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The clinical investigation of static and dynamic balance

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Abstract. *The clinical investigation of static and dynamic balance.* This article describes the clinical examination of static and dynamic balance. The purpose is to illustrate the guideline for the diagnosis and management of vertigo. For most of the tests, indicative normal values are given and discussed. The paper also looks at the clinical examination of gait.

1. Index test

This test is performed on a seated patient whose eyes are closed. The aim is to look for the presence of past pointing, the tendency for the outstretched arms and fingers to drift unidirectionally. In peripheral vestibular disorders, lateral deviation of the index is directed towards the side of the lesion (or towards the slow phase of the spontaneous nystagmus). Non-harmonious past pointing, the deviation of only one index or vertical deviation suggest a central vestibular disorder. Vertical deviation of the arms and fingers may also result from motor or proprioceptive disorders.

This test is mainly interesting for the diagnosis of acute vertigo. It is useful to compare the direction of the nystagmus (observed with Frenzel spectacles) and the direction of the postural deviations. Furthermore, in the case of acute vertigo, this is the only test that can be performed in a patient confined to bed. On the other hand, in a patient with chronic vertigo, a simple weakness may induce a deviation. Furthermore, this sign disappears progressively as vestibular compensation is established.

A dynamic variation of this test, looking at the tendency for the repetitively elevated and lowered outstretched fingers to drift unidirectionally, may be performed to enhance sensitivity. Another dynamic variation is the finger-pointing test. It is more sensitive than the finger-to-nose test for cerebellar dysmetria or hypermetria. The patient is instructed to follow the finger of the clinician by rapidly pointing towards each new position it takes.

2. Romberg test

The patient stands, feet together with eyes open then closed (to eliminate visual clues) in order to compare static balance in these two states. Normally, there is no body sway or directional fall.

In unilateral peripheral vestibulopathy, the patient slowly deviates towards the side of the lesion. This observation must be reproducible. In neurological pathology, postural balance is less affected by eye closure (except in sensory ataxia). However, this test is not very sensitive, so more difficult variations of the Romberg are described:

- Jendrassik's manoeuvre: the patient is asked to pull both hands in opposite directions with the fingers linked together, resulting in an enhancement of muscular relaxation in the lower members.
- Romberg test in tandem: patient places one foot directly in front of the other (heel to toe): this test is very difficult and few elderly people are able to manage it.
- Push test: the patient is put off balance by an antero-posterior push followed by a lateral push. This variation of the test is often used if malingering is suspected.
- Clinician may distract the patient by writing numbers on his forearm if a psychological disorder or malingering is suspected.

It is interesting to investigate how head position influences the direction of postural deviation as postural reactions initiated by vestibulospinal reflexes are usually opposite to the direction of the fast phase of nystagmus. Patients with right peripheral vestibular lesion will show lateral body deviation towards the right. Asking the patient to turn the head to the right (left) will result in a backward (forward) fall.

Normal values for the Romberg standing test were reported by Nyabenda *et al.*[1] in a sample of 120 healthy subjects broken down into different age categories (ten-year brackets, with each age category including 20 subjects). In this study, postural deviation was measured in standing subjects with eyes closed and arms outstretched as described by Gill *et al.*[2] Lateral drift of the fingers was measured by reference to the vertical axis. Lateral deviation was considered to be significant if maintained during 30 seconds.

Significant index deviation was found in four subjects only: a subject aged 69 years (5 cm, 5% of the age category) and three subjects in the 70-79 age category (3-10 cm, 15% of the age category).[1]

Romberg's standing test was also investigated using craniocorpography (CCG).[3,4] The patient is marked with lights upon both the shoulders and the head by means of a hard hat containing marker lights above the forehead and the occiput. Lights are reflected through a mirror system on the ceiling into a video camera and a computer which receives, analyses and prints the signal (a newer marking method uses ultrasound markers and an ultrasound receiver unit instead of light markers).

