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Development of a Music-Based Wearable Biofeedback System to Improve Lower Limb Amputee Gait Symmetry

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ABSTRACT

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Lower-limb amputees (LLAs) can exhibit asymmetric gait, commonly observed as stance-time asymmetry, which may contribute to the development of secondary conditions [1]. Access to conventional gait training is often impeded by factors such as healthcare funding, long travel times, or occupational obligations [2]. This has created a growing interest in technology-based alternatives for in-community gait rehabilitation. One such promising technique is the use of wearable biofeedback systems (WBSs) for gait training, with multiple studies utilizing various feedback modalities (visual, auditory, and vibrotactile) to attain positive outcomes for LLA participants, including a more normal gait pattern and improved gait symmetry [2]. Within the realm of auditory stimuli, rhythmic auditory stimulus (RAS), and more specifically music, may provide distinct advantages when applied to LLA gait. The entrainment of walking cadence and music tempo is a well-documented phenomenon, with studies having shown that music stimulus can improve the gait symmetry of hemiparetic stroke patients [3]. However, to date, there are no gait training systems that have applied music-based feedback to correct gait asymmetry of LLAs. To address this gap, the goal of this project is to design and validate a wearable biofeedback system that employs a music-based strategy to improve the temporal gait symmetry of LLAs.

The physical WBS consists of two inertial sensors to measure cadence and gait symmetry, an Android phone to run the feedback algorithm, and headphones. Twenty able-bodied participants and ten LLA participants will be recruited to evaluate the effectiveness of the proposed system. Participants will first complete a baseline assessment without RAS, to determine their average gait symmetry and cadence. They will then perform RAS walking trials with three different closed-loop feedback strategies, as well as with open-loop RAS. The music used in walking trials will be of

a constant tempo matching the participant's average cadence, and rhythmically enhanced via metronome tones using beat detection algorithms [4]. Spotify's API was used to generate a library of music with movement inducing features [5], across a range of tempos and covering a variety of genres. The developed closed loop feedback strategies include: 1) the metronome fades as the participant improves symmetry, 2) the volume of the music increases in response to better symmetry, and 3) a combined strategy where both effects occur simultaneously. Participants will complete questionnaires to assess system usability [6], as well as the enjoyment [7], and task load [8] of each strategy.

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