THE EFFECT OF VARIATION IN ANATOMICAL FEATURES ON KNEE JOINT LOADING: A POPULATION-BASED MODELLING APPROACH

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1. Introduction

Excessive mechanical knee joint loading during activities of daily living has been hypothesized to play a crucial role in the development and progression of knee osteoarthritis [1]. One important key factor that is assumed to greatly contribute to variations in mechanical knee joint loading is the variation in joint geometry [2]. Recent developments in medical imaging processing techniques allow to accurately segment various anatomical geometries, that can be integrated in highly personalised *in silico* musculoskeletal models. Given that MRI images have now been collected in larger clinical cohorts, datasets have become available that allow us to describe the geometrical variation. In this study, we present how population-based modelling approaches, in particular statistical shape model (SSM)-based musculoskeletal modelling, can be exploited to understand the effect of variation in anatomical shape features on knee joint loading.

2. Materials and Methods

A workflow was developed to incorporate population-specific tibiofemoral joint geometry in a musculoskeletal model with a detailed 12 DOF knee joint [3]. Anatomical geometries were adopted from an existing SSM [4], built from MRI-images of 524 patients with knee osteoarthritis. We performed a dynamic gait pattern simulation for the extremes (+/- 3 standard deviation) of each of the first seven modes of variation using a healthy control gait pattern. The healthy control gait pattern was defined using the average of 2 minutes treadmill gait data of 23 healthy subjects (age = 36.69 +/- 4.16 , BMI = 23.85 +/- 3.59). Variations in peak knee contact forces (KCF) were evaluated.

3. Results

The peak knee joint loading varied largely dependent on the individual SSM mode. Maximal variations up to 0.8 BW were found for mode 3 (tibial anterior/posterior position), whereas only limited variation in joint loading was observed for mode 2 (internal/external rotational alignment). Interestingly, the first mode of variation (frontal plane alignment/ ab-adduction alignment), that explained 21.7% of variation in the tibiofemoral population geometry, resulted only in a moderate change in knee contact forces of 0.15 BW.

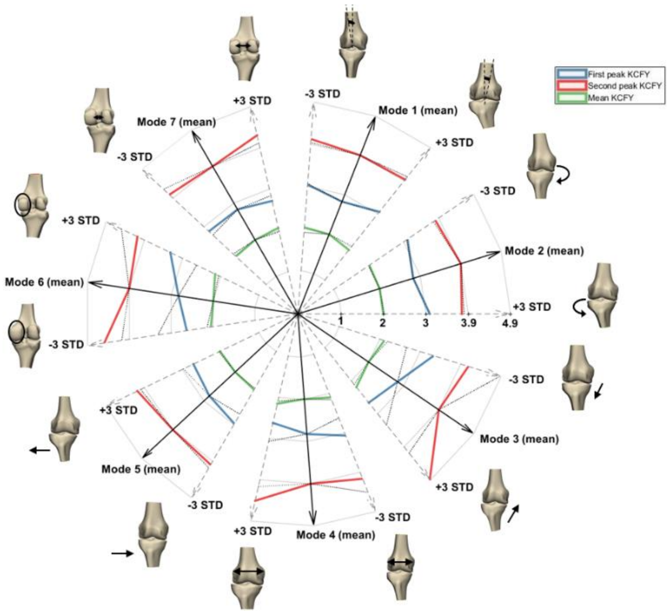

Figure 1: *7 modes of SSM with +/- 3 deviations on the SSM mean. Mean KCF (green), first peak KCF (blue) and second peak KCF (red) are displayed and expressed in bodyweights (BW). Dotted lines are the opposite output to highlight variation in KCF.*

4. Discussion and Conclusions

Population-based approaches, such as combining a SSM with a musculoskeletal simulation workflow, allow the identification of relevant tibiofemoral joint anatomical features that explain variability in knee joint loading. Our results highlight that relative anterior-posterior position of the tibia with respect to the distal part of the femur plays a key role in knee joint loading variability between patients with different anatomy.

5. References

1. Andriacchi, et al. 2006 Current Opinions in Rheumatology
2. Vaienti et al. 2017. Acta bio-medica : Atenei Parmensis
3. Lenhart et al., Ann Biomed Eng, 43(11): 2675-85, 2015
4. Van Dijck et al., Comp Meth Biomech Biomed Engin.,21(9):568-78, 2018

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