Assessment of clinical and laboratory tests in predicting risks of fall in the elderly
Hesham Mohammed Othman Taha a, Amr Gouda Shafik b and Naira Zakhlool Saber c

Introduction
Falls and unstable balance are multifactorial problems and rank high among serious clinical problems faced by the elderly. They are a cause of substantial rates of mortality and morbidity as unintentional injuries.

Aim of the work
The aim of the study was to explore the most common risk factors for falls in the elderly and to construct the most specific test battery including clinical and laboratory tests capable of determining risk for falls in the elderly.

Materials and methods
A 6-month prospective study was carried out on a sample of 30 elderly persons of age at least 60 years, reporting more than one fall within last 6 months. Detailed history on neuro-otological symptoms, previous falls, dizziness episodes, and symptoms of systemic disease or osteoarthritis was taken. Visual acuity, musculoskeletal examination, complete neurological examination, and a complete vestibular test battery in the form of the videonystagmography (VNG) test battery, vestibular-evoked myogenic potentials, and computerized dynamic posturography was performed. All participants underwent radiological diagnosis and grading of the osteoarthritic knee and hip. The mobility and gait screening protocol was used, which includes the timed up and go test (TUG), fall risk assessment screening tool (FRAST), and Dynamic Gait Index (DGI).

Results
Most patients suffered from peripheral vestibular dysfunction and the most frequent VNG abnormality was unilateral vestibular lesion. Radiological assessment of knee and hip osteoarthritis revealed 36.76% with grades II and III. Significant impairment of vision was found in 40% of the elderly. TUG test revealed high risk of falls in those elderly. In total, 20 participants revealed moderate or high risk for falls by FRAST. There was significant correlation between the number of falls and SOT tests (C5 and C6) together with adaptation tests reflecting vestibular pattern of dysfunction. Functional test of dynamic posturography revealed a highly significant correlation between limits of stability reaction time, movement velocity, and tandem of gait step and the number of falls. TUG showed a highly significant correlation in elderly people who experienced falls, whereas DGI showed only significant correlation and FRAST showed nonsignificant correlation. A highly significant correlation was found between SOT C5 and C6 scores and TUG and DGI with a weak correlation with FRAST. Vestibular-evoked myogenic potential asymmetry and unilateral canal paresis revealed nonsignificant results with all functional tests except DGI, which revealed a weak correlation with them. Analysis of variance test revealed that the vestibular dysfunction group is more vulnerable to falls than other groups.

Conclusion
The VNG test battery and computerized dynamic posturography in conjunction with stance tests in the elderly who complain of dizziness can identify those with high risk of a fall.

Keywords:
balance in elderly, falls, gait in elderly, vestibular tests
Meanwhile, 5% of the falls result in fractures or hospitalization. The risk increases with increasing age for those aged over 75 years; the rates of falling and associated complications are doubled [2].

Balance and gait problems can stem from simple age-related changes in gait and balance as well as from specific dysfunctions of the vestibular, nervous, muscular, skeletal, circulatory, and respiratory systems, or from simple deconditioning after a period of inactivity. The major reported cause of falls is vestibular dysfunction, which is an extremely common symptom among the elderly [3]. Other specific causes of falls include disorders of the central nervous system, cognitive deficits, poor vision, side effects of drug, foot problems, severe osteoporosis with spontaneous fracture, and acute illness [4].

As falls are usually multifactorial in origin, identifying risk factors for falls is much more useful than trying to classify specific precipitating causes retrospectively. Trials on multidisciplinary assessments and interventions to prevent falls [5] are underway. With regard to risk prediction, there are a number of risk assessment tools in the literature whose derivation, weighting, validation, and usefulness are obscure. The most important of these risk factors are muscle weakness and balance and gait dysfunction [4].

Moreover, various balance tests and measurements have been developed and presented to obtain appropriate information on balance capabilities during standing. Although tests for postural control with functional balance scales are easy to perform and are suitable for daily clinical use, they often lack accuracy. Technology based laboratory systems such as computerized dynamic posturography (CDP) may give more detailed information about balance control through objective quantifiable assessments of underlying impairments, as well as functional capacity, but is often difficult to use in a clinical setting. Accordingly, this study will be conducted to identify the most appropriate test battery that could be applied to identify the risk for falls in the elderly.

**Aim of the work**

1. To explore the most common risk factors for falls in the elderly.
2. To construct the most specific test battery including clinical and laboratory tests capable of determining risk for falls in the elderly.

