EVALUATION OF THE MECHANICAL EFFICIENCY OF KNEE BRACES: A COMBINED EXPERIMENTAL-NUMERICAL APPROACH

Baptiste Pierrat[1,2], Jérôme Molimard[1], Laurent Navarro[1], Stéphane Avril[1], Paul Calmels[3]

[1] CIS-EMSE, CNRS:UMR5307, Saint-Etienne, France; [2] Pôle des Technologies Médicales, Saint-Etienne, France; [3] LPE (EA4338), Hôpital Bellevue, Saint-Etienne, France

Introduction

Knee orthoses are commonly prescribed by physicians and medical practitioners for preventive or therapeutic purposes. In spite of clinical benefits, the mechanical actions of these devices remain poorly understood and characterised [Thoumie, 2001]. Although some experimental studies focused on the motion restriction of specific braces on surrogate knee joints [Lunsford, 1990], this procedure has never been standardised. An original approach based on a combined FE model and instrumented surrogate limb is presented and used to provide a more objective mechanical assessment of these orthotic devices.

Methods

The surrogate limb consists in two cone-shaped rigid parts connected by a silicon ring, mimicking the thigh, leg and knee (Figure 1A). Different movements were simulated: flexion, varus and anterior displacement (drawer). The reaction forces and moments from the orthosis along these 3 axes were measured during the movements. Two FE models were built to validate the realism of this machine (Figure 1B): the surrogate limb with rigid parts, and a deformable, morphological leg with hyper-elastic soft tissues and an outer skin layer. In a first step, a cross-validation was performed by testing a generic brace both numerically and experimentally. Finally, the robotic limb was used to test a panel of commercially available knee orthoses and rank them.

Results

The numerical model of the brace successfully predicted the experimental response measured by the machine. The behaviour of the surrogate limb was found to be mechanically similar to a deformable limb for the drawer movement, but not for a flexion or varus kinematic due to soft tissue deformation and morphological dissimilarities. A ranking based on measured brace reaction force against the drawer movement was established within each

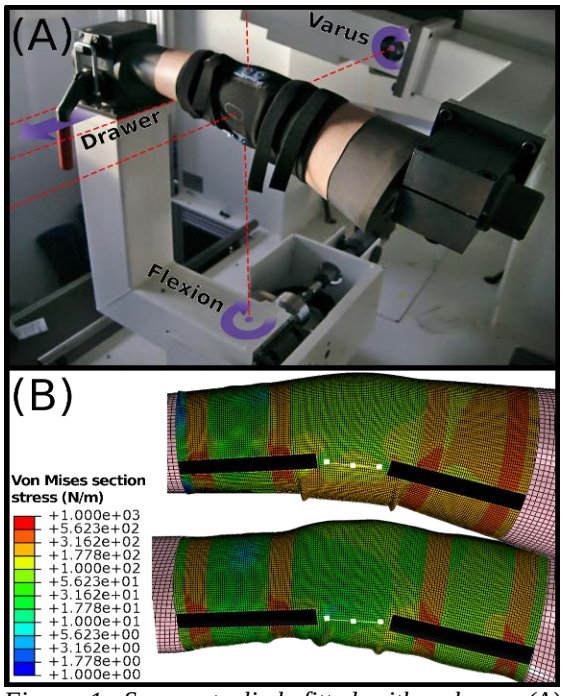

Figure 1: Surrogate limb fitted with a brace (A) and von Mises stresses in the fabric for the rigid (top) and deformable (bottom) FE models (B).

category: compression sleeves (0.83±0.2 N/mm), fabric braces with straps and hinged reinforcements (2.3±0.6 N/mm), rigid hinged orthoses (3.2±0.8 N/mm) and immobilisation splints (6.9±2.8 N/mm).

Discussion

Although dynamic and proprioceptive effects may play a role in the stabilisation of the knee joint, this study provides a quantitative evaluation index of the stiffening effect of common orthoses. Results remain to be confronted to the required levels of action for different pathologies to gauge the clinical effects of these devices. Thanks to these tools, novel brace designs can be evaluated for an optimal mechanical efficiency.

References

Lunsford *et al*, Journal of Prosthetics and Orthotics, 2:274, 1990.

Thoumie *et al*, Annales de Réadaptation et de Médecine Physique, 44:567–580, 2001.