The sensitivity and specificity of the Timed “Up & Go” and the dynamic gait index for self-reported falls in persons with vestibular disorders

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Abstract. The purpose of this study was to determine the sensitivity and specificity of the Timed “Up & Go” (TUG) and Dynamic Gait Index in identifying self-reported fallers among persons with vestibular dysfunction. One hundred three patient charts were included from a tertiary vestibular physical therapy practice. The patients ranged in age from 14–90 years and had vestibular diagnoses, falls reported in the patient chart, and completed the TUG and/or the Dynamic Gait Index (DGI). Thirty-one persons reported falling one or more times in the previous 6 months during their initial assessment. Persons who took longer than 13.5 seconds to perform the TUG test were 3.7 times more likely to have reported a fall in the previous 6 months. Those persons with scores less than or equal to 18 on the DGI were 2.7 times (\(p = 0.03\)) more likely to have reported a fall in the previous 6 months. The sensitivity of the DGI at 18 or less was 70% and the specificity was 51%. People who scored greater than 11.1 seconds on the TUG were 5 times (\(p = 0.001\)) more likely to have reported a fall in the previous 6 months. Sensitivity (80%) and specificity (56%) were calculated for TUG scores of greater than 11.1 seconds. The TUG and the DGI appear to be helpful in identifying fall risk in persons with vestibular dysfunction. Slower scores on the TUG (>11.1 seconds) and lower scores on the DGI (18) correlated with reports of falls in persons with vestibular dysfunction.

Keywords: Vestibular, falls, gait

1. Introduction

The relationship between falls and vestibular dysfunction is not well understood [1–3], yet recent reports suggest that falls are a potential concern for those living with vestibular dysfunction [4,5]. Thirty percent of older community living adults report falling [6]. Whitney et al [5] reported slightly higher reported falls in people with various vestibular disorders under 65 years of age (35%) compared to those over 65 (39%). Herdman et al [4] found that 51% of persons with bilateral vestibular disorders between the ages of 65–74 reported falls. The identification of falls risk in persons...
with vestibular and balance dysfunction is a concern to physicians and therapists. Simple tools to quickly identify fall risk are essential in order to initiate treatment or to provide precautions to minimize the risk. One method commonly used to help identify falls risk is to query the patient about recent past falls and determine their present functional abilities in order to establish if the relationship between falls and a balance assessment tool [7–29].

Many gait and balance tools have been shown to predict fall risk in older adults, yet it is not known if these same gait and measurement tools would indicate increased fall risk in persons with vestibular and balance disorders. The Timed “Up & Go” (TUG) test is a gait measurement tool that is commonly used in balance clinics. It involves standing, walking 3 meters, turning, and returning to the start position [30]. The TUG was originally developed as a mobility performance task in older adults [30] with multiple co-morbidities and has been used by others to assess fall risk [31–35] and postural control [36,37]. The TUG has also been related to difficulty in performing activities of daily living [30].

Podsiadlo and Richardson [30] reported the TUG’s test retest reliability as \( r = 0.99 \) in persons with stroke, Parkinsons disease, arthritis, and other comorbid conditions. In community dwelling older persons the TUG’s inter rater reliability was \( r = 0.97 \) [35], in persons with Parkinson’s disease \( r = 0.73–0.99 \) [38], and in adults living in a senior citizen high rise the ICC was \( r = 0.92 \) [39]. In persons with dementia the test-retest reliability has recently been reported to be \( r = 0.56–0.87 \) [37,40,41]. The moderate test-retest reliability (ICC = 0.56) reported by Rockwood et al [41] could have been because the time between test sessions was a mean of 112 days and some of their subjects had cognitive impairment with possible changes in mental status between test sessions. Timed “Up & Go” scores increase with increasing age [42] and are affected by the use of an assistive device [26,42] and the height of the chair [43]. Timed “Up & Go” scores have been moderately related to gait speed (\( r = -0.61 \)) to the Berg Balance Scale (\( r = -0.81 \)), and the Barthel Index (\( r = 0.78 \)) which is a measure of ADL function [30].

The TUG has been able to identify functional mobility problems in persons with Parkinson’s disease [44] and between those who have cognitive impairment versus those with normal cognition [41].

Sensitivity and specificity for the TUG have been reported in older adults who were at risk for falling [26, 45,46] with scores ranging between 59% [46] to 89% [45]. All three studies included older adults who were either one time or recurrent fallers.

Scores on the TUG relate to falls risk [47,48]. In older adults, a score of greater than or equal to 13.5 seconds has recently been related to falls risk [26]. Scores on the TUG have been able to discriminate between persons who have experienced multiple falls from non fallers [45]. The TUG has previously been used in studies with persons with vestibular disorders [49–52] yet little is known about whether TUG scores indicate fall risk in persons with dizziness and balance disorders.

