TOWARDS A 'NO-THIGH MARKERS' PROTOCOL OF GAIT ANALYSIS

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SUMMARY
An attempt to reduce the need for markers on the thigh is being carried out by modelling the knee joint constraints. By using MRI and fluoroscopy, the relative movements of femur, tibia and patella were captured in vivo during knee flexion. The length and orientation of cruciate ligaments were identified all along the range of movement. This information was then used in a four-bar, variablelength linkage model of the tibio-femoral connection. By knowing the location of the hip joint centre (fixed within the pelvis) and the shank in space, the rotation of the thigh can be determined from geometrical relationships. Preliminary results show that knee joint kinematic estimation errors are less than those due to markers being affected by skin artefacts.

CONCLUSIONS
Our experience shows that an approach to gait analysis which makes use of individual anthropometry coming from biomedical images can be deepened. In fact, it seems effective in reducing the effects of skin motion artefacts and to improve the estimation of joint kinematics. Moreover, the reduction in the number of markers positioned over the body would improve the feasibility of the protocol in clinical applications.

INTRODUCTION
Markers on the thigh are particularly affected by skin motion artefact [1], especially those used to define the position of the knee (femoral condyles). Problems exist also for pelvis and shank, but bony surfaces far enough from muscles can be identified. Medical imaging was used to study knee joint kinematic, but mainly in knee replacement [2]. The purpose of our study was to ascertain if the knee joint kinematics imposed by a model-based on anatomical images, although affected by parameters estimation inaccuracy, could be more effective than marker-based protocols used in clinical gait analysis for defining the femur position.

PATIENTS/MATERIALS AND METHODS
Fluoroscopy was used to define the relative position of femur, patella and tibia during flexion/extension exercises. Modified reflective markers were positioned over the skin as to identify the commonly used anatomical landmarks, and were also visible on the fluoroscopic images (FI). Magnetic Resonance Images (MRI), collected on the same subject, were used to identify ligaments. A best match algorithm was implemented to register the whole set of images with the femur as a reference, and the relative movements of tibia and patella were then measured. By fusing MRI and FI data, cruciate ligament's insertion areas visible in the MRI, could then be identified on the FI sequence. The changes of both ligaments lengths were inputted into a four-bar linkage mechanism as to reproduce the bone movements observed through fluoroscopy.

RESULTS

From the many methodological aspect faced out to implement the method, ranging from calibration of the fluoroscope (to correct for distortions), image registration algorithms, MRI segmentation and projection, to kinematic description of the knee joint constraint, several outputs of the model were of interest: the changes in length of the cruciate ligaments in the FI projection, the relationship between their orientation and knee joint angle, the trajectory of the patella, the orientation of the patellar ligament. Skin motion artefacts were also estimated: the skin-marker on the femoral condyle moved by 17 mm during full range knee flexion.

DISCUSSION

The need for simple protocols of gait analysis sufficiently accurate and exempt from skin motion artefact is particularly perceived in the clinical field. Our approach was intended to test a possibility of integrating the usual motion capture data with information from medical images and modelling. The results show that such a method can be feasible and yields some advantages in relation to traditional methods. After implementing this methodological set-up, our objective is to be able to adapt our models to each single individual on the basis of simple external measurements.

REFERENCES

[1] Cappozzo A, et al., 1996, Clin Biomech, 11(2), 90–100.
[2] Banks SA, Hodge WA, 1996, IEEE Trans Biomed Eng, 43(6), 638–49.