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CHOICE OF REFERENCE FRAME AFFECTS THE VALUES OF STEP LENGTH, STEP WIDTH AND MARGIN OF STABILITY DURING TURNING GAIT

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Introduction

Despite most gait research examining straight locomotion, humans routinely have more complex walking trajectories in everyday life. Common spatial measures of gait, including step width (SW), step length (SL), and margin of stability (MoS), become more difficult during turning compared to linear ambulation because turning gait is kinematically asymmetrical and the global, local and velocity reference frames fall out of alignment.[1,2] This study uses positional marker data to investigate whether SW, SL, and MoS change between global, local, and velocity-based reference frames when walking with turns. We predicted that we would find differences in the values of SL, SW and MoS when using a global, local or velocity reference frame, and when comparing between inside and outside limbs.

Methods

One healthy adult completed walking trials around a 0.4m wide circular track (inner radius: 1.2m, outer radius: 1.6m). As part of a larger protocol, the participant completed eight randomized normal walking trials, four clockwise and four counter-clockwise. The participant was paced by a metronome to maintain a consistent speed in all trials. Kinematic data were collected from a retroreflective marker-based motion capture system and were used to calculate the body center of mass (CoM) and foot trajectories.

SW, SL, and MoS were calculated in global, local, and velocity-based reference frames. The global reference frame was defined by the center of the circular track. The local reference frame was defined based on the orientation of the vector from the average position of the PSIS markers to the average position of the ASIS markers. The velocity reference frame was defined based on the instantaneous velocity of the CoM. SL and SW were calculated as the difference in x and y positions of successive heel strikes (e.g., right to left) in each reference frame. MoS was calculated as the distance between the extrapolated CoM and the lateral border of the BoS during single support for each step at the time of contralateral toe-off. For each trial, steps were categorized into either inside or outside steps, based on which direction they moved around the circle (i.e., clockwise or counter-clockwise).

Two-way ANOVAs were performed to analyze the effect of reference frame and limb difference on SL, SW and MoS, using an alpha of 0.05.

Results and Discussion

There was a statistically significant interaction between the effects of reference frame and limb difference on SL ($p < 0.001$), SW ($p < 0.001$) and MoS ($p < 0.001$). SL ($p < 0.001$), SW ($p < 0.001$) and MoS ($p < 0.001$) all differed by reference frame. SL ($p < 0.001$), SW ($p < 0.001$) and MoS ($p < 0.001$) all also differed by inside versus outside limbs.

SL and SW were consistently different in the pelvis frame across inside and outside steps relative to the other two frames. However, MoS decreased in the pelvis frame for the inside limb, but increased in the pelvis frame for the outside limb.

Differences were most noticeable in the pelvis frame. This result is likely because the pelvis is not oriented directly forward during a given step, whereas global and velocity frames are generally aligned because CoM velocity runs tangential to the circle. Our initial findings demonstrate that reference frame should be considered when assessing stability during turning gait. The primary limitation of this study is that we only used data from one subject. Future work should expand on these findings to standardize the measurement of dynamic stability during turning gait, and evaluate turning gait with perturbations.

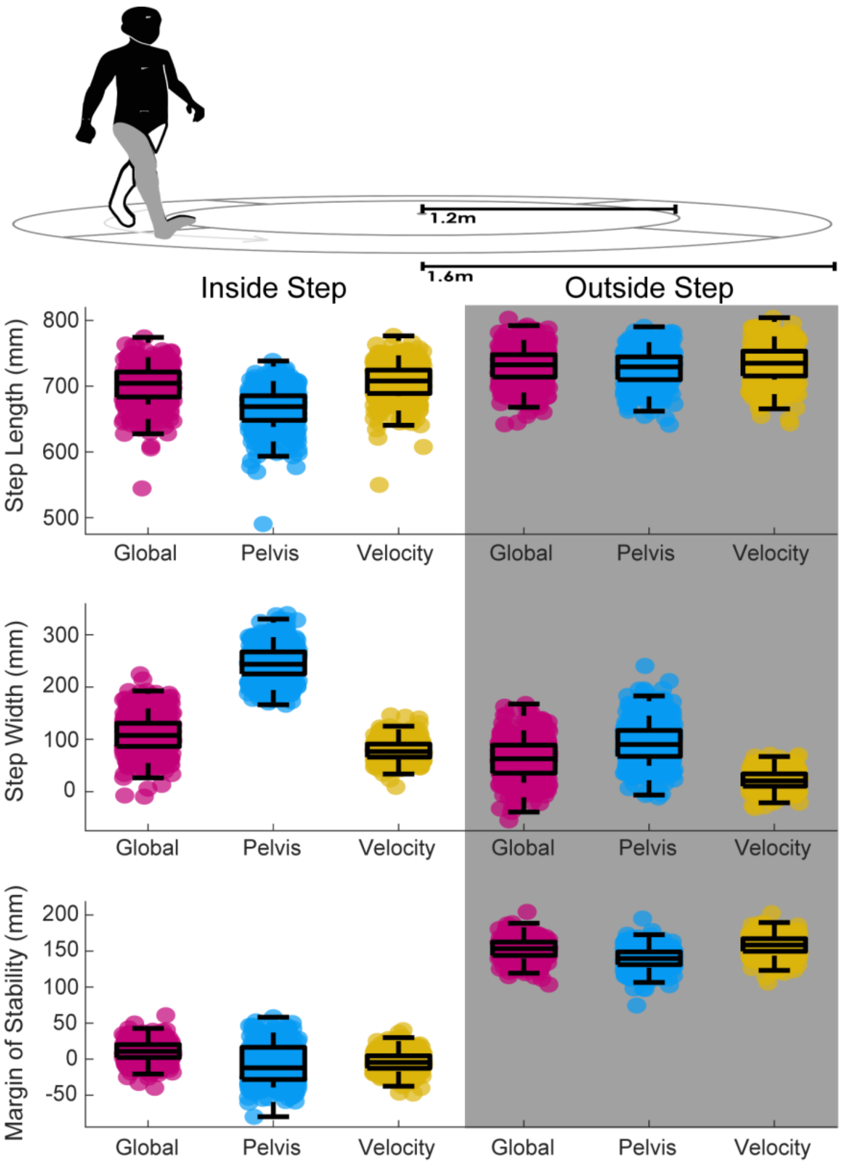

Figure 1: diagram of testing conditions (top) and SL, SW, and MoS for the three reference frames (bottom). SL, SW and MoS were calculated for inside (white) and outside (grey) steps in the global (dark blue & purple), pelvis (orange & green), and velocity (yellow & light blue) reference frames.

Significance

The choice of reference frame may produce different values of gait characteristics such as SL, SW and MoS. Further, the reference frame changes the asymmetry between inside and outside limbs. Studies should justify their choice of reference frame for turning, and clearly report the methodologies.

Acknowledgments

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References

[1] Huxham et al., 2006. Gait & Posture. 159-163: 0966-6362.

[2] Orendurff et al., 2006. Gait & Posture. 106-111: 0966-6362.