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Wearable Biofeedback Gait Training System: Advancing Mobility Rehabilitation for Individuals with Lower Limb Impairments

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Extended Abstract

Gait training and physiotherapy are essential for individuals with lower limb impairments, including lower limb amputees, to gaining or restoring mobility. However, traditional approaches to gait rehabilitation often present challenges in terms of time, cost, and accessibility due to the need for frequent in-person sessions. To overcome these limitations, researchers have explored the use of wearable technology for at-home or out-of-clinic gait training and monitoring [1]. One promising approach is biofeedback gait training, which provides real-time feedback based on specific gait parameters, showing promise in improving gait patterns [2–4]. Recognizing temporal gait asymmetry (TGA) as a significant factor contributing to inefficient gait among unilateral amputees, our research focuses on developing and validating a novel wearable biofeedback gait training system to address this challenge.

Our system integrates a real-time gait event detection (GED) algorithm, validated across both able-bodied and amputee gait patterns, with rhythmic auditory stimulation (RAS) cues aimed at modulating temporal gait symmetry [5]. The GED algorithm, known for its simplicity and real-time capability, accurately detects critical gait events necessary for biofeedback interventions. While previous GED algorithms using acceleration and/or angular velocity signals have shown reasonable performance, many are unsuitable for real-time applications involving clinical populations. The primary objectives of our study were to develop and validate (1) a real-time heuristics GED algorithm with low latency and high accuracy and sensitivity across able-bodied (AB) and lower-limb amputee (LLA) participants using a single inertial sensor, and (2) a wearable biofeedback gait training system using RAS to induce changes in temporal symmetry.

The GED algorithm, utilizing a single gyroscope signal on each leg, successfully detected critical gait events with an overall mean sensitivity of >93% and a median error of <30 ms and <1% of a gait cycle for both AB and LLA groups. Subsequently this, the GED algorithm was integrated into a wearable biofeedback system, consisting of two triaxial inertial sensors connected to a smartphone via Bluetooth and headphones providing RAS, enabling real-time feedback delivery. A custom mobile application was developed to receive the streamed angular velocity signals, which were used for detecting key gait events using the GED algorithm. The application then calculated gait parameters (e.g., stance–time symmetry ratio, cadence) and provided the corresponding auditory metronome beat (RAS-based BFB) to the user. To measure TGA, a stance–time symmetry ratio (STSR) was used, calculated as the timing difference ratio between the right and left sides of the time between the TO and HS. A metronome generator was developed and integrated into the mobile application. The intervals for each step were determined by the gait cycle duration and the target STSR. The RAS-based BFB was designed to modulate the metronome based on the individual's level of improvement in temporal symmetry. Initial testing with AB participants confirmed the system's effectiveness in eliciting gait changes, with average STSR changes ranging from 4% to 10% compared to baseline.

This study presents a promising avenue for optimizing gait training protocols and improving interventions, particularly through wearable technology using RAS-based biofeedback strategies aimed at achieving gait symmetry. Future research should focus on translating these findings to relevant patient populations.

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