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Utility of Stepping, Walking and Head Impulses for Screening Patients for Vestibular Impairments

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Abstract

Objective—To determine if some common screening tests predict scores on detailed, objective diagnostic tests of the vestibular system.

Study design—Sixty patients with vestibular disorders were compared to 60 asymptomatic controls.

Setting—Vestibular diagnostic laboratory, tertiary care center.

Subjects and Methods—Subjects were screened with head impulse tests (HT), Fukuda Stepping Tests while walking and marching in place, and tandem walking tests (TW) with eyes open and closed. All subjects had bi-thermal caloric tests and Dix-Hallpike maneuvers; patients had low frequency sinusoidal tests of the vestibulo-ocular reflex in darkness, and cervical vestibular evoked myogenic potentials.

Results—On TW patients differed significantly from controls but Receiver Operating Characteristic (ROC) scores were < 0.8. On Fukuda tests patients turned significantly more than controls for walking but not marching, but ROC values were considerably < 0.80. For HT patients with bi-thermal caloric weakness ≥ 20% and < 60% did not differ from controls but patients with severe bi-thermal caloric weakness, ≥ 60%, differed significantly from controls. ROC values were > 0.80 only for subjects with severe bi-thermal caloric weakness and were highest, 0.88, for subjects with severe weakness and age ≥ 60.

Conclusion—The Fukuda is a poor screening test because it does not correlate well with objective test findings. TW is best used for screening older patients for vestibular disorders. A

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positive HT is probably consistent with severe peripheral vestibular impairment and may be most useful in older patients. In younger patients with vertigo a negative HT may not be informative.

Keywords

vestibular system; diagnosis; tandem walking; Fukuda stepping test; head impulse test

Introduction

Clinicians use a variety of screening tests in the office to assess patients who they suspect have vestibular disorders. Although some tests are established and widely used they may have limited value for screening people to detect vestibular impairments. In this study we examined three such tests: the Fukuda stepping test, the tandem walking test and the head impulse test. All of these tests have the value of being inexpensive, easy to administer with minimal equipment, in less than one minute per test.

To perform the Fukuda stepping test the patient walks in place with eyes closed. The dependent measure is the angle turned. Fukuda [1] modified tests described by earlier investigators [2]: having the blindfolded subject stand in the middle of a circle with 15° increments marked on the floor, and having the subject walk at approximately 2 Hz for 50 to 100 steps. Dependent measures were postural sway, changes in the relative positions of the head and body, the angle of rotation and the distance of rotation used to calculate the angle of displacement from the straight ahead. Fukuda reported that patients with vestibular impairments rotated and deviated more than controls. Toussaint et al showed that scores were significantly worse when the test was performed with the head pitched downward.[3]

Several studies have indicated poor test-retest reliability of various versions of the test. Using Fukuda's original paradigm Bonani and Newton found considerable variability and only moderate test-retest reliability. [4] Several studies have shown that the test has poor sensitivity and specificity, does not indicate the side of lesion reliably and is variable even in normal controls. [5–8] Despite these problems the Fukuda stepping test continues to be used in many clinics.

Similarly the well-known tandem walking test has been used for many years.[9,10] Originally developed for use on rails but performed with eyes open, tandem walking is now typically performed with eyes closed. Performance seems to decline slightly with age.[11–14] It is challenging for patients as well as for healthy controls. [15] When performed with 10 steps and eyes closed, using patients and controls who had no joint limitations, the test had moderately high sensitivity to lower extremity peripheral neuropathy. [16] In subjects without peripheral neuropathy or joint replacement it had high specificity compared to healthy controls but poor sensitivity to patients with unilateral vestibular weakness. [17] The patients in that study, however, were fairly homogenous and may not have represented the general population of vestibularly impaired patients. Also, control subjects were screened with Dix-Hallpike maneuvers and head impulse tests but were not tested on objective diagnostic tests.

The head impulse test performed without instrumentation[18,19] is newer than the other tests but has become well established and is now recommended for use by therapists as well as

physicians. [20,21] The test is performed by having the patient stare at a central focal point, such as the examiner's nose, and then the examiner briskly rotates the patient's head in yaw, either left or right, approximately 20°. The test is positive (abnormal) if the examiner observes a saccade during counter-rotation of the eye.