The Dynamic Gait Index [53] (DGI) score has previously been related to falls in persons with vestibular dysfunction [5] and is another gait tool that is commonly used in vestibular clinics [5,50–52.54] and with older adults [26,55–57]. The tool was developed for use with older adults [53] and has been recently used as an outcome measure to determine if there were changes in gait and balance after an exercise program [57]. In addition, the DGI has been used with older adults to quantify their walking and falls risk [26,55]. Wrisley et al [58] have recently reported the inter-reliability of the DGI in persons with peripheral vestibular disorders as moderate (\( k =0.64 \)). Scores of 19 or less have been shown to indicate fall risk in older adults [55] and in persons with vestibular disorders [5]. There are no sensitivity or specificity papers published to date related to the DGI.

It is often reported by persons with vestibular disorders that moving their head while walking makes them unstable. The DGI includes 2 items that involve walking with head movements, one in the pitch plane and one in the yaw plane. Patients with vestibular disorders demonstrated the lowest scores on these 2 items of the DGI in comparison to other test items [58]. It was hypothesized that these items that involve head movements would show greater sensitivity and specificity in predicting fall risk and might prove to be helpful as single items for use in a physician’s office to determine fall risk in persons with vestibular dysfunction.

Gait performance criteria suggestive of falls have not been clearly established in persons with vestibular disease. The purpose of this paper was to determine the sensitivity and specificity of two clinical measures of gait recorded during the initial physical therapy assessment in identifying fall risk. It was hypothesized that the TUG, the total DGI, and the items of the DGI evaluating walking with vertical and horizontal head turns would display adequate sensitivity and specificity for possible use in identifying potential fallers in persons with vestibular disease. It was expected that the individual DGI items of walking with horizontal and vertical head turns (items 3 and 4) would display a stronger relationship with falls in persons with vestibular disease than item 1, walking with head forward.
2. Materials and methods

One hundred three subjects were identified from a retrospective chart review of all patients that were seen from January to December 2000 at a tertiary balance and vestibular clinic. All charts that met the following inclusion criteria were included: 1. the person had a vestibular diagnosis provided by a neurologist or neurotologist, 2. referred for physical therapy, and 3. the history of falls and either the Timed “Up & Go” (TUG) and/or the Dynamic Gait Index (DGI) had been recorded. Patient records were excluded if information about falls history or both the DGI and the TUG were not recorded in the medical record. All of the diagnoses were confirmed after reviewing their laboratory testing and physician chart by one of the investigators (AS). The study had been designated as exempt by the University of Pittsburgh’s Biomedical Institutional Review Board and was conducted at the Centers for Rehab Services Balance and Vestibular Clinic.

The descriptive information about the patients is included in Table 1. The mean age of the patients was 60 years with a range of 14–90 years. The patients were further divided by age into 2 groups: those older than 60 years and those younger than 60 years to determine if age affected their functional balance scores. Sixty-two percent (64/103) of the patients were female and the mean duration of symptoms was 40 ± 68 months.

Fifty-two persons had peripheral vestibular diagnoses (51%), 45 had central diagnoses (44%), and 6 persons had a mixed central and peripheral vestibular diagnoses (5%). The primary diagnoses included Meniere’s disease (n = 4), unilateral peripheral vestibular hypofunction (n = 34), bilateral vestibular hypofunction (n = 5), multisensory dysequilibrium (n = 14), head trauma (n = 2), cerebellar dysfunction (n = 1), anxiety related dizziness (n = 7), central vestibular dysfunction (n = 5), labyrinthine concussion (n = 1), cervicogenic dizziness (n = 4), benign paroxysmal positional vertigo (n = 12), and migraine related dizziness (n = 14). Of the 90 charts that had symptoms recorded, 16 reported only dizziness symptoms, 7 reported only balance complaints, and 67 reported having balance and dizziness concerns.

Between 70 and 80 percent of the patients had completed at least one vestibular laboratory test prior to the start of the physical therapy intervention. Forty-four percent of the sample had abnormal caloric testing (n = 78), 11% had abnormal ocular motor testing (n = 85), 48% had abnormal rotational chair findings (n = 77), and 21% had abnormal positional testing (n = 82). All vestibular laboratory findings were classified as either normal or abnormal by an otolaryngologist.

Three physical therapists evaluated the patients. All of the therapists had experience in the evaluation and treatment of patients with vestibular dysfunction and had been trained by one of the authors (SLW) in the performance of the TUG and DGI. The physical therapist asked each patient about his or her history of falls in the last 6 months and the number of falls were recorded on the initial intake form. The questions about falls were standardized and were included as part of the initial physical therapy intake form. Thirty percent of the patients reported falling at least once in the last 6 months and 18% reported falling more than 1 time in the previous 6 months (recurrent faller). A fall was defined for the patients as “unexpectedly coming to rest on the ground or floor” [59].

