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Clinical balance testing to screen for patients with vestibular disorders. A retrospective case-control study.

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Abstract

Objective: Identify clinical screening tests to proficiently screen for patients with vestibular disorders.
Study design: Retrospective case-control study.
Setting: Tertiary referral center.
Patients: 318 healthy individuals and 331 subjects with vestibular disorders.
Interventions: All subjects performed Romberg and Jendrassic maneuver with eyes closed (ROMJec), standing on foam with eyes open (SOFeo) and eyes closed (SOFec), Tandem Romberg with eyes open (TReo) and eyes closed (TRec), single leg stance with eyes open (SLSeo) and eyes closed (SLSec), Tandem gait (TG) and Timed Up and Go (TUG).
Main outcome measures: Significant differences in performance on the balance tests.
Results: For the age-group <40 years, TUG >6seconds (OR 102.4; p <0.0001) and SLSec <30seconds (OR 48.0; p <0.0001) proved to be the most predictive combination of testing (AUC 0.9; LR+ 15.8; LR- 0.2), with a positive predictive value (PPV) of 88.4%. For the age-group 40–60, TUG >7seconds (OR 4.0; p=0.0107) and TRec <30 seconds (OR 63.1; p<0.0001) was the most predictive combination of tests (AUC 0.9 LR+ 6.0; LR- 0.1), with a PPV of 93.8%. For the age-group >60 the combination of TUG >8 seconds (OR 17.4; p<0.0001) and SOFec <30 seconds (OR 10.4; p<0.0001) was the most predictive (AUC 0.9 LR+ 6.3; LR- 0.2), with a PPV of 84.8%.
Conclusions: Combinations of clinical tests are proposed to promptly screen for vestibular disorders in specific age groups. To interpret the results for the individual patient, the physician must take the history and the general examination into consideration.

Key Words: Clinical tests— Disequilibrium—Dizziness—Patients—Screen—Vertigo— Vestibular disorder.

Introduction

The body's balance system consists of a complex, continuous feedback control system integrating different sources of sensory input, including proprioceptive, visual, and vestibular systems. Defects in any of the organs involved can cause complaints of dizziness and/or impaired postural control. In general medical practice, dizziness accounts as a chief complaint for 2.6% of all encounters. General practitioners are the first-line clinicians in 45% of all outpatients with dizziness (1). In patients with complaints of dizziness and/or disequilibrium, the differential diagnosis is broad-ranging, and multifactorial in up to 50% of the patients (2). Based on the patient history and clinical evaluation, additional tests like audiometry, video-oculography, video head impulse testing, electronystagmography (ENG), and vestibular evoked myogenic potentials testing (VEMP) may be requested (3). However, these tests are not easily accessible to every physician or therapist dealing with patients with dizziness and/or disequilibrium, which emphasizes the importance of accurate first line selection/screening.

The literature describes many clinical test batteries to assess balance performance in patients, to determine underlying reasons for balance deficits and/or screen for vestibular disorders. However, these are very extensive, time-consuming, and therefore difficult to implement during a regular consultation (4,5). In clinical practice many stand-alone clinical tests are currently used to assess patients with balance disorders, such as the Tandem Romberg (6) and Fukuda stepping test (7). Unfortunately, they are of limited value when it comes to screening (8–10). Furthermore, these tests show an age dependent performance (11). Our goal is to identify a set of clinical tests which can objectively evaluate balance motor skills and screen for vestibular disorders. This set will complement the patient history and general clinical examination and aid the clinician in making a well-founded decision regarding treatment or referral for further evaluation.