The purpose of this study was to determine the utility of those three tests in screening patients for vestibular disorders. Specifically, we examined the Fukuda Stepping Test performed while walking in place with small steps and marching in place with higher steps, the tandem walking test performed with eyes open and eyes closed, and the un-instrumented head impulse test. We included patients with peripheral neuropathy and joint replacements if they were ambulatory without gait aids and we verified that healthy controls had no unilateral weaknesses on bi-thermal caloric testing.

Methods

Subjects

Two groups of ambulatory participants, 60 per group, were recruited. No subject was excluded due to peripheral neuropathy or joint replacements. The asymptomatic controls, including 33 females and 27 males, were screened with a health history and Dix-Hallpike maneuvers, and were given bi-thermal caloric tests, on which they all had normal range responses, i.e., unilateral weakness of < 20%. The patient subjects, including 28 females and 32 males, were recruited from the caseload of patients by the senior author and from patients who were tested in the laboratory with a complete battery of vestibular diagnostic tests, including bi-thermal caloric tests, Dix-Hallpike maneuvers, low frequency sinusoidal tests of the vestibulo-ocular reflex in darkness in the rotatory chair, and cervical vestibular evoked myogenic potentials. No patients in this study had benign paroxysmal positional vertigo or abnormal responses on Dix-Hallpike tests; all patients had ≥ 20% unilateral weakness on bi-thermal caloric tests and the neurotologist who read those tests (RAW) determined that each patient's responses were consistent with a peripheral vestibular weakness. Control subjects were slightly but not statistically significantly younger than patient subjects: controls, mean age 54.0 yrs, SD 15.4, range 23 to 66, 38 subjects < age 60; patients, mean age 58.7 yrs, SD 13.5, range 35 to 86, 32 subjects < age 60; p=0.08.

All subjects gave informed consent prior to participation in the study. The study was approved by the Institutional Review Board for Baylor College of Medicine and Affiliated Hospitals.

Procedure

Subjects were tested on tandem walking, 10 steps per condition, with the arms crossed, under two conditions: eyes open (EO) and eyes closed (EC). The test was scored by the number of consecutive heel-to-toe steps taken without stepping out of line, moving the arms, or opening the eyes during eyes closed tests. Subjects were tested on the Fukuda Stepping Test on a plastic mat on which a large semicircle was marked in 10° increments. Subjects stood at the 0° mark, held their arms at their sides, closed their eyes, and performed two conditions for 20 steps each: walking in place and marching in place. For the walking

condition, subjects were instructed to walk in place and lift their feet off the floor. For the marching condition, subjects were instructed to lift their knees as high as possible. The dependent measures were the angle of rotation away from the center line, the distance walked forward and the distance walked to the side.

For head impulse tests the subject sat in a comfortable chair and the examiner crouched in front of the subject. The examiner held the subject's head with both hands and, after briefly assessing passive range of motion in yaw to be sure that the participant had at least 30° of yaw rotation to either side, pitched the head downward 30° and then the examiner briskly moved the head 20° to one side while the subject stared at the examiner's nose. Two trials per side were performed. The dependent measure was the presence or absence of a saccade. To obtain inter-rater reliability data were collected by two raters simultaneously, for 84 subjects.

Examiners who performed head impulse tests knew which subjects were patients and controls but did not know the level of unilateral weakness in patients. Thus, testing was partially blinded.

Statistical Methods

Patients and controls were initially compared via t-test for continuous variables and chi-square test for grouped variables. We examined the validity of the various tests by receiver operative characteristic curves (ROC) for continuous variables and sensitivity/specificity for discrete variables. These analyses were also stratified by age (<60 and ≥ 60 years old) because standing balance decreases significantly around age 60[22] and vestibular function decreases with age. [23] Inter-observer reliability of the tests was assessed by kappa coefficient for discrete variables and correlation coefficients for continuous variables. All analyses were performed in SAS statistical software (9.3, Cary, NC). P<0.05 was considered statistically significant.

Results

Tandem walking

Tests for EO and EC were performed separately. For both conditions the total control and patient groups differed significantly, p< 0.0001. Patients less than 60 and older than 60 also differed significantly from controls, p< 0.0008 to p< 0.0001. See Table 1. More importantly for the value of the test for screening, however, with the age groups collapsed and also with the age groups divided at age 60 ROC values were mostly < 0.80. As shown in Table 1 the ROC value was higher only for subjects ≥ 60 years old, ROC=0.83. Sensitivity was 0.75 and specificity was 0.78. The level of agreement between the two observers was high for eyes open (r = 0.99) and for eyes closed (r = 0.93).