**Patients and methods**

**Patients**

To study risk factors for falls, we conducted a 6-month prospective study on a sample of 30 elderly participants with the following general inclusion criteria:

1. Age at least 60 years.
2. Report of more than one fall within the last 6 months.
3. Ability to walk without support.

Exclusion criteria were as follows: the elderly were excluded if they reported a major musculoskeletal disorder, parkinsonism, major sequelae after a stroke, significant pain that limited daily activities, or known uncorrected visual or cognitive problems. Patients who had a combination of vestibular dysfunction and severe osteoarthritis and/or diminution of vision were also excluded.

**Methods**

After giving informed consent, detailed neuro-otological history with stress on medication used, depressive symptoms, previous falls, and occurrence of dizziness episodes with emphasis on character and duration was taken. History suggestive of diabetes, heart failure, hypertension, angina, myocardial infarction, strokes, chronic obstructive lung disease, and osteoarthritis was obtained.

Vital signs were recorded, especially orthostatic changes in blood pressure/pulse; visual acuity was measured with a Snellen chart and the participants were tested binocularly wearing normal glasses for walking; the test log scores were converted into a rank scale: 0.0, normal (3 points); 0.1–0.4, subnormal (2 points); 0.5–0.9, weak sight (1 point); at least 1, very weak sight (0 points). Musculoskeletal examination for osteoarthritic hip and knee as well as foot problems (deformities, bunions, amputations) or previous joint fractures was performed. In addition, complete neurological examination including standardized measures of mental status by Mini Mental State Examination was carried out. Participants with a score less than 24 were excluded.

**Vestibular test battery**

All participants underwent a complete videoystagmography (VNG) test battery utilizing ICS equipment searching for spontaneous, gaze-evoked, positional, and positioning nystagmus. The oculomotor test battery including tracking, saccades, and optokinetic tests was performed to exclude central vestibular dysfunction. The bithermal caloric test was also performed to exclude peripheral vestibular dysfunction.

Vestibular-evoked myogenic potentials (VEMP) were recorded using the two channel-evoked potential system Bio-logic Navigator. The surface active electrode was placed over the sternomastoid muscle on one side, whereas the reference electrode was placed in the middle of the anterior surface of the clavicle. A forehead electrode was used as earthing and 90 dB normal hearing level alternating acoustic clicks were used as stimuli.

**Radiological diagnosis**

All participants underwent radiological diagnosis and grading of the osteoarthritic knee and hip according to the protocol described by Kellegren and Lawrence [6], which was later modified by Petersson et al. [7] as follow:

Grade 0 (none): no features of osteoarthritis.

Grade I (doubtful): minute osteophytes, doubtful narrowing of joint space.

Grade II (definite): definite osteophytes, mild narrowing of joint space.

Grade III (probable): considerable osteophytes, moderate narrowing of joint space.

Grade IV (certain): severe osteophytes, considerable narrowing of joint space.

Grade V (severe): severe osteophytes, severe narrowing of joint space.

Grade VI (severe osteoarthritis): severe osteophytes, severe narrowing of joint space with collapse or erosion of articular cartilage.
Grade II (minimal): definite osteophytes and narrowing of the joint space.

Grade III (moderate): moderate multiple osteophytes, definite narrowing of the joints space, and some sclerosis.

Grade VI (severe): large osteophytes, marked narrowing of the joints space, and definite deformity of bone contour.

The mobility and gait screening protocol was used, which includes the following:

(1) Timed up and go test (TUG) [8]: rise from an armchair, walk 3 m, turn around, return, and sit again. A normal adult without impairments could complete this test in less than 10 s. The TUG test does appear to be capable of distinguishing between elderly who have balance problems and those who do not, on the basis of the objective measure of time taken to complete the task.

(a) Less than 0 s: low fall risk;
(b) Less than 20 s: moderate fall risk;
(c) 20–29 s: high fall risk, ‘gray zone’
(d) At least 30 s: very high fall risk

(2) Fall risk assessment screening tool (FRAST):

(a) Low risk: 0.1–12
(b) Medium risk: 13–19
(c) High risk: greater than 20

(3) Dynamic Gait Index (DGI): designed to test eight facets of gait, including gait on even surfaces, gait when changing speeds, gait and head turns in a vertical or horizontal direction, stepping over or around obstacles, and gait with pivot turns and steps [9,10].

Time: 15 min

Scoring: a four-point ordinal scale, ranging from 0 to 3. ‘0’ indicates the lowest level of function and ‘3’ the highest level of function.

