IMU-BASED GROUND REACTION FORCES AND KNEE CONTACT FORCES ESTIMATION IN PATIENTS WITH KNEE OA

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1. Introduction

Osteoarthritis (OA) is the most common chronic joint disease. Current therapies for OA patients are limited to symptom relief and in advanced stages of the disease, joint replacement surgery. Altered joint loading is a critical and agreed risk factor for the onset and progression of OA. Therefore, ambulatory monitoring of joint loading-related parameters such as ground reaction forces and moments (GRFM) and tibiofemoral knee contact forces (KCF) have the potential to impact disease management of patients with knee osteoarthritis (PwKOA). However, OA knee joint loading in free-living situations is not well documented as so far inertial measurement units (IMUs) have rarely been combined with musculoskeletal modelling (MSK) workflows. Moreover, estimating KCF using IMUs is still lacking in literature to date. Establishment of such a workflow would impact the clinical management of OA based on objective joint loading measurements in an ecological context.

2. Materials and Methods

Twenty-eight PwKOA (18 females; age: 66.6 ± 7.3 y) walked on treadmill and overground at self-selected speed. A Vicon and an Xsens systems recorded the marker position and the body segment orientations. Using an enhanced MSK workflow - OpenSim Joint Articular Mechanics - with 12DOF knee, the motion capture (MoCap) data was used to calculate the KCF (gold standard). The IMU-based dataset was used as input for the inverse kinematics using a previously developed calibration method [1]. A customized probabilistic principal component analysis (PPCA) model that combines kinematic parameters (events, angles) was used to estimate GRFM based on a training dataset (18 PwKOA) [2]. The estimated GRFM were used as input in the zero moment point (ZMP) method to calculate the COP [3]. The inverse kinematics and external load (GRFM) were used to calculate the KCF that was then compared with the reference MoCap-based KCF.

3. Results

The KOA-based PPCA mean absolute error (MAE) was of <0.047 BW and <0.015 BWm for the estimated GRFM. The estimated COP revealed a moderate-strong correlation (R^2: 0.60-0.96) in the anterior-posterior and medio-lateral direction with an average RMSE 1.5±0.4 and 1.0±0.3 cm, respectively. The KCF RMSE ranges between 0.22-0.55 BW with moderate-strong correlation (R^2: 0.49-0.96). Compared to the MoCap-based KCF (Fig. 1), the IMU-based KCF average error was <0.5 BW at first and second peak as well as the impulse (<0.5 BWs).

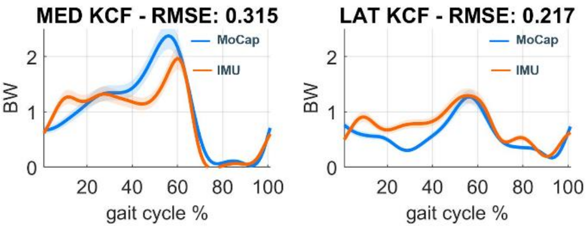

Figure 1: *MoCap-based (blue) vs IMU-based (orange) KCF in BW (body weight) in the knee compartments (medial, lateral)*

4. Discussion and Conclusions

The results show that the developed workflow accuracy would allow the detection of reported differences in KCF between healthy and PwKOA, which are in the order of 0.45-0.60 BW for the first KCF peak and 0.30-0.45 BW for the second KCF peak [4]. The customized probabilistic principal component analysis model, trained based on a PwOA showed an accuracy comparable to the previously developed model based on healthy adults. The developed workflow would eventually allow monitoring KCF in an ecological context and consequent impact of specific gait interventions on an individual patient's locomotor function and joint loading. This is of high clinical importance to inform and help clinical practitioners to induce joint loading changes as part of the regular therapy sessions with the aim to reduce activity-related pain and disease progression.

5. References

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