Table 1 shows the normal values for the CCG of the standing test.

Table 1

Normal values for the longitudinal and lateral sway as measured by craniocorpography during Romberg's test. These data were derived from a neuro-otological data bank with 10,335 normal and neuro-otological cases [Claussen CF: communication at the 30th Annual Meeting of the Neurootological and Equilibriometical Society (NES) Porto – Portugal, April 3-5, 2003]

Parameters for standing CCG	Normal range – Lower border	Normal range – Upper border
Longitudinal sway	1.75 cm	10.53 cm
Lateral sway	1.74 cm	7.06 cm

Romberg's test is a useful method for studying patient with symptomatic falls. If cerebral vascular hypoxia, epilepsy, cerebellar ataxia, intoxication or sensorimotor loss are the main aetiology of pathological falls, vestibular dysfunction is a significant differential diagnosis for these patients. Brandt and Dieterich[5] classified central and peripheral vestibular falls in relation to the preferred direction of falling.

Peripheral vestibular syndromes

Vestibular neuritis results in slow falling towards the side of the lesion.

Benign paroxysmal positioning vertigo: patients in whom attacks of vertigo are elicited by head tilt exhibit large sway amplitudes, predominantly in the fore-aft direction. Instability decreases progressively in parallel with the reduction of nystagmus and vertigo.

Tumarkin's otolithic crisis: in this particular version of Ménière's disease, patients feel as if they are thrown to the ground without warning. This "drop attack" is not preceded or accompanied by vertigo. Patients remain conscious.

Otolithic Tullio phenomenon: diagonal and backwards towards the unaffected ear.

Bilateral vestibulopathy: instability is multidirectional with the largest amplitude in the fore-aft direction. Patients often complain of oscillopsia associated with head movement or when walking.

Central vestibular syndromes

Several vascular or tumour disorders at the level of the brainstem may involve the central vestibular pathway. Ipsiversive postural deviation usually results from lateral medullar lesions while contraversive postural drift results from pontomesencephalic brainstem lesions. Thalamic lesions involve either ipsi- or contraversive postural deviation.

Postural imbalance is frequently combined with central ocular signs or symptoms (nystagmus with central features, ocular tilt reaction, failure of vertical gaze, lateropulsion of the closed eyes, tilt of perceived visual vertical, Claude Bernard Horner's syndrome, internuclear ophtalmoplegia,…), with sensorimotor signs affecting the limbs or cranial nerves, and with cerebellar syndromes. A careful examination is therefore required, since the main apparent symptom is the patient's inability to maintain an upright posture.

One exception should be noted: in some cases of Wallenberg's syndrome, the nystagmus may be horizontal-rotatory beating in the opposite direction from postural deviations ("harmonious nystagmus").

Lesions of otholitic central pathways or some thalamic diseases may occur without paresis or sensory or cerebellar deficit. In these cases, ocular signs are of particular importance.

Downbeat nystagmus syndrome is often associated with a tendency to fall backwards.

Diagnostic elements

- Backward falls suggest sensory ataxia, especially when the eyes are closed. When the eyes are open, the backward deviation suggests frontal-lobe or fronto-pontine disorders. These features are also observed in a range of degenerative syndromes or in diffuse cerebral arteriosclerosis.
- Fore-aft deviations are often associated with cerebellar ataxia.
- In sensory ataxia, the Romberg test results only in slight unsteadiness when the eyes are open. When patients close their eyes, large and disordered oscillations occur. This contrasts with the slow and progressive deviation observed in patients with peripheral vestibular disorders.

3. Unterberger and Fukuda's stepping test

The stepping test initially described by Unterberger is commonly used to assess individuals with peripheral vestibular dysfunction or balance instability. Patients are required to step on the spot with arms outstretched. In the initial form of this test, normal subjects show no deviation or rotation while patients with peripheral vestibular dysfunction rotate progressively towards the side of their lesion.

