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Reliability and minimal detectable change of gait variables in community-dwelling and hospitalized older fallers

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ABSTRACT

Purpose: Gait variables may constitute surrogate outcomes for fall risk. Their reliability in a specific population of older fallers has not been fully established, which limits their research and clinical applications. This study aimed to determine test–retest reliability and minimal detectable change (MDC) values for selected fall-related gait variables in older adults with a recent fall history.

Methods: Community-dwelling (n = 30) and hospitalized (n = 30) fallers aged ≥ 65 years were assessed twice using an instrumented pressure-sensitive walkway, under single- and dual-task gait conditions. Intraclass correlation coefficient ($ICC_{(2,1)}$), standard error of measurement (SEM; SEM%) and MDC at 95% confidence level (MDC_{95}; MDC_{95}%), were used as reliability estimates.

Results: The $ICC_{(2,1)}$ for gait velocity was greater than 0.84 across all gait conditions and groups; SEM% and MDC_{95}% did not exceed 6.5% and 18.1%, respectively. Gait variability measures returned lower $ICC_{(2,1)}$ (range 0.18–0.79), and markedly higher SEM% (16.3–31.9%) and MDC_{95}% (45.3–88.3%). Overall, hospitalized fallers exhibited larger SEM and MDC_{95} values for variability measures compared to community-dwellers in all gait conditions, while larger values were found for all variables while dual-tasking compared to single-tasking in both groups.

Conclusions: Gait velocity was found to be highly reliable and likely to be sensitive to change over repeated sessions in community-dwelling and hospitalized older fallers, both under single- and dual-task conditions. Gait variability measures showed lower reliability, irrespective of gait condition or group, displaying consistently larger measurement error, particularly under dual-task conditions. Clinicians should consider MDC_{95} values before using gait variability variables as evaluative outcome measures at patient level.

1. Introduction

Falls are common, devastating and costly features of aging [1]. About one-third of people aged 65 years or older fall at least once a year. This rises to almost half for those over 85 years [2]. Growing recognition of the escalating issue of falls has spurred research efforts to identify, develop and implement effective prevention interventions and policies. Current evidence-based clinical practice guidelines strongly endorse widespread and regular screening of at-risk older adults, namely those with recent falls or gait abnormalities. This is because (i) impaired gait ranks among the most prevalent and sensitive risk factor for falling and (ii) most falls occur during some form of locomotion [1,3].

Over the last decade, instrumented gait analysis has become a significant method of fall risk detection, with major implications for early diagnosis, prognosis and rehabilitation [4]. Alterations in gait pattern have been closely related to falls in relatively healthy or clinical older adult samples. Changes in spatio-temporal gait parameters and variability measures – assessed using instrumented pressure-sensitive walkways or body-fixed motion sensors – have been identified as independent predictors of future falls [4–6]. Quantitative gait assessment under dual-task conditions (e.g., walking while concurrently performing concurrent "attention-demanding" arithmetic tasks), an ecologically valid proxy of daily living situations that older adults may encounter, has also recently gained much research attention and clinical interest to test for the risk of falling [4,7,8]. During the past decade, a substantial body of research has suggested the clinical value of dual-task gait assessments, and their superiority over single-task assessments, for fall prediction. However, some studies suggest the opposite [8–10]. These discrepant results may be partially attributable to differences in the population studied, and the type and level of complexity of the secondary task used [7]. To date, gait velocity and gait variability

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measures (i.e., the stride-to-stride fluctuation in the value of a gait parameter) have emerged as among the most successful predictors in the field [2,5,6,8,11]. As such, they provide key targets for primary to tertiary prevention interventions, and may constitute primary outcome measures in clinical trials or in daily clinical practice to monitor patient progress toward risk reduction [5].

Despite their significant potential for evaluation purposes, to our knowledge, there is to date no information available pertaining to the reliability of spatio-temporal gait parameters and gait variability measures in a specific population of older fallers, neither under single-task nor under dual-task conditions, which limits their research and clinical applications. Thus, the Minimal Detectable Change (MDC) values (i.e., the smallest change threshold that indicates a real change in an individual patient beyond that attributable to measurement error) [12] for fall-related gait variables among this population are not known. Therefore, as an essential requirement to support the use of gait features as outcome measures and a critical step for clinical decision-making, we aimed to (i) determine the test–retest reliability and (ii) establish the MDC values of selected fall-related gait variables under single- and dual-task conditions, in community-dwelling and hospitalized older fallers.

