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The Dynamic Gait Index in Healthy Older Adults: The Role of Stair Climbing, Fear of Falling and Gender

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Abstract

The Dynamic Gait Index (DGI) was developed as a clinical tool to assess gait, balance and fall risk. Because the DGI evaluates not only usual steady-state walking, but also walking during more challenging tasks, it may be an especially sensitive test. The present investigation evaluated the DGI and its association with falls, fear of falling, depression, anxiety and other measures of balance and mobility in 278 healthy elderly. Measures included the DGI, the Berg Balance test (BBT), the Timed Up and Go (TUAG), the Mini-Mental State Exam (MMSE), the Unified Parkinson's Disease Rating Scale (UPDRS) motor part, the Activities-Specific Balance Confidence (ABC) scale and the number of annual falls. The DGI was moderately correlated with the BBT ($r=0.53$; $p<0.001$), the TUAG ($r=-0.42$; $p<0.001$) and the ABC ($r=0.49$; $p<0.001$). Fallers performed worse on the DGI compared to non-fallers ($p=0.029$). Scores on the DGI were near perfect in men (23.3 ± 1.2), but among women, there was a small, but significant ($p<0.001$) decrease (22.5 ± 1.6). The reduction in the DGI score in women was due to stair climbing performance, with many women (65%) choosing to walk while holding a handrail, compared to only 39% of men. Scores on the BBT, the TUAG, the UPDRS and the MMSE were similar in men and women. Conversely, ABC scores and fall history were different. These findings suggest that the DGI, although susceptible to ceiling effects, appears to be an appropriate tool for assessing function in healthy older adults.

Keywords

gait; functional testing; aging; balance; falls

INTRODUCTION

Screening and identifying older adults at risk of falling is a major medical concern [1,2]. Measures that quantify this risk are needed for appropriate evaluation and referral for

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest to disclose.

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intervention. Several tools have been developed to objectively assess postural control and ambulatory abilities in elderly populations via clinical performance-based measures, in conjunction with other self-report measures (e.g., scales to assess depression or fear of falling). The Dynamic Gait Index (DGI) is one of the tools frequently used to quantify dynamic balance abilities. The purpose of the present study is to better understand its properties and the factors that contribute to this commonly used test in healthy older adults.

The DGI was primarily developed to assess a subject's ability to modify gait in response to changing task demands [3]. The eight abilities assessed are: steady-state walking, walking while changing gait speed, walking while moving the head vertically and horizontally, walking while stepping over and around an obstacle, pivoting during walking, and stair climbing. The items of the DGI are graded on a four point scale from 'normal performance' (3) to 'severely impaired' (0), yielding a maximum score of 24 points. The examiner's rating is based on the subject's ability to maintain a normal gait pattern and pace, without deviating or stumbling. It takes approximately 10 minutes or less to carry out the DGI. A score lower than 19 points has been associated with impairment of gait and fall risk [3,4].

Since it was first presented, the DGI has been applied in various conditions: multiple sclerosis [5], chronic stroke [6], Parkinson's disease [7], older adults with dizziness or balance problems [8,9] and relatively healthy independent older adults [4,10]. Whitney et al. [11,12] showed that gait instability, as measured by the DGI, is a good indicator of fall status for both elderly and young individuals with vestibular disorders. Fall history was significantly associated with gait instability after stratification by age (e.g., above 65 years) using a DGI score of 19 as a cut-off. In another study in patients with peripheral vestibular dysfunction [13], the DGI was strongly correlated ($r=0.72$) with fear of falling, as measured by the Activities-specific Balance Confidence scale (ABC), in young adults (20–39 years old), while moderate correlations ($r=0.61$) were seen in the older adults (≥ 65 years).

A few studies have examined the DGI as a tool for assessing community-dwelling older adults [4,8,10]. When applied to 44 community-dwelling older adults, the DGI had good inter-rater ($r=0.96$) and test-retest reliability ($r=0.98$). However, a score of 19 or less on the DGI correctly classified only 59% of those with a history of falls while correctly classifying only 64% of those without a positive fall history [4]. Boulgarides et al. [8] also suggested that a DGI score of 19 is useful as a cutoff value for distinguishing fallers from non-fallers when assessing independent older adults. Still, they noted a possible ceiling effect. For example, some of the multiple-fallers in their study achieved a high DGI score, suggesting that for highly functioning older adults, this test might not be challenging enough or that some other factor may contribute to the association with falls. These studies in older adults included subjects with known impairments. In the first report on "normative data" on the DGI, Vereeck et al. [14] found age-associated differences in the DGI and concluded that the test shows a ceiling effect up to 60 years of age, with rapid performance decline for subjects in their seventies. This possible limitation of the DGI and the paucity of investigations applying it to healthy older adults raise the need for further study of this commonly used measure of functional mobility.