Methods

Study Population and Data Collection

A retrospective case-control study was set up and a comparison was made between healthy subjects and subjects with complaints of dizziness and/or disequilibrium. Subjects were recruited from the otorhinolaryngology clinic of a tertiary care hospital in Antwerp, Belgium. Inclusion in our database occurred from 1999 to 2008. Inclusion criteria for our study population is that subjects have chronic complaints of dizziness and/or disequilibrium of at least 3 months due to a proven underlying vestibular disorder, e.g., unilateral vestibular hypofunction, bilateral vestibular hypofunction, vestibular schwannoma, central vestibular disorder, neurotrauma, and post cochlear implantation. The patients in our study population were subdivided into the different subcategories after detailed clinical assessment by an otorhinolaryngologist and additional technical examination (e.g., electronystagmography and medical imaging, etc.). Bithermal caloric irrigation as part of ENG was performed based on the methodology and normative values reported by Van der Stappen et al. (12). In summary, unilateral vestibular hypofunction was defined as asymmetry of > 18% using Jongkees' formula based on the maximum slow-component velocities (SCV) (in degrees/second). Bilateral areflexia was defined as the sum of binaural bithermal maximum SCV of < 27˚/s. Patients who, in addition to a vestibular disorder, have another disorder that affects their balance were excluded from our study population.
Subjects in the control group were recruited by means of advertisement in the greater metropolitan area of Antwerp, Belgium. Exclusion criteria used for the control group were: 1) actual complaints or a history of vertigo or dizziness; 2) neurologic, otologic, orthopedic, or other medical conditions impeding balance (e.g., diabetes mellitus, orthostatic hypotension); 3) nursing home residents; 4) dependence on the assistance of another person or the assistance of a support device (e.g., cane, crutch, walker); 5) a fall within the last 6 months. From all participants the following characteristics were noted: age, sex, height, weight, and body mass index. For the subjects in the study population the cause of dizziness was noted. The study has been approved by the Ethical Committee of the Antwerp University Hospital (18/13/182). Furthermore, this study has been conducted according to the Declaration of Helsinki.

Balance Tests

All subjects were evaluated by the following tests (11): Romberg and Jendrassik manoeuver; Standing on foam; Tandem Romberg; Timed Up and Go; Single leg stance and Tandem gait. All tests, except the Romberg and Jendrassik maneuver, Timed Up and Go and Tandem gait, were performed with eyes open and eyes closed. The Romberg and Jendrassik maneuver were only performed with eyes closed and the tandem gait and Timed Up and Go with eyes open. With exception of Standing on foam, all tests were performed on level vinyl flooring with stable shoes. Time measurements were made with a digital stopwatch. Without affecting performance of the participant, the investigator stood close to the subject throughout the entire experimental session to prevent falls or injuries. The best performance of a maximum of three trials was considered.

Romberg and Jendrassik Maneuver

The subjects were instructed to stand with their eyes closed, feet together and performing the Jendrassik maneuver (clasping hands while abducting arms thus producing tension) for a maximum of 30 seconds. The Jendrassik maneuver was added to the Romberg test to distract subjects and to make the test more difficult. Timing started when the subject assumed the proper position. Timing stopped if the subject moved his feet, unclasped his hands, opened his eyes, or reached the 30-second limit. The test was considered positive if timing stopped before the 30-second limit.

Standing on Foam

Subjects were asked to stand for 30 seconds with their hands clasped on a 12-cm thick, medium-density ($60kg/cm^3$) foam pad measuring 45 by 45cm (NeuroCom International Inc., Clackamas, OR). The distance between the feet was approximately 5 cm. By separating the feet, a too high point-concentrated load is avoided, so subjects will not sink too deep, thereby following the instructions of the manufacturing company. The test was performed as depicted in image 1. The participants performed the test with their eyes open (EO) and closed (EC). If needed, three trials were allowed in each condition. Timing started when the subject assumed the correct position and indicated he was ready to begin the test. Timing stopped if the subject moved either foot from the proper position, unclasped his hands, opened his eyes in the EC-trials, or reached the 30-second limit. The test was considered positive if timing stopped before the 30-second limit.

Image 1.

Tandem Romberg

Subjects were instructed to stand with one foot just in front of the other (heel to toe, no angle allowed). Arms were free to move. Participants could choose which leg they wanted in front and they could alternate between legs as they wished in between trials, the test was performed with the eyes open and closed. Timing started when the subject assumed the proper position and indicated he was ready. Timing stopped if the participant moved either foot from the proper position, opened his eyes in the EC-condition, or reached the 30-second time limit. The test was considered positive if timing stopped before the 30s econd limit.

