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Validity of the Gait Variability Index in older adults: Effect of aging and mobility impairments

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ABSTRACT

Gait variability, defined as the fluctuation in spatiotemporal characteristics between steps, is suggested to be a sensitive indicator of mobility deficits with aging and pathological processes. A challenge in quantifying gait variability is the decision of which spatiotemporal parameters to assess because gait parameters may exhibit different amounts of variability and may differentially relate to mobility performance. The Gait Variability Index (GVI), a composite measure of variability across several gait parameters, was previously developed to overcome this challenge. The present study seeks to validate the use of GVI in the older adult population. A retrospective analysis of gait and clinical data was conducted using data pooled from five prior studies. The final data set included 105 younger adults (YA, age < 65) and 81 older adults (OA, age ≥ 65). The GVI of OA (91.92 ± 8.75) was significantly lower compared to the GVI of YA (100.79 ± 7.99). Within OA, the GVI was significantly lower ($p < 0.0001$) in individuals with mobility deficits (84.35 ± 9.03) compared to those with high mobility function (96.35 ± 8.86). Furthermore, GVI was associated with mobility function, including walking speed and performance on the Berg Balance Scale. Our findings imply that the GVI is a valid assessment for gauging spatiotemporal gait variability in older adults, is sensitive to differentiate between high-functioning older adults and those with mild to moderate mobility deficits and is associated with some clinical measures of functional mobility and balance.

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1. Introduction

Gait variability, defined as the fluctuation in spatiotemporal characteristics between steps, is a sensitive indicator of mobility deficits [1]. For example, variability in spatiotemporal parameters is reported to predict mobility deficits and future falls better than the mean of spatiotemporal parameters in older adults [2]. Gait variability is altered by pathological conditions of disease and injury [3]. An investigation of the magnitude of these fluctuations has received considerable attention and is the focus of the current study. Particularly, the magnitude in gait variability is an important outcome measure in older adults since altered gait variability has shown to be associated with advancing age, mobility deficits, cognitive impairments and fall risk [4–7]. A majority of the literature in older adults report that gait variability is increased in older adults [1]. However, decreased gait variability has also been reported in some spatiotemporal parameters (such as step width) and related to mobility deficits [8]. Despite the mounting evidence supporting use of gait variability as an outcome measure in the older adult population, there has been limited use of gait variability measures in clinical settings or in randomized controlled trials.

The lack of widespread use of gait variability as an outcome measure may, in part, be due to methodological challenges [9]. First, it is unclear which spatiotemporal measures are of greatest importance when assessing gait variability. Variability has been reported for at least 11 spatiotemporal parameters, but it is unclear which are most relevant to mobility function and the deficits that they reflect. For instance, step width variability was associated with age-related sensory impairments in a study by Brach et al. [10], whereas Richardson et al. reported that step time and not step width variability was associated with sensory impairments [11]. Second, there is a lack of consensus regarding how best to quantify gait variability [e.g., standard deviation (SD),

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coefficient of variation (CV)]. Some researchers have proposed that until a consensus can be reached, gait variability should be analyzed multiple ways [9]. Third, for individuals with impaired mobility the increase in gait variability can be observed across many different spatiotemporal parameters. This inter-dependence confounds statistical analysis because it is not clear which parameters are the best indicators of mobility deficits.

These methodological issues motivated the development of the Gait Variability Index (GVI). The GVI is a conglomerate measure of gait variability derived from nine spatiotemporal parameters and was developed to improve objective quantification of gait variability [12]. Preliminary validity was demonstrated by a decrease in GVI for individuals with Friedreich's Ataxia, suggesting that the GVI was linked to mobility function [12]. While the GVI seems to be a promising outcome measure because it avoids some of the methodological problems surrounding variability measures, it is not yet validated as an outcome measure in older adults. Therefore, the purpose of this study was to investigate the validity of the GVI as an outcome measure of mobility deficits in older adults.

2. Methods

2.1. Participants

This study retrospectively analyzed data pooled from 5 studies (Table 1). Participants aged 18–90 years ($n = 186$) were included. Participant data was categorized into two broad categories: younger adults (YA) less than 65 years of age and older adults (OA) greater than or equal to 65 years of age. Study protocols were approved by the Institutional Review Boards at the respective institutions and all participants gave their informed consent before participation.

2.2. Procedures

Procedures of included studies have been described in detail elsewhere [12–15]. Here we report only those procedures that impacted the data analysis for the current study (Table 1). Our primary data of interest were the spatiotemporal gait measures acquired by an instrumented walkway (GAITRite), a valid and reliable tool to evaluate spatiotemporal gait measures [16].

