Variability and Specificity in Reactive Stabilization Movements to Diverse Slip Perturbations

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Study Protocol

For all gait collections, participants will arrive at the Biomechanics Research Building on the University of Nebraska at Omaha campus. All participants will be consented and screened prior to gait testing. During the consent process, participants will be asked if they can be contacted again for future research studies. During the screening, participants will undergo a short medical history and a physical activity questionnaire. participants will be asked to report their previous falls before the intervention. Participants will also be asked to be contacted through a phone call 6-months post intervention to record their fall history within the 6 months period.

Participants will be asked to put on a form fitting suit for data collection. Body weight, height and extremity anthropometry will be collected (length of arm and leg segments). Retroreflective markers will be placed on the legs, arms, torso and head to obtain whole- body kinematic data. A ceiling-mounted safety harness will also be fitted to each participant. Prior to performing any walking trials, the participants will be allowed to "sit" in the harness to experience how it feels when it catches them.

On the initial visit, participants will perform informed consent, then be asked to provide demographic information (age, gender), height and body mass measurements, and a medical questionnaire to assess exclusion criteria. Questionnaires to assess for physical activity, and previous falls will be administered. Upper and lower body strength will be measured using a hand held dynamometer during the first and last visits. On each of the three visits, participants will perform a gait variability assessment followed by a diverse slip perturbation assessment.

Functional design and validation of a wearable apparatus for administering lifelike slip perturbations: To investigate slips under diverse slipping conditions, a Wearable Apparatus for Slipping Perturbations (WASP) has been developed and validated by students working in the Biomechanics Research Building under supervision of the PI. Currently, the WASP can be worn over standard athletic shoes and triggered remotely by the experimenter. Before the WASP is triggered, the participant walks with a high friction interface between the rubber external sole and laboratory floor. When the experimenter wirelessly triggers the WASP, the external sole releases from the participant's shoe, transitioning available friction to a low friction interface between two layers of PTFE film within 10 milliseconds. Friction is reduced from a dynamic coefficient of approximately m=0.55 (athletic shoes on a basketball court) to m=0.10 (akin to shoes on ice).

Gait variability assessment procedures: Before recording data, retroreflective markers will be placed on specific anatomical locations. These locations are defined to create a full- body dynamics model. Following familiarization, subjects will walk on a treadmill for 5 minutes at a prescribed pace of 1.3 meters per second while whole body kinematics are collected with a 17-camera motion capture system. Both linear and nonlinear measures of gait variability will be calculated to determine possible relationships between these measures and other outcome variables such as learning rate for reactive movements and fall rate.

Diverse slip perturbation assessment procedures: subjects will outfitted with WASP and a safety harness connected to an overhead rail system and walk overground back and forth across a large motion capture area. Previous studies show that walking speed is highly correlated with some

outcome measures, specifically variations in whole body angular momentum, gait variability measures, and loss of balance following a slip.

Therefore, investigators will control gait speed across all subjects to 1.3 m/s, a typically comfortable speed for older adults. Participants will be informed that a slip may occur, and that if slipped, they should attempt to maintain balance and continue walking. Participants will then be slipped without warning at a randomly chosen time after 1 to 3 minutes of walking. Slips will be administered to both feet simultaneously during early, middle or late stance in a randomized order. After each slip, participants will rest seated for 5 minutes. During this rest period, motion capture data and force data from the harness will be downloaded, and the WASP will be outfitted on the participant for the next trial. Participants will complete four slips in each of early, middle, and late stance on each visit. Measures of falls, slip severity, and reactive stabilization movements will be calculated. Since falls will be prevented from a harness system in this study, a trial will be classified as a fall if the load cell in the harness system measures a peak force in excess of 30% of the participant's body weight.

Statistical Analysis Plan

For each outcome variable (e.g., slip severity, reactive stabilization movements, fall rates), normality assumptions will be assessed using Shapiro–Wilk tests and visual inspection of histograms and Q-Q plots. Descriptive statistics (means ± SD or medians with interquartile ranges) will be reported based on these assessments.

To determine differences between age groups (younger vs. older adults) on continuous outcomes (e.g., slip severity measures, reactive stabilization kinematics), linear mixed- effects models will be employed, with participant included as a random factor to account for repeated measurements within individuals. Post-hoc comparisons, when necessary, will be adjusted using Tukey or Holm–Bonferroni corrections.

For binary outcomes (fall/no fall, defined by harness load exceeding 30% of body weight), generalized linear mixed-effects models (logistic regression) will be used, again with participant included as a random effect and age group as the primary fixed factor.

All statistical analyses will be performed using R statistical software, with significance determined at $\alpha = 0.05$. Any data transformations or handling of missing data will be clearly documented and justified.