In 1956, Fukuda[6] added a spider's web drawn on the floor, within which the patients had to perform their stepping. This makes it possible to quantify displacement after a series of 50 steps. Angle of rotation (spin), angle of displacement and distance of displacement are measured. The most reproducible parameter is the spin: Fukuda considers a rotation of more than 30 degrees while stepping to be pathological.

A common variation of this test is a stepping test with the arms alongside the body. Results are globally similar.[7]

However, the test-retest reliability of the Fukuda's stepping test is a subject of discussion.[8] Several authors have reported that the stepping test does not appear to be useful for the detection of abnormalities in the vestibular system or for distinguishing normal individuals from patients. In a prospective study of 131 normal and pathological subjects, they found considerable inter- and intra-individual variation in direction and width of rotation and in displacement.[9] Others studies reported the same results and conclusions.[10,11]

A quantification study for the Fukuda stepping test has been published.[1] The protocol included 45 steps, with arms alongside the body. Of 120 normal subjects in different age categories, only two presented no deviation and there were four subjects in whom there was no spin. Subject displacement was always forwards, never backwards. The mean values for distance of displacement, angle of displacement and angle of rotation are reported in Table 2. The correlation between age and angle of deviation or angle of rotation was significant ($r = 0.56$, $p < 0.000$). The correlation between age and forward displacement was not significant ($r = 0.17$, $p = 0.06$). Unfortunately, the authors did not report the percentage of healthy subjects (they were all normal in this study) who performed an abnormal test (*i.e.*, more than 30° spin as described by Fukuda), which would be more significant for clinical practice. However, it seems obvious from their table of results that this percentage also increased with the age of the subjects.

In a study of 48 healthy subjects ranging from 20 to 35 years, Wintgens reported mean spin values of 27° (+/- 4° SD) after a 50-step test (communication presented at the Journées de Posturologie, December 6-7, 2002, Brussels). During the first trial of the stepping test, 75% of the healthy subjects performed the classic Fukuda stepping test in the normal range (defined by these authors as 32° spin) and 71% of the subjects performed a normal Fukuda's test with arms alongside the body (Table 3).

Using CCG, Claussen reported a normal spin value of 82° after a 100-step test.[3,4]

As for the reliability of the test, which was also discussed above, Nyabenda reported good test-retest reliability for body spin and angle of deviation.[1] A change in the direction of the rotation from one test to another was only observed for one subject. Reiss *et al*.[12] reported similar results.

Wintgens also reported good test-retest reliability for the mean spin value and for the global percentage of abnormal tests (communication presented at the Journées de Posturologie, December 6-7, 2002, Brussels). A major problem persists: subjects do not present consistently abnormal spin values in the first and second parts of the test (a subject may be normal (spin <32°) in the

Table 2

Mean values (and standard deviation) of distance of displacement, angle of displacement and angle of rotation measured during a stepping test.[1] The protocol included 45 steps, arms alongside the body

	Forward displacement (cm)		**Angle of deviation (d°)**		**Angle of rotation (d°)**	
Age category	Mean	SD	Mean	SD	Mean	SD
20-29	60.7	30.7	19.9	7.8	13.9	6.9
30-39	62.5	26	32	10.1	23.2	10.6
40-49	71.7	35	35	12	26.7	11.3
50-59	73.3	40.7	37.8	13.4	31.9	10.6
60-69	76.2	40.2	39.1	9.8	34.7	11.4
70-79	75	33	41.5	10.9	42.1	10.1

Table 3

Number of subjects in whom spin is within the normal range (here: 32°) after the 50th step in the first and second run and in the two runs, and subjects outside the normal range in the same conditions. Fukuda = arms extended; Fukuda repeat = arms alongside the body. The subjects considered to be normal or abnormal, Fukuda or Fukuda repeat, identical in the first and second run or not, are not necessarily the same in each line

		Number of subjects with abnormal spin		
	Test component	Abnormal left spin	Normal	Abnormal right spin
Fukuda	First	5	36	7
	Second	4	37	7
	Identical	2	29	3
Fukuda repeat	First	9	34	5
	Second	5	40	3
	Identical	2	29	1

first part and abnormal in the second). Table 3 contains more detailed results.

