ESTIMATION OF KNEE JOINT CONTACT FORCE MAXIMA DURING GAIT USING A VIDEO CAMERA AND DEMOGRAPHIC DATA

Jere Lavikainen (1), Lauri Stenroth (1), Paavo Vartiainen (1), Tine Alkjær (2), Mimmi K. Liukkonen(3), Rami K. Korhonen (1), Mika Mononen (1)

1. Department of Technical Physics, University of Eastern Finland, Finland; 2. University of Copenhagen, Denmark; 3. Department of Clinical Radiology, Kuopio University Hospital, Finland

Introduction

Joint loading has a role in maintaining tissue homeostasis and contributes to the onset and development of joint conditions such as osteoarthritis [1]. Subject-specific load estimation could help in planning of treatment strategies, such as personalized rehabilitation, of such conditions [2]. Currently, subject-specific knee loading can be estimated with musculoskeletal modeling and simulation (MS) [3] but typically requires measurement in a motion laboratory, which involves time (participant preparation, analysis) and cost (large space, personnel, equipment). These limitations would be eliminated if knee joint contact forces (KJCFs) could be estimated from simple input predictors using artificial neural networks.

Methods

We trained feedforward artificial neural networks (ANNs) to estimate tibiofemoral KJCF maxima based on subjects' mass, height, age, gender, walking speed, and peak knee flexion angle. First, the ANNs were trained with data from 5 existing motion capture datasets [4–8] and included 5000 trials from 296 subjects. Next, we measured the overground gait of 10 healthy voluntary participants, unrelated to the training data, using optical motion capture, while simultaneously recording their sagittal-plane motion with a video camera. Ten trials were recorded per participant. From each participant's demographic data (mass, height, age, gender) and data extracted from video data using OpenPose [9] (walking speed, peak knee flexion), KJCF maxima in the medial and lateral compartments and the sum of the KJCF of both compartments were estimated with the trained ANNs. Reference KJCF maxima were MS-estimated from optical motion capture data using OpenSim. The estimation accuracy of the ANNs was quantified by the root mean square errors normalized to the mean of the MS-estimated maxima (NRMSE) and Pearson correlation coefficients (R) between the ANN-estimated and MS-estimated KJCF maxima.

Results

The NRMSE (normalized to the mean of MS-estimated maxima) and Pearson correlation coefficients between ANN-estimated and MS-estimated KJCF maxima across all subjects were 0.18 and 0.86 for loading of both compartments summed (Figure 1); 0.19 and 0.79 for the medial compartment; and 0.26 and 0.84 for the lateral compartment, respectively.

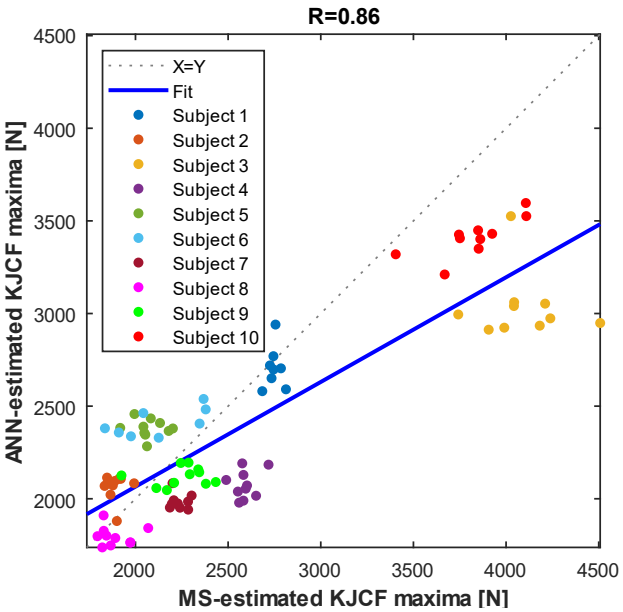

Figure 1: Regression plot of ANN-estimated total KJCF maxima with respect to the reference maxima (MS-based). Dashed line X=Y shows line of equality and the solid blue line a linear fit into the data points. Trials under different subjects shown in different colors.

Discussion

We showed that ANNs can be used for approximating KJCF maxima during walking with demographic and video camera data. ANNs underestimated the loading maxima for all participants except those with very low loading, the reason for which will be examined in the future and the model refined accordingly. The use of ANNs eliminates the need for measurements in a laboratory setting and skips time-consuming MS analysis steps. Thus, the estimation of KJCF maxima could be done more portably, e.g., with a webcam during a physician's appointment. Effortless estimation of KJCF maxima could support physical rehabilitation and gait retraining-based interventions.

References

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