The Journal of International Medical Research
2011; 39: 1432 – 1437 [first published online as 39(4) 9]

Reliability of the Fukuda Stepping Test to Determine the Side of Vestibular Dysfunction

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The Fukuda stepping test (FST) is widely used in neurology and for the diagnosis of vertigo-associated disease, but its reliability is disputed. This study assessed the accuracy of the FST in determining the side of vestibular dysfunction in 126 patients with unilateral vestibular lesion. Abnormal deviation towards the side of the lesion occurred in 50.0% of cases and towards the intact side in 24.6% of cases, with 25.4% of patients within the normal range (< 45° deviation). An equal percentage of patients with acute stage vertigo (0 – 3 days after onset) deviated towards the intact and lesion sides, however the percentage of patients deviating to the intact side decreased over time. A subset of patients who originally deviated towards the intact side gradually began to deviate towards the lesion side. Care should be taken when using the FST to determine the side of the lesion, particularly in acute stage vertigo.

KEY WORDS: Fukuda stepping test; Spontaneous nystagmus; Vestibular dysfunction; Vertigo

Introduction

The stepping test with closed eyes was first proposed for the diagnosis of vertigo-associated disease by Unterberger in 1938,1 and was improved and quantified by Fukuda.2 In the Fukuda Stepping Test (FST), a circle with a radius of 1 m is divided into sections by lines passing through the centre. The angle of rotation (deviation) and the distance of displacement (lateral shift) are used to determine the side of any lesion. A study of > 500 normal subjects determined that a deviation > 45° and a lateral shift > 1 m was abnormal, and that the deviation was a more reliable indicator than the distance of displacement.2 The average angular deviation of the normal population has been variously reported as 24.2° and 16.1 ± 12°.2,3 A single study has shown that a test with 100 steps is more reproducible than 50 steps,4 and digital craniocorpography analysis of the motion rate and latency of deviation of the head, shoulder and trunk improves test precision and detail.5,6

The stepping test with closed eyes has been shown to be more sensitive than the Romberg test, where the patient is required to stand still with closed eyes.1 – 9 Some physicians, however, do not consider the stepping test to be reliable.10 – 12 Opinions vary on whether the test is influenced by right/left handedness or right/left leg dominance.10,13,14 Patients who walked for 2 h on a treadmill subsequently deviated in the same direction as the treadmill, suggesting that somatosensory and locomotor stimulation can influence FST.15

The present study examined FST findings in patients with unilateral vestibular deficit in order to assess the value of the FST in determining the side of the lesion and whether the direction of deviation is
correlated with stage of disease (time since onset of vertigo).

Patients and methods

Patients with unilateral vestibular dysfunction (vertigo) of varying duration who were attending the Department of Otolaryngology, Eye and ENT Hospital of Fudan University, Shanghai, China were recruited prospectively between October 2008 and June 2010. Idiopathic sudden sensorineural hearing loss was diagnosed according to US National Institute for Deafness and Communication Disorders guidelines, and vestibular neuritis was diagnosed according to the recommendations of Baloh. All patients underwent pure tone audiometry, spontaneous nystagmus testing, caloric reflex testing and computed tomography. The side of the lesion was determined by combining test results and medical history information. Patients whose lesion side could not be determined were excluded from the study, as well as those with dysfunction of the spine, muscle or limbs. Normal controls were recruited from among hospital staff during the same period and were matched for gender and age to the patient group. Normal controls had no vertigo, history of other ear diseases, or dysfunction of the spine, muscle or limbs.

The Ethics Review Board of The Eye and ENT Hospital of Fudan University, Shanghai, China approved the study and written informed consent was obtained from all participants. The study was performed in accordance with the ethical standards of the Declaration of Helsinki.

Fukuda stepping test in vestibular dysfunction

FUKUDA STEPPING TEST
Subjects stood on a marked grid on the floor, extended their arms and stepped in place with closed eyes for 50 steps while attempting to stay in their original location and orientation. Subjects counted out loud in order to assist their concentration. The examiners remained close by in silence in order to protect the subjects from falling. The examination room was quiet and dimly lit, preventing the subjects from orientating through sound or light. The examiners demonstrated the task prior to testing and patients confirmed their understanding by return demonstration with open eyes. The test was aborted if the patient fell; the direction of fall was recorded. Results were defined as abnormal if the patient fell, deviated by > 45°, or had a lateral shift of > 1 m. The direction of all deviations and lateral shifts were recorded. The test was performed as part of the routine physical examination before making the exact diagnosis, and was repeated 2 weeks after the first clinic visit (follow-up period of 2 weeks).