Total score = 2

Interpretation: less than 19/24, predictive of falls in the elderly; greater than 22/24, safe ambulators.

All patients underwent a multidimensional geriatric balance assessment [8] on CDP using the following tests: sensory organization test and limits of stability test, to assess volitional postural control; the motor control test and adaptation test, to assess nonvolitional postural control; tandem walk test and sit to stand test.

CDP was performed using an EquiTest Balance Master System and the sensory organization test was used to evaluate the pattern of dysfunction (somatosensory, visual, or vestibular), the center of gravity, and presence or absence of preference. The motor control test was used to determine weight asymmetry, latency, and amplitude. Scaling during the adaptation test was performed to assess the patient’s ability to maintain his/her center of gravity (COG) on an irregular surface.

Tandem walk test

It was performed to quantify several characteristics of gait as the patient walks a tightrope; the measured parameters include step width, endpoint velocity, and gait velocity.

Sit to stand test

To assess sitting and standing balance by quantifying several movement characteristics as the patient rises from the seated to the standing position. The measurement parameters include rising index, weight transfer time, and sway velocity.

Limits of stability

To assess the patient’s ability to voluntarily sway to various positions in space and briefly maintain those positions. The measured parameters include the reaction time, endpoint excursion, directional control, sway velocity, and maximum excursion for each of the eight trials.

Results

Thirty individuals with ages ranging from 61–72 years participated in this study; of these, 20 were men and 10 were women. The number of falls ranged from 1 to 9 with the mean number of falls in the study group being 2.2 ± 0.67 falls in the last 6 months before examination, giving a fall incidence of 36.6%. In total, 12 patients (40%) suffered from frequent dizziness episodes. After performing vestibular battery tests, carrying out radiological assessments for osteoarthritis, and measuring visual acuity measurements in all participants, they were categorized as participants with vestibular dysfunction and osteoarthritis (20) and participants without vestibular dysfunction but with osteoarthritis or vision impairment (10).

According to the data listed in Table 16 there is a nonsignificant difference between the two groups. Tables 15 and 16 emphasize that the number of falls is mainly affected by deleterious vestibular dysfunction, whereas it is not significantly affected by osteoarthritis or visual impairment.

Discussion

Prevention strategies for falls in the elderly population have yet to be properly studied. It is therefore important to identify those people most at risk of falling to maximize the effectiveness of any proposed intervention. Published studies have identified specific risk factors for falls and related injuries. As risk factors can be classified into two categories: intrinsic and extrinsic factors, this study presented potential intrinsic risk factors (vestibular, musculoskeletal and vision) through objective and subjective assessments using specific clinical and laboratory tools. We believe that a valid and reliable measure of fall risk could also be used as an outcome measure for interventions designed to reduce an individual’s risk for falls.

In this study, the possible predictors of fall risk, on the basis of a review of the literature (vestibular battery test, CDP, vision, osteoarthritis, TUG test, FRAST, and DGI),
were thoroughly studied [11,12]. The mean age of the participants was 64.5 years to ensure an active population with independence in activities of daily living. Moreover, 40% of them reported dizziness with instability, which reflected vestibular and balance dysfunction, considered to be one of the major risks for falls [13].

A specific battery test was implemented to select participants with vestibular balance problems using VNG, VEMP, and CDP equipment. In total, 66.6% (20) of elderly showed evidence of vestibular and balance dysfunction in association with or without other balance-related problems (osteoarthritis, vision impairment; Table 1). Similar results were obtained by Murray et al. [14], who conducted a study on the elderly discharged home from the Emergency Department following a fall and found that 75% of them suffered from vestibular and balance dysfunction. John et al. [15], reported that falls in the in the elderly are often of multifactorial origin. The relevant pathogenetic factors include sensory deficits (vestibular, visual, somatosensory), neurodegenerative processes (cortical, extrapyramidal motor, cerebellar), toxic factors (medications, alcohol), and anxiety (primary or concerning falls).

In the present study, the vestibular test battery (Tables 2–5) revealed that most patients suffered from peripheral vestibular dysfunction. The most frequent VNG abnormality was a unilateral vestibular lesion. Posterior canal benign paroxysmal positional vertigo was diagnosed in three patients (25%), whereas only two patients (16.6%) suffered from central vestibular dysfunction and were referred for further radiological and neurological evaluation (Table 3). One of them was diagnosed as suffering from subacute cerebellar hemorrhage, whereas the other was diagnosed as suffering from old brainstem infarction. In contrast, Imbaud Genieys [16] performed vestibular function tests in the elderly and reported that 68% had benign paroxysmal positional vertigo, 9% had neurologic problems, 5% had Meniere’s disease, 4% had vestibular areflexia, 8% had a psychiatric or vascular disorder, and 6% had no disorder.