Selected clinical measures of functional mobility and balance were retrospectively available from some included studies and were used to further validate the GVI. These included the Berg Balance Scale (BBS), Timed Up and Go Test (TUGT), Dynamic Gait Index (DGI), Community Balance and Mobility Scale (CB&M), Activities-specific Balance Confidence (ABC) scale, Short Physical Performance Battery (SPPB) and Functional Reach Test (FRT). Each of these measures have shown to be valid and reliable to assess functional mobility and balance in older adults [17–21].

2.3. GVI calculation

Data were exported from the GAITRite software, version 4.7.4 and GVI was calculated if a minimum of five absolute differences (at least 13 consecutive steps for a walk) were available.

The GVI was calculated using the macro that was available as supplemental material provided by Gouelle et al. [12]. The parameters used for GVI computation is based on the weighting identified using a PCA that determines the main correlation pattern among multiple measures of gait variability. Step time (0.930) and stance time (0.919) are the most contributing parameters, but the majority of the parameters have weighting above 0.80. A lower factor value indicates that either the parameter is contributing less to overall gait variability and/or showing naturally more variance within an asymptomatic gait.

The GVI quantifies the distance between the amount of variability observed for a reference group and the amount of variability observed for an individual [12]. To enhance applicability, GVI is transformed into a score with 100 representing the mean score for the reference group. The standardized mean score and SD of the reference population are defined as 100 and 10, respectively [12]. GVI ≥ 100 indicates that the individual has a similar level of variability as the reference group. For GVI < 100, each 10-point difference corresponds to a separation of 1 SD from the reference group score. For instance, an individual with a GVI of 70 would have gait variability that deviates from the control group mean by 3 standard deviations. In contrast, an individual with a score greater than 100 would have gait variability that is closer to the control group's mean variability than is the average member of the control group.

2.4. Statistical analyses

Parameteric t-tests investigated whether the GVI (1) differed in OA from YA and (2) discriminated high-functioning older adults (HFOA) from older adults with mild to moderate mobility deficits (MDOA) in a subset of the pooled sample. The area under the curve (AUC) of an ROC curve was computed to further assess the discriminatory power of the GVI. Discriminatory power $0.7 \leq \text{AUC} \leq 0.8$ is suggested to be acceptable [22]. Sensitivity and specificity of the GVI were also calculated. Pearson correlation coefficients investigated the relationship between GVI and clinical measures of functional mobility and balance. Correlational analyses were also replicated with regression models adding study as the dummy variable to test if combining data sets may have confounded the results. The results were similar so findings from the correlational analyses are presented. Data were analyzed using SPSS (19.0).\

3. Results

Data reduction steps (i.e., ensuring enough steps to compute variability through GVI) resulted in a reduced data pool of 105 individuals in the YA group and 81 individuals in the OA group. The characteristics of the study pool and relevant characteristics of sub-groups of participants from each study are presented in Table 2.

3.1. Effect of aging on GVI

The GVI of OA (91.93 ± 8.75) was significantly lower ($p < 0.0001$) when compared to the GVI of YA (100.79 ± 7.99). An inspection of the raw data suggested that the relationship between age and GVI is likely not linear throughout the age continuum (Fig. 1). Visual inspection of the raw data suggested that the relationship between age and GVI changes at approximately age of 50 years. Prior to 50 years, there seemed to be no clear association between GVI and age but after 50 years there was a negative association such that GVI reduced with advancing age (Fig. 1). Linear regression modeling confirmed these visual analyses and demonstrated a modest but significant proportion of variance explained by GVI in adults aged 50 years and older ($r = 0.39$, $R^2 = 0.15$, $p < 0.001$).

3.2. Ability of GVI to discriminate older adults based on their level of mobility function

GVI in MDOA (84.35 ± 9.03) was significantly lower ($p < 0.0001$) compared to the GVI in HFOA (96.35 ± 8.86). The discriminatory power of the GVI was also acceptable (AUC = 0.841, $p = 0.002$, Table 3).

3.3. Relationship between GVI and clinical measures of functional mobility and balance

In the OA group, GVI was significantly correlated with walking speed ($r = 0.42$, $p < 0.001$) and BBS ($r = 0.49$, $p < 0.001$). Relationships between GVI and other clinical data were not statistically significant ($p > 0.05$), as shown in Table 4. However, there were trends supporting an association between GVI and falls history ($r = -0.315$, $p = 0.061$) and GVI and TUG ($r = -0.330$, $p = 0.057$).