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Net joint moments versus internal joint loading: Can we trust correlations between joint moments and contact forces from generic-scaled models?

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Background

Net joint moments, quantified via inverse dynamic, are influenced by the person's kinematic and ground reaction forces. Joint contact forces (JCF), estimated via musculoskeletal (MSK) simulations, additionally depend on the person's musculoskeletal geometry [1] and muscle recruitment strategy [2].Altered joint loading is associated with degenerative diseases, e.g. osteoarthritis, and should therefore be avoided. Recent research showed that joint moments can be used as surrogate measure to quantify hip and knee joint loading [3] [4]. These studies, however, analyzed the correlation between joint moments and JCF based on generic-scaled MSK models and therefore neglected the subject-specific geometry. The aim of this study was to evaluate if accounting for the subject-specific geometry would alter the correlations between joint moments and JCF.

Methods

We analyzed three-dimensional motion capture and magnetic resonance image (MRI) data of twelve typically developing children (10.5 ±2.3 years, height: 144.5±8.5 cm, weight: 36.8±9.5 kg). Femoral neck-shaft (NSA) and anteversion angles (AVA) were quantified based on the segmented MRI with a customized Matlab script. For each participant, two MSK models based on the "gait2392"-model were scaled to the anthropometry of each child. One model included the generic femur and the other one included the subject-specific AVA and NSA. Both models were therefore identical except for the femoral geometry. Joint moments were calculated via inverse dynamics and MSK simulations were performed with OpenSim to estimate JCF.Similar to previous studies, peaks of the knee and hip JCF during the first and second half of the stance phase were identified and correlated to the occurring joint moments in the frontal and sagittal plane of the corresponding joint.

Results

The analyzed dataset, included a wide range of AVA and NSA with angles ranging from 10.5° to 48.4° and 124° to 141.5°, respectively. Significant ($p<0.01$) linear correlations were found between knee flexion moment and the first peak of knee JCF. The first peak of hip JCF can be predicted by the hip adduction moment while the second peak strongly correlates with the hip extension moment. These significant correlations were found in the generic and personalized MSK models.

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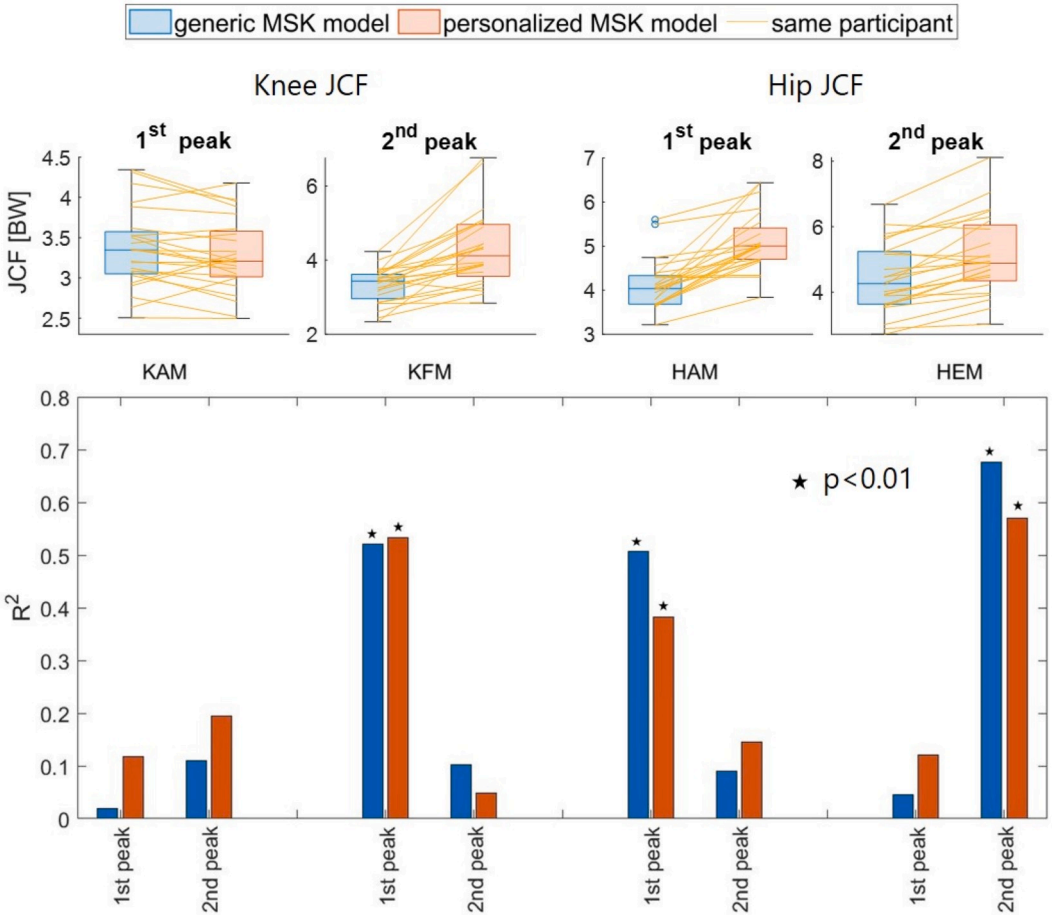

First and second peak of knee and hip JCF for different MSK models. Yellow lines represent the same participants. Coefficients of determination (R2) of the linear correlations between knee adduction (KAM), knee flexion (KFM), hip adduction (HAM) and hip extension (HEM) moments to corresponding JCF

Conclusions

We found similar correlations between joint moments and JCF based on generic and imaging-based MSK models. Nevertheless, JCF showed often big differences between models. It seems acceptable to use joint moments as a rough surrogate measure to estimate internal joint loading. Quantifying the magnitude of JCF based on joint moments, however should be avoided due to potential errors and misleading conclusions.

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