Single Leg Stance

Subjects were asked to stand on one leg and the arms were free to move. Participants could choose which leg they wanted to stand on and could alternate between legs in between trials. The test was performed with the eyes open and closed. Timing started when the participant closed his eyes while standing on one leg or when he raised one foot of the ground in the EO-condition. Timing stopped if the subject repositioned the weight-bearing foot, touched the floor with the suspended foot, used the suspended foot for support on the weight-bearing foot, required support by the investigator, opened his eyes in the EC-condition, or reached the maximum time of 30 seconds. The test was considered positive if timing stopped before the 30 second limit.

Tandem Gait

The subject was asked to walk heel to toe on a straight line for 20 steps at his own pace. The ability to see the seam in the linoleum floor was checked. Counting the steps commenced once the participant started placing one foot before the other and stopped once a foot touched the floor before proper placement, the heel was not touching the toes, the foot was not placed on the line or the 20 steps limit was reached. The last unsuccessful step was not incorporated in the score. The test was considered positive if the 20 steps limit could not be reached.

Timed Up and Go Test

The subjects were asked to sit on a standard (arm) chair (46cm high) with his back against the chair and feet flat on the floor. They were then instructed — on the word ‘‘start,’’ after the warning ‘‘ready’’ — to rise and to walk as fast as possible to a mark on the floor 3 m away, turn around, walk back to the chair, and sit down again. Timing commenced on the word ‘‘start’’ and ceased once the subjects back touched the back of the chair. The participant performed the test three times with his preferred turn (first choice) and then three times with a turn to the other side. The fastest time was considered for analysis.

Statistical Analysis

Outcomes of the balance tests were used as dichotomized points and were converted to categorical variables. So, when subjects were able to successfully complete a test, the test was marked as negative and otherwise positive. Continuous variables were presented as the mean with the corresponding standard deviation (SD). Differences between the groups (healthy controls – study population) were assessed using independent samples t-test or chi-squared analysis. This includes age, weight, height, BMI, and the clinical tests mentioned earlier.

Our study population was subsequently subdivided into seven subcategories based on clinical diagnosis. The largest group consists of patients with unilateral vestibulopathy with 117 subjects, followed with patients with a vestibular schwannoma with 112 subjects. The further distribution is displayed in Table 1. When performing statistical analysis, no distinction was made between the subcategories. The subjects in our study population were considered as a whole.

In a previous study performed by Vereeck et al., normative values for each test were identified. Notably, some of these tests showed an age-dependent distribution (11). So, because age is a possible confounder the study population was subdivided into the following age categories: <40, 40–60, and 60+ years. To identify optimal cut-off values for the Timed Up and Go test, ROC curve analysis was performed per defined age category.

Furthermore, multivariate stepwise logistic regression analysis was conducted per age category to identify the most predictive test or set of tests for a vestibular disorder. The tests included in analysis are as follows: Romberg and Jendrassik maneuver, Tandem Romberg with eyes open and closed; Single leg stance with eyes open and closed, Standing on foam with eyes open and closed; Timed Up and Go and Tandem gait. To determine the predictive values and likelihood ratios, ROC-curve analysis was performed. For all analyses, a p-value of <0.05 was considered statistically significant. All statistical analyses were performed using MedCalc Statistical Software.

TABLE 1. *Subcategories of study population*

Category	Total
Unilateral vestibulopathy	117
Preoperative vestibular schwannoma	112
Bilateral vestibulopathy	32
Central vestibular disorder	28
Endolymphatic hydrops	24
Post neurotrauma	14
Postop cochlear implantation	4

Results

Patient Demographics

In total, 331 individuals were included in our study population and 318 subjects were included in the control group. Data concerning subjects from our control group were already published in a previous study (11). In the healthy population age ranged from 20 to 83 years with a mean of 49 years. In the study population age ranged from 15 to 90 years with a mean of 53 years. The most common underlying disorder in our study population was unilateral vestibulopathy with 117 subjects, followed by vestibular schwannoma with 112 subjects. Further details are displayed in Table 1. Our study population was than subsequently divided into three age categories.