VEMP abnormal in 55% of patients, with the unilateral absent response being the most frequent abnormality found (Table 4). Loss of balance and increased fall risk are common problems associated with aging. Changes in vestibular function occur with aging, but the contribution of reduced vestibular otolith function to fall risk remains unknown. Serrador et al. [17] reported that the loss of vestibular otolith–ocular function is associated with increased mediolateral measures of sway, which have been shown to be related to an increased risk of falls. These data suggest that loss of otolith function contributes to fall risk in the elderly. Further prospective, longitudinal studies are necessary to confirm these findings.

CDP was applied as an objective and quantitative measure of balance and postural instability in this study and was used to make an appropriate differential diagnosis in patients presenting with falls or balance impairment. It was also used to reliably identify participants who are at risk of falling. In this study, besides the classical protocol, geriatric evaluation protocols including limits of stability, sit to stand, and tandem walk tests were applied. The most frequent abnormalities were SOT conditions C5 and C6 reflecting a vestibular pattern of dysfunction, an abnormal adaptation test reflecting high tendency to fall when encountering an irregular or uneven surface, and an abnormal limit of stability (Table 5). Whitney et al. [18] found that the elderly prone to falls have lower SOT scores than those who are not prone to falls. On the contrary, Cortés et al. [19] stated that the stability limits and rhythmic weight shift tests are of little utility in the functional evaluation of the elderly with vestibular disorders and in the detection of patients with greater risk of falls. Similarly, knee and hip osteoarthritis, a disabling musculoskeletal disease that affects the lower

<table>
<thead>
<tr>
<th>Risk</th>
<th>Abnormality number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vestibular dysfunction</td>
<td>20/30</td>
<td>66.6</td>
</tr>
<tr>
<td>Osteoarthritis*</td>
<td>11/30</td>
<td>36.6</td>
</tr>
<tr>
<td>Visual dysfunction*</td>
<td>12/30</td>
<td>40</td>
</tr>
<tr>
<td>Cardiac</td>
<td>5/30</td>
<td>16.6</td>
</tr>
<tr>
<td>Neurological</td>
<td>5/30</td>
<td>16.6</td>
</tr>
</tbody>
</table>

The most frequent abnormality was unilateral vestibular function. Osteoarthritis of grades II and above was considered as a risk for falls. In addition, weak sight and very weak sight are considered risk for falls.

<table>
<thead>
<tr>
<th>Test</th>
<th>Abnormality number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>VNG</td>
<td>12/20</td>
<td>60</td>
</tr>
<tr>
<td>VEMP</td>
<td>11/20</td>
<td>55</td>
</tr>
<tr>
<td>CDP</td>
<td>14/20</td>
<td>70</td>
</tr>
</tbody>
</table>

CDP, computerized dynamic posturography; VEMP, vestibular-evoked myogenic potentials; VNG, videoystagmography.

The most frequent abnormalities encountered were in CDP.

<table>
<thead>
<tr>
<th>Test</th>
<th>Abnormality number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral weakness</td>
<td>4/12</td>
<td>33.3%</td>
</tr>
<tr>
<td>Bilateral weakness</td>
<td>2/12</td>
<td>16.6%</td>
</tr>
<tr>
<td>Positional nystagmus</td>
<td>3/12</td>
<td>25%</td>
</tr>
<tr>
<td>BPPV</td>
<td>3/12</td>
<td>25%</td>
</tr>
<tr>
<td>Abnormal oculomotor test</td>
<td>2/12</td>
<td>16.6%</td>
</tr>
</tbody>
</table>

The most frequent abnormality was unilateral caloric weakness. Two patients suffered from unilateral caloric weakness and BPPV at the same time. BPPV, benign paroxysmal positional vertigo.
The TUG test was used as simple reliable screening test for impaired strength or imbalance [8,25]. The mean score of the TUG test was 21.3 ± 5.312, denoting high risk of falls in elderly with impaired strength or imbalance. This is in accordance with the findings of Bischoff et al. [26] and Nordin et al. [27], who reported similar values in community dwelling elderly and suggested they should undergo CDP testing. Moreover, DGI was used to evaluate the ability to adapt gait to changes in task demands. It assesses various mobility interactions in the gait cycle. In this study, abnormal test results that were high for falls were found in 17 patients (56.6%) and the mean DGI score was 16.7 ± 3.46, which strongly predicted falls. This is consistent with the findings of Shumway-Cook et al. [9], who previously reported in their study a DGI mean of 15.6 ± 5.7 in the elderly prone to falls. In addition, FRAST, used as a screening and referral community-based tool, is simple and shows 97% specificity in identifying those living in the community with high risk of falls [28]. In this study, 20 (66.6%) participants revealed moderate or high risk for falls by FRAST.

