Considerations for experimental investigation of knee biomechanics.

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The knee joint has been and is currently studied from a biomechanical viewpoint. The study of the joint degrees of freedom and of the forces/moments loading the joint is aimed at determining the function of a healthy or injured joint. Several methods are used to investigate the biomechanics of knee joint, including:

- Clinical analysis/evaluation: this may be done qualitatively by clinical "feel", or using dynamic imaging (e.g. using an open access MRI scanner);
- Experimental evaluation *in vivo*: these studies might include invasive implantation of load or strain gauges and can be ethically challenging and/or limited from a design of experiment viewpoint (not all parameters can necessarily be measured or controlled). Alternatively, techniques such as Gait-analysis (including force plate measurements and/or motion capture) are used;
- Experimental investigation *ex vivo*: this has the advantage that experimental parameters can be controlled and systematically varied, under reproducible conditions, however, the muscle action is neglected or imposed, not measured;
- Numerical simulations: such as kinematic modeling (e.g. multi-body dynamics) or structural analysis (e.g. Finite Element Analysis) are used although an a-priori knowledge of the joint is necessary, while validation of model predictions is required.

Ex vivo testing offers the chance to study deeply the knee joint biomechanics. However, there are some key considerations for *ex vivo* testing including:

<u>Degrees of freedom</u>:
The influence of enabling full knee motion (i.e. unconstrained) or constraining its motion alters the loads acting through the knee. A constrained system could be easily controlled but tests conducted in this manner cannot necessarily represent the *in vivo* kinematics of the knee.

<u>Loading conditions</u>:
Estimated physiological loads can be applied to determine the displacement induced per load (or vice versa). The loading can be controlled, and replicated, although the loading scenario could not replicate exactly the *in vivo* loading condition.

<u>Condition of retrieved knee joint</u>:
It is necessary to maintain all the structures of the knee intact, although this can complicate the experimental procedure.

<u>Measurements using experimental set-up:</u>
Using an experimental set-up, it is possible to replicate clinical experiments in order to determine the stiffness of the joint when intact and after rupture of ligaments. For example, clinically relevant measurements of stiffness, replicating either drawer tests or rotation, can be made.

Experimental *ex vivo* methods are planned in our laboratory to determine the natural biomechanics of the knee, with two main outcomes: firstly, that of determining the biomechanical behaviour of healthy knees (which can then be used as a control to evaluate knee replacement devices, surgical repair, or the contribution of different components to physiological biomechanics); secondly, to provide data useful for development of knee joint models.