In conclusion, it is not easy to state a normal reference value for the stepping test since the protocols described earlier are dissimilar. Nyabenda's study[1] clearly demonstrates that age is an important factor to take into account when interpreting the Fukuda test. The reliability and the specificity of this test are debated. So clinicians should interpret the results of the stepping test with caution, especially if it is used as a screening tool. Clinicians should make different static and dynamic tests of balance and compare their results in order to arrive at clear conclusions about balance in their patients.

4. Standard gait and star gait (Babinski-Weill test)

The standard gait test was first described by Fregly and Graybiel.[13] The patient is required to walk 3.5 metres, with eyes closed, in three successive runs. Deviation from the straight line is measured. This simple test, which is easier than Fukuda's test or than the star gait test, may be the most useful test for evaluating the evolution of vestibular compensation.

During the star gait test (Babinsky-Weill), subjects are required to walk 3 to 5 steps forwards then backwards, with their eyes closed. The star gait is a result of the systematic unilateral postural deviation that occurs in peripheral vestibular pathology. It is not always easy to conduct the test in practical terms since a large space is required to ensure that subjects cannot orient themselves within the room.

Normative values are difficult to report since the variations in the method are even greater than for the stepping test. To provide an indication, the results of a study by Nyabenda *et al*.[1] are reported in Table 4. There is considerable correlation between age and deviation, as was seen in the stepping test ($r = 0.71$; $p < 0.000$).

5. Examination of walking

Gait examination may sometimes help to determine whether a posture and walking disorder is induced by a vestibular or a central disorder. Of the various neurology syndromes that may induce walking difficulties, falls and dizziness are often associated with central vestibular and cerebellar syndrome, with sensory ataxia, Parkinson's syndrome and frontal lesions. Gait examination starts when the patient enters the examination room. Some gait features would appear to be immediately characteristic.

Clinical examination continues with the patient barefoot. A careful observation of trunk posture, stance and walking is performed. The clinician should notice the overall pattern of body movement during walking, the swinging motion of arms and legs, the

Table 4

Mean values (and standard deviation) of angle of displacement during a standard gait test (patient are required to walk 5 m with their eyes closed in a straight line) and a star gait test (three series of three paces forwards and backwards)

	Standard gait		**Star gait (Babinsky Weill)**	
Age categories	**Mean (°)**	**SD (°)**	**Mean (°)**	**SD (°)**
20-29	10.3	4.8	1.7	0.8
30-39	18	5.6	2.3	0.7
40-49	21	7.2	2.8	1.1
50-59	23.6	10	3.4	0.8
60-69	26.3	14	4.0	1.1
70-79	28	11	4.5	0.9

regularity and the size of the strides, the speed of walking and the synergy of head, trunk and leg movements.

Subtle syndromes may be revealed by asking the patient to stop and go, to walk in a straight line heel-to-toe (tandem gait), to walk and turn quickly. Other special manoeuvres consist of asking the patient to crouch, to sit and to stand up, to walk on their heels and then to walk on tiptoe.

Akinetic-rigid gait

The classic and most common akinetic-rigid gait disorder is seen in Parkinson's disease. Of course, falls are induced by walking difficulties but interestingly, late in the syndrome, patient falls result from the loss of postural and righting reflexes (that do not respond to levodopa medication).