In this study, as regards vestibular testing, a significant correlation was found between the number of falls and SOT tests C5 and C6 together with adaptation tests (Table 9), reflecting that vestibular pattern of dysfunction with low scores in C5 and C6 can be a good predictor for falls together with abnormal adaptation tests, which reflects the tendency to fall when walking on an irregular surface. In contrast, as regards the functional test of dynamic posturography, a highly significant correlation was found between number of falls, limits of stability, reaction time, and movement velocity, as well as the tandem walk step width test (Table 10).

The limit of stability quantifies the maximum distance by which a person can intentionally displace their COG—That is lean their body in a given direction without losing balance, stepping, or reaching for assistance. The measured parameters are reaction time, COG movement velocity, directional control, endpoint excursion, and maximum excursion. Reaction time delays are commonly associated with difficulties in cognitive processing and/or motor diseases. Reduced movement velocities are indicative of extremities, was assessed for radiologically by the modified Kellegren and Lawrence diagnostic score, and the results showed that 11 participants (36.6%) had grade II and III osteoarthritis (Table 6). This is in accordance with many reports in the literature, which state that arthritis and chronic diseases are associated with 32% increased risk of falls [20,21]. Lower extremity osteoarthritis together with muscle weakness and increased reaction time are all considered risks for falls in the elderly [22].

Furthermore, poor vision reduces postural stability and significantly increases the risk for falls and fractures in the elderly. Most studies have found that poor visual acuity increases the risk for falls. However, studies that have included multiple visual measures have found that reduced contrast sensitivity and depth perception are the most important visual risk factors for falls [23]. Accordingly all patients were examined for visual acuity and field of vision, and the results revealed that 12 participants (40%) suffered from significant impairment in vision (Table 7). This is agreement with the findings of Chew et al. [24], who reported that impaired visual acuity, stereopsis, contrast sensitivity, and visual field defects are associated with an increased risk for falls and recommend that all patients aged at least 55 years should undergo an annual ophthalmological examination that includes testing for visual acuity, contrast sensitivity, stereopsis, and visual field to assess the risks for falls and low fragility fractures.

In the current study, clinical screening tests were used to assess risk of falls among 30 participants, 25 of whom (83.4%) revealed a moderate or high risk for falls (Table 8). The TUG test was used as simple reliable

| Table 5 Types of computerized dynamic posturography abnormalities |
|----------------------|-----------------|
| Test                  | N (%)           |
| Abnormal SOT C4, 5 and C6 | 3/14 (21.4%)   |
| Abnormal SOT C5 and C6  | 5/14 (35.7%)    |
| Abnormal motor control test | 4/14 (28.5%) |
| Abnormal adaptation test | 5/14 (35.7%)   |
| Limits of stability    | 5/14 (35.7%)    |
| Sit to stand           | 4/14 (28.5%)    |
| Tandem walk            | 3/14 (21.4%)    |

The most frequent encountered CDP abnormality was abnormal SOT C5 and C6, abnormal limit of stability and abnormal adaptation test. CDP, computerized dynamic posturography.

<table>
<thead>
<tr>
<th>Table 6 Osteoarthritis grades in patients in study group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grades of osteoarthritis             N (21%)</td>
</tr>
<tr>
<td>Grade I                               10 (47.6)</td>
</tr>
<tr>
<td>Grade II                              7 (33.3)</td>
</tr>
<tr>
<td>Grade III                             4 (19)</td>
</tr>
</tbody>
</table>

The commonest OA grade was grade I in radiological score. OA, osteoarthritis.

