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 Zakhlol Saber[c]

[a]Audiology Unit, ENT Department, [b]ENT Department and [c]Physical Medicine Department, Ain Shams University, Cairo, Egypt

Correspondence to Amr Gouda Shafik, 4-Eldherka Elwatania, Hosny Othman St., El-sefarat Area, Nasr City, Cairo, Egypt
Tel: +002 01222416594;
e-mail: amrgouda@hotmail.com

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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

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Introduction

Falls and unstable balance rank high among serious clinical problems faced by the elderly. They are a cause of substantial rates of mortality and morbidity as unintentional injuries, which are considered the fifth leading cause of death in older people [1]. Over 30% of people over 65 years, living in the community, have at least one fall per year and half of them fall at least twice.

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, sideeffects 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 videonystagmography (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 (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 was 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 1 Classification of the risk for falls encountered in study group

Risk	Abnormality number	%
Vestibular dysfunction	20/30	66.6
Osteoarthritis[a]	11/30	36.6
Visual dysfunction[a]	12/30	40
Cardiac	5/30	16.6
Neurological	5/30	16.6

The most frequent risk for falls was abnormal vestibular function.
[a]Osteoartheritis 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 2 Vestibular function test abnormalities (*N*=20 patients with vestibular dysfunction)

Test	Abnormality number	%
VNG	12/20	60
VEMP	11/20	55
CDP	14/20	70

CDP, computerized dynamic posturography; VEMP, vestibular-evoked myogenic potentials; VNG, videonystagmography.
The most frequent abnormalities encountered were in CDP.

Table 3 Videonystagmography test abnormalities

Test	*N* (%)
Unilateral weakness	4/12 (33.3%)
Bilateral weakness	2/12 (16.6%)
Positional nystagmus	3/12 (25%)
BPPV	3/12 (25%)
Abnormal oculomotor test	2/12 (16.6%)

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.

Table 4 Vestibular-evoked myogenic potential test abnormalities

Test	*N* (%)
Unilateral absent	5/11 (21.5)
Bilateral absent	2/11 (14.2)
Shifted latency	4/11 (14.2)

The most frequently encountered VEMP abnormality was a unilateral absent response reflecting dysfunction of the corresponding saccule and/or inferior vestibular nerve.
VEMP, vestibular-evoked myogenic potential.

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 6 Osteoarthritis grades in patients in study group

Grades of osteoarthritis	*N* (21%)
Grade I	10 (47.6)
Grade II	7 (33.33)
Grade III	4 (19)

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

Table 7 Visual abnormalities in patients in the study group

Test	*N* (%)
No abnormality	3/30 (10%)
Subnormal	15/30 (50%)
Weak sight	8/30 (26.66%)
Very weak sight	4/30 (13.33%)

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 8 Functional mobility test abnormalities

Functional mobility tests	*N* (%)
Timed up and go	
Low fall risk	5/30 (16.6)
Moderate fall risk	13/30 (43.3)
High fall risk	7/30 (23.3)
Very high fall risk	5/30 (16.6)
Dynamic gait index	
Normal	13/30 (43.3)
Abnormal	17/30 (56.6)
FRAST	
Low fall risk	10/30 (33.3)
Moderate fall risk	14/30 (47.6)
High fall risk	6/30 (20)

The TUG test result was >12 s in 90% of the study participants with a mean of 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.

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

Table 9 Correlation between number of falls and vestibular findings and functional tests

Number of falls	Correlation coefficient	*P*-value
Degree of caloric weakness	0.52	≤0.05*
VEMP asymmetry	0.039	>0.05
CDP composite score	0.55	≤0.05*
CDP C4 score	0.11	>0.05
CDP C5 score	−0.987	<0.001**
CDP C6	−1.198	<0.001**
MCT latency	0.59	≤0.05*
MCT amplitude score	0.17	>0.05
Adaptation test score	0.73	<0.001**

The number of falls in geriatric patients is highly significant correlated with C5 and C6 score as well as the adaptation test score.
CDP, computerized dynamic posturography; MCT, motor control test; VEMP, vestibular-evoked myogenic potentials.
*Significant.
**Highly significant.