Fukuda stepping test

Similarly for the Fukuda stepping test we used the entire cohort and then divided the groups at age 60. For the degrees turned in walking and in marching, the patient group was significantly greater than the control group when walking: p=0.002, but not marching:

p=0.47, for the entire cohort. No differences were found between the groups for the number of steps taken, the distance walked forward or the distance walked to the side. When the groups were divided by age 60 for both younger and older groups in the walking condition, but not the marching condition, patients turned significantly more than controls: younger, p=0.02, older, p=0.03. No other significant differences were found between patients and controls in younger and older groups. See Table 2.

As shown in Table 2, ROC values were well below 0.80 for all measures. Therefore sensitivity and specificity tests were not performed. Inter-observer reliability was high for all subtests (r = 0.95 to 1.0), except the distance walked forward in the walking, as opposed to the marching, condition (r= 0.44).

Head impulse tests

For this test we divided the age range and also divided patients into mild unilateral weakness (≥ 20% and < 60%) and severe unilateral weakness (≥ 60%). For the total cohort and when the groups were broken down by age significantly fewer controls than mild patients and significantly fewer controls than severe patients had no response to the test: total cohort, p=0.0003; younger, p<0.0001; older, p=0.0006; but the number of positive responses did not differ significantly between groups. See Table 3.

As shown in Table 4 with the total cohort, and with groups broken out at age 60, ROC values were > 0.8 only for patients with severe disease. Not surprisingly the best ROC value was found for older patients with severe disease: ROC=0.88, sensitivity was 88.9 and specificity was 86.4. The level of inter-observer agreement was high, with kappa coefficients ranging from 0.90 to 0.95.

Discussion

The significant differences between groups were expected and are also misleading. Based on those significant differences the clinician may believe that these tests are useful for screening. As indicated by the weak ROC values, however, none of these tests are excellent for screening patients suspected of having vestibular disorders. The Fukuda stepping test is particularly poor, since no ROC values were ≥ 0.80. One way to think about these findings is that t-tests show that groups differ at least somewhat. ROC values, however, show if groups are different enough to be really useful for testing.

Because the ROC values were so low for the Fukuda Stepping Test we recommend that this test should not be used. The ROC values for Tandem Walking were also poor. In the eyes closed condition with older subjects it is most useful. Clinicians may learn something further but should consider the possibility that the patient may have peripheral neuropathy, central ataxia, or some other disorder causing a balance problem. For the older patient who is able to perform the test the clinician should not abandon the potential diagnosis of vestibular disorder because the patient might have mild vestibular disease and still be able to perform the test. Thus the ability to perform the test might lead the clinician who relies on the test too strongly to consider a false negative.

The head impulse test is somewhat more complicated. Ideally a test should have sensitivity and specificity ≥ 0.95. No test here meets that criterion. To be at least adequate for an initial screening specificity and sensitivity should be ≥ 0.85. Based on that criterion the head impulse test may be useful in detecting a severe impairment in an older patient, if the patient has adequate cervical range of motion, is able to relax enough to allow the clinician to perform the test, and is able to follow instructions for the test. Some older patients may not meet those criteria.[24] If the test is positive it may indicate severe peripheral vestibular impairment. Recent evidence suggest that a positive, un-instrumented head impulse test in elderly patients may be associated with increased falls. [25] Therefore, a positive finding suggests the need for further testing. Given the less than ideal sensitivity and specificity of the test, however, if the test is negative the physician should not necessarily abandon the potential diagnosis of vestibular disease because the patient may have a weakness too mild to be detected by the test. Therefore, relying on a negative result too strongly might lead the physician to consider a false negative. The physician should consider the history and other aspects of the office screening when making the initial diagnosis.

This study had some limitations. Some inherent subjectivity by the examiner is involved in determining the exact number of degrees turned in the Fukuda Stepping Test. We did not take into account the speed of stepping in either the Fukuda or the tandem walking test. We did not perform careful sensory examinations of subjects' lower extremities for peripheral neuropathy or proprioceptive dysfunction. This omission may have skewed the data but the effect would be expected to be mild because patients were screened by history of significant peripheral neuropathy. Head impulse testing can also vary by patients related to age, speed of head movement and range of motion, as well as comfort with the exam. Finally, a larger sample size would have allowed more thorough stratification in the subjects by age and by caloric weakness, rather than just the division between those above and below 60 years of age. Additional age-specific data would be useful clinically in this population.

