EXPERIMENTAL IDENTIFICATION OF A CONTINUOUS, NON-LINEAR MAP OF THE KNEE COMPLIANCE

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Introduction

Understating the knee response to loads is paramount to identify the causes of knee injuries and pathology [1]. Alternatively to explicit model of the joint, we present a present a continuous, non-linear map of the knee compliance: for any flexion angle and load, the map returns the relative position and orientation of the joint. In this work, we present how the map has been built and we will test it reliability versus experimental measure.

Methods

Three cadaveric legs were tested on a loading rig [2]. The femur reference system was set according to [3], while the tibia one was set as coincident with the femur one at leg full extension. Relative motion was expressed according to [4].

The rig is design to impose the knee flexion and a generic force and/or torque, leaving the remaining tibia-femoral motion components free to be determined by the joint equilibrium, while measuring the tibio-femoral motion with a stereophotogrammetric system.

First we measure the knee natural motion, i.e. without external loads.

To map the knee compliance, we then applied constant forces and torques along and about each axis of the tibia reference system, flexing the knee up to 140°. Each axis was loaded independently, varying the magnitude and the sing of the applied forces and toques (Tab. 1).

Foer each loaded motion, knee compliance was defined as the variation with respect to the natural motion; an approximating polynomial surface of fourth degree in knee flexion and third degree in load magnitude was fit to experimental data.

To obtain knee response to a generic load, we assume it is possible to superimpose the effect of the individual loading components.

To test the method, we compare the predicted knee compliance with experimental data obtained with four combined loading condition on each leg: a compressive load equal to 150 or 350 N in combination ± 10 Nm torque of internal/external rotation.

Results

Figure 1 shows the complice map in case of the drawer test, on the direcly loaded AP components and on the IE. The compliace is non linear: both anterior and posterior loads are associated with interanal rotation of the knee. AP displacement varies non-monotonically with flexion. Table 2 report the Root Mean Squared error for the predicted vs measured knee displacemente for the composed loading senario considered.

	x-axis AP/AA	y-axis PD/IE	z-axis ML
Force [N]	± [50,80,100]	+ [50,80,100, 150,200,250 300,350]	± [50,80,100]
Torque [Nm]	± [10,15,20]	± [5,8,10]	---

Table 1: Sign and magnitude of the applied load for the characterization of knee compliance: AA = abduction/adduction, IE = internal/external rotations; AP = antero/posterior, PD = proximo/distal, ML = medio/lateral translation.

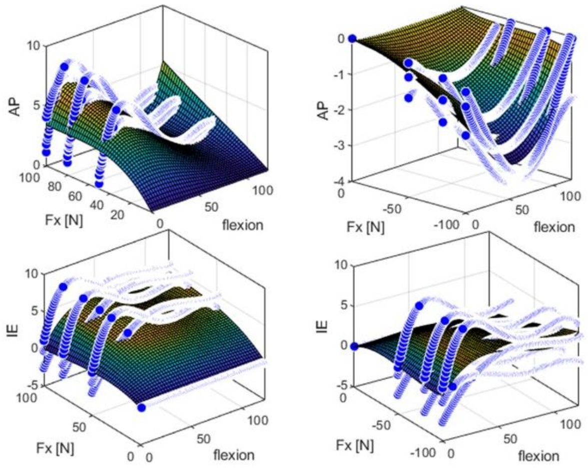

Figure 1: Compliance surface for positive (left) and negative (right) AP loads. Blue dots represent experimental data.

	AA	IE	AP	PD	ML
RMSe	2.3 °	4.1°	3.2 mm	2.0 mm	2.3 mm

Table 2: Root mean squared error between predicted and measure knee displacement under combined loads.

Discussion

Although other examples are available [5], to the authors knowledge this is the first continuous quantification of the knee compliance. This characterization of the knee could help in understanding ethology of knee pathology and in the design of better treatment and medical devices.

References

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