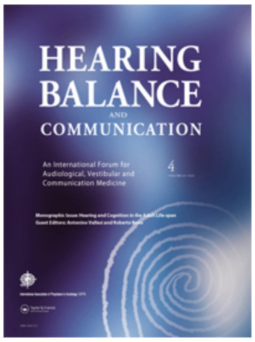

Hearing, Balance and Communication

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ihbc20

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HEARING, BALANCE AND COMMUNICATION
https://doi.org/10.1080/21695717.2022.2125243

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ORIGINAL ARTICLE

Vestibulo-Spinal reflex tests to determine unilateral vestibular loss

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ABSTRACT

Objective: The purpose of this study was to investigate subjective vestibulo-spinal reflex test sensitivity in subjects with unilateral vestibular loss.
Method: Forty subjects diagnosed with UVL within 7 days of onset and 30 subjects without dizziness/balance disorder complaints were included in the study as the unilateral vestibular loss and control groups (70 subjects aged 18–60 years [mean: 42.95 ± 10.82]). Bithermal caloric test, Fukuda, Babinski Weil, tandem walking, and past pointing tests were performed. The subjective VSR tests' sensitivities were compared among the various methods.
Results: The Fukuda test was determined to have the highest sensitivity value (65%; kappa coefficient: 0.352). The sensitivity values of the other tests, in descending order, are: Babinski Weil (55%, Kappa coefficient: 0.274), tandem walking (10%, Kappa coefficient: 0.022), and past pointing (2.5%, Kappa coefficient: −0.014). A positive moderate correlation was obtained between canal paresis asymmetry and Fukuda deviation degree ($p = 0.009$, $r = 0.407$). There was no correlation between Babinski Weil ($p = 0.619$), tandem walking ($p = 0.538$), and past pointing test results and canal paresis asymmetry ($p > 0.05$).
Conclusions: Fukuda and Babinski Weil tests can be used under conditions where all subjective tests are not performed because of limited time. However, these tests must be used alongside objective vestibular test batteries owing to their limited specificity and sensitivity.

KEYWORDS
Unilateral vestibular loss; vestibulo-spinal reflex; caloric test; Fukuda; Babinski Weil; tandem walking; and past pointing tests

Introduction

Peripheral vestibular diseases are the result of dysfunction at any point in the production, integration, or modulation of stimuli in vestibular pathways. There are numerous objective and subjective methods for the vestibular assessment of patients experiencing dizziness and patients with balance disorders.

Due to the multimodal features of the vestibular system, the need to evaluate many structures has led to the emergence of numerous objective and subjective laboratory tests. Subjective evaluations are most frequently implemented to evaluate the vestibulo-spinal reflex (VSR) [1]. Fukuda test is one of the VSR tests which may indicate asymmetric labyrinth function [2,3]. Past pointing (PP) is a VSR test evaluating deviations in the upper limb. The Babinski Weil (BW) test reveals unilateral vestibular hypofunction through an uneven labyrinth effect on the ipsilateral skeletal muscles [4]. Tandem walking (TW) tests are widely used to screen for vestibular and neurological disorders [5].

Although there are many objective test methods for evaluating the vestibular system, subjective tests are preferred by clinicians. Patients' reactions are evaluated with these tests, which are similar to daily life movements. In studies by Honaker et al. [3] and Zhang and Wang [6], participants were evaluated by caloric testing, an objective test method, and subjective methods such as the Fukuda test.

Although many evaluation methods have been proposed in the literature, it is difficult to apply all these tests to patients in any given study. Hence, there is a need to determine which subjective tests are more reliable in the differential diagnosis of peripheral vestibular pathology. Research on the sensitivity of subjective VSR tests is limited. In previous studies, the Fukuda test was found to be more focussed than other tests. In a study by Zhang and Wang [6] evaluating 126 subjects with unilateral vestibular loss

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

(UVL), 63 participants deviated >45° from the lesion direction in the Fukuda test, with a sensitivity of 50%. Correlations between subjective and objective tests have not been studied and few studies have examined differences between the sensitivities of subjective VSR tests for detecting UVL. In this study, we aimed to examine correlations between Fukuda, BW, TW, and PP tests and objective caloric tests and to determine the most reliable test method for the diagnosis of UVL.

Patients and methods

This study was conducted at Hacettepe University Adult Hospital Audiology Unit and the Faculty of Health Sciences Department of Audiology between March 2019 and March 2020, with the approval of Hacettepe University Non-Interventional Clinical Research Ethics Committee numbered GO19/131 (19/03/2019).

Subjects

Seventy volunteer participants were enrolled in the study. Forty participants (18–60 years, mean: 42.95 ± 10.82) who were diagnosed with UVL were included in the study (as the UVL group). Thirty participants (18–60 years, mean: 43.36 ± 11.49) with no history of dizziness or balance disorders and with normal computerised dynamic posturography test results were included in the study as a control group. Both groups had maximal manual resistance (grade 5) based on muscle testing.