STATISTICAL ANALYSES
Continuous variables and categorical variables are presented as mean ± SD and number (percentage), respectively. All data were analysed using the SAS software package, version 9.2 (SAS Institute Inc., Cary, NC, USA). The percentages of patients showing FST deviation to the intact side or to the lesion side for vertigo ≤ 30 days’ versus > 30 days’ duration were compared by continuity adjusted χ² test. The percentages of patients showing FST deviation at the different disease stages (times since onset of vertigo) were compared by Cochran–Mantel–Haenszel test and weighted statistics. The Cochran–Armitage trend test was applied to analyse change trends over time. A P-value < 0.05 was considered statistically significant.

Results
A total of 126 patients with unilateral vestibular dysfunction (vertigo) (age range 20 – 70 years, mean ± SD 46.8 ± 13.0 years;
48 males/78 females), and 50 normal controls (age range 20 – 67 years, mean ± SD 43.3 ± 12.0 years; 19 males/31 females) were recruited to the study; there were no significant differences in gender and age distribution between two groups. The patient group included 94 cases of idiopathic sudden sensorineural hearing loss, 11 of temporal bone trauma and 21 of vestibular neuritis.

The mean ± SD angle of deviation in the FST for normal controls was 18.88 ± 11.37° (maximum 42°), with a mean ± SD lateral displacement distance of 21.98 ± 10.90 cm (maximum 55 cm). The mean ± SD angle of deviation in the FST for patients with abnormal deviation to the lesion side was 68.14 ± 20.70° (maximum 135°), with a mean ± SD lateral displacement distance of 31.89 ± 16.11 cm (maximum 100 cm). The mean ± SD angle of deviation in patients with abnormal deviation to the intact side was 65.45 ± 19.30° (maximum 110°), with a mean ± SD lateral displacement distance of 29.84 ± 15.19 cm (maximum 80 cm).

The effect of time after onset of vertigo on the direction and extent of deviation in the FST for the patients showed significant between-group differences (\(P < 0.0004\); Table 1). The percentage of patients with abnormal deviation towards the side of the lesion and towards the intact side at days 1 – 3 after vertigo onset was the same (39.1%). Although the percentage of patients with abnormal deviation towards the side of the lesion showed no significant trend with time (range 48.3% – 61.1%), the percentage with abnormal deviation to the intact side decreased significantly with time (\(P = 0.0006\)). In contrast, the percentage of patients with deviation within the normal range increased significantly with time (\(P = 0.0005\)).

A total of 17 patients had abnormal deviation to the intact side within 7 days after the onset of vertigo. During the subsequent 7
days, six of these patients developed abnormal deviation to the lesion side, with the remaining cases recovering to within the normal range. None of the patients who originally deviated to the lesion side deviated to the intact side at the end of the 2-week follow-up period.

There was a significant difference in the number of cases deviating towards the intact side in patients with vertigo of > 30 days’ duration (1/22, 4.5%) compared with those with vertigo of ≤ 30 days’ duration (30/104, 28.8%; P = 0.033). There was no significant difference in the number of cases deviating towards the lesion side in patients with vertigo of > 30 days’ duration (10/22, 45.5%) compared with those with vertigo of ≤ 30 days’ duration (53/104, 50.1%). The study included 14 patients with vertigo of > 2 months’ duration and, of these, seven (50.0%) deviated to the lesion side and seven (50.0%) had normal deviation.

Spontaneous nystagmus arose in 35 patients within 45 days after onset of vertigo; no patients presented with spontaneous nystagmus after 45 days. Of these cases, 22 (62.9%) deviated in the opposite direction to the fast phase of the spontaneous nystagmus, eight (22.9%) deviated to the same direction, and the remaining five (14.3%) were within normal deviation range (Table 2). Spontaneous nystagmus was directed towards the lesion side in three (8.6%) cases. A subset of five patients who deviated within the normal range developed spontaneous nystagmus toward the intact side (15.6%). The direction of the FST deviation had no correlation with the direction of spontaneous nystagmus.