The inter rater reliability of the TUG was determined to be high (ICC = 0.99) when tested in a separate sample of nine patients and two therapists at the study clinic. The inter rater reliability of the total DGI was moderate to high (ICC = 0.77) when tested in the same patient and clinician sample. Patients were asked to complete the TUG test once during the initial evaluation by the physical therapist. The patients were asked to stand from a chair with armrests, walk 3 meters, turn and go back to their seat at their normal pace. Timed “Up & Go” scores have been previously shown to be dependent on chair height [43] so the same chair was used for all testing. The chair height was 43 cm from

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Mean: 60 ± 17</th>
<th>Range: 14–90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral</td>
<td>52 (50%)</td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>45 (44%)</td>
<td></td>
</tr>
<tr>
<td>Mixed peripheral and central</td>
<td>6 (6%)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>64 females (62%)</td>
<td></td>
</tr>
<tr>
<td>Total duration of symptoms (months)</td>
<td>Mean: 40 ± 68</td>
<td></td>
</tr>
<tr>
<td>Less than 6 months</td>
<td>28 (27.2%)</td>
<td></td>
</tr>
<tr>
<td>6 months-1 year</td>
<td>21 (20.4%)</td>
<td></td>
</tr>
<tr>
<td>1 year and greater</td>
<td>53 (51.5%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>102</td>
<td></td>
</tr>
</tbody>
</table>

| Fall status                      |               |              |
| Non-faller                       | 72 (69.9%)    |              |
| One-time faller                  | 13 (12.6%)    |              |
| Recurrent faller                 | 18 (17.5%)    |              |
| Total                            | 100%          |              |
Table 2: Distribution of subjects who fell by age and diagnosis (total = 103)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Age less than 60 who reported a fall n (%)</th>
<th>Age 60 or greater who reported a fall n (%)</th>
<th>Total number of people and percent of reported falls by diagnosis n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral (n = 52)</td>
<td>7 (7%)</td>
<td>9 (9%)</td>
<td>16 (16%)</td>
</tr>
<tr>
<td>Central (n = 45)</td>
<td>7 (7%)</td>
<td>5 (5%)</td>
<td>12 (12%)</td>
</tr>
<tr>
<td>Mixed (n = 6)</td>
<td>0 (0%)</td>
<td>3 (3%)</td>
<td>3 (3%)</td>
</tr>
<tr>
<td>Total (n = 103)</td>
<td>14/55 (25%)</td>
<td>17 (35%)</td>
<td>31/103 (30%)</td>
</tr>
</tbody>
</table>

the ground to the seat, seat depth was 49 cm, and height of the armrest from the floor was 63.5 cm. A standard digital stopwatch was used that recorded the time to the nearest tenth of a second. The stopwatch was depressed when the patient was given the command “Go” and stopped when the buttocks touched the chair. Subjects had their hands on the armrest at the start of the test and ambulated on a thin carpet covering a concrete floor while wearing their normal footwear. Subjects walked at their preferred gait speed.

Patients were also asked to perform the DGI as part of their normal physical therapy evaluation. The DGI consists of performing 8 gait tasks including walking, walking at different speeds, walking with the head moving in the pitch and yaw planes, walking over and around objects, turning while walking, and ascending and descending stairs [53]. The test is scored on an ordinal basis with 3 = normal performance, 2 = minimal impairment, 1 = moderate impairment, and 0 = severe impairment or unable to perform. The scoring (3–0) also has specific qualifiers that guide the clinician in choosing the correct score for the patient.

3. Data analysis

Mean Timed “Up & Go” and Dynamic Gait Index scores were calculated for age group, diagnostic group, and symptom duration. One-way analysis of variance (ANOVA) with a least significant difference (LSD) pairwise comparison was used to compare the mean TUG and total DGI between subjects who report a non-falling, one-time and recurrent fall history.

Receiver operating characteristic curves with area under the curve (AUC) analysis were derived for the determination of optimal cut point values for the association between the TUG, DGI, and self-reported falls. The relationship between the TUG, the DGI, and self-reported falls using previously published criteria and the values obtained through the ROC analysis were assessed using the Pearson chi-square with odds ratio (OR) and 95% confidence interval to determine screening characteristics of sensitivity, specificity, positive predictive value, and negative predictive value. The areas under the ROC curves for the TUG and DGI were compared using methods described by Hanley and McNeill [14]. This method for comparing curves derived from the same cases compares the differences in the areas normalized to a pooled standard area that is adjusted for the correlation coefficient describing the relationship between the two measures.