To better characterize the DGI and associated factors in a highly functional group of healthy older adults, the present study examined its relationship to other balance and gait tests and specifically addressed the following questions: 1) how does the DGI relate to fall history and other tests of mobility in a large cohort of healthy elderly adults? 2) how does the DGI relate to the level of confidence, anxiety, and fear of falling (i.e., the ABC scale)? 3) are there gender differences in DGI performance? and 4) what is the role of the DGI's stair climbing component, an especially challenging and hazardous activity, known to have severe consequences [10]?

METHODS

Subjects

We invited healthy community dwelling older adults to participate in a three year prospective study designed to assess the interaction between gait and mental abilities. Volunteers were recruited from local senior centers and the surrounding community via lectures, flyers, advertising, and word of mouth. The present report is based on the baseline characteristics of this cohort. Subjects were included in the study if they were: (1) 70–90 years of age, (2) living independently in the community, (3) walking without any aid (e.g., no cane, walker or caregiver assistance), (4) free of neurological or musculoskeletal diagnosis likely to affect gait or cognition (such as a history of a cerebro-vascular accident, Parkinson's disease, brain trauma, significant orthopedic disabilities or acute illness), and (5) free of dementia, i.e., Mini Mental State Exam (MMSE) ≥ 24 [15].

After providing informed written consent as approved by the local Helsinki committee (approval number 05–108), subjects who met the inclusion criteria underwent a comprehensive physical assessment. The evaluations collected information about health status and medical history, medication usage and history of falls (e.g., numbers of falls during the past year). The motor part (part III) of the Unified Parkinson's Disease Rating Scale (UPDRS) assessed extra-pyramidal symptoms common in aging [16]. The Mini-Mental State Exam (MMSE) was used as a screen for dementia and a general measure of cognitive function.

Performance-based Measures of Balance and Mobility

In addition to the DGI, the Berg Balance Test (BBT), a widely used measure of balance and mobility was used to evaluate these properties [17]. Performance is rated on 14 different tasks, e.g., standing with eyes closed, tandem standing, single leg stand, reaching, 360° turning and stepping. The highest possible score on the BBT is 56, which indicates excellent balance, while scores lower than 45 have been associated with a high risk of falls [17]. The Timed Up and Go (TUAG) was also used to quantify functional mobility [18]. A cut-off point of 13.5 seconds has been used to identify fallers [19], while another study reported a 12 seconds cut-off time to differentiate fallers from non-fallers [20].

Fear of Falling, Depression and Anxiety

Fear of falling was measured using the Activities-specific Balance Confidence scale (ABC) [21]. In this questionnaire, the subject is given 16 activities and is asked to rate his/hers confidence level when performing each activity, on a scale ranging from 0%–100%. The highest score (100%) represents full confidence, i.e., no fear of falling. ABC scores under 50% indicate a very low level of balance confidence; scores between 50%–80% indicate moderate confidence, and scores higher than 80% reflect high confidence and are typical for physically active older adults [13]. Previously, a cut-off point of 85% was suggested, 2 standard deviations below the mean confidence level of a group of healthy older adults [22], to identify subjects with excessive fear of falling.

The Geriatric Depression Scale (GDS) [23] was used to assess the emotional wellbeing of the study participants. It includes 30 yes/no questions. A score of 0–10 is considered normal, 11–20 is a sign of mild depression, while 21 and above suggests more severe depression. The State-Trait Anxiety Inventory (STAI) quantified the level of general and specific anxiety [24]. Scores on each part range from 20 to 80; higher scores indicate increased anxiety.

Statistical analysis

Pearson's correlations were used to quantify the bivariate associations between the DGI and other measures. Chi-square analysis and the student's t-test were used to compare groups.

Summary measures are reported as mean \pm SD. Statistical analyses were performed using SPSS 14.0 for Windows.

RESULTS

Subjects Characteristics

278 healthy community dwelling older adults, (60% women) were studied. Subject characteristics are summarized in Table 1. The BBT, TUAG, and UPDRS mean scores were all near the ideal values and indicative of good functional ability for the group as a whole. MMSE mean scores were also close to the 30 point perfect score. The GDS scores were within normal ranges. The scores on the State-Trait Anxiety Inventory reflected mild anxiety levels.

DGI and Fall History

Among all participants 26.2% reported one or more falls in the past year. Fallers and non-fallers were similar ($p>0.4$) with respect to the BBT, TUAG, UPDRS and MMSE scores. In contrast, although their scores were still relatively good, fallers performed significantly worse ($p=0.029$) on the DGI (22.5 ± 1.8) compared to non-fallers (23.0 ± 1.4), i.e., their DGI scores were slightly lower (worse). When using a DGI score of 19 or less as a cut-off (as previously recommended [3,4]), there was good sensitivity for detecting fallers (91%), but poor specificity (3%) in this cohort of healthy older adults. Adjustment of the threshold to higher values improved specificity, but decreased sensitivity; no threshold resulted in both good ($\geq 80\%$) sensitivity and specificity.

