Feasibility of Real-Time Musical Feedback to Cue Center of Pressure Shifts in Subjects with Chronic Knee Pain

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INTRODUCTION: Osteoarthritis (OA) is the most common joint disease in adults and is influenced by abnormal joint loading during walking. Gait modifications can reduce joint loading and improve pain and function in people with knee OA [1,2], yet retraining gait is challenging, and not all patients respond equally. One biomechanical target of interest is the center of pressure (CoP): medializing the CoP during walking has been shown to reduce a surrogate measure of knee loading in healthy adults [2]. To support this retraining, our team developed a real-time musical feedback system that cues individuals to shift CoP medially. While promising, the feasibility of this approach in patients with chronic knee pain remains unknown. Therefore, our study aimed to evaluate whether individuals with chronic knee pain can engage with and respond to musical feedback–based gait retraining, with a specific focus on its effects on CoP shifts and patient-reported experience.

METHODS: Adults reporting knee pain for over 6 months were recruited to experience and practice with our musical feedback device and provide their perception on it. Exclusion criteria included the use of an assistive device while walking, hearing impairments, or neurological diagnoses affecting gait. To provide musical feedback with the aim of medializing CoP, pressure was measured using 16-sensor wireless insoles (Moticon ReGo, Insole 3) and transmitted data via Bluetooth to a smartphone app (OpenGo), which was relayed via Wi-Fi to desktop software and processed in Max 8 (Cycling '74). Musical feedback was delivered by applying a low-pass filter to muffle the sound of a popular song whenever the participant's average peak lateral CoP exceeded a 25% reduction threshold relative to baseline, producing a muffled sound. Participants were instructed to prevent muffling by shifting plantar pressure medially while maintaining a comfortable gait. The IRB-approved protocol consisted of 5 minutes of baseline walking in a Figure-8, followed by 5 minutes of training with musical feedback, performed in standardized lab shoes. Outcomes included CoP and spatiotemporal parameters (paired t-test, $p < 0.05$; gait line via Statistical Parametric Mapping - SPM), Visual Analogue Scale (VAS) for pain, NASA Task Load Index (TLX) to assess the perceived workload, and a custom post-session questionnaire (Likert-scale and open-ended items).

RESULTS: Preliminary data are presented for five participants (4 females, 68.2 ± 6.5 years old, 76.1 ± 10.4 Kg, 1.66 ± 0.1 m). Gait analysis showed a favored medialization (Fig.1), confirmed by the peak medial lateral CoP (CoPy), lateral and medial plantar pressure (Table 1), and peak percentage of difference analysis (-4.44% ± 6.9). Three participants demonstrated notable medialization of the CoP (Fig.1a-c), while two showed lateralization. Spatiotemporal parameters were not significantly affected (Table 1). Pain level at baseline (VAS 0.3- 8.2) improved in three participants post-training with the musical feedback; the subject with the highest baseline pain reported complete pain relief during training. Another subject reported initial discomfort while adapting to the new pattern, followed by pain relief after "adopting to the music". One subject reported increased pain (4/10) attributed to attentional demands. NASA TLX indicated moderate workload (35.5 ± 3.2/100), with the highest domain being physical demand (12.2/20). Questionnaire results indicated participants felt engaged, confident, and motivated, and expressed willingness to use the system in rehabilitation (Table 2).

DISCUSSION: Like previous studies investigating plantar pressure-based feedback, initial findings in this study suggest a varied response across subjects. Three of the five individuals with knee pain understood and responded to the musical feedback cueing without excessive physical or mental effort. Most of the participants reported pain relief, suggesting potential therapeutic benefit in such individuals. Conversely, one participant lateralized their gait line (Fig.1e). Individual variability highlights the importance of identifying responders versus non-responders in future studies. Qualitative feedback emphasized that music improved motivation and distraction from pain. One participant reported being "surprised she could do that much walking without the cane", since she "didn't have pain at all". Another subject felt the music was "a good distraction" from pain. Only one subject reported discomfort at the ankle. Overall, real-time musical feedback appears feasible, acceptable, and motivating for gait retraining in patients with chronic knee pain, supporting larger trials to assess clinical effectiveness.

SIGNIFICANCE/CLINICAL RELEVANCE: These findings provide early evidence that musical feedback can be feasibly integrated into gait retraining, supporting further investigation of its clinical effectiveness in reducing joint loading and improving outcomes in knee OA.

REFERENCES: [1] Ulrich et al. (2025) Lancet [2] Reh et al. (2021) Front. Sports Act. Living, 3; [3] Cedin et al. (2025) Healthcare, 13(2).

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Table 1. Center of pressure, plantar pressure, and spatiotemporal gait parameters.

	Baseline	Training
Mean Peak COPy [-Lat/+Med]	-0.15 ± 0.1	-0.12 ± 0.1
Lateral plantar pressure (N/cm^2)	17.05 ± 5.8	15.03 ±7.3
Medial plantar pressure (N/cm^2)	17.37 ± 5.7	19.39 ± 7.7
Cadence (stride/min)	49.22 ± 7.2	47.2 ± 10.3
Stride length (m)	1.11 ± 0.2	1.06 ± 0.2
Walking speed (m/s)	0.92 ± 0.2	0.87 ± 0.3

Table 2. Sample questions from the post-session questionnaire (Likert Scale).

	%Agree or Strongly Agree	% Disagree or Strongly Disagree
I was able to detect when the music muffled	100	0
The musical feedback was intuitive and easy to interpret	100	0
I was confident in my balance while walking with the new movement pattern	80	0
I would feel comfortable using this device without supervision	100	0
The music increased my motivation to walk during the testing session	80	20
The insoles were comfortable to wear	100	0
I would be willing to walk with musical feedback as part of my knee rehab.	100	0

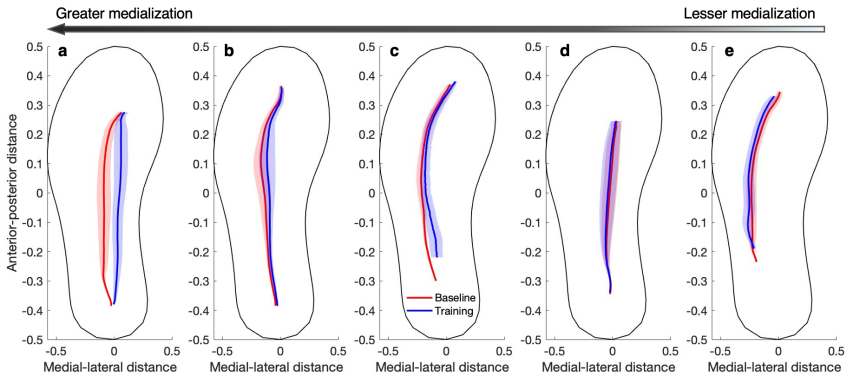

Figure 1. Mean gait line at baseline and at training with musical feedback for each subject. Shaded regions represent ± SD. +Med/-Lat, +Pos/-Ant, no measurement unit.