Vision-based stability assessment for older adults using low-cost RGB-D camera: an experimental validation study M. Kunz, D. Jiang, N. Jafari, M. Lim, H. Owens, K. Ho. *Gerontechnology* 25(s)

Purpose Gait and stability analysis in older adults is a major focus in biomechanics, rehabilitation, gerontology and emergency care due to its importance in fall risk assessment, mobility monitoring, and diagnosing abnormalities. Age-related changes in musculoskeletal and nervous systems can alter gait patterns, balance control, and overall stability (1). Postural stability is the ability to maintain the body's center of mass (COM) within its base of support. Previous research has shown a strong correlation between the movements of the center of pressure (COP) and COM in quiet standing (2). Static balance, an indicator of postural stability, is typically measured by assessing COP sway. Sway measures provide objective assessments of mobility and balance but currently require specialized equipment. This study investigates the technical feasibility of a COM measurement method using a single low-cost RGB-D camera as a cost-efficient, user-friendly, and mobile solution for sway measurement. Results of the proposed vision-based method were compared to the COP measurements collected with smart insoles. These wearable, sensor-equipped shoe inserts capture data on foot pressure distribution while offering the advantage of preserving users' privacy. **Methods** Twenty participants 65 years and older performed two eyes-open (EO) and two eyes-closed (EC) 20-second trials (80 trials total). Vision data were collected using a single Femto Bolt RGB-D camera (Orbbec, Troy, MI, USA) which captures RGB images and depth maps. The camera was placed in a distance of about 2.5-3m from the participant, facing the participant frontally. For each frame, a 32-point 3D pose was estimated using the AI-driven Azure Kinect Body Tracking SDK ('https://www.microsoft.com/en-us/research/project/skeletal-tracking-on-azure-kinect/', November 2025) and the COM was calculated using an anthropometric model from Plagenhoef (3). Simultaneously, COP was measured with smart insoles. Insole and vision data were spatially aligned and resampled to 20 Hz. Insole-based COP sway served as the gold standard, and COM sway was derived by projecting COM onto the floor. We compared sways' magnitude, directions and EO–EC differences between methods. **Results and Discussion** On average, the maximum magnitude of sway measured in each trial was 2.09 times larger (SD 2.8) for vision-based measurements in the mediolateral (M/L) direction and 3.18 times larger (SD 9.3) in the anteroposterior (A/P) direction compared to insole-based sway. After normalization, sway patterns showed an 83% correlation in the frontal plan and a 64% correlation in the sagittal plane, indicating strong movement pattern similarity, especially in the M/L direction. Vision-based COM sway increased 1.31 times (SD 0.87) between EO and EC in the M/L direction and decreased by 0.98 times (SD 0.37) in the A/P direction. These results closely aligned with insole-based results (1.32 times (SD 1.19) and 1.03 times (SD 0.7), respectively). Despite magnitude differences, both methods showed similar sway behavior and EO–EC trends, particularly in the M/L direction. Overall, these findings demonstrate that vision-based measurements can provide a reliable and practical alternative for sway measurement. Applying an approach to model human pose as a 32-point skeletal representation enables center-of-mass (COM) calculation while offering a privacy-preserving alternative to traditional video analysis techniques. Furthermore, due to the much lower cost of the single RGB-D camera compared to smart insoles, pressure mats, or traditional gait analysis setups, this vision-based method provides a cost-efficient alternative and offers new opportunities for accessible balance evaluation and movement analysis in both research and clinical contexts. Future work is needed to examine user acceptance, clinical applicability and social ethical consideration to ensure the proposed solution can be transferred into practice.

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