Development of a novel gait perturbation system for the study of stumble recovery

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Summary

This Abstract summarizes a novel automated system to introduce stumble-inducing gait perturbations that are: (1) realistic, (2) are unanticipated by subjects, and (3) accurately controllable in their timing. Furthermore, this system (4) allows for kinematic and kinetic evaluation before and after the perturbation. Human subject data is also presented, which demonstrate that people are unable to anticipate the perturbation and that the system can target specifically-timed perturbations during swing phase (accurate within 25 ms). This system will enable the study of stumble recovery in both healthy individuals and individuals with disabilities. Next, a systematic study on the effect of perturbation timing will be performed to gain an improved understanding of how people recover and to inform the design of interventions (e.g., prostheses) for fall prevention.

Introduction

Stumbling is a common occurrence which can result in a fall and injury, particularly for individuals with gait pathologies [1]. It is important to study the reflexive recovery response to stumble events in order to inform interventions that can reduce the incidence of falling in susceptible populations. Researchers have previously developed overground and treadmill-based systems for studying stumble recovery. However, overground systems tend to be constrained by walkway length and the inability to accurately time perturbations [2]; while treadmill studies often use rope blocking or belt speed perturbations which do not replicate a physical obstacle which the swing foot must clear [3]. Some treadmill-based systems have used obstacles in the past, however, they encountered issues with controlling timing and preventing the subject from anticipating the perturbation due to obstacle-induced vibrations [4]. To date, no gait perturbation system has been able to introduce (1) realistic, (2) unanticipated, and (3) accurately-timed obstacle perturbations while (4) allowing for kinematic and kinetic analysis. The objective of this work was to develop a novel gait perturbation system that overcomes limitations of prior systems and has capabilities (1)-(4).

Methods

The system in this study consists of two primary components: a ramp-based obstacle delivery apparatus and a predictive targeting algorithm. The ramp guides the obstacle down to the surface of the treadmill gradually, minimizing the impulse and subsequent vibrations as it enters the treadmill belt to prevent the subject from perceiving the presence of the obstacle before perturbation. The predictive targeting algorithm calculates the time of release of the obstacle required to perturb the subject at a specified time during swing phase. The algorithm uses real-time data from the subject's center of pressure to predict the timing and location of their future gait events and then to calculate when to release the obstacle onto the treadmill.

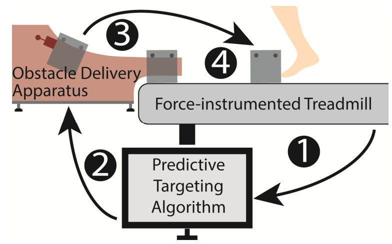

Figure 1: Schematic of the gait perturbation system.

A seven-subject experiment was conducted on healthy individuals to validate the system. Ground reaction forces and motion capture data were collected. A perception test was performed to assess if subjects could perceive the obstacle entering the treadmill. A perturbation test was performed to assess the accuracy of the targeting algorithm.

Results and Discussion

Across 84 trials, no subjects reported that they could perceive the entry of the obstacle onto the treadmill.

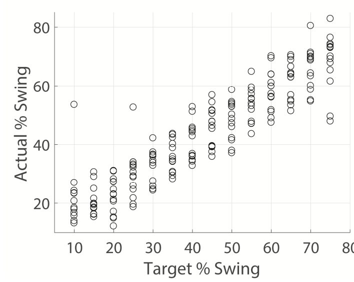

Figure 2: Targeted versus actual perturbation percent swing.

The system's absolute mean targeting error was 6.2% of swing phase, or 25 ms. The system's ability to provide such accurately-timed perturbations without the subject's perception allows for numerous trials to be collected quickly. The accuracy also allows for a higher analytical resolution with respect to perturbation timing than previous studies.

Conclusions

Overall, the system achieved the goals of introducing realistic, unanticipated, accurately-timed perturbations, while enabling the collection of kinematic and kinetic data. Next, the system will be used to aid in the design of a new stumble recovery control system for a robotic transfemoral prosthesis.

References

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