1. Age category <40 years contained 119 healthy individuals and 59 subjects in the study population.
2. Age category 40–60 years contained 80 healthy individuals and 172 subjects in the study population.
3. Age category >60 years contained 119 healthy individuals and 100 subjects in the study population.

Univariate Analysis

Additionally, univariate analysis showed that BMI was significantly higher in the study population with 25.7kg/ m^2 compared with healthy controls with 23.4kg/m^2 ($p<0.001$). When repeating the analysis per age category, BMI remained significantly higher in all age categories except in subjects >60 years. Balance performance was also significantly more compromised in this group. There were no significant differences in sex between the two groups. Table 2 summarizes the results of the univariate analysis.

TABLE 2. *Univariate analysis comparing healthy controls and study population*

Total	Healthy Controls (n = 318)	Study Population (n = 331)	*p* Value
Age, years	49,2	53.5	< 0.001
Male, %	43.4	50.2	0.0850
Height, cm	172.3	170.0	0.001
Weight, kg	69.6	74.5	< 0.001
BMI	23.4	25.7	< 0.001
TUG, sec	6.9	9.6	< 0.001
Positive ROMJec, %	0.0	8.9	< 0.0001
Positive SOFeo, %	0.0	14.4	< 0.0001
Positive SOFec, %	14.1	69.6	< 0.0001
Positive TReo, %	0.0	31.6	< 0.0001
Positive TRec, %	34.9	89.7	< 0.0001
Positive SLSeo, %	14.1	40.4	< 0.0001
Positive SLSec, %	56.7	95.5	< 0.0001
Positive TG, %	12.9	43.1	< 0.0001
DHI total score	3.1	35.7	< 0.001

BMI indicates body mass index; DHI, dizziness handicap inventory; ROMJec, Romberg + Jendrassik maneuver with eyes closed; SLSec, single leg stance with eyes closed; SLSeo, single leg stance with eyes open; SOFec, standing on foam with eyes closed; SOFeo, standing on foam with eyes open; TG, tandem gait; TRec, Tandem Romberg with eyes closed; TReo, Tandem Romberg with eyes open; TUG, timed up and go.

Clinical Tests

The most predictive cut-off value, for a vestibular disorder, for the Timed up and go test was 6, 7, and 8 seconds for respectively the age categories of <40 years, 40–60 years, and >60 years. Details are shown in Table 3.

TABLE 3. *ROC-curve analysis to determine most predictive cut-of values for the Timed Up and Go test*

Age Category (Years)	Cut-off Value (s)	Area Under the Curve (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	*p* Value
<40	6	0.7 (0.7–0.8)	93.0 (83.0–98.1)	47.9 (38.7–57.2)	<0.0001
40–60	7	0.8 (0.7–0.8)	81.0 (74.2–86.6)	69.6 (58.2–79.5)	<0.0001
60+	8	0.9 (0.9–1.0)	85.9 (76.5–91.4)	84.0 (76.2–90.1)	<0.0001
Total	8	0.8 (0.8–0.8)	64.0 (58.5–69.2)	81.1 (76.3–85.2)	<0.0001

These values were then added in the following analysis. With the aid of logistic regression analysis and ROC curve analysis the following tests or set of tests were identified as most predictive for vestibular disorders. In the age category <40 years, timed up and go > 6 seconds (OR 102.4; p <0.0001) and single leg stance with eyes closed <30 seconds (OR 48.0; p <0.0001) proved to be the most predictive combination of testing (AUC 0.9; LR+ 15.8; LR- 0.2), with a positive predictive value (PPV) of 88.4%. For the age group 40–60, timed up and go > 7seconds (OR 4.0; p=0.0107) and Tandem Romberg with eyes closed < 30 seconds (OR 63.1; p <0.0001) was the most predictive test (AUC 0.9; LR+ 6.0; LR- 0.1), with a PPV of 93.8%. For the age group of 60+ years the combination of Timed up and go > 8 seconds (OR 17.4; p <0.0001) and Standing on foam with eyes closed < 30 seconds (OR 10.4; p <0.0001) was the most predictive test (AUC 0.9; LR+ 6.3; LR- 0.2), with a PPV of 84,8%. These results are displayed in Table 4, Table 5 and Figure 1. Furthermore, supplemental Table 1A, B, and C (see supplemental Digital Content 1, http://links.lww.com/MAO/B41) describe differences between the balance tests individually per age category, which are then visualized in Figure 2 by means of box and whisker plots.

