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Rethinking the neurological examination II

Dynamic balance assessment

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ABSTRACT
The authors propose that the neurological exam needs reevaluation with respect to the dynamic balance test (walking). Validated tests such as: preferred and maximum gait speed, dynamic gait index, five-times-sit-to-stand test, timed up & go cognitive and manual, should be part of the neurological examination routine. In the neurological exam of older patients, these same bedside tests bring the plus of evaluation the risk of occasional falling.
Key words: neurological examination, dynamic balance, dynamic gait Index, timed up & go, risk of falling.

Repensando o exame neurológico II: avaliação do equilíbrio dinâmico

RESUMO
Os autores propõem que o exame neurológico tradicional seja reavaliado no que diz respeito ao exame do equilíbrio dinâmico (marcha). Testes validados tais como: velocidade da marcha - preferencial e máxima; índice dinâmico da marcha, teste senta-levanta cinco vezes e o tempo levanta-e-anda cognitivo e manual, deveriam fazer parte do exame neurológico de rotina. Na avaliação neurológica dos pacientes idosos, esses mesmos testes à beira do leito trazem benefício adicional ao aferir o risco de queda ocasional.
Palavras-Chave: exame neurológico, equilíbrio dinâmico, índice dinâmico da marcha, tempo levanta-e-anda, risco de queda.

For all animals, walking is a complex neurological activity that involves multiple levels of the nervous system focusing on two main essential components: mobility and balance[1,2]. In human beings, safe walking is a universal marker of the quality of life. Studenski[3] registered that walking represents a final summation of multiple physiological inputs and should be considered the 4th geriatric vital sign.

The study of the dynamic balance evolution is based not only on analyzing patients but, substantially, also on animals. These studies demonstrated several "intensity stimulation dependent areas" – locomotor subthalamic, midbrain, cerebellar, pontine tegmentum and ponto-medullar reticular formation – that affect the walking. So as the stimulus becomes more intense on these areas, the gait pattern also changes, ranging from walking to trotting, galloping, and running[4,5].

The central integration governing the maintenance of stability, both static and dynamic, reacts quickly and relies on the integrity of proprioceptive, visual and vestibular functions. It is considered that 65% of the relevant information to maintain dynamic equilibrium comes from the vestibular system, while the highest contribution to maintain static equilibrium comes from proprioceptive system[6]. The

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vestibular system is responsible for sensing motion of the head, stability of images on the fovea, and postural control. When functioning normally, the vestibular receptors in the inner ear provide an exquisitely accurate representation of the motion of the head. On the other hand, disorders of vestibular function lead abnormal information about motion[7