EFFECTS OF MATERIAL SELECTION ON BRACE PROTECTION OF THE MCL

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Over the past two decades knee bracing, in various forms, has become a common method of buttressing a knee joint that is weak or subjected to excessive forces. Much controversy exists over the beneficial or perhaps even harmful effects of their use. Prophylactic braces are used to prevent injuries or lessen the extent of injuries that occur during either contact and non-contact sporting activities (Podesta & Sherman, 1988; Millet & Dres, 1987; 1988). Consequently, individuals with uninjured or otherwise normal knees are the primary users of this type of brace. The prophylactic brace, designed to prevent injuries, must also be lightweight, inexpensive, and not restrict movement or they will not be worn by the athlete.

Many methods have been used to test the efficacy of knee braces, including *in vivo*, cadaver, and mechanical models of the knee joint ranging from simple to complex. Each approach has benefits and limitations. Numerous researchers (France, 1987; Paulos, France, Rosenberg, Jayaraman, Abbott, & Jaen, 1987) have compared one brace style to another attempting to determine which design provides better protection. These comparisons, however, sidestep the more fundamental issue of which variables make one brace design more effective than another. To this end, the present study tested the effect of a single variable, material strength of the brace uprights, using a single brace design. The objective of this study was to determine if the material chosen for manufacturing bi-lateral prophylactic brace uprights influences the level of protection provided the medial collateral ligament (MCL) by the brace.

METHODOLOGY

The apparatus used consisted of a wooden framework which supported a pendulum, an artificial leg, and sensors. A computer was used to collect and analyze the data. This supporting frame was constructed to support a solid half inch diameter steel pin which held the leg at hip height while the ankle pin was held in a separate hinged frame within the main frame.

The pendulum pivoted on an axle inserted into bearing sleeves placed at the same height as the hip pin and was located so that it impacted the knee joint at the lowest point of its swing.

The leg was made from square aluminum tubing with one eighth inch wall thickness. The length of the leg was chosen to match the estimated average male (Webb

& Associates, 1978): a tibia of 35.1 cm and femur of **45.7** cm, giving a total leg length from ankle to hip of 80.8 cm. The thigh and calf circumferences were also **constructed** to match the average male to provide the **proper** soft tissue bulk under **the** cuffs of the brace (59.5 cm and 37.5 cm, **respectively).** The knee joint itself was modeled as a simple hinge. The pendulum impacted on the side of the leg held by the hinge (the lateral side of **the** model knee) causing it **to** bend open on the medial side. This bending action was resisted by an artificial MCL. The **MCL** was modeled by a three-eighth inch diameter, seven by nineteen **stranded** steel cable with a working load rating of nine hundred eighty pounds similar to Mason, et al. (1989). The proximal end of the cable was clamped onto a bar attached to a **set** of six springs which transmitted pressure via a steel "U" bolt and flat plate to a quartz load cell.

The **brace** style used in this research was the **Ampro Knee** Guard. a **bi-lateral** prophylactic brace whose uprights are fabricated of nylon (Randall, Miller, & **Schurr,** 1984). The **Ampro Knee Guard** was modified for use in the two other experimental conditions by replacing the original uprights with **6061-T6** aluminum as well as graphite fiber. **A** load cell, capable of sensing forces up to 22.000 N), was used to measure tension in the cable. The load cell was connected to a **Kistler** Model 568 Universal Electrostatic Charge Amplifier to convert the static electrical discharge of the quartz load cell into DC volts per unit of force on the cell. This output was fed into a Keithley analogue to digital converter and then to a personal computer. In **addition** to the load cell. a displacement sensor was used during the lower weight impacts. The transducer was clamped to the frame of the testing apparatus with the moving core rod attached to the knee joint. The voltage output of the transducer was connected directly **to** a Keithley **A/D** converter.

The pendulum initiated the start of **the** data collection loop in the **data** acquisition program. **A** photo cell gate, fixed to the frame of the apparatus in **the** path of **the** pendulum. was connected to the Keithley A/D converter and **constantl**y monitored by the program. Just prior to impact, the photocell was tripped by **the** pendulum to start the data collection.

RESULTS

The study involved four cases of cable (ligament) tension **data** for each of the two pendulum weights (low and high momentum). The four cases represented the control data (impacts on the leg with no brace). the nylon **Ampro** brace (as manufactured). the **Ampro** modified with aluminum uprights. and the Ampro modified with graphite uprights. There were fifty impacts on each brace, with each mal having two hundred samples. These samples were averaged over the set of mals for each **case** and compared to the other cases under the same pendulum impact condition.

The brace material results for both the low and high **momentum** cases are **summarized** in the following tables.

Table 1. Low Momentum Tension Results (Plastic-Control difference not significant; all other values significant at p <0.01)

	Maximum Tension	Standard Deviation	% of Control	% Reduction of Control
Control	98.56 lb.	0.765 lb.	100	0
Nylon	98.43 lb.	0.513 lb.	99.9	0.1
Aluminum	80.63 lb.	.548	81.8	18.2
Graphite	81.62 lb.	0.225 lb.	82.8	17.2

Table 2. High Momentum Tension Results. (All values significant at p<0.01)

	Maximum Tension	Standard Deviation	% of Control	% Reduction of Control
Control	299.84 lb.	5.76 lb.	100	0
Nylon	326.57 lb.	3.32 lb.	108.9	- 8.9
Aluminum	249.70 lb.	7.87 lb.	83.3	16.7
Graphite	268.26 lb.	4.18 lb.	89.5	10.5

DISCUSSION

The present research investigated brace rigidity as one factor in preventing MCL injury. Common intuition suggests that a stronger and stiffer material would protect the MCL to a greater degree. The results of the present research did demonstrate a marked reduction in force transference to the knee strength of the brace material increased. These results suggest a similar reduction might be expected on an actual living subject. However, further study would be necessary to confirm these results.

Past research has indicated the importance of brace mechanical and material properties, particularly relating to the factors of force distribution, absorption. and transmission. It has been noted that the importance of brace rigidity is in distributing the impact force away from the knee and that most current braces are less than half as rigid as the knee itself (Paulos, et al., 1987). The data collected in this study support this hypothesis. Based on the results of this study, controlling the duration of the impact by manipulating the materials and design of the next generation of braces will be of critical importance. Materials that provide both increased bending strength and increased impact duration are needed to protect the knees of tomorrow's professional and amateur athletes.

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