Methods

Participants were subjected to detailed history taking, videonystagmography following an otolaryngological examination. All vestibular tests were performed during a single session.

Objective evaluation

Bitermal caloric test

Caloric tests and test preparation stages were conducted in accordance with the principles of the British Society of Audiology. Using Test Micromedical VisualEyes 4 Channel Videonystagmography (Spectrum 9.1, Chatham, United States), a cold stimulus was applied at 24 °C and a warm stimulus was applied at 47 °C with an air irrigator. Patients were asked to say the names of people and cities in alphabetical order to generate cognitive stimulation (mental alerting) during nystagmus recording.

Determined slow phase speeds were calculated using a computerised system in accordance with Jongkee's formula. Canal paresis, directional preponderance, and fixation index results were recorded. Asymmetric weaknesses >24% for canal paresis and values >25% for directional preponderance were considered significant. Fixation indices >75% for nystagmus suppression and canal paresis values >25% were interpreted as UVL diagnostic indicators.

Subjective evaluation

Subjective VSR tests were used to evaluate motor reactions in the head and neck, which are linked with vestibular sensory input. Safety measures were taken to prevent falls. The tests were repeated three times.

Tandem walking test

Participants were asked to walk for approximately 3 m on an imaginary straight line in tandem (one-foot tip touching the other's heel) and with eyes open. The direction of falling during TW was recorded.

Fukuda test

Participants were asked to take 50 steps with their eyes closed on a floor marked with angle degrees; patients were at the zero angle point. Rotations >30° at the end of 50 steps were considered meaningful. The direction and degree of rotation were noted.

Babinski Weil test

Participants were asked to walk three steps forward and backward and repeat this process three times without opening their eyes. The direction of deviation in the forward walk was recorded.

Past pointing test

While participants were in a sitting position, they were asked to stretch their arms at the index finger level of the clinician. The patient was asked to raise his or her arms up perpendicular to the ground with their eyes closed and move back to the starting position. This movement was repeated 20 times and the direction of the deviation was recorded.

Statistical analysis

The IBM SPSS Statistics Program Version 23 was used for data evaluation (IBM Corp., Armonk, NY, USA). Statistical comparisons between groups were performed using independent sample *t*-tests.

Participants' VSR test results were evaluated using cross tables and the sensitivity and specificity values were obtained. Correspondence analysis for VSR tests and caloric test canal paresis were examined through Kappa coefficients.

Caloric canal paresis directions were classified as right or left. Associations between Fukuda deviation degree and caloric test asymmetry were monitored using Spearman correlation. Kruskal Wallis tests were used to determine differences in caloric test asymmetry for TW, BW, and PP tests.

Results

We found that, in the UVL group, 22 (55%) had right UVL and 18 (45%) had left UVL.

Subjective VSR tests

For the Fukuda test, four (10%) subjects in the UVL group did not show deviated movements; 36 participants showed deviation (90%; 22 [55%; right] and 14 [35%; left]). Fukuda and caloric test results are listed in Table 1. The matching percentage ratios between the Fukuda deviation and caloric test canal paresis directions were 40% (right) and 25% (left), with a sensitivity of 65.0% for the UVL group. The Kappa coefficient was 0.352 ($p = 0.009$), corresponding to low-level fitness.

The matching percentage ratios between BW deviation and caloric test canal paresis directions were 32.5% (right) and 22.5% (left), with a sensitivity of 55.0% for the entire UVL group (Table 2). The Kappa coefficient was 0.274 ($p = 0.012$), corresponding to weak fitness.

The matching percentage ratios between TW deviation directions and caloric test canal paresis directions were 10.0% (7.5% [right], 2.5% [left]) (Table 3). The Kappa coefficient was 0.022 ($p = 0.497$), showing no evidence of associations between TW deviation and caloric test canal paresis directions.

Table 1. Comparison of Caloric and Fukuda test results in subjects with UVL.

	Caloric test		
Fukuda test	Right UVL ($n = 22$)	Left UVL ($n = 18$)	Total ($n = 40$)
Right-Deviation	**16 (40%)**	6 (15%)	22 (55%)
Left-Deviation	4 (10%)	**10 (25%)**	14 (35%)
No deviation	2 (5%)	2 (5%)	4 (10%)
Total	22 (55%)	18 (45%)	40 (100%)

UVL: Unilateral Vestibular Loss, n: number of participants.
The bold values show the number of results and ratios where the UVL direction and the VSR tests' deviation direction are consistent.