TABLE 4. *Multivariate logistic regression analysis per age category*

Test	Odds Ratio	95% CI Interval	*p* Value
Age category: <40 years			
Timed up and go (6 s)	102.4	11.2 to 936.0	<0.0001
Single leg stance with eyes closed	48.0	14.6 to 157.7	<0.0001
Age category: 40–60 years			
Timed Up and Go (7 s)	4.0	1.3 to 11.4	0.0107
Tandem Romberg with eyes closed	63.1	23.6 to 168.4	<0.0001
Age category: 60+ years			
Timed up and go (8 s)	17.4	7.1 to 42.6	<0.0001
Standing on foam with eyes closed	10.4	4.2 to 25.3	<0.0001

TABLE 5. *ROC curve analysis per age category*

Age Category (Years)	Most Predictive Set of Tests	AUC (95% CI)	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	Positive Predictive Value (%) (95% CI)	Negative Predictive Value (%) (95% CI)	Positive Likelihood Ratio (95% CI)	Negative Likelihood Ratio (95% CI)	*p* Value
<40	Timed Up and Go (6 s) - Single leg stance with eyes closed	0.9 (0.9–1.0)	80.4 (66.1–90.6)	95.0 (88.7–98.4)	88.4 (75.7–94.6)	90.5 (85.4–95.0)	15.8 (6.8–38.3)	0.2 (0.1–0.4)	<0.0001
40–60	Timed Up and Go (7 s) Tandem Romberg with eyes closed	0.9 (0.9–0.9)	92.5 (86.6–96.1)	84.5 (72.6–92.7)	93.8 (88.9–96.4)	83.7 (71.4–88.8)	6.0 (3.3–10.9)	0.1 (0.1–0.2)	<0.0001
>60	Timed Up and Go (8 s) Standing on foam with eyes closed	0.9 (0.8–0.9)	84.0 (73.2–90.0)	86.6 (78.9–92.3)	84.8 (74.8–88.6)	85.8 (80.2–91.2)	6.3 (3.8–10.0)	0.2 (0.1–0.3)	<0.0001

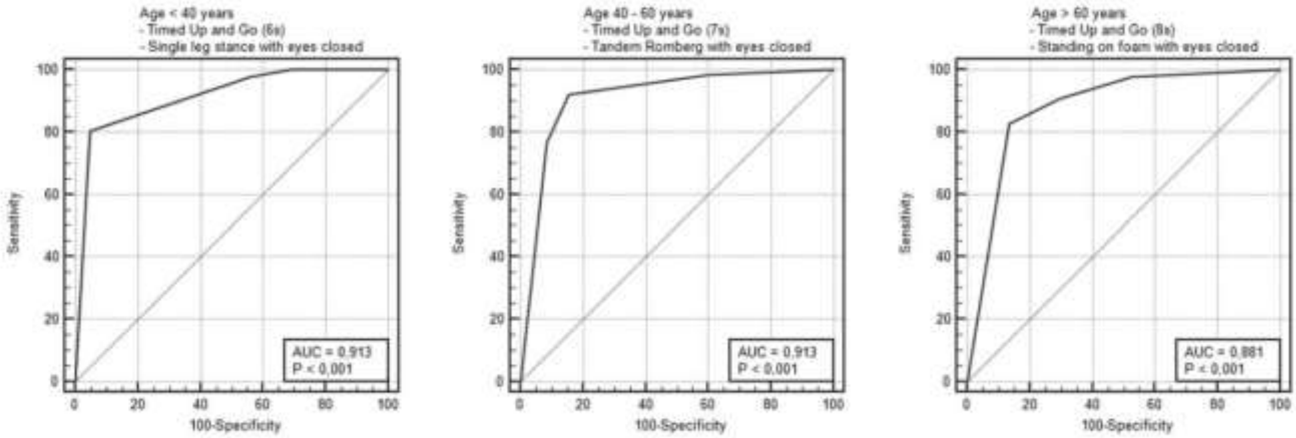

FIG. 1. ROC curve analysis per age category. AUC indicates area under the curve.