Patients adopt a flexed truncal posture with stooped trunk, shoulders and neck. Gait is slow and rigid with small paces and loss of the swinging of one or two arms. Tremor of the upper limbs might be present but is less commonly observed in the lower limbs. Initiating the first step is difficult so that patients begin walking with a few rapid, very short, shuffling steps (start hesitation); sometimes patients actually step up and down in the same place without any forward progress. Episodes of freezing (complete cessation of movement, "feet glued to the floor") are also typically observed in patients with Parkinson's disease. Freezing may also be present if a doorway or another obstacle is encountered; shuffling and freezing may be revealed if the patient is asked to turn back quickly. To maintain balance when walking, patients may move forwards in a series of very small steps (festination) while bent forwards (subjects look as though they are running after their centre of gravity).

Cerebellar syndrome

Patients adopt a wide base stance. Backward and forward rhythmic swaying occurs. This instability is not influenced by eye closure but is greatly increased if patients bring their feet closer together. Gait is slow, strides are irregular and variable in timing (dyssynergia) and the steps are erratic as if the patients are drunk. This particular gait is often observed in alcoholism (selective damage affecting the cerebellar vermis) where legs and gait are usually affected while ocular movement, speech and upper limbs are spared. With lesions confined to one cerebellar hemisphere, anomalies will be limited to the affected ipsilateral limb and will affect coordination of movement more than balance (if the vermis is not involved). Patients tend to fall towards the side of the lesion and throw their leg on the affected side too high and outwards. Finally, in lesions affecting the vestibular part of the cerebella, symptoms resemble those observed in peripheral unilateral vestibular disease.

Unilateral peripheral vestibular syndrome

Clinicians should be attentive to sudden changes in gait direction or lateropulsion, especially if these abnormalities depend on head movements. Paradoxically, lateropulsion away from the side of the lesion may occur as a result of voluntary efforts to correct balance.

Cautious gait

Putting aside the typical cases described above, it is important to note that patients with any decline in walking ability and balance tend to develop compensation mechanisms that may disguise the underlying problem. Those patients will adopt a slower gait with shorter and shallower steps in order to keep contact with the ground for a longer time (cautious gait). This cautious and guarded gait is often present in the elderly. Factors contributing to a decline in the mobility of the elderly in crude degenerative joint disease, reduced range of limb mobility and limited exercise capacity due to cardiovascular fitness decline. Additional factors might be sensory deficit (vision, vestibular and proprioceptive function) without any one lesion being severe enough to explain the observed walking difficulty. Another common factor might simply be the fear of falling. Clinicians should not diagnose Parkinson's disease in all these patients, even if some aspects of gait look similar!

In all these cases, gait examination will not immediately lead to a diagnosis and a complete vestibular and neurological examination should be performed.

7. Dynamic gait index

The Dynamic Gait Index was developed by Anne Shumway-Cook[14] and has been used in older adults to determine their likelihood of falling. Scores of 19 or less are related to falls in older adults. The index tests 8 facets of gait and can be used with an assistive device. Self-reported falls in the past six months and Dynamic Gait Index scores have been found to be related in persons with vestibular disorders.[15] The dynamic gait index has also been used to determine the effect of vestibular rehabilitation on the reduction of fall risk in individuals with unilateral vestibular hypofunction.[16]

1. Gait level surface

Instructions: walk at your normal speed from here to the next mark (20')
Grading: mark the lowest category that applies.

(3) Normal: walks 20', no assistive devices, good speed, no evidence of imbalance, normal gait pattern.
(2) Mild impairment: walks 20', uses assistive devices, slower speed, mild gait deviations.
(1) Moderate impairment: walks 20', slow speed, abnormal gait pattern, evidence of imbalance.
(0) Severe impairment: cannot walk 20' without assistance, severe gait deviations or imbalance.

2. Change in gait speed

Instructions: begin walking at your normal pace (for 5'). When I tell you "go", walk as fast as you can (for 5'). When I tell you "slow", walk as slowly as you can (for 5').
Grading: mark the lowest category that applies.