In the PP test, only one subject with UVL showed deviated movement. The matching percentage ratio between the PP deviation and caloric test canal paresis directions was 2.5% (2.5% [right], 0% [left]). The Kappa coefficient was −0.014 ($p = 0.522$), corresponding to a very weak fit.

Subjective VSR tests

VSR test results for the control group are presented in Table 4. The specificity values of the VSR tests were 36.7%, 93.3%, 100%, and 100% in the Fukuda, BW, TW, and PP tests, respectively.

Objective and subjective tests

We examined correlations between deviations and deviation angles in subjective VSR tests and caloric test asymmetry. For subjects with a right caloric test canal paresis direction, we observed a moderate positive association between caloric percentage and Fukuda deviation degree ($p = 0.033$). For subjects with left caloric weakness, we observed no association between caloric weakness and Fukuda deviation degree ($p = 0.335$).

No association was observed between caloric asymmetry and TW test results ($p = 0.538$). The median caloric asymmetry of participants with right deviations was higher than the values for no deviation and

Table 2. Comparison of Caloric and Babinski Weil test results in subjects with UVL.

	Caloric test		
Babinski-Weil test	Right UVL ($n = 22$)	Left UVL ($n = 18$)	Total ($n = 40$)
Right-Deviation	**13 (32.5%)**	4 (10%)	17 (42.5%)
Left-Deviation	4 (10%)	**9 (22.5%)**	13 (32.5%)
No deviation	5 (12.5%)	5 (12.5%)	10 (25%)
Total	22 (55%)	18 (45%)	40 (100%)

UVL: Unilateral Vestibular Loss, n: number of participants.
The bold values show the number of results and ratios where the UVL direction and the VSR tests' deviation direction are consistent.

Table 3. Comparison of Caloric and Tandem Walking test results in subjects with UVL.

	Caloric test		
Tandem-Walking test	Right UVL ($n = 22$)	Left UVL ($n = 18$)	Total ($n = 40$)
Right-Deviation	**3 (7.5%)**	2 (5%)	5 (12.5%)
Left-Deviation	0 (0%)	**1 (2.5%)**	1 (2.5%)
No deviation	16 (40%)	9 (22.5%)	25 (62.5%)
Deviation to both sides	3 (7.5%)	6 (15%)	9 (22.5%)
Total	22 (55%)	18 (45%)	40 (100%)

UVL: Unilateral Vestibular Loss, n: number of participants.
The bold values show the number of results and ratios where the UVL direction and the VSR tests' deviation direction are consistent.

Table 4. Control group VSR test results.

	Fukuda *n* (%)	Babinski Weil *n* (%)	Tandem Walking *n* (%)	Past pointing *n* (%)
Right-Deviation	11 (**36.7**)	28 (**93.3**)	30 (**100**)	30 (**100**)
Left-Deviation	12 (40)	1 (3.3)	0 (0)	0 (0)
No deviation	7 (23.3)	1 (3.3)	0 (0)	0 (0)
Both deviation	0 (0)	0 (0)	0 (0)	0 (0)
Total	30 (100)	30 (100)	30 (100)	30 (100)

UVL: Unilateral Vestibular Loss, n: number of participants.
The bold values represent the specificity values of the VSR tests.

both deviations, but this increase was not statistically significant.

The BW test was not statistically significant ($p = 0.619$). Since the groups had <3 observations for the PP test, we did not assess fit statistics. Only one subject deviated from this test; there were no correlations between caloric test asymmetry and deviations.

Discussion

In this study, we evaluated subjective VSR tests in subjects with UVL, with the highest sensitivity found for the Fukuda test. This test may be a measure of asymmetric labyrinth function. However, reviews on the performance of this test have reported different opinions in the context of peripheral vestibular lesion identification. Peitersen et al. [7] used the Fukuda test to observe subjects with the chronic unilateral inner ear or vestibular nerve damage and suggested that subjects with UVL deviated towards the lesion direction, in line with our study.

Some studies have indicated that the Fukuda test is unreliable for screening peripheral vestibular asymmetry in patients with chronic dizziness [3,6,8]. In our study, we observed a sensitivity of 65%. Honaker et al. [3] reported a sensitivity of 61% and concluded that the test was not adequately consistent. Other studies [6,8] report that the Fukuda test sensitivity for UVL is approximately 50%. An asymmetry value >25% is considered significant when examining caloric tests for UVL. Differences in the sensitivity of the Fukuda test may be due to variations in caloric test asymmetry and symptom severity. In our study, the mean caloric test asymmetry was 51.6%; caloric test asymmetry values were not presented in other studies.

Although Fukuda testing shows deviations in UVL patients, the unilateral weakness level required for deviation has not been identified. Our study examined correlations between caloric test asymmetry and Fukuda test deviation. For subjects with right canal paresis, we found a moderate positive relationship ($p = 0.033$). Honaker et al. [9] reported that the overall diagnostic performance of the Fukuda test increased as caloric asymmetry increased and this finding partially supports our results.