The Mantel-Haenszel chi square statistic and adjusted odds ratios were used to assess the relationship in the presence of age as potential confounder. The association between the TUG, DGI, and self-reported falls (using previously reported cut off scores of TUG >13.5 and DGI ≤ 19) was analyzed using contingency table chi-squared analysis (age stratification at 60, 65, and 70 years) with odds ratios, and calculation of sensitivity, specificity, positive predictive values, and negative predictive values were performed.

Contingency table chi square analysis was used to determine the relationship between subject performance on item 1 and items 3–4 of the DGI and the relationship of these items with fall history. The sensitivity and specificity of these individual items was calculated.

4. Results

Recurrent falls (2 or more) were reported by 18 (18%) of the sample, and recurrent fallers comprised 58% of the fallers (Table 1). The distribution, by age and diagnosis, of subjects who report falling are included in Table 2. Thirty percent of the 103 patients reported at least one fall in the last 6 months. A greater percentage of those patients greater than or equal to 60 years of age (35%) reported falls compared to those less than 60 years of age (25%) (Table 2).

The mean, standard deviation, and 95% confidence intervals of the DGI and TUG for patients reporting no falls, one fall, or recurrent falls are reported in Table 3. Higher total DGI and lower TUG scores were found for the non-falling group followed by one time
Table 3
The mean timed “Up & Go” and total dynamic gait index scores plus the standard deviation
and 95% confidence intervals based on falls status

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fall status</th>
<th>N</th>
<th>Mean</th>
<th>Std. deviation</th>
<th>95% Confidence interval for mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower bound</td>
<td>Upper bound</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total DGI*</td>
<td>Non-faller</td>
<td>71</td>
<td>17.9</td>
<td>4.2</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>One-time</td>
<td>13</td>
<td>14.3</td>
<td>6.1</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>Recurrent</td>
<td>18</td>
<td>14.2</td>
<td>5.4</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>102</td>
<td>16.8</td>
<td>4.9</td>
<td>15.8</td>
</tr>
<tr>
<td>TUG†</td>
<td>Non-faller</td>
<td>63</td>
<td>11.2</td>
<td>2.7</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>One-time</td>
<td>12</td>
<td>13.5</td>
<td>3.8</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>Recurrent</td>
<td>18</td>
<td>13.9</td>
<td>3.6</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>93</td>
<td>12.0</td>
<td>3.3</td>
<td>11.3</td>
</tr>
</tbody>
</table>

*ANOVA F = 6.62, p = 0.002, df = 101.
†ANOVA F = 7.07, p = 0.001, df = 97.

Fig. 1. The receiver operator curve (ROC) for the TUG and the total DGI for self-reported falls in persons with vestibular disorders.

and recurrent fallers. The mean TUG score for all patients was 12.0 ± 3.3 seconds. Seventy-two percent of patients scored below 13.5 seconds on the TUG. Persons reporting one fall had mean TUG scores of 13.5 seconds, those reporting recurrent falls 13.9 seconds as compared to 11.2 seconds for those not reporting a fall.

The mean DGI score for all patients was 16.8 ± 4.9 (range 4–24). Fifty-six persons out of 102 (one person did not complete the DGI) had DGI scores below 19 (55% of the sample). Persons who reported one fall had mean DGI scores of 14.3 and recurrent falls 14.2 vs. 17.9 on the DGI for those not reporting a fall.

Significant differences were found across fall groups on both measures. Post-hoc between-group comparisons (Least Squares Difference (LSD)) for both measures indicated significant differences between the non-fallers and both falling groups (p < 0.02 for all comparisons). There was no significant difference between the one-time or recurrent falling group on either measure.

The ROC curve for the TUG and DGI is demonstrated in the Figure. The AUC analysis for curve difference between the TUG (0.71) and DGI (0.67) was performed using 93 subjects from whom both measures were obtained. The p-value associated with the normal
value \((Z = 1.00, p = 0.16)\) for the AUC difference indicates that there is no difference between the two curves.

The sensitivity and specificity for reported falls at TUG values between 11.1 and 13.5 are illustrated in Table 4. There is over a thirty percent increase in sensitivity using the 11.1 seconds versus the 13.5 second cutoff. The specificity of the TUG at 11.1 seconds is 56%. At 11.1 seconds, the positive predictive value (PPV) was 46% and the negative predictive value (NPV) was 85%. The odds ratio in favor of falling with a TUG of >11.1 seconds was 5.0 (95% CI 1.80–13.91). The relationship between a self reported fall and a TUG score of >11.1 seconds was statistically significant \((p = 0.001)\).