Discussion

The FST is based on the vestibulospinal reflex and is widely used in neurology and the diagnosis of vertigo-associated disease. It can help in identification of the side of the lesion in bilateral vestibular dysfunction asymmetry.1,2 Previous studies have demonstrated FST to be more sensitive than the Romberg test in the detection of unilateral vestibular abnormalities,8 and that FST time, body spin and angular deviation are significantly increased in patients with peripheral vestibular disease.6 The reliability of the FST is, however, disputed.19 – 21 In comparison with caloric reflex testing, the FST has been determined as unreliable for peripheral vestibular asymmetry screening in chronically dizzy patients,22 in contrast to the findings of others.23 A study of patients with nearly compensated peripheral vestibular defects found FST to be of no diagnostic value.24

The FST findings in normal control subjects in the present study were similar to those from previously published data.2,7 A subset of

TABLE 2: Incidence of spontaneous nystagmus and direction of deviation in the Fukuda stepping test (FST) for 126 Chinese patients with unilateral vestibular dysfunction

<table>
<thead>
<tr>
<th>FST deviation</th>
<th>To intact side (n = 32)</th>
<th>To lesion side (n = 3)</th>
<th>No nystagmus (n = 91)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal deviation (&gt; 45°) to lesion side</td>
<td>20</td>
<td>1</td>
<td>42</td>
</tr>
<tr>
<td>Abnormal (&gt; 45°) to the intact side</td>
<td>7</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>Normal (&lt; 45°)</td>
<td>5</td>
<td>0</td>
<td>27</td>
</tr>
</tbody>
</table>

Data presented as numbers of patients. The direction of FST deviation had little consistency with the direction of spontaneous nystagmus: weighted \( \kappa = 0.1129; 95\% \) confidence interval 0.0025, 0.2232.
patients in the present study who originally deviated in the direction of the intact side, gradually began to deviate to the side of the lesion, before finally falling within the normal range. This is in contrast to patients who originally deviated to the lesion side, none of which changed direction of deviation to the intact side. Direction reversal of shaking-induced and vibration-induced nystagmus has been shown to occur in 25% of vestibular neuritis cases, and is believed to be accounted for by central nervous system (CNS) compensation. In follow up of 55 patients with vestibular dysfunction for 6 months, 71% presented with direction reversal of spontaneous nystagmus, directional preponderance and FST deviation during compensation. The present study found that an equal number of cases (39.1%) with unilateral vestibular dysfunction (vertigo) for ≤ 3 days deviated towards the intact side and towards the lesion side in the FST, suggesting that FST during the acute stage is unreliable as an indicator of vestibular lesion side. The identification of the lesion side should be based on a combination of medical history and serial examinations.

The direction of spontaneous nystagmus is generally opposite to the side of the lesion, and the direction of deviation in the FST is the same as the lesion side, so the direction of spontaneous nystagmus should, theoretically, be opposite to the direction of deviation in the FST. In the present study, 62.9% of cases conformed to this rule compared with 22.9% who deviated in the same direction as the nystagmus. A subset of patients who deviated within the normal range developed spontaneous nystagmus toward the intact side (15.6%). This may be due to the different compensation processes for FST and nystagmus, or to differences in the reflex path. Spontaneous nystagmus was directed towards the lesion side in 8.6% of cases, indicating considerable unreliability in the use of spontaneous nystagmus in identifying the side of the lesion.

The number of patients in the present study who deviated to the intact side decreased over time and some began to deviate to the side of the lesion. A consequence of peripheral vestibular organ lesion is increased discharge in the ipsilateral vestibular nuclei and CNS-mediated inhibition of contralateral vestibular nucleus activity. A study in guinea-pigs found that animals with an intact CNS developed spontaneous nystagmus after bilateral vestibular neurectomy, suggesting that vestibular excitation asymmetry could result from incongruity of CNS compensation. The changes in direction of deviation observed in the present study could, therefore, be due to CNS over-compensation and to CNS hypo-compensation.

In conclusion, the present study found the FST to be unreliable in identifying the lesion side in acute vestibular dysfunction. The phase of disease (time since vertigo onset) influenced the FST findings but the mechanism of this effect remains unclear. It is possible that CNS over-compensation may account for the deviation towards the intact side observed in some patients.

Acknowledgements
We thank Dr Y Yu, Department of Biostatistics, School of Public Health, Fudan University, for assistance with the statistical analysis. The study was supported by grants from the National Natural Science Foundation of China (No. 30700939) and Research Foundation of Shanghai Health Bureau (No. 2006y09).

Conflicts of interest
The authors had no conflicts of interest to declare in relation to this article.
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