Preliminary Title: A foot placement strategy for the active control of gait stability

Motivation:

Maintaining gait stability is a challenging problem both in human clinical populations and in bipedal walking robots. Even among healthy, uninjured humans, it is not clear how individuals prevent themselves from falling over. A better understanding of how human gait stability is typically maintained could: 1) motivate the development of assistive technology to prevent falls; 2) help clinicians develop training paradigms to reduce fall risk; 3) provide ideas for designing more stable walking robots.

State of the Art:

Investigations of gait stability in humans often focus on predicting whether an individual is at a risk for falls by quantifying some measure of their walking performance. For example, an increased fall risk has previously been associated with metrics of various complexity, including: decreased stride period [1]; increased step width [2]; increased stride period variability [3]; increased Lyapunov exponents [4]; and increased Floquet multipliers [5]. However, even a perfect correlate of fall risk will not provide insight into the mechanism underlying decreased stability, and thus will not provide a clear basis for addressing the problem.

Own approach to this question:

In contrast to previous work focusing on correlations, we are interested in identifying the physiological mechanisms humans use to prevent themselves from falling over. Principles from dynamic walking serve as a starting point. For example, model simulations have demonstrated that walking can be passively stable in the sagittal plane, but stability in the frontal plane requires active control which can be effected through appropriate foot placement [6]. Therefore, we are currently investigating the factors which drive the active control of mediolateral foot placement in a population with minimal fall risk.

Discussion outline:

We are in the process of conducting experiments to investigate how healthy subjects control lateral stability (Questions 1 and 2), and plan to extend our findings through future investigations into clinical populations and the underlying physiological mechanisms (Questions 3 and 4).

Question 1. *Is the mediolateral position of the swing foot actively controlled during walking?*

We hypothesized that mediolateral foot placement can be controlled through activation of the hip abductors and adductors during swing. Traditionally, hip abductor (i.e. gluteus medius) activity has been primarily investigated during stance, and is often described as remaining silent during swing. However, we found that while the gluteus medius appears to be inactive during swing when many strides are averaged together, some individual strides do exhibit clear bursts of swing phase activity (typically 60-80% gait cycle). We were able to differentiate QUIET (essentially no swing phase gluteus medius activity) and LOUD (clear bursts of swing gluteus medius activity) strides. The LOUD strides resulted in significantly more lateral foot placement, indicating that hip abductor muscle activity influences mediolateral foot placement. Therefore, we are able to use the presence of swing phase gluteus medius activity as an indicator of active control of foot placement.

Question 2. *How do humans decide if active control of foot placement is necessary?*

We hypothesized that humans use sensory feedback providing information about the body's mechanical state to determine if the gluteus medius should be activated during swing. To test this, we compared the mechanical states of the body prior to the potential gluteus medius activation. We found that immediately prior to LOUD swing phases, the vertical projection of the body's center of mass was significantly farther from the contralateral stance foot than prior to QUIET swing phases. Therefore, the mechanical state of the stance leg and torso, specifically abduction of the stance hip, appears to predict whether humans choose to actively control their subsequent foot placement.

Question 3. *Do populations with an increased fall risk use the same mediolateral foot placement strategy as young, healthy subjects?*

We hypothesize that an inability to sense the body's mechanical state and appropriately control foot placement will increase fall risk. We have access to gait mechanics and muscle activity data from stroke patients and age matched controls. We plan to use analysis methods similar to those described above to determine whether a relationship between mechanical state and active control exists in these populations.

Question 4. *What physiological feedback sources drive the control of foot placement?*

We hypothesize that the active control of mediolateral foot placement is attributable to feedback from physiological sensors. While our results described under Question 2 suggest that feedback is important, they do not provide insight into the physiological source of this feedback. We plan to test which feedback source(s) (e.g. muscle spindles, Golgi tendon organs, efferent drive, etc.) contribute to active control of foot placement by varying the mechanical context in which subjects walk.

Format:

I would prefer a talk if possible.

Keywords :

Balance; Lateral stability; Motor control

References:

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