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A subject-specific musculoskeletal model to estimate joint loading at different walking speeds

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INTRODUCTION

Physical activity, i.e. walking and jogging, are nowadays highly recommended by physicians for reducing the occurrence of fall and injury in elderly [1]. Little is known about whether these tasks might increase joint loading and represent a risk for articular integrity. Previous studies, in fact, have only investigated the link between walking speed (WS) and hip joint loading in young healthy adults [1]. This study aimed at investigating the effect of WS on the lower limb joint contact forces (JCFs) estimated using a patient-specific musculoskeletal model in a group of women with osteoporosis.

METHODS

Seven women (69.6±4.0y, 67±8kg, 160±3cm) underwent 3D gait analysis (Vicon and Kistler, UK) and lower limb MRI (T1-weighted VIBE). Bones and muscles (21 from each limb) were segmented using Mimics 20.0 (Materialise, Belgium) and used to build personalised anatomical models (NMS Builder, [2]) using a previously established modelling technique [3]. Values of muscular maximal isometric force F_{max} were calculated based on segmented muscle volumes according to: $F_{max}=k*Volume/l_{opt}*\cos(\alpha)$, where k is the specific tension (61 N/cm^2), l_{opt} is the optimum fibre length and α is the pennation angle at l_{opt}. MRI-visible markers were included in the model and used for the registration with gait data. Simulations of walking tasks at slow, self-selected, and fast speed were run in OpenSim [4] and the estimated JCFs were compared through 1-way ANOVA (α=0.05) using 1d Statistical parametric Mapping (SPM) package [5].

RESULTS

JCFs, scaled to bodyweight (BW), varied significantly with WS in the first peak of hip and knee stance phase (0.9 BW and 1.1 BW average group increase, respectively). Ankle JCF peak decreased by 0.7 BW on average, but this was not significant at group level due to three subjects presenting slightly increased JCFs.

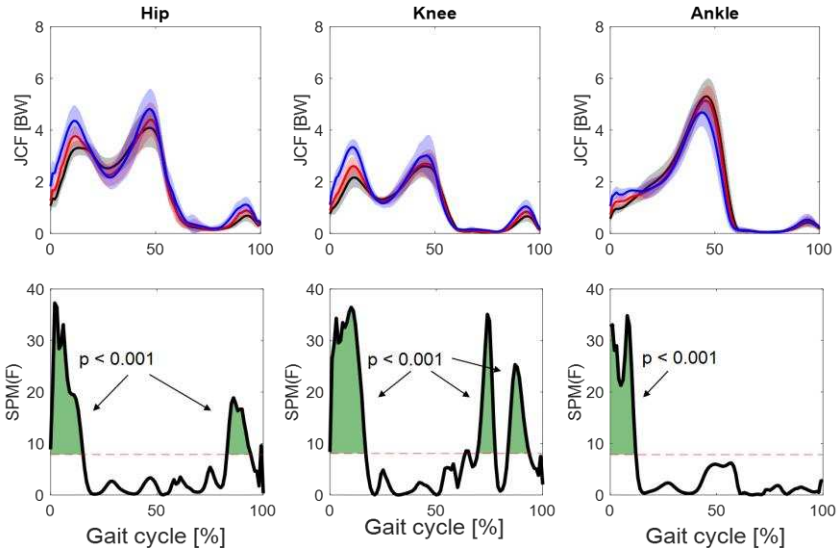

Fig 1 Average JCFs at slow (1.1±0.2m/s, black), self-selected (1.3±0.1m/s, red), and fast (1.6±0.1m/s, blue) speed and corresponding ANOVA distribution (SPM(F)) with supra-threshold clusters (green) and *p-values* throughout the gait cycle.

DISCUSSION

The values of hip JCFs estimated for our group of osteoporotic women were in line with those reported for young adults (4.2 BW at 0.8 m/s vs 5.7 BW at 1.7 m/s) [1]. Peak JCFs increased by 45% and 65% at hip and knee joints, respectively, however loading remained always well below the values previously observed for possible spontaneous fracture in osteoporosis [6]. The ankle JCF showed inconclusive evidences, suggesting variable loading strategies between individuals. Current investigation is focusing on possible relation between ankle JCF and F_{max} of muscles acting on the ankle joint.

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