The sensitivity and specificity for reported falls at DGI values of less than 17 through less than 20 are included in Table 5. The sensitivity of the DGI at less than 19 was 71% and the specificity was 53%. The PPV for the DGI at less than 19 was 39% and the NPV was 81%. The odds ratio in favor of falling with a DGI of <19 was 2.66 (95% CI 1.08–6.57). The relationship between the self reported fall and a DGI score of <19 was statistically significant \((p = 0.03)\).

It was noted that using 17 as the cut-point resulted in a 10% specificity decrease with a 3% sensitivity increase. Total DGI score of less than 17 was significantly associated with falls, \(p = 0.008\), OR = 3.21, 95% CI 3.34–3.75.

Table 6 shows the TUG results of the contingency table analysis for the entire sample and stratified by age at 60, 65 and 70 years. The relationship between TUG and falls was not significant in the older sub-sample in any of the age stratifications.

In Table 7, a subject with a DGI score of 18 or less was 2.7 times more likely to have a positive fall history than a subject with a score of 19 or greater. The
Table 6
The relationship between the timed “Up & Go” score and falls for the entire sample and at age cut offs of 60, 65, and 70 years of age

<table>
<thead>
<tr>
<th>TUG analysis</th>
<th>Chi square</th>
<th>Significance</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire sample</td>
<td>7.69</td>
<td>0.006</td>
<td>3.72</td>
<td>1.43–9.65</td>
</tr>
<tr>
<td>Age adjusted*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 years</td>
<td>5.22</td>
<td>0.02</td>
<td>3.60</td>
<td>1.27–10.2</td>
</tr>
<tr>
<td>65 years</td>
<td>4.97</td>
<td>0.03</td>
<td>3.36</td>
<td>1.20–9.34</td>
</tr>
<tr>
<td>70 years</td>
<td>5.85</td>
<td>0.02</td>
<td>3.70</td>
<td>1.34–10.24</td>
</tr>
</tbody>
</table>

*Mantel-Haenzel chi square and estimate for common odds ratio.

Table 7
The chi square analysis OR and 95% CI for the relationship between the Dynamic Gait Index less than 19 and self-reported falls for the entire sample and stratified by age at 60, 65 and 70 years

<table>
<thead>
<tr>
<th>DGI analysis</th>
<th>Chi square</th>
<th>Significance</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire sample</td>
<td>4.64</td>
<td>0.03</td>
<td>2.66</td>
<td>1.07–6.57</td>
</tr>
<tr>
<td>Age adjusted*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 years</td>
<td>2.81</td>
<td>0.09</td>
<td>2.41</td>
<td>0.98–6.09</td>
</tr>
<tr>
<td>65 years</td>
<td>2.68</td>
<td>0.10</td>
<td>2.35</td>
<td>0.93–5.90</td>
</tr>
<tr>
<td>70 years</td>
<td>3.22</td>
<td>0.07</td>
<td>2.51</td>
<td>1.00–6.25</td>
</tr>
</tbody>
</table>

*Mantel-Haenzel chi square and estimate for common odds ratio.

The relationship between DGI scores and falls was not significant in older age groups regardless of the stratification point, which accounts for the failure to achieve significance in the age adjusted conditions.

As the age stratification point for the DGI was increased, the frequency of subjects performing at 19 or above on the DGI decreased from 29% at age 60+ to 26% at age 70+. The fall prevalence across the three older age strata remained fairly constant (35–37%). The relationship between the total DGI and falls was significant in the younger group in each age-stratified analysis \( (p < 0.05) \). Fall prevalence in the younger groups of each stratified analysis was lower than the older group (25–28%). The frequency of subjects performing at 19 or higher on the DGI provided sufficient power for the relationship to reach significance in the older groups.

The influence of walking with head forward (DGI item 1), walking with head movement in the yaw plane (DGI item 3) and walking with head movement in the pitch plane (DGI item 4) was investigated (Table 8). Both level gait and gait with vertical head movements displayed a significant relationship with falls. Fifty one percent (51/101) of patients scored a 0 or 1 (moderate to severe impairments) with head movements in the pitch plane and 33/101 (33%) patients with head movements in the yaw plane. A stronger relationship was found between walking with vertical head movements and self reported falls. A person who had difficulty while walking with head movements in the pitch plane on the DGI was over four times more likely to have a positive fall history than a subject with normal performance. The sensitivity of this item for falls was 90%, indicating that this item may be beneficial for fall screening and prevention.

There was a high degree of dependence displayed by performance on all three DGI items. Normal or abnormal performance on item 1 was strongly associated with similar performance of items 3 and 4 \( (p < 0.001) \). Performance on items 3 and 4 displayed similar dependence \( (p = 0.001) \), however a greater proportion of subjects (60%) who were able to walk normally with yaw head movements had difficulty walking with vertical head movements.

