Minimal toe clearance in older adults when walking on level, uphill and downhill conditions

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Purpose As people age, changes in gait parameters are commonly observed, and have been shown to increase the risk of mobility decline and falls. Minimal Toe Clearance (MTC) is the minimum vertical distance between the toe and the ground during the mid-swing phase of the gait cycle. MTC is a key gait parameter indicative of tripping. However, research on MTC is limited to walking on level surfaces, which do not reflect normal daily activities (Al Bochi et al., 2021; Avalos et al., 2024). We aimed to evaluate how MTC and its variation differ among level, uphill, and downhill walking conditions in older adults. This information is important for creating gerontechnology systems to evaluate mobility and fall risk in older adults in real-world environments with diverse challenges. **Method** This study is part of a larger cross-sectional research project, Gait features in different environments contributing to participation in outdoor activities in old age (GaitAge) (Rantakokko et al., 2023). A volunteer sample of 40 individuals was recruited via senior organizations and a university of third age. The inclusion criteria were community-dwelling, aged 70 years or over, able to walk 1 km without assistive devices, able to communicate, and living in a local area. The exclusion criteria were the use of a walking aid, severe sensory deficit (vision, hearing), memory impairment (Mini-Mental State Examination score ≤23), or neurological condition. The participants walked on a level, five degrees uphill and five degrees downhill motor-driven treadmill (Gymstick Walking Pad Pro) at a self-selected constant speed. On the level surface, the participant walked for three minutes and on the uphill and downhill surfaces for two minutes. The uphill and downhill tests were performed in random order. Body movement was recorded using a 3D motion capture system (Vicon Motion Systems, Oxford, UK) with 16 cameras . Six reflective markers (heels, proximal heads of the second metatarsals, and anterior superior iliac spines) were used in the MTC algorithm. A PlugInGait pipeline (MATLAB, b2022, The MathWorks, Inc.) was used for the analysis. For each gait cycle, the MTC was computed as the minimum vertical distance from the toe marker to the ground, which occurred between two local maximas of the trajectory during the swing phase. The values of the right and left legs were combined for the analysis. The gait variability (within-person differences in steps) was calculated as the Coefficient of Variation (CoV%) of the MTC (%) in the level, uphill, and downhill conditions. Data were analyzed using repeated measures analysis of variance. **Results and Discussion** Thirty-seven community-dwelling older adults (mean age 76 (SD 5.2) years, 62% female) had a complete dataset and were included in the analyses. Mean MTC was 21.3 mm (SD 10.7) on level, 21.9 mm (SD 9.5) on uphill, and 20.8 mm (SD 11.3) on downhill walking. The mean MTC did not differ between the conditions. CoV% for MTC was 26.0% (SD 12.0) for level walking, 25.0% (SD 12) for uphill walking, and 29.9% (SD 9.6) for downhill walking. Downhill walking resulted in greater variation ($p=0.023$) than uphill walking did. In conclusion, our results suggest that older adults have increased variation in minimal toe clearance in downhill conditions and that walking modifications are likely to increase with increasing environmental challenges. Real-life measurements of the variation in the spatiotemporal characteristics of walking in various outdoor environments are required to better understand the risks of mobility limitations and falls in the daily activities of older adults.

References

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