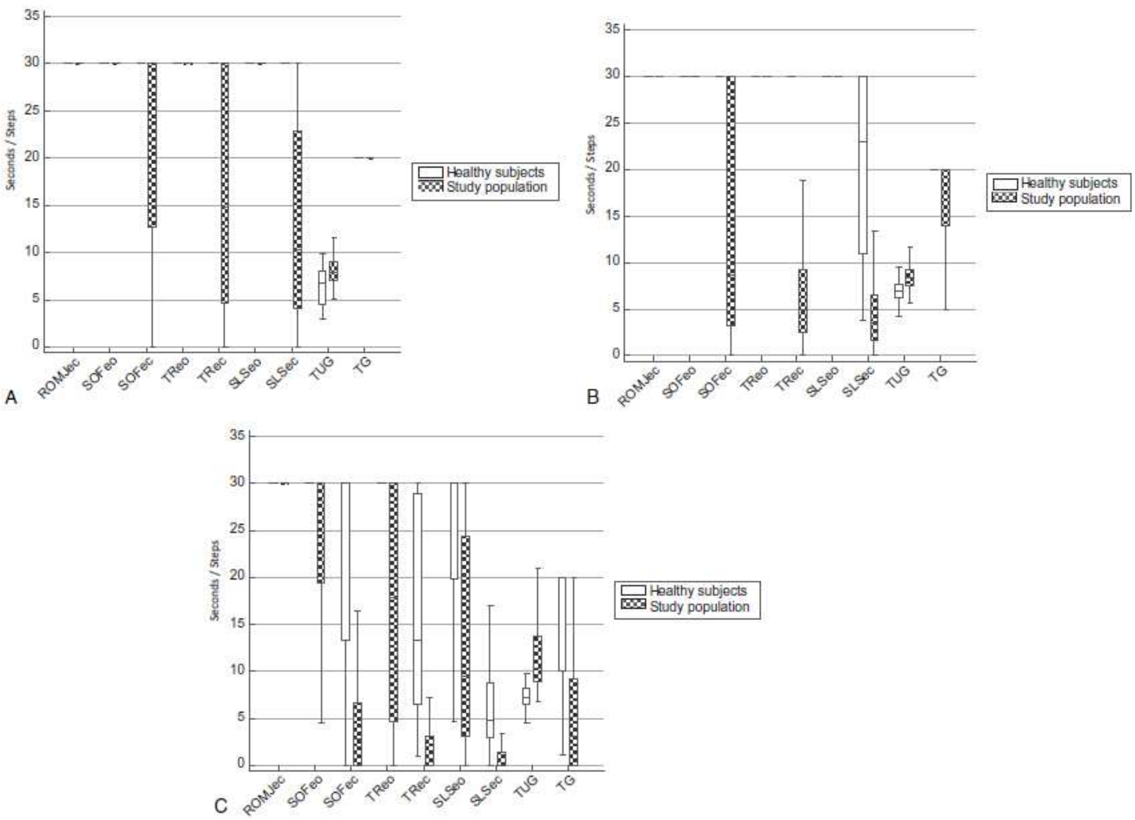

FIG. 2. *A*, Box and whiskers graphs comparing the balance tests for subjects < 40 years. ROMJec indicates Romberg + Jendrassik maneuver with eyes closed (sec); SLSec, single leg stance with eyes closed (sec); SLSeo, single leg stance with eyes open (sec); SOFec, standing on foam with eyes closed (sec); SOFeo, standing on foam with eyes open (sec); TG, tandem gait (steps); TRec, tandem Romberg with eyes closed (sec); TReo, tandem Romberg with eyes open (sec); TUG, timed up and go (sec). *B*, Box and whiskers graphs comparing the balance tests for subjects 40–60 years. ROMJec indicates Romberg + Jendrassik maneuver with eyes closed (sec); SLSec, single leg stance with eyes closed (sec); SLSeo, single leg stance with eyes open (sec); SOFec, standing on foam with eyes closed (sec); SOFeo, standing on foam with eyes open (sec); TG, tandem gait (steps); TRec, tandem Romberg with eyes closed (sec); TReo, tandem Romberg with eyes open (sec); TUG, timed up and go (sec). *C*, Box and whiskers graphs comparing the balance tests for subjects >60 years. ROMJec indicates Romberg + Jendrassik maneuver with eyes closed (sec); SLSec, single leg stance with eyes closed (sec); SLSeo, single leg stance with eyes open (sec); SOFec, standing on foam with eyes closed (sec); SOFeo, standing on foam with eyes open (sec); TG, tandem gait (steps); TRec, tandem Romberg with eyes closed (sec); TReo, tandem Romberg with eyes open (sec); TUG, timed up and go (sec).

Discussion

Disequilibrium and dizziness are potentially incapacitating symptoms, significantly affecting patients' quality of life. Its prevalence increases significantly with age and potential causes vary widely. Nevertheless, a significant number of these patients is first evaluated by general practitioners. In this setting, technical tests to assess vestibular function and the available assessment tools are too expensive and time consuming to perform during a regular consultation. In this study we aimed to identify a short performant clinical tool to aid the clinician in his decision making.

We compared healthy subjects with patients with dizziness and/or disequilibrium due to an underlying vestibular problem. This way we were able to identify the following set of tests as most predictive:

1. Under 40 years: Timed up and go (>6s) and Single leg stance with eyes closed (<30s).
2. Between 40 and 60 years: Timed up and go (>7s) and Tandem Romberg with eyes closed (<30s).
3. Above 60 years: Timed up and go (>8 s) and Standing on foam with eyes closed (<30 s).