5. Discussion

It appears that the TUG and the DGI are sensitive measures that could be used to assess fall risk in persons with balance and vestibular disorders. There have been frequent reports of falls in persons who present to vestibular clinics [4,5,60] suggesting that determining the risk of falling is an important consideration in the optimal assessment of a patient.

The TUG with cut off of 11.1, the DGI with cut off of <19, and walking with pitch head movements can aid the clinician in identifying people with vestibular disorders who are at risk for falling. The characteristics of the TUG will be discussed first.

The TUG sensitivity was 47% with a cut off score of 13.5 seconds and it increased to 80% with a cut off score of 11.1 seconds. A TUG sensitivity score of 80% is similar to the sensitivity results reported by Dite and Temple [45] who reported sensitivity scores of 89% for multiple fallers and 67% for nonmultiple fallers. Chiu et al. [46] reported a sensitivity score of the TUG of % with a cut off score of 20 seconds. Both Chiu et al. [46] and Dite and Temple’s [45] studies reported only older adults. The present study represents the distributed population of persons presenting to a vestibular clinic.

Although the TUG specificity was only 56% (false positive rate) with the cut off score of 11.1 seconds, it was felt that a cut off score should be chosen that was
overly inclusive of those at risk. Using a cutoff of 11.1 seconds would result in an increased false positive rate. The consequences in this change in cut-point might mean identification of many persons at borderline risk for falls that have not yet fallen. These patients may benefit from intervention aimed at preventing future falls. This result is preferable to the consequence of accepting lower sensitivity for increased specificity at a decision point that may fail to identify potential fallers.

The utility of a screening test is described in terms of the positive and negative predictive values of the cutoff scores. These values factor in the prevalence of the disorder or event of interest in the screened population. In this case 30.1% fall prevalence. The positive predictive value (PPV) is the probability of a positive fall history if the screening test is positive for fall risk. The negative predictive value (NPV) describes the probability of not having fallen given a negative screen.

The highest certainty that a positive screened patient had reported a fall (PPV) was 54% with a TUG cutoff of 13.5 seconds. The likelihood that a negatively screened patient had not fallen (NPV) was greatest at 85% certainty with a TUG cutoff of 11.1 seconds. A TUG cutoff of 13.5 seconds was sensitive to 47% of the patients who had reported a fall. A cutoff score of 11 seconds increases the sensitivity to 80% at the cost of only an 8% decrease in the PPV (46%). Thus a TUG cutoff of 11.1 seconds appears to display the best balance between sensitivity (80%) and PPV (46%) in this group of patients with vestibular dysfunction.

The consequences of not identifying a faller outweigh the risk of providing intervention when it is not necessary. Falls intervention is not likely to hurt the patient, so there is little risk to the patient if they are identified as being at risk. For a quick clinical tool that takes under 3 minutes to perform, the TUG appears to provide valuable data in making a determination of falls risk.

The mean TUG score of the present sample was 12.0 seconds. Persons with mild Alzheimer’s disease had mean TUG scores of 11 seconds [36], and Steffen et al [35], and Podsiadlo and Richardson [30] reported a mean TUG score of 8.5–9 seconds for healthy men and women in their 70’s. The mean of the patients in the present sample was 60 years of age, yet their scores were slower than the scores of the healthy people in their eighites.

Newton reported TUG scores of 15 seconds in community living older adults [34], yet her subjects walked further (3.05 meters instead of the 3 meters in this study) and some used an assistive device. In persons with Parkinson’s disease (Hoehn and Yahr stages I-II and I-IV) mean scores of 14.6 and 20.9 have been reported [37,44]. The TUG score appears to be age dependent [35,61] and slow TUG scores have been related to nursing home placement and risk of death [62].

Shumway-Cook et al [26] suggested that scores greater than 13.5 indicated falls risk in older persons living in the community. Twenty-eight percent of the persons with vestibular disorders had scores greater than 13.5 seconds and 30 percent of the 103 patients reported falls in the last six months. With the cut-off of >13.5 seconds, persons with vestibular disorders were 3.7 times more likely to have reported a fall.

Based on the ROC analysis, 11.1 seconds appears to the optimal cut-off score for identifying those who are at greater risk for falling in persons with vestibular dysfunction. Either 11.1 or 13.5 seconds could be used, yet the sensitivity was much higher at 11.1 seconds (80% vs. 47%).

