Subject-Specific Biofeedback for Gait Retraining Outside of the Lab

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***Abstract*— Knee osteoarthritis is a progressive degenerative disease that has been linked to knee loading. Targeted gait intervention with biofeedback to decrease joint loading is a potential conservative treatment strategy. Here we describe a method to evaluate the efficacy of vibrotactile feedback outside of a constrained laboratory setting.**

Keywords—biofeedback, knee osteoarthritis, gait retraining

I. Introduction

Knee osteoarthritis (KOA) is a painful and disruptive joint disease, thought to be worsened by suboptimal knee loading during ambulation [1]. Although knee joint forces generally cannot be measured *in vivo*, the knee adduction moment (KAM) is a good proxy measure of loading on the medial compartment of the knee [2]. Decreasing KAM has been the target of gait retraining protocols that aim to decrease pain and slow structural degradation. Targeted gait intervention with vibrotactile feedback has been shown to successfully modify KAM in controlled lab settings [3]. Real-time biofeedback on variables assumed to influence KAM, such as foot progression angle (FPA), is a promising conservative treatment strategy (Fig. 1).

While gait retraining in the laboratory is a promising start, there are currently no tools to monitor long-term patient adherence in natural environments. Laboratory studies on biofeedback to change KAM have focused on level-ground walking only, but this simplified setting may not be an accurate representation of natural activity. To address this challenge, we are using a new wearable haptic device (SageMotion LLC, USA) that uses inertial measurement units (IMUs) to measure the kinematics of interest, compare them against the desired target, and provide the patient with real-time vibrotactile feedback. We aim to understand how one's ability to learn a new gait that decreases KAM is affected when walking outdoors as compared to walking over a laboratory treadmill. Given the increased challenge of natural walking, we hypothesize that the percent of successfully modified steps will be lower when walking outside than on a laboratory treadmill. Here we describe a study protocol to quantify whether subject-specific biofeedback can be used for gait retraining outside of the lab.

II. Methods

This study will be conducted over the course of three days. In the first visit, each participant will walk at a self-selected speed on an instrumented treadmill, and we will find their target FPA, defined as the angle that decreases the peak knee adduction moment: either a toe-in or toe-out angle. Participants will wear one IMU on top of each foot for measuring FPA, and two vibrotactor units for haptic feedback on the inside and outside of one shank. A post-hoc analysis of the knee adduction moment will be used to determine each subject's target FPA. On the second and third days, the cohort will be split into two counterbalanced groups: those who first receive gait retraining outside, and those who first retrain gait inside. Each participant will be informed of their target foot progression angle and prompted by vibratory feedback to maintain it while walking for 20 minutes. The outcome of interest is the number of successful steps (FPA within target tolerance), expressed as a percentage of the total steps.

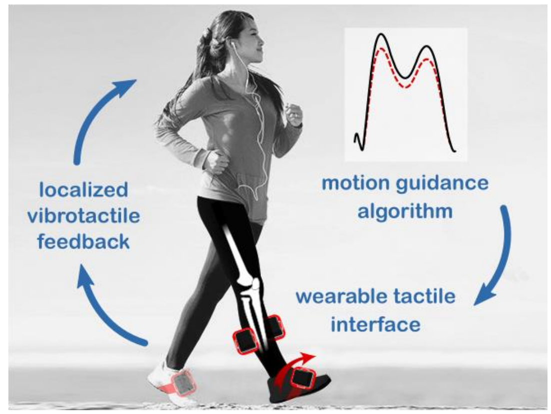

Fig. 1. To optimize feedback delivery in natural environments, we must first understand how effective standard vibrotactile feedback is outside of a constrained laboratory setting.

III. Conlcusion

Haptic wearables can enable independence from in-lab or in-clinic gait retraining, empowering patients to continue their rehabilitation in their everyday lives and increase adherence to therapeutic programs. Determining the extent to which haptic feedback can assist with gait retraining in realistic environments is foundational to the future design of intelligent or context-aware wearable biofeedback strategies.

References

[1] T.P. Andriacchi, A. Mundermann, R.L. Smith, E.J. Alexander, C.O. Dyrby, and S. Koo, Annals of Biomedical Engineering, 2004.

[2] I. Kutzner, A. Trepczynski, M.O. Heller, G. Bergmann, PLoS One, 2013.

[3] P.B. Shull, A. Silder, R. Shultz, J.L. Dragoo, T.F. Besier, M.R. Cutkosky, S.L. Delp, Journal of Orthopaedic Research, 2013