In a preceding study, we identified normative values for each test. Because these tests showed an age-dependent distribution, we do not think there is a suitable set of tests universal for all ages, hence the reason of dividing our study population into age categories (11).

We initially identified the most ideal discrimination threshold per age category for the Timed up and go test, before including it in our logistic regression analysis. Probably, this is one of the reasons that this test always came out as significant. In several studies, considering subjects with peripheral vestibular hypofunction, Timed up and go ranged from 13.5 to 19.5 (14,15). Breelan et al. identified normative values per age category, by asking subjects to perform the Timed up and go test at a normal speed. The mean hereof varied between 8.57 and 9.90 (16). These results are comparable to our findings, considering the fact we asked our subjects to perform this test as fast as possible.

Furthermore, univariate analysis showed that subjects with a balance disorder had a significantly higher BMI. A balance disorder can cause fear for movement, resulting in less activity and subsequently leading to an increase in bodyweight. Studies also show a negative correlation between postural control and increased BMI, thus leading to a vicious cycle (17,18).

In healthy subjects performance of the Single leg stance test with eyes closed starts decreasing after the age of 40 (11). When comparing our study population with healthy controls in this age category, performance was significantly more disturbed. This test can be subdivided in a dynamic and static phase. During the dynamic phase, there is an increased force variability reflecting postural adjustments to achieve standing balance. The static phase is characterized by less force variability. In the elderly, research shows that the force variability is decreased during the dynamic phase, thus putting them in a less favorable position to maintain balance leading to an increased force variability during the static phase. Possibly, this is due to ageing of the musculoskeletal and nervous system. Since this is less of an issue in a young population, it has probably led to inclusion of this test in the age category <40 years (19).

Tandem Romberg test and Standing on foam, both with eyes closed, have proven to be less susceptible to the ageing process, since performance starts declining after the age of respectively 40 and 60 years in a healthy population (11). This is most probably the reason that led to their inclusion as significant tests in their respective age categories. Furthermore, the model that emerged per age category tests both static and dynamic aspects of balance, increasing its discriminating properties.