Normal Fukuda test results in the presence of UVL may indicate adequate vestibulospinal compensation [10]. In our study, we observed normal Fukuda test findings for four participants with UVL. Future studies are needed to determine whether a deviation in the Fukuda test is an indication of a compensated vestibular system.

A study on the reliability of the Fukuda reported test-retest reliability of 91.8% [11]. Another study found that the angle of rotation changed between tests, though there was a weak correlation between test results [12]. In our study, the direction of deviation in at least 2/3 repetitions and the angle of rotation were taken into account.

In the BW test, deviation towards the ipsilateral direction during forwarding steps and to the other side during backward steps was observed as a result of postural asymmetry. When these deviations come together in successive trials, they constitute a star shape. Miranda et al. [13] evaluated the BW test and found that deviations were not affected by gender or age and that walking speed affected the angle of deviation in healthy subjects as well as those with vestibular disorders. Walking at a frequency of 1 Hz resulted in a greater degree of deviation than walking at a frequency of 3 Hz [14]. Although walking speed was not taken into account in our study, participants were asked to walk at a normal speed.

Few studies have evaluated the sensitivity of the BW test, and current information on methodologies is insufficient to measure deviations in this walking model. Our study reports a sensitivity of 55% and a specificity of 93.3% for UVL diagnosis.

TWis recommended for the evaluation of numerous neurological and vestibular diseases. This test is difficult for UVL patients. However, uncertainties that may affect validity include: eyes being opened or closed, wearing shoes during the test, and a number of steps. Subjects with a diagnosed pathology can show normal results as a result of uncertainties in these assessment techniques. We conducted tests with participants wearing shoes and walking a distance of approximately 3 m.

Cohen et al. [5] performed a 10-step TW test in adults with vestibular disorders. Subjects with UVL had less accurate tandem steps than the control group. The sensitivity of the closed-eyes TW test for the diagnosis of vestibular pathology was 67%; the specificity was 71%, with moderate reliability. The sensitivity of the open-eyes test was low (10%), while its specificity is thought to be 100%. Our findings illustrate that the TW test alone is not the best method for identifying vestibular disorders. Similar to our results, Cohen et al. [15] noted that the TW test has high specificity but low sensitivity in patients.

The PP test is a VSR test evaluating deviations in the upper limb. It is the least researched VSR test method in the literature. Babic et al. [16] stated that this test showed the lesion side correctly in the first two weeks of the disease, but test sensitivity was <50% even during the first week. Mukasa et al. [17] performed this test in patients with UVL and reported a sensitivity of 25.8%; sensitivity was 2.5% in our study. Upper limb weakness or other diseases that may cause deviations in this test may not have been sufficiently excluded; this may be the reason our results are much lower than those obtained in the aforementioned study. The low sensitivity may also be due to the test being performed in a sitting position.

Gait includes the integration of information from visual, vestibular, and somatosensory systems. Visual afferents are particularly important for walking activities. In the absence of visual input, vestibular information is integrated with somatosensory inputs, making an important contribution to targeted movement [13]. Walking performance (especially walking speed) has been defined as the gold standard for evaluating balance and functional performance in vestibular disorders [18]. Deviations in walking, tenure, and loss of balance are qualitative ways to score these tasks. It is controversial whether walking tests can reliably distinguish individuals with vestibular disorders when quantified.

Fukuda, TW, and BW tests are modified states of walking. The extent to which these tests provide accurate information in the diagnosis of UVL has been explored in prior studies and different values have been observed. These results should not be interpreted as representing the functioning of a particular organ. Upright posture and walking physiology are extremely complex and are the result of a number of functions. Vestibular, proprioceptive, acoustic, and visual stimuli are of decisive importance. Changes in many factors (such as having eyes closed) increase the effectiveness of the vestibular function. In our study, Fukuda and BW tests were conducted with eyes closed; the fact that the TW test was conducted with eyes open may have caused the vestibular system to be adequately evaluated. All tests were conducted in a quiet environment as acoustic stimuli may affect test results.

The most significant limitation of the current study is that upper and lower extremity preferences were not explored. Fukuda, TW, and BW tests may be impacted by leg dominance. The PP test may be affected by hand dominance. The small sample size is accepted as another limitation of the current study.

In the absence of objective methods for conducting vestibular evaluation, the Fukuda test is the preferred subjective evaluation. Although this test yields more sensitive results for UVL than other tests, it would be beneficial for clinicians to use it with objective methods owing to its low sensitivity. In addition, it would be useful to repeat all tests three times in clinical settings to obtain more reliable findings. Further studies are needed in patients with and without vestibular compensation to examine the effects of vestibulospinal compensation on subjective VSR test results.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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