<table>
<thead>
<tr>
<th>Table 7 Visual abnormalities in the study group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
</tr>
<tr>
<td>No abnormality</td>
</tr>
<tr>
<td>Subnormal</td>
</tr>
<tr>
<td>Weak sight</td>
</tr>
<tr>
<td>Very weak sight</td>
</tr>
</tbody>
</table>

The mean score of the TUG test was 21.3 ± 5.312 s, denoting balance problems, and the mean of FRAST was 14.7 ± 3.21 denoting medium risk of falls, whereas the DGI was ≤ 19 s in 75% with a mean of 16.7 ± 3.46 s, which is predictive of falls. DGI, Dynamic Gait Index; FRAST, fall risk assessment screening tool; TUG, timed up and go test.
Tandem walk test tends to be more specific to impairments affecting balance. Abnormal results may reflect a high tendency to fall in the elderly. Girardi et al. [30] reported that in the elderly, CDP was a more sensitive test for identifying patients who had fallen, with limits of stability testing the most significant part of the CDP battery. In contrast, in ENG studies the best indicator for falls was the ocular motor battery. The high level of abnormalities in the results of the oculomotor test battery in this study may reflect that the sample was biased and that most patients suffered from central vestibular dysfunction. On the contrary, Cortés et al. [19] reported that limits of stability and rhythmic weight shift correlated poorly in the elderly prone to falls.

As regards the functional gait test, the TUG test showed a highly significant correlation in elderly people who experienced falls, whereas DGI showed only significant correlation and FRAST showed a nonsignificant correlation (Table 11). In this study, the mean score of TUG was 21.3, whereas that of DGI was 16.7. Whitney et al. [25] reported that both TUG and the DGI appear to be helpful in identifying fall risk in individuals with vestibular dysfunction. Moreover, Whitney et al. [31] reported that patients with a DGI score of 19 or less have a 2.5% higher risk for falls than patients with higher scores.

Vestibular function tests and functional tests revealed a highly significant correlation between SOT C5 and C6 scores and TUG and DGI with a weak correlation with FRAST (Table 12). In contrast, VEMP asymmetry and unilateral canal paresis revealed nonsignificant results with all functional tests except DGI, which revealed a weak correlation with them (Table 13). In addition, the composite score of SOT was found to be highly correlated with TUG and DGI (Table 14). To further evaluate the model, we use the analysis of variance test to compare the three intrinsic variables with regard to the number of falls that strongly affect fall status, to find out which one is the most significant.
A significant difference between the three groups is observed.

### Visual impairment

Osteoarthritis

Dysfunction

The composite score of SOT is highly correlated with TUG and DGI.

### Timed up and go test

FRAST, fall risk assessment screening tool; TUG, timed up and go test.

Table 14 Correlation of the C5 and C6 score average with the Dynamic Gait Index, fall risk assessment screening tool, and timed up and go test

<table>
<thead>
<tr>
<th>CDP (C5 and C6)</th>
<th>Correlation coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timed up and go</td>
<td>0.99</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Dynamic Gait Index</td>
<td>-1.123</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>FRAST</td>
<td>0.651</td>
<td>&lt;0.05**</td>
</tr>
</tbody>
</table>

The composite score of SOT is highly correlated with TUG and DGI. CDP, computerized dynamic posturography; DGI, Dynamic Gait Index; FRAST, fall risk assessment screening tool; TUG, timed up and go test.

*Significant.

**Highly significant.

Table 15 Analysis of variance test to compare between the number of falls in patients with and without vestibular dysfunction

<table>
<thead>
<tr>
<th>Program</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vestibular dysfunction</td>
<td>3.3</td>
<td>≤0.05*</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual impairment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A significant difference between the three groups is observed.

*Significant.

Table 16 The analysis of variance test to compare between the number of falls in patients with osteoarthritis and patients with visual impairment

<table>
<thead>
<tr>
<th>Program</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoarthritis</td>
<td>0.84</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Visual impairment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A significant difference between the three groups is observed.

Table 17 The analysis of variance test to compare between the number of falls in patients with and without vestibular dysfunction

<table>
<thead>
<tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

A significant difference between the three groups is observed.

*Significant.

The composite score of SOT is highly correlated with TUG and DGI. CDP, computerized dynamic posturography; DGI, Dynamic Gait Index; FRAST, fall risk assessment screening tool; TUG, timed up and go test.

*Significant.

**Highly significant.

### Conclusion

Balance impairment in the elderly is a multifactorial problem. Patients who suffer from dizziness have a higher risk for falls, and as many of them also have mobility problems, the risk for falls is much higher in them than in younger patients with balance impairment. The VNG test battery and CDP in conjunction with stance tests are capable of indentifying elderly individuals with a high risk for falls.

### Acknowledgements

Conflicts of interest

There are no conflicts of interest.

### References