Effects of perturbation timing on step placement predictability using a linear model

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I. Background

Maintaining stability during locomotion can be challenging in the face of perturbations. A key recovery strategy employed to correct for sizable amounts of instability is step placement, used to induce large changes in the center of mass vs. center of pressure relationship [1]. Methods for stability intervention, such as wearable robots that assist in appropriate step placement, may require the ability to predict placement before it occurs. Linear models are a promising approach for predicting step placement [2,3]. These models use an instance of the center of mass (CoM) state during the gait phase to predict foot placement at the subsequent heel contact. However, the onset timing of real-world perturbations can vary, potentially challenging the capabilities of fixed-phase sampling models. Here, we aim to determine if and how step width predictability is affected by the onset timing of instability.

II. Methods

One subject walked at 1.25 m/s on a treadmill mounted on a Stewart platform that executed translational perturbations at various magnitudes (5, 10, 15 cm), directions (mediolateral, anteroposterior, diagonals), and times during the gait cycle (50% double stance (DS), 25, 50, 75% single stance (SS)). We collected a full body marker set and markers on the platform. The commanded perturbation onset time was used to divide the perturbed steps into the four groups, shown in Figure 1. The gait phase variable was calculated using the methods established in [2,3]. The predicted step width was determined using the equations determined in [2] from $\phi = -0.25$ to $\phi = +0.25$ at 0.01 increments. The R^2 value was calculated between the predicted placement and the actual placement.

III. Results & Discussion

The results show how the reliability of the step width predictions (R^2 value) change based on phase. When examining the accuracy of the model across phases, onset times of 50% DS, 50% SS, and 75% SS show similar predictability from $\phi = -0.1$ to $\phi = 0.25$, while an onset time of 25% SS shows less predictability in the same range. Perturbed steps at 25% SS may be difficult to predict because, though an early stance perturbation would seemingly affect the COM state during the perturbed step, there is little variation in step width relative to other onset times. More subjects will be incorporated to this analysis to evaluate if similar trends persist.

IV. Conclusion

Perturbation onset time may affect the reliability of step width predictions using a linear model, specifically perturbations in early single stance phase. Future work will also examine step length predictability using this data set.

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References

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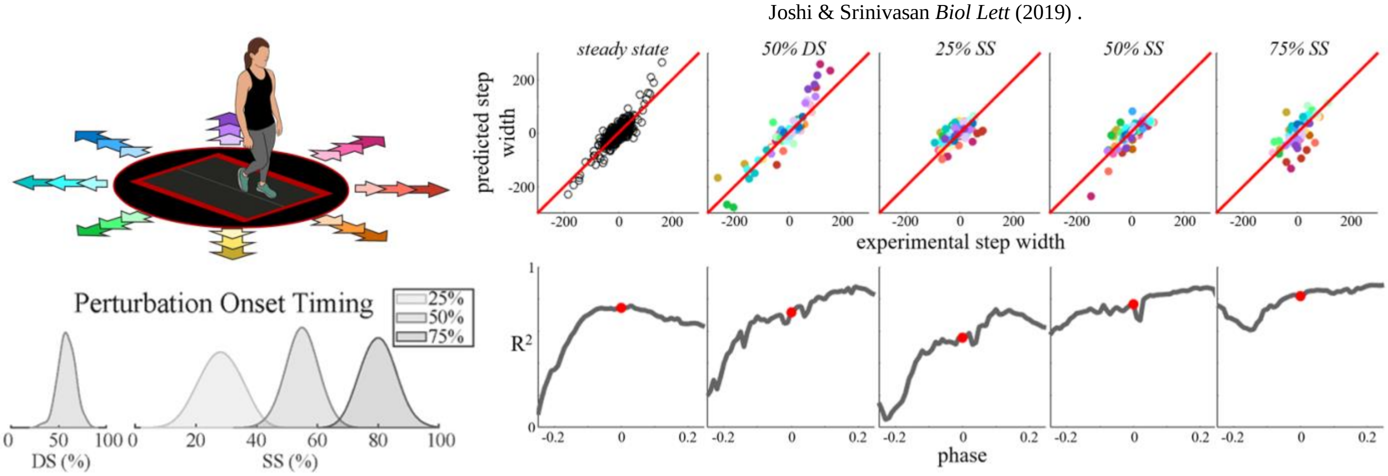

Figure 1. *Upper left.* The platform perturbed in eight directions at three magnitudes. *Lower left.* Histograms show the actual onset timing of perturbations while colors show the commanded time used for analysis. *Upper right.* Plots show the experimental step width vs. predicted step width for steady state and each of the four onset times using $\phi = 0$. Colors show the perturbation magnitude and direction. Red lines represent a perfect model prediction (i.e. experimental=predicted). *Lower right*. Plots show how the explained variance changes with phase for each perturbation onset time. Red dots at $\phi = 0$ represent the phase represented in the scatter plots.