The battery of clinical tests used in our study was composed of common used tests in clinical practice to assess vestibular function (15,20–23). Furthermore, they cover different aspects of balance, like standing and walking. Sensory information from the peripheral vestibular apparatus, eyes, and proprioceptors are processed by the central vestibular system and translated in adequate postural control. In subjects with vestibular loss, compensation occurs by relying more on remaining sensory organs. The balance tests used in this study, challenge these organs, making a vestibular disorder more apparent. When one or more of the remaining sensory organs are affected, balance dysfunction will be more prominent. In this case, our test battery will also be positive, warranting further evaluation. However, this is not a problem since our goal is too screen. Final diagnosis will be made after further evaluation.

Vestibular hypofunction also results in impaired locomotion as reflected by a widened base of support while walking and a gait pattern influenced by head movements (e.g., while standing up or making a 180-degree turn). This aspect is evaluated with the dynamic balance tests (13,24,25). This is very important because a vestibular disorder can affect balance on many ways. For example, in patients with a central vestibular pathology, gait disorders are more outspoken when compared with a peripheral vestibular disorder (26). In the present study, we decided to build further on the foundation laid by our previous study and use the same clinical tests (11). To assess the value of these tests for screening we looked at the likelihood ratios, rather than predictive values because these are prevalence dependent. Although the prevalence of balance disorders due to a vestibular disorder varies widely between primary, secondary, and tertiary care, these tests can still be utilized throughout the different levels of healthcare (27).

In the literature there is a comparable measure instrument available called the ‘‘clinical test of sensory interaction on balance.’’ The goal hereof is to quantify postural control under various sensory conditions with the use of six clinical tests. A drawback of the original clinical test of sensory interaction on balance was that only static balance tests were considered. Recently, this test battery was expanded by adding head movements in the static conditions and the tandem gait test. Subsequently, age-based norms were identified. By adding these head movements, the vestibular system is additionally challenged. This increases the difficulty level, especially when closing the eyes and when challenging proprioceptive input by standing on foam. This might yield too many false positives in the most difficult condition, because at that time no adequate sensory input is available. Therefore, we did not choose to incorporate head movements in the test protocol at the time. Other instruments assessing balance are the Berg balance scale and the Dynamic Gait Index, evaluating static and dynamic function respectively.

Originally, these tests are developed to predict falls. Individually, these instruments have proven to be insufficient in identifying vestibular patients, but by combining these tests their sensitivity increases. So, preferably both aspects, static and dynamic, should be included when assessing a patient (28). Numerous individual tests of balance are described in the literature, but there are some points of criticism to be made. Separately, these tests cannot adequately distinguish subjects with and without vestibular disorders. Moreover, most of these tests only assess one aspect of balance, either static or dynamic, and thus not fully assessing vestibular function (6,8,9,29).

A strength of our study is the large study population representing subjects of all age categories. This allowed us to create subdivisions and adequately perform statistical analysis. A limiting factor is that all subjects with dizziness and/or disequilibrium are recruited from a tertiary hospital, possibly causing referral bias. Another limiting factor is that no comparison was made with subjects with dizziness and/or disequilibrium due to another cause, besides vestibular disorder. For this reason, we do not know if our tests can adequately differentiate between these etiologies. With increasing age, the prevalence of musculoskeletal disorders and other medical disorders (e.g., diabetic neuropathy) impeding balance increase. Since these subjects were excluded from our study population these tests should be used with caution when encountering such a patient in the clinic.

Even though the utricle and saccule contribute to balance, their function was not systematically assessed in our study. Although animal studies show that VEMP is the test that correlates the most with saccule/utricle function, it is unknown what its efficacy is in identifying vestibular function specifically related to the saccule/ utricle. So, we do not think inclusion of otolith function measures would substantially change the outcome of our results. Furthermore, VEMP was only performed when there was a clinical or radiological suspicion for semicircular canal dehiscence (30).

It would be of significant clinical value if our instrument would be able to adequately differentiate between a central and peripheral vestibular disorder. Potentially these tests can also be used to evaluate patients after administration of therapy to assess progress. In summary, this study provides a valuable and easy to administer clinical instrument for physicians and other healthcare professionals dealing with patients with dizziness and/or disequilibrium. However, the outcome of these tests should always be considered in combination with history and general examination of the patient. This will then aid the physician in his diagnostic decision-making process.

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