.93)
BRACE 1	0.33	(0.47)
BRACE 3	0.00	(0.00)

SUMMARY

The results in this research project produced some noteworthy comments. First, knee appliances do indeed alter the stiffness and laxity parameters at the knee joint. They also produce unique stiffness and laxity profiles when measured throughout the range of motion. There is no doubt that each brace model interacts with the knee resulting in unique restraining characteristics throughout the range of motion. In addition the anterior, medial plateau translation of the tibia during external rotation and anterior lateral plateau translation during the internal rotation increased rather dramatically under Brace #1 and #2 conditions. This is quite disturbing as it imposes a stress on the knee joint that is not present in the unbraced condition. Results characterizing the range of motion allowed by the braces also revealed profiles unique to each brace. These data support the contention that each knee brace is unique.

There is no doubt that the stiffness, laxity and range of motion characteristics of the injured knee changes depending on the type of knee brace employed. In fact each brace expresses a unique profile when evaluated throughout the range of motion. In some cases the braces provide support similar to the intact knee however in most cases the characteristics are dramatically different under the bracing condition. While the majority of the changes reflect improved support there is evidence that the brace is in fact causing abnormal laxity values. Clearly this is a concern and requires further investigation.

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