DGI and other clinical measures

The DGI was moderately correlated with the BBT ($r=0.53$; $p<0.001$), the TUAG ($r=-0.42$; $p<0.001$) and the ABC ($r=0.49$; $p<0.001$). The DGI was also modestly correlated with age ($r=-0.21$; $p<0.001$), and the motor part of the UPDRS ($r=-0.34$; $p<0.001$). The DGI was not correlated with the MMSE ($r=0.07$; $p=0.26$) or with State and Trait anxiety ($r=-0.008$; $p>0.93$). Interestingly, the DGI was very mildly but significantly associated with GDS ($r=-0.18$; $p=0.026$).

DGI, gender and stair climbing

Gender was related to falls status ($p=0.006$): only 17% of the men had a history of falls, compared to 32% of the women. This raises the question: were other measures also related to gender? Test scores stratified by gender are summarized in Table 2. Scores on the DGI were near perfect in men (23.3 ± 1.2), but among women, there was a small, but significant ($p<0.001$) decrease in the DGI (22.5 ± 1.6). Whereas pivoting, walking while rotating the head, and other DGI items were not different in men and women, this reduction in the total DGI score in women, compared to men, was primarily due to stair climbing performance, with many women (50.6%) choosing to ascent and/or descent stairs while holding a handrail (the 8th item of the DGI), compared to only 19.6% men ($p<0.001$). In fact, 65.0% of the women had imperfect DGI performance (total score < 24), while only 39.3% of the men received imperfect scores ($p<0.001$). Both men and women achieved similar scores on the BBT and the TUAG ($p=0.74$, $p=0.28$, respectively), indicating good balance and mobility performances. UPDRS and MMSE scores were also similar in men and women ($p>0.22$). On the other hand, ABC scores, depression, anxiety, and fall history, as noted, were different. Still, the gender-difference in DGI scores persisted if subjects were stratified by fall history.

When looking carefully at the fall history of subjects, women, both non-fallers and fallers, reported a greater loss of confidence when climbing stairs, perhaps explaining the rail holding

(recall Table 2). Furthermore, ABC scores, both total score and stair climbing item score, were lower for women than men, even when stratifying by fall history.

DISCUSSION

Most previous studies that used the DGI included older adults with significant gait and balance disorders or vestibular problems. Although a few studies assessed community dwelling older adults without disability or dementia, subjects were included if they had leg claudication, osteoarthritis or other factors likely to have a major impact on mobility. Vereeck et al. [14] described some findings in healthy older adults, but the present study is the first large scale report on the DGI and associated factors among healthy older adults. The results indicate that in this cohort the DGI is related to falls, gender, and stair climbing performance. While in agreement with previous reports that found an association between the DGI and falls [3,4], the DGI was not an optimal classifier of faller (vs. non-fallers) in this healthy cohort where somewhat of a ceiling effect was observed. This finding is consistent with previous claims that the DGI may suffer from ceiling effects [8,14].

DGI item #8 evaluates stair negotiation. There is limited research on the underlying factors that impair performance in this important activity of daily living. Limitation in stair negotiation is one of the markers of disability and functional decline and can be a critical factor in loss of independence [25]. Stair navigation, particularly stair descent, is an extremely challenging and hazardous locomotor task, especially in the elderly [26,27], and it is not surprising that more than 10% of fatal fall accidents are reported to be a result of stairs [28]. Climbing up and down stairs was among the top 5 tasks that community-residing older adults rated as being most difficult due to old age [25]. Since stair climbing places great demands on various systems that deteriorate with aging (e.g., musculo-skeletal, somato-sensory), a decline in mobility may result in problems with the negotiation of stairs and in a higher fall risk. In practice, stair negotiation is an important aspect of daily living activity and needs to be assessed carefully [29]. Tiedemann et al. [30] observed that many factors were associated with stair climbing abilities including knee strength, vision, balance and fear of falling. They also found that men completed stair ascent and descent at a faster speed than women, while there were no gender differences between men and women in age or previous falls. Interestingly, the present results suggest that the most gender-specific sensitive DGI item was *stair climbing*: women more often held onto the railing than men, even when comparing healthy, non-fallers. Thus, the DGI's measure of stair climbing was found to be a measure that is sensitive to subtle differences between the performance of men and women.