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Table 1

Tandem walking. Descriptive statistics and ROC values for both tests. The best sensitivity/specificity pairs are shown for ROC ≥ 0.80.

	Median steps (range) controls	Median steps (range) patients	ROC	Sensitivity	Specificity
Total group EO	10 (3–10)	4.5 (0–10)	0.75	-	-
< 60 years EO	10 (5–10)	8 (3–10)	0.73	-	-
≥ 60 years EO	10 (0–10)	2 (0–10)	0.76	-	-
Total group EC	4 (0–10)	1 (0–10)	0.78	-	-
< 60 years EC	4 (0–10)	2 (0–10)	0.78	-	-
> 60 years EC	3.5 (0–10)	0 (0–4)	0.83	0.75	0.78

EO, eyes open; EC, eyes closed.

Table 2

Fukuda stepping test. ROC values for all tests. Sensitivity and specificity values are not shown because no ROC values were ≥ 0.80. UW, patients with unilateral weakness. Control, control subjects. All control subjects walked for 20 steps and 19 control subjects marched for 20 steps.

	Degrees turned			Number of steps		
	Mean (SD)		ROC	Median (range)		ROC
	UW	Control		UW	Control	
Total group Walking	8.7 (12.5)	2.8 (6.0)	0.66	20 (2–20)	20	0.51
< 60 years walking	7.5 (9.0)	2.8 (6.3)	0.68	20 (14–20)	20	0.53
≥ 60 years walking	10.0 (15.6)	3.0 (5.5)	0.63	20 (2–20)	20	0.52
Total group marching	12.2 (16.0)	7.2 (10.7)	0.58	20 (1–20)	20	0.52
< 60 years marching	8.8 (12.0)	5.0 (7.3)	0.57	20 (3–20)	20 (7–20)	0.51
> 60 years marching	16.0 (19.1)	11.1 (14.2)	0.58	20 (1–20)	20	0.55

	Distance forward			Distance to side		
	Mean (SD)		ROC	Mean (SD)		ROC
	UW	Control		UW	Control	
Total group Walking	24.6 (14.1)	25.1 (14.8)	0.52	4.1 (5.8)	4.8 (10.5)	0.51
< 60 years walking	23.5 (11.8)	22.7 (12.1)	0.50	9.5 (14.5)	7.4 (11.2)	0.46
≥ 60 years walking	25.9 (16.4)	29.2 (18.3)	0.57	3.4 (5.4)	3.5 (3.5)	0.57
Total group marching	35.4 (18.7)	38.6 (10.1)	0.54	7.3 (11.3)	7.1 (10.1)	0.50
< 60 years marching	36.7 (20.1)	37.0 (17.7)	0.50	4.8 (6.2)	5.5 (12.9)	0.52
> 60 years marching	33.8 (17.3)	41.5 (21.4)	0.60	4.8 (5.0)	6.6 (7.9)	0.52

Table 3

Head impulse test, number of negative and positive responses by age group and severity of disease. UW, patients with unilateral weakness. Mild, patients with unilateral weakness ≥ 20% and < 60%; severe, patients with unilateral weakness ≥ 60%. Young, aged 21 to 59; older ≥ age 60 years.

	Number negative	Number positive
All controls	59	1
Young controls	38	0
Older controls	20	1
All UW	31	29
All young UW	18	14
All young UW mild	10	4
All young UW severe	7	11
All Older UW	13	15
All older UW mild	12	7
All older UW severe	1	8

Table 4

Head impulse test. ROC values for all tests. The best sensitivity/specificity pairs are shown for ROC ≥ 0.80. Mild, patients with unilateral weakness ≥ 20% and < 60%; severe, patients with unilateral weakness ≥ 60%.

	ROC value	Sensitivity	Specificity
All ages/all subjects	0.73	-	-
All ages, control vs. mild weakness	0.64	-	-
All ages, control vs. severe weakness	0.83	70.4%	95%
< 60, all subjects	0.73	-	-
< 60, control vs. mild weaknesses	0.64	-	-
< 60/ control vs. severe weakness	0.81	61.1%	100%
≥ 60, all subjects	0.70	-	-
≥ 60, control vs. mild weakness	0.62	-	-
≥ 60, control vs. severe weakness	0.88	88.9%	86.4%