Reducing gastrocnemius activity during walking decreases knee loading in individuals with knee osteoarthritis

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Summary

Reducing knee loading during walking is a promising target for knee osteoarthritis interventions. We evaluated the effects of muscle coordination retraining that used haptic feedback to encourage walking with reduced gastrocnemius activity. 13 of 18 individuals with knee osteoarthritis were able to reduce their gastrocnemius activity with feedback. These individuals reduced the second peak of knee contact force by 0.38 ± 0.47 body weights (p = 0.01).

Introduction

Knee osteoarthritis affects approximately 23% of individuals over the age of 40 [1]. Higher knee contact forces during walking accelerates disease progression [2], making reducing joint loading an important goal. Muscle forces are the main contributor to knee contact force (KCF) [3]. Prior work has shown that reducing gastrocnemius activation reduces KCF in individuals without knee osteoarthritis [4]. This study investigated the ability of individuals with knee osteoarthritis to reduce their KCF by receiving vibrational haptic feedback instructing them to reduce gastrocnemius activation while walking. We also evaluated compensatory changes in joint kinematics and kinetics.

Methods

Adults with tibiofemoral knee osteoarthritis participated in one or two gait retraining sessions. We measured surface electromyography (EMG) from the medial gastrocnemius while participants walked naturally at a self-selected speed on a force-instrumented treadmill (baseline). Participants then aimed to reduce their gastrocnemius activity during 5 trials of 6 minutes, in which they received haptic feedback after each step based on their muscle activity change from baseline. Eighteen participants completed the first session. Thirteen were able to reduce gastrocnemius activity by 10%, making them eligible to complete the second session. During the second session individuals repeated the training with haptic feedback, and we collected motion capture data for use in musculoskeletal simulations to estimate KCFs.

We simulated data from five baseline and five feedback steps for each participant during the second session (n=13). Using inverse kinematics and inverse dynamics in OpenSim 4.5 [5], we solved for ankle, knee, and hip sagittal-plane angles and moments. Knee contact force was estimated using a static optimization algorithm [4] that minimized the sum of squared muscle activations and matched the measured change in gastrocnemius activation. We compared peak KCF during early stance and late stance. We also assessed changes in kinematics and kinetics with a paired t-test or Wilcoxon signed rank test (α=0.05).

Results and Discussion

During the second session, participants reduced gastrocnemius activation by 25±15% (p<0.001). This reduced the second peak of the KCF by 0.38±0.47 bodyweight (BW) (12%, p = 0.01, Figure 1). With feedback, individuals walked with 3.0±3.2° (p<0.001) more dorsiflexion during early stance and 2.8±3.9° (p=0.02) more dorsiflexion during late stance. There were no significant changes in knee or hip kinematics or early stance peak joint moments. The late stance peak plantarflexion moment decreased by 0.92±0.83% BW*height (p=0.002), knee flexion moment decreased by 0.64±0.45% BW*height (p<0.001) and hip flexion moment increased by 0.28±0.58% BW*height (p=0.03). The reductions in late stance ankle and knee moments suggest that redundant muscles (i.e., soleus and hamstrings) did not fully compensate for reduced gastrocnemius force.

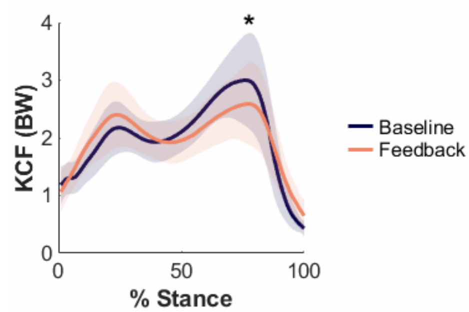

Figure 1: Mean (line) and standard deviation (shaded region) of simulated knee contact force. Feedback to reduce gastrocnemius activity reduced the second peak of knee contact force (*p=0.01).

Conclusions

Individuals with knee osteoarthritis were able to reduce their gastrocnemius activity and KCF with haptic feedback. The 0.38 BW reduction in KCF is similar to weight-loss interventions that improved pain [6]. The pain-relieving effects of this retraining intervention should be investigated.

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