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Short communication

Training multi-parameter gaits to reduce the knee adduction moment with data-driven models and haptic feedback ☆

Pete B. Shull [a,]*, Kristen L. Lurie [b], Mark R. Cutkosky [a], Thor F. Besier [c]

[a] Department of Mechanical Engineering, Stanford University, Center for Design Research, Stanford, CA 94305-2232, USA
[b] Department of Electrical Engineering, Stanford University, Stanford, CA, USA
[c] Department of Orthopaedic Surgery, Stanford University Medical Center, Stanford, CA, USA

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ABSTRACT

The purpose of this study was to evaluate gait retraining for reducing the knee adduction moment. Our primary objective was to determine whether subject-specific altered gaits aimed at reducing the knee adduction moment by 30% or more could be identified and adopted in a single session through haptic (touch) feedback training on multiple kinematic gait parameters. Nine healthy subjects performed gait retraining, in which data-driven models specific to each subject were determined through experimental trials and were used to train novel gaits involving a combination of kinematic changes to the tibia angle, foot progression and trunk sway angles. Wearable haptic devices were used on the back, knee and foot for real-time feedback. All subjects were able to adopt altered gaits requiring simultaneous changes to multiple kinematic parameters and reduced their knee adduction moments by 29–48%. Analysis of single parameter gait training showed that moving the knee medially by increasing tibia angle, increasing trunk sway and toeing in all reduced the first peak of the knee adduction moment with tibia angle changes having the most dramatic effect. These results suggest that individualized data-driven gait retraining may be a viable option for reducing the knee adduction moment as a treatment method for early-stage knee osteoarthritis patients with sufficient sensation, endurance and motor learning capabilities.

1. Introduction

At least 12% of U.S. adults over age 60 have symptomatic knee osteoarthritis (OA) (Dillon et al., 2006), and this percentage is growing due to an aging baby boomer generation, increased life expectancy and rising rates of obesity (Clarfield, 2002; Elders, 2000). Gait modification has been proposed as a method for lowering the knee adduction moment (KAM), a surrogate measure of medial compartment loading linked to the presence, severity, rate of progression and treatment outcome for medial compartment knee OA (Schnitzer et al., 1993; Baliunas, 2002; Sharma et al., 1998; Miyazaki et al., 2002; Wada et al., 1998; Hurwitz et al., 2002). Foot progression and lateral trunk angle modifications have been shown to influence the KAM (Guo et al., 2007; Lynn et al., 2008; Mündermann et al., 2008). In one study a model-based subject-specific gait was determined using a variety of gait parameters (Fregly et al., 2007).

Real-time feedback is a promising strategy for gait modification training. Visual, audio, and tactile feedback have been implemented to alter knee loading (Barrios et al., 2010; Riskowski et al., 2009; Dowling et al., 2010). Wheeler et al. (in press) calculated the KAM in real-time, displayed this value through visual or tactile feedback, and allowed subjects to self-select gait modifications to reduce the KAM.

Most gait modification interventions tend to prescribe universal kinematic changes for all subjects. While this approach is straightforward to implement, large subject-to-subject variations (Chang et al., 2007; Mündermann et al., 2008) imply that for many subjects the intervention may be inadequate. In contrast, we propose an approach for predicting novel gaits based on data collected from experimental walking trials specific to each subject, hence 'data-driven'. Our primary objective was to determine whether data-driven gaits aimed at reducing the KAM by 30% or more could be identified and trained in a single training session. In addition, we sought to discover the association between the KAM and the tibia angle and compare it with modifications to foot progression and trunk sway angles.

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* Corresponding author. Tel.: +650 723 4258; fax: +650 725 8475.
E-mail address: pshull@stanford.edu (P.B. Shull).

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