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## Musculoskeletal modelling informed muscle coordination re-training to reduce knee joint loads

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### Introduction

Excessive loads at lower limb joints can lead to pain and degenerative diseases [1]. Real-time biofeedback training can be used to alter muscle recruitment strategies and therefore potentially decrease joint loads [2,3]. Knowing which muscles have the biggest impact on joint loads is crucial for subject-specific gait re-training.

### Research question

Which muscles have the biggest impact on knee loads?

### Methods

Musculoskeletal simulations were performed based on motion capture data of 5 healthy adolescents (femoral torsion 10°-29°, tibial torsion 19°-38°) and 5 patients with idiopathic torsional deformities at the femur and tibia (femoral torsion 18°-52°, tibial torsion 3°-50°). For each participant, a generic model [4] was modified to match the femoral and tibial geometry obtained from magnetic resonance image [5]. Each participant's model and the corresponding motion capture data were used as input for Monte Carlo Analyses. A modified optimization approach [2], which allowed to allocate different penalty weights to each muscle, was used to calculate muscle forces and joint contact forces (JCF). The same random combination of muscle weights (n = 10,000) was used for each model. OpenSim [6] was used to run 10,000 simulations for each model. Root-mean-square of muscle forces and peak JCF were compared between simulations. Furthermore, we compared our results to reference simulations based on static optimization with equal weightings for all muscles.

### Results

Depending on the participants, knee JCF were reduced in 8% to 45% of all simulation compared to the reference simulation with maximum reduction in JCF between 4% and 45%. Patellofemoral JCF were reduced in 17% to 58% of all simulation with maximum reduction in JCF between 16% and 37%. In some but not all participants reducing knee loads increased hip loads. In most participants, increasing soleus and decreasing gastrocnemius medialis and vastus lateralis forces reduced knee JCF (Fig. 1). Decreasing vastus lateralis, increasing tensor faciae latae and adductor magnus muscle forces decreased patellofemoral forces in most participants. A high variability in muscle coordination strategies to decrease joint loads was observed between participants.

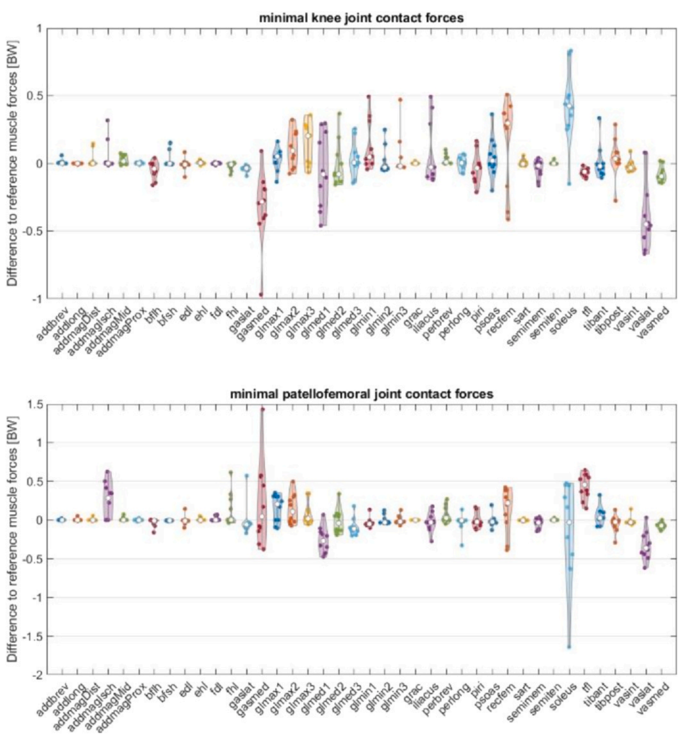


**Figure 1.** Difference in root-mean-square muscle forces between the reference simulations and simulation with the lowest knee (top subplot) and patellofemoral (bottom subplot) joint loads. Each dot in the violin plot represents the results from one participant.

## Discussion

We determined subject-specific muscles, which alterations have the potential to reduce JCF. Our findings agree with experimental studies [2] and previous simulations based on different approaches [3,7]. We showed that the potential of reducing JCF with altered muscle coordination is highly subject-specific and depends on the person's musculoskeletal geometry and gait pattern. Our workflow can be used to (i) evaluate if muscle coordination re-training might be useful for a patient to reduce knee loads, and (ii) pinpoint subject-specific muscles, which should be targeted during the training.

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## Age related changes in lower-limb joint coordination during gait in children with bilateral cerebral palsy

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### Introduction

Human movement is a complex task that requires precise multi-joint coordination to achieve functional movement patterns [1]. For children with cerebral palsy (CP), multi-joint coordination has been shown to be impaired when compared to their typically developed (TD) peers [2]. Specifically, children with CP demonstrate a more in-phase gait strategy at the beginning and end of the gait cycle with in-phase coordination linked to increased gait deviations [2]. Examining multi-joint coordination could be a useful tool in developing intervention and treatment patterns in children with CP. However, before it can be used as an outcome measure for assessment in clinical practice, it is important to understand how joint coordination patterns progress naturally over time, particularly in the absence of surgical intervention. Treatment aimed at improving lower-limb joint coordination in children with CP can then only be deemed successful if outcomes either match or exceed these changes [3].

### Research question

How does lower limb multi-joint coordination change over time in children with CP without a history of surgical intervention?