Table 10 Correlation of the number of falls and functional tests of computerized dynamic posturography

Number of falls	Correlation coefficient	*P*-value
LOS reaction time	−1.382	<0.0001
LOS movement velocity	−1.79	<0.001
LOS maximum excursion	0.547	≤0.05*
LOS endpoint excursion	0.55	≤0.05*
LOS directional control	0.66	≤0.05*
Tandem walk step width	−1.99	<0.001
Tandem walk speed	−1.0	≤0.05*
Tandem walk end sway	−1.22	<0.001**
Sit to stand (right/left asymmetry)	−1.172	<0.001**
Sit to stand (rising index)	0.55	≤0.05*
Sit to stand (weight transfer)	−0.79	<0.001**

A significant correlation is observed between the number of falls and limits of stability reaction time, movement velocity, and also tandem walk step width test.
LOS, limits of stability.
*Significant.
**Highly significant.

high-level central nervous system deficits such as that in age-related disorders. Limitations in a patient's limit of stability may correlate to risk for falls or instability during weight shifting activities such as leaning forward to take objects from a shelf or opening the refrigerator door or leaning back for hair washing in the shower [29].

Tandem gait is a high-demand activity requiring careful control of both COG movements (head, trunk, and pelvis) and the successive re-establishment of a stable, narrow base of support. Compared with normal gait, the 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.

Table 11 Correlation of the number of falls with the Dynamic Gait Index, fall risk assessment screening tool, and timed up and go test

Number of falls	Correlation coefficient	*P*-value
Timed up and go	0.97	<0.001*
Dynamic Gait Index	−0.855	≤0.05*
FRAST	0.24	>0.05

Significant correlation was found between the number of falls and TUG and Dynamic Gait Index.
FRAST, fall risk assessment screening tool; TUG, timed up and go test.
*Significant.

Table 12 Correlation of caloric weakness with the timed up and go test, Dynamic Gait Index, and the fall risk assessment screening tool

Caloric weakness	Correlation coefficient	*P*-value
Timed up and go	0.91	≤0.05*
Dynamic Gait Index	−0.89	≤0.05*
FRAST	0.11	>0.05

A significant correlation between the degree of caloric weakness and TUG and the Dynamic Gait Index is observed.
FRAST, fall risk assessment screening tool; TUG, timed up and go test.
*Significant.

Table 13 Correlation of vestibular-evoked myogenic potential asymmetry with the timed up and go test, Dynamic Gait Index, and fall risk assessment screening tool

VEMP asymmetry	Correlation coefficient	*P*-value
Timed up and go	0.22	>0.05
Dynamic Gait ndex	−0.651	≤0.05*
FRAST	0.14	>0.05

A significant negative correlation between VEMP asymmetry and DGI is observed, which reflects that discrepancy of vestibular function in both sides affects gait stability, which increases the risk of falls.
DGI, Dynamic Gait Index; FRAST, fall risk assessment screening tool; VEMP, vestibular-evoked myogenic potentials.
*Significant.

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

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

CDP (C5 and C6)	Correlation coefficient	*P*-value
Timed up and go	0.99	<0.001**
Dynamic Gait Index	−1.123	<0.001**
FRAST	0.651	≤ 0.05*

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

Program	*F*	*P*
Vestibular dysfunction Osteoarthritis Visual impairment	3.3	≤ 0.05*

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

Program	*F*	*P*
 Osteoarthritis Visual impairment	0.84	>0.05

predictive variable for falls. It appears that the vestibular dysfunction group is more vulnerable to falls than the other groups (Tables 15 and 16).

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.

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Conflicts of interest

There are no conflicts of interest.

References

1 Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. Age Ageing 2006; 35 (Suppl 2): ii37–ii41.

2 Rubenstein LZ, Josephson KR. The epidemiology of falls and syncope. Clin Geriatr Med 2002; 18:141–158.

3 MacIntosh G, Joy J. Assessing falls in older people. Nurs Older People 2007; 19:33–36, quiz 37.

4 Peeters GM, de Vries OJ, Elders PJ, Pluijm SM, Bouter LM, Lips P. Prevention of fall incidents in patients with a high risk of falling: design of a randomised controlled trial with an economic evaluation of the effect of multidisciplinary transmural care. BMC Geriatr 2007; 7:15.

5 Oliver D, Daly F, Martin FC, McMurdo ME. Risk factors and risk assessment tools for falls in hospital in-patients: a systematic review. Age Ageing 2004; 33:122–130.

6 Kellgren JH, Lawrence JS. Radiological assessment of rheumatoid arthritis. Ann Rheum Dis 1957; 16:485–493.

7 Petersson IF, Boegård T, Saxne T, Silman AJ, Svensson B. Radiographic osteoarthritis of the knee classified by the Ahlback and Kellgren and Lawrence systems for the tibiofemoral joint in people aged 35–54 years with chronic knee pain. Ann Rheum Dis 1997; 56:493–496.

8 Podsiadlo D, Richardson S. The timed 'Up and Go': a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991; 39: 142–148.

9 Shumway Cook A, Baldwin M, Polissar NL, Gruber W. Predicting the probability for falls in community-dwelling older adults. Phys Ther 1997; 77:812–819.

