CAN ALTERED MOTOR CONTROL DECREASE JOINT LOADS IN PEOPLE WITH TYPICAL AND INCREASED ANTEVERSION ANGLES?

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Introduction

Excessive loads at lower limb joints can lead to pain and degenerative diseases [1]. Increased femoral anteversion angle (AVA) can alter a person's gait and lead to skeletal disorders [2]. Our previous work showed how large AVA increase muscle co-contraction during walking and lead to significantly increased hip and knee joint loads [3,4]. Real-time biofeedback training can be used to alter muscle recruitment strategies and therefore potentially decrease joint loads [5,6]. The aim of the current study was to investigate how different muscle recruitment strategies can alter joint loads in people with typical and increased femoral AVA.

Methods

Musculoskeletal simulations were performed to estimate muscle forces and joint contact forces (JCF) based on 3D motion capture data of one healthy, typical person (TYPper, AVA of 12°) and a patient with idiopathic increased femoral AVA (AVApat), i.e. AVA of 39°. A musculoskeletal model was scaled to each participant's anthropometry. For the AVApat, the model's femoral AVA was modified to match the subject-specific values obtained from magnetic resonance images [7]. Both models and the corresponding motion capture data were used as input for Monte Carlo Analyses. A modified static optimization approach [5], which allowed to allocate different penalty weights to each muscle, was used to calculate muscle forces. The same random combination of muscle weights (n=10,000) was used for each model. OpenSim [8] was used to run 10,000 simulations for each model. Root-mean-square of muscle forces during the stance phase and peak JCF were compared between models. Pearson correlation coefficients (R) and regression slopes (S) between muscle forces and JCF were used to investigate each muscle's impact on JCF. Furthermore, we compared our results to reference simulations based on static optimization with equal weightings for each muscle. To evaluate the practical implication of our simulation results, we conducted the following additional experiments. In six healthy participants real-time feedback of electromyography signals of important muscles (specified with our simulations) was used to evaluate if people can alter their muscle recruitment strategies during walking.

Results

TYPper walked faster (1.41m/s) than the AVApat (1.15m/s). For most simulations, hip JCF were higher whereas patella and ankle JCF were lower in the AVApat compared to the TYPper (Fig. 1). In both participants, soleus (R=-0.87/-0.89, S=-1.7/-2.2 for TYPper/AVApat) and gastrocnemius medial forces (R=0.75/0.68, S=1.7/1.7) had a big impact on knee JCF, whereas peroneus longus (R=0.80/0.58, S=3.8/2.9) forces influenced ankle JCF. Hip JCF could be reduced by decreasing semimembranosus forces (R=0.41, S=1.9) in the TYPper. For the AVApat, the rectus femoris (R=0.58, S=1.0) and gluteus maximus (R=0.43, S=2.1) forces had the biggest impact on hip JCF. In the TYPper hip, knee, patella and ankle JCF were reduced in 9%, 19%, 39% and 40% of all simulation compared to the reference simulation with maximum reduction in JCF by 8%, 11%, 33% and 4%, respectively. In the AVApat hip, knee, patella and ankle JCF were reduced in 41%, 31%, 20% and 37% with maximum reduction in JCF by 26%, 19%, 21% and 3%, respectively. All participants of the biofeedback experiments could alter the muscle activity of the soleus. 83%, 33% and 50% of participants were able to alter gastrocnemius, rectus femoris, and semimembranosus activity, respectively.

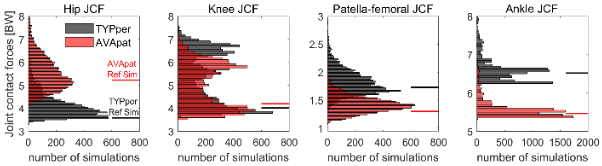

Fig. 1: JCF obtained from the Monte Carlo simulations.

Discussion

This is the first study that showed the potential to alter JCF with different muscle recruitment strategies. Our findings agree with experimental studies [5] and previous simulations based on different approaches [6,9]. Our healthy participants walked with very low rectus femoris activity, which might explain why a reduction in rectus activity was not feasible during the biofeedback training in 4 out of 6 participants. In summary, we showed that (i) altered muscle coordination can significantly reduce (up to 30%) hip, knee and patella JCF but not ankle JCF (less than 4%), (ii) the potential of reducing JCF with altered muscle coordination strategies is highly subject-specific and depends on the person's musculoskeletal geometry and gait pattern, (iii) muscle recruitment re-training seems to have more potential in patients compared to healthy participants, and (iv) unfavorable muscle coordination can significantly increase JCF.

References

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