2. Methods

2.1. Participants

Sixty older adults from both community ($n = 30$) and hospital ($n = 30$) settings were enrolled. All participants met the following inclusion criteria: (i) aged 65 years and over, (ii) have experienced at least one fall in the previous year, (iii) able to walk independently for 10 meters with or without an assistive device, and (iv) able to follow the testing instructions. A fall was defined as "an unexpected event in which the individual comes to rest on the ground, floor or lower level". No fall was related to an intrinsic major event (e.g., stroke) or an overwhelming hazard. Individuals not medically stable or diagnosed with a serious medical condition that might directly impact gait, including any neurological or orthopedic disease (e.g., Parkinson's disease) based upon a physical examination and medical history, were excluded from the study. The community group consisted of a consecutively selected subsample of 30 participants (mean ± SD age, 75.2 ± 6.9 years; 30 women) enrolled in a randomized controlled trial of a music-based multitask exercise program, for gait, balance and reducing fall risk [13]. The hospital group comprised 30 consecutively selected geriatric hospital inpatients (mean ± SD age, 83.5 ± 5.5 years; 23 women, 7 men), admitted following a fall to an acute and rehabilitation ward, and referred to a dedicated unit for enrollment into a multifactorial fall-and-fracture risk assessment and management program [14]. A total of 39 and 35 consecutive cases were considered for community and hospital groups, respectively, to constitute our study population (i.e., 30 participants per group). Nine community individuals were not included owing to the absence of a fall history in the previous year. Five hospitalized individuals were excluded due to neurologic disease.

Ethical approval for the study was obtained from the institutional ethics review committee (Geneva University Hospitals), and all participants agreed to participate after being informed of the procedures. Written informed consent was not required for the hospitalized patients due to the nature of the quality assessment of this study, which corresponds to the standard care procedure, and the strict maintenance of anonymity.

2.2. Instrumentation and procedures

Spatio-temporal gait parameters, as variability measures, were collected using the GAITRite® system (CIR Systems Inc., Havertown, PA, USA), a walkway embedded with pressure sensors activated at footfall and deactivated at toe-off, with an active recording surface of 732 cm × 61 cm and a sampling frequency of 80 Hz. Spatio-temporal data were processed using the GAITRite® application software version 3.8. For comparability with most studies in the field [15], and as a dimensionless and normalized measure, coefficient of variation (CoV) was used as a measure of variability for each gait parameter ($CoV = [SD/mean] \times 100$). All parameters were collected under single- and dual-task conditions following published guidelines [16], with participants beginning and stopping walking two meters from either end of the active surface to counter acceleration and deceleration effects.

All assessments were carried out in a dedicated room using a standardized protocol [16] After appropriate instructions, participants were asked to perform three gait tasks presented in a fixed order: walking at their self-selected comfortable and fast speed, as a single-task, and walking at their self-selected speed while simultaneously counting aloud backwards by ones starting from 50, as a dual-task. Stride time variability in dual-task walking condition using this mental tracking task has previously distinguished fallers from non-fallers in older inpatients [9]. No instruction was given to the participants to prioritize either the gait or cognitive task. For safety purposes, the assessor walked alongside and slightly behind participants who wore their regular footwear and used their customary assistive device, if required.

Each participant underwent quantitative gait assessment during two separate testing sessions conducted by the same experienced assessor and repeated at an average time interval of 1 h, with a slightly longer interval on average in hospitalized participants to prevent overuse or fatigue. Every effort was made to follow identical testing procedures across sessions and to ensure that no significant medication change or intervention occurred between scheduled sessions.

2.3. Statistical analysis

Sample size for the two studied groups was estimated based on Walter et al's approximation method [17]. Assuming a minimal intraclass correlation coefficient (ICC) of 0.5 (p_o) against a desired of 0.8 (p_1), based on $\alpha = 0.05$ and $\beta = 0.20$, at least 22 participants per group were required.

Data for selected gait variables were examined separately for the community and the hospital groups. Mean and SD were determined for all measures. Bland–Altman plots and correlation coefficients were computed to check for systematic bias, heteroscedasticity and outliers across the two testing sessions [18]. Relative reliability, which reflects the ability of a measure to differentiate between individuals on repeated testing, was assessed using the calculation of intraclass correlation coefficient with a 2-way random effects model ($ICC_{(2,1)}$) and interpreted following Landis and Koch's benchmarks where 0.00–0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80 and 0.81–1.0 correspond to slight, fair, moderate, substantial, and almost perfect reliability, respectively [19]. Absolute reliability, which reflects agreement (i.e., measurement error occurring with repeated testing), was assessed using standard error of measurement (SEM) and minimal detectable change with a confidence level of 95% (MDC_{95}) [19]. SEM was computed as $SD \times \sqrt{(1 - \textit{estimated reliability coefficient})}$, where SD is the pooled standard deviation of test–retest measures, and used to calculate the MDC_{95} (i.e., a measure of sensitivity to change) as follows: $1.96 \times \sqrt{2} \times SEM$ [18,20,21]. The SEM and MDC_{95} values, expressed in the unit of measurement, describe the limits for change required to indicate a real change for a group of individuals or at individual level, respectively. They were also expressed as a percentage of the mean (i.e., SEM% and MDC_{95}%), to produce unitless indicators and allow for comparisons.