10 Woollacott MH, Tang PF. Balance control during walking in the older adult: research and its implications. Phys Ther 1997; 77:646–660.

11 Harwood RH, Foss AJE, Osborn F, Gregson RM, Zaman A, Masud T. Falls and health status in elderly women following first eye cataract surgery: a randomised controlled trial. Br J Ophthalmol 2005; 89: 53–59.

12 Barak Y, Wagenaar RC, Holt KG. Gait characteristics of elderly people with a history of falls: a dynamic approach. Phys Ther 2006; 86: 1501–1510.

13 Tinetti ME. Clinical practice. Preventing falls in elderly persons. N Engl J Med 2003; 348:42–49.

14 Murray KJ, Hill K, Phillips B, Waterston J. A pilot study of falls risk and vestibular dysfunction in older fallers presenting to hospital emergency departments. Disabil Rehabil 2005; 27:499–506.

15 Jahn K, Zwergal A, Schniepp R. Gait disturbances in old age: classification, diagnosis and treatment from a neurological perspective. Dtsch Arztebl Int 2010; 107:306–315, quiz 316.

16 Imbaud Genieys S. Vertigo, dizziness and falls in the elderly. Ann Otolaryngol Chir Cervicofac 2007; 124:189–196.

17 Serrador JM, Lipsitz LA, Gopalakrishnan GS, Black FO, Wood SJ. Loss of otolith function with age is associated with increased postural sway measures. Neurosci Lett 2009; 465:10–15.

18 Whitney SL, Marchetti GF, Morris LO, Sparto PJ. The reliability and validity of the four square step test for people with balance deficits secondary to a vestibular disorder. Arch Phys Med Rehabil 2007; 88:99–104.

19 Ortuño Cortés MA, Martín Sanz E, Barona de Guzmán R. Value of dynamic postural control tests on elderly people with vestibulopathy. Acta Otorrinolaringol Esp 2009; 60:149–154.

20 Graafmans WC, Ooms ME, Hofstee HMA, Bezemer PD, Bouter LM, Lips P. Falls in the elderly: a prospective study of risk factors and risk profiles. Am J Epidemiol 1996; 143:1129–1136.

21 Lawlor DA, Patel R, Ebrahim S. Association between falls in elderly women and chronic diseases and drug use: cross sectional study. Br Med J 2003; 327:712–715.

22 Hale LA, Waters D, Herbison P. A randomized controlled trial to investigate the effects of water-based exercise to improve falls risk and physical function in older adults with lower-extremity osteoarthritis. Arch Phys Med Rehabil 2012; 93:27–34.

23 Lord SR, Smith ST, Menant JC. Vision and falls in older people: risk factors and intervention strategies. Clin Geriatr Med 2010; 26:569–581.

24 Chew FLM, Yong CK, Mas Ayu S, Tajunisah I. The association between various visual function tests and low fragility hip fractures among the elderly: a Malaysian experience. Age Ageing 2010; 39:239–245.

25 Whitney SL, Marchetti GF, Schade A, Wrisley DM. The sensitivity and specificity of the Timed 'Up & Go' and the Dynamic Gait Index for self-reported falls in persons with vestibular disorders. J Vestib Res 2004; 14:397–409.

26 Bischoff HA, Stähelin HB, Monsch AU, Iversen MD, Weyh A, von Dechend M, *et al.* Identifying a cut–off point for normal mobility: a comparison of the timed 'up and go' test in community–dwelling and institutionalised elderly women. Age Ageing 2003; 32:315–320.

27 Nordin E, Rosendahl E, Lundin Olsson L. Timed 'Up & Go' test: reliability in older people dependent in activities of daily living – focus on cognitive state. Phys Ther 2006; 86:646–655.

28 Tromp AM, Pluijm SMF, Smit JH, Deeg DJH, Bouter LM, Lips P. Fall-risk screening test: a prospective study on predictors for falls in community-dwelling elderly. J Clin Epidemiol 2001; 54:837–844.

29 González Ravé JM, Sánchez Gómez A, Santos García DJ. Efficacy of two different stretch training programs (passive vs. proprioceptive neuromuscular facilitation) on shoulder and hip range of motion in older people. J Strength Cond Res 2012; 26:1045–1051.

30 Girardi M, Konrad HR, Amin M, Hughes LF. Predicting fall risks in an elderly population: computer dynamic posturography versus electronystagmography test results. Laryngoscope 2001; 111:1528–1532.

31 Whitney SL, Hudak MT, Marchetti GF. The dynamic gait index relates to self-reported fall history in individuals with vestibular dysfunction. J Vestib Res 2000; 10:99–105.