The present findings are *not* fully in agreement with the results reported by Vereeck et al. [14] and Hamel et al. [10]. The former study found no gender difference in the DGI among older adults and the latter found no gender differences in handrail scores during stair ascent. These differences could be attributed to the larger sample size of the present study and the dichotomized nature of the DGI (i.e., use/no use of rail) in comparison to the Observational Stair Parameter and Scoring System which takes into account the qualitative properties of handrail use. However, when handrail score was dichotomized in the Hamel et al. study, there was still no significant difference. Nevertheless, the women had significantly lower scores on the Stair Efficacy Scale compared to men, but the difference between men and women in the ABC scores were not significant ($p=.29$). In contrast, a significant difference ($p=0.025$) in ABC scores between men and women was seen in the present study. Although women were more anxious than men, which may partially explain the rail holding, no correlation was found between anxiety and the DGI.

The present findings also do not support a recently developed 4-item DGI [31]. This short version includes only the first 4 items of the original DGI, with the stair item (#8) omitted.

Marchetti and Whitney proposed that the properties of the shorter version were equivalent to the original one, without compromising important clinical information. This is in contrast to the present findings, which showed that the stair item was very sensitive and revealed gender differences. This discrepancy could be attributed to differences in methodology and the health and age of the cohorts. For example, whereas in Marchetti and Whitney's study the mean age of the participants was 56.7 years, in the present cohort, the mean age was 76.3 years. In contrast to the present cohort of healthy adults, about 54% of the previous study's participants had balance disorders.

The present study has several limitations. For example, the self-report of falls history may have resulted in recall bias, possibly affecting the relationship between the DGI and falls. An intriguing association between the DGI and stair-negotiation performance was observed using a coarse measure of this ability. In the future, it may be helpful to study the relationship between the DGI, stair climbing abilities, and falls using a prospective design and more detailed testing of stair negotiation abilities.

In summary, the DGI was able to identify subtle changes in performance and appears to be an appropriate tool for assessing function in healthy older adults. Although the main limitation of using the DGI is the ceiling effect, application of this index indicates that even among healthy older adults, the approach to stair climbing is different in men and women. While fear of falling and fall history contribute to this gender-specific attitude towards stair climbing, much of the variance in the DGI remains unexplained and other still unknown factors apparently also play an important role. These findings should be considered when applying the DGI and when evaluating functional independence and fall risk in older adults. Low scores on the DGI are likely to provide a good indication of fall risk and this metric is apparently sensitive to changes that may be missed by other measures of mobility. However, because of the observed ceiling effect in healthy older adults and since falls in the elderly are typically multi-factorial in nature, a comprehensive assessment of fall risk will likely benefit from the combination of several tests including the DGI.

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Table 1

Study participant characteristics

	All subjects (n=278)
Gender (% women)	60%
Age (yrs)	76.3±4.6
Berg Balance Test (BBT)	54.1±2.3
Timed Up and Go (sec)	9.5±1.7
Mini Mental State Exam (MMSE)	28.7±1.3
Activities-specific Balance Confidence scale - Total	91.8±10.4
Activities-specific Balance Confidence scale - Only stair item	89.7±17.6
Dynamic Gait Index (DGI)	22.8±1.5
DGI Item 8, stairs	2.6±0.6
State Anxiety Inventory	32.2±10.1
Trait Anxiety Inventory	33.9±8.7
Geriatric Depression Scale (GDS)	5.2±4.6
Unified Parkinson's Disease Rating Scale (UPDRS)	4.1±2.8
% reported a fall (1 or more)	26.2

* Entries are mean±SD or % as indicated.

Table 2

Test scores stratified by gender*

	Women (n=166)	Men (n=112)	p-value
Age (yrs)	75.9±4.0	76.8±5.3	0.10
Berg Balance Test (BBT)	54.0±2.8	54.3±2.3	0.74
Timed Up and Go (sec)	9.7±1.7	9.3±1.8	0.28
Mini Mental State Exam (MMSE)	28.7±1.3	28.7±1.2	0.22
Activities-specific Balance Confidence scale – Total	89.9±11.4	94.5±8.3	0.025
Activities-specific Balance Confidence scale - Only stair item	86.9±19.9	94.0±12.1	<0.001
Dynamic Gait Index (DGI)	22.5±1.6	23.3±1.2	<0.001
DGI Item 8, stairs	2.4±0.6	2.8±0.4	<0.001
State Anxiety Inventory	33.8±10.5	29.9±9.1	0.002
Trait Anxiety Inventory	35.8±8.7	30.9±7.8	<0.001
Geriatric Depression Scale (GDS)	6.0±4.9	4.1±3.8	0.001
Unified Parkinson's Disease Rating Scale (UPDRS)	4.3±2.8	3.96±2.5	0.22
% reported a fall (1 or more)	32%	17%	0.006

* Entries are mean±SD or % as indicated.