(3) Normal: able to change walking speed smoothly without loss of balance or gait deviation. Shows a significant difference in walking speeds between normal, fast, and slow speeds.
(2) Mild impairment: is able to change speed but demonstrates mild gait deviations, or no gait deviations but unable to achieve a significant change in velocity, or uses an assistive device.
(1) Moderate impairment: makes only minor adjustments to walking speed, or accomplishes a change in speed with significant gait deviations, or changes speed but loses significant gait deviations, or changes speed but loses balance but is able to recover and continue walking.
(0) Severe impairment: cannot change speeds, or loses balance and has to reach for wall or be caught.

4. Gait with horizontal head turns

Instructions: begin walking at your normal pace. When I tell you to "look right", keep walking straight, but turn your head to the right. Keep looking to the right until I tell you to "look left", then keep walking straight and turn your head to the left. Keep your head to the left until I tell you to "look straight" then keep walking straight but return your head to the centre.
Grading: mark the lowest category that applies.

(3) Normal: performs head turns smoothly with no change in gait
(2) Mild impairment: performs head turns smoothly with slight change in gait velocity, *i.e.*, minor disruption to smooth gait path or uses walking aid.
(1) Moderate impairment: performs head turns with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk.
(0) Severe impairment: performs task with severe disruption of gait *i.e.*, staggers outside 15" path, loses balance, stops, reaches for wall.

4. Gait with vertical head turns

Instructions: begin walking at your normal pace. When I tell you to "look up", keep walking straight but tip your head and look up. Keep looking up until I tell you, "look down". Then keep walking straight and turn your head down. Keep looking down until I tell you, "look straight", then keep walking straight, but return your head to the centre.
Grading: mark the lowest category that applies.

(3) Normal: performs head turns with no change in gait.

(2) Mild impairment: performs task with slight change in gait velocity i.e., minor disruption to smooth gait path or uses walking aid.
(1) Moderate impairment: performs task with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk.
(0) Severe impairment: performs task with severe disruption of gait *i.e.*, staggers outside 15" path, loses balance, stops, reaches for wall.

5. Gait and pivot turn

Instructions: begin walking at your normal pace. When I tell you to "turn and stop", turn as quickly as you can to face the opposite direction and stop.
Grading: mark the lowest category that applies.
(3) Normal: pivot turns safely within 3 seconds and stops quickly with no loss of balance.
(2) Mild impairment: pivot turns safely in >3 seconds and stops with no loss of balance.
(1) Moderate impairment: turns slowly, requires verbal cueing, requires several small steps to catch balance following turn and stop.
(0) Severe impairment: cannot turn safely, requires assistance to turn and stop.

6. Step over obstacle

Instructions: begin walking at your normal speed. When you come to the shoebox, step over it not around it, and keep walking.
Grading: mark the lowest category that applies.
(3) Normal: is able to step over box without changing gait speed; no evidence of imbalance.
(2) Mild impairment: is able to step over box, but must slow down and adjust steps to clear box safely.
(1) Moderate impairment: is able to step over box but must stop, then step over. May require verbal cueing.
(0) Severe impairment: cannot perform without assistance.

7. Step around obstacles

Instructions: begin walking at normal speed. When you come to the first cone (about 6' away), walk around the right side of it. When you come to the second cone (6' past first cone), Walk around it to the left.
Grading: mark the lowest category that applies.
(3) Normal: is able to walk around cones safely without changing gait speed; no evidence of imbalance.
(2) Mild impairment: is able to step around both cones, but must slow down and adjust steps to clear cones
(1) Moderate impairment: is able to clear cones but has to slow down significantly to accomplish task, or requires verbal cueing.
(0) Severe impairment: unable to clear cones, walks into one or both cones, or requires physical assistance.

8. Steps

Instructions: walk up these stairs as you would at home (i.e., using the rail if necessary). At the top, turn around and walk down.
Grading: mark the lowest category that applies.
(3) Normal: alternating feet, no rail.
(2) Mild impairment: alternating feet, must use rail.
(1) Moderate impairment: two feet to a stair, must use rail.
(0) Severe impairment: cannot do safely.

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