The mean age of the present sample was 60 years of age yet their mean TUG score was 12.0 seconds, indicating that our subjects performed worse on the TUG than healthy persons in their eighties [35] and are similar to those with mild Alzheimer’s disease [36]. Timed “Up & Go” scores in persons with unilateral

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<table>
<thead>
<tr>
<th>DGI Item</th>
<th>Chi Square</th>
<th>Significance</th>
<th>OR 95% CI</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait level</td>
<td>5.18</td>
<td>0.23</td>
<td>2.87</td>
<td>1.14–7.27</td>
<td>74</td>
</tr>
<tr>
<td>Surface</td>
<td>0.64</td>
<td>0.42</td>
<td>1.62</td>
<td>0.49–5.41</td>
<td>87</td>
</tr>
<tr>
<td>Gait with horizontal head turns</td>
<td>5.13</td>
<td>0.23</td>
<td>4.10</td>
<td>1.12–14.95</td>
<td>90</td>
</tr>
</tbody>
</table>

*Score of 3 on items compared with score of 0–2. OR = Odds Ratio.
†df = 1.
peripheral vestibular dysfunction have been reported to be 19.5 seconds [49]. Those with bilateral dysfunction had slower mean TUG scores of 23 seconds [49]. Our patients were much faster than those reported by Gill-Body and colleagues with a mean TUG score of 12.0 seconds. Gill Body et al.’s [49] patients with unilateral and bilateral vestibular dysfunction had mean durations of symptoms of 2.6 and 3.3 years respectively which is similar to our mean of 3.4 years. The mean age of Gill Body et al.’s subjects was 62.5 years compared to 60 years for this study.

Fast movements are often experienced during everyday movement, which can cause oscillopsia in persons with vestibular disorders [63]. It was surprising that the mean TUG scores in the present sample was 12.0 seconds. Our patients had chronic dizziness symptoms and may have developed compensatory mechanisms to prevent dizziness while ambulating. Often persons with vestibular disorders walk stiffly and do not move their trunks or head. These actions may have permitted our subjects to walk faster than Gill-Body et al.’s subjects with unilateral and bilateral vestibular disorders [49].

One of the limitations of this study is that the use of an assistive device was not recorded. Assistive device use has been shown to significantly affect TUG scores [42]. Medley and Thompson [42] reported that TUG times in community living older adults increased by 2 seconds with the use of a cane and by 31 seconds with the use of a standard walker compared to no assistive device. The use of an assistive device would have slowed the walking of the patients in the study, yet they still walked faster than those patients reported by Gill-Body et al [49].

Different cut off scores were attempted to determine which score provided the best discriminative value for use in persons with vestibular disorders by use of the ROC. The authors feel that a score of <19 on the DGI was the better score because less people will be missed who are at risk for falling. The consequences of making the wrong determination about falls risk can be catastrophic. Whitney et al. [5] suggested that >19 was the best cut off score for persons with vestibular disorders. Their sample was much larger and it is possible that the smaller n in the present study may have been the result of a Type II error.

Dynamic Gait Index scores of 10 [26] and 13 [57] have been reported in elderly fallers with a mean age of 83 and 85. In contrast, elderly non fallers with a mean age of 75 had DGI scores of 23 [56]. The mean DGI score in this sample was 16.8, suggesting that persons with vestibular disorders are impaired yet not as impaired as persons in the 80’s who are recurrent fallers. Whitney et al [5] reported DGI scores in persons with vestibular disorders and related the score to reported falls but did not report the mean DGI, making comparison impossible. The DGI and Berg Balance Scale have been compared in persons with vestibular disorders and the mean DGI score was reported as 16.7, which is almost exactly the same as the present study [64].

A four point change on the DGI has been reported as being a clinically significant change in persons with vestibular disorders [51]. There was a 3.7-point difference in the mean DGI of the reported fallers and those not reporting a fall. Since the 3.7 was approaching clinical significance, one might consider that patients who fall differ in their functional gait abilities from patients who do not fall.

Those patients in this study who exhibited gait instability while walking and moving their head in the pitch plane were more likely to have reported a fall within the last 6 months. Increased input from the cervical afferents occurs during head movement while walking. Input regarding the amount of head on trunk movement from the cervical afferents may conflict with the abnormal information being received in the vestibular nucleus from their existing vestibular dysfunction and lead to further disruption of the altered sense of position in space [65,66]. Kerber reports that people with vestibular disorders walk slower, have a wide base of support, and that they turn “en bloc” [60]. Head turning during gait may disturb the fragile equilibrium that persons with vestibular disorders have attained through this “en bloc” response maintained during ambulation.

During the DGI, scores of 1 or 0 while walking with movement of the head in the yaw plane indicate that the person has at least a moderate change in gait velocity and staggered but continued to walk for a score of 1 and had a severe disruption of their gait with moving outside a 38.1 cm path, lost their balance or reached for the wall. Thirty-three percent of the patients in this study had scores of either 1 or 0 indicating that movement in the yaw plane during ambulation is a very difficult task for persons with vestibular disorders. Although not statistically significant between persons who report a fall and those who do not, walking with head movements in the yaw plane was clearly very difficult for the patients seen in the balance and vestibular clinic.

Movement of the head in the pitch plane was associated with reports of falls. Persons who scored a 1 or 0 on the DGI with walking with head movement in the pitch plane had at least a moderate disruption of
indicating that the falls rate for this relatively young disorder is higher than expected. The mean of the present sample was 60 years of age, with patients reporting a fall within the last 6 months, indicating that falls may be more of a concern than previously thought.

Walking with head movements in the pitch plane could be used to screen for fall risk in persons with vestibular dysfunction and could easily be performed in a physician’s office hallway. Most of our patients reported that 37% of persons with various vestibular disorders reported a fall in the last 6 months, yet they did not report falls by diagnosis so a direct comparison is not possible.

Demonstrating difficulty with walking on a level surface, walking with head turns, and walking with head movement in the pitch plane all were associated with fall risk. The sensitivity of the items was 74%, 87%, and 90% respectively. Thus, one could ask the patient to walk and if they did not look steady, 74% of the time the clinician would be correct that the patient is at risk for falling. Walking with movement in the pitch plane is a more sensitive item in identifying falls risk (90% sensitivity, 31% specificity). Having the patient walk with head movements is easy to perform in a physician’s office and can aid the health care provider in determining if the person with a vestibular disorder is at fall risk.

Overall it appears that the optimal sensitivity and specificity is with a total DGI score of <19, although clearly using only one of the above walking tasks of the DGI provides helpful information for clinical decision making. The sensitivity and specificity of the total DGI are almost equal at 61% and 65%, which is most frequently considered to be better than having a high sensitivity rating and a lower specificity.

The number of people with central and peripheral vestibular disorders in this sample were fairly representative of the distribution seen in vestibular physical therapy practices [67]. The mean duration of symptoms was 40 months, indicating that many of these patients had sub-acute or chronic disorders. With thirty percent of the sample reporting a fall within the last 6 months, it suggests that falls may be more of a concern that has previously been reported in persons with vestibular disorders [60,68,69].

The mean of the present sample was 60 years of age, indicating that the falls rate for this relatively young group appears to be high compared to community living older persons. Forty-five percent of the reported falls in this study were in persons under 60 years of age.

More persons with peripheral vestibular disorders (16%) reported a fall than persons with central vestibular disorders (12%) (see Table 2). Intuitively, it would be expected that persons with central vestibular disorders would report more falls than those with peripheral vestibular disorders. Previously, Whitney et al [5] reported that 37% of persons with various vestibular disorders reported a fall in the last 6 months, yet they did not report falls by diagnosis so a direct comparison is not possible.

Fifty percent of the persons with mixed central and peripheral vestibular disorders in the present sample (n = 6) reported falling. This percentage is similar to the percentage of persons with bilateral vestibular dysfunction reported by Herdman et al [4]. They reported less falls in those 75 years of age and older with bilateral vestibular loss than those younger than 75 years of age. No studies were identified that report falls with persons with mixed peripheral and central vestibular disorders.

When non-fallers were compared to the one-time and recurrent fallers, the scores on the DGI and the TUG were similar with both falls groups with the non-fallers demonstrating better scores. It is unclear whether the fall affected their walking performance or their walking performance prior to the fall resulted in their falling.

Either the DGI or the TUG could be used with persons with vestibular disorders to ascertain fall risk. These balance tools may be particularly helpful since people often underreport falls [70], and scores on the DGI and TUG can help guide the health care professional in deciding on appropriate interventions. Optimally, a prospective study to investigate fall risk in persons with vestibular disorders is needed to determine whether the values identified in the present study have predictive validity. This project is an initial attempt to establish if there is a relationship between TUG plus DGI scores and reported falls. The TUG is slightly more sensitive than the DGI, yet the DGI provides the clinician with greater information about the patient’s functional gait deficits. Both tools identified the same persons as having reported a fall as evidenced by the ROC.

6. Conclusion

The Timed “Up & Go” and Dynamic Gait Index appear to be helpful in determining fall risk in persons with vestibular disorders.
with vestibular disorders. The TUG is slightly more precise (sensitive) in identifying persons who have reported a fall and is faster than the DGI to complete. The clinician may be able to use these measures to justify referring the patient for fall intervention. Instability while walking with pitch head movements may be the most sensitive measure in determining fall risk and can be used as a screening examination of persons with vestibular disorders. Persons with vestibular disorders should be closely guarded if walking with head movements in the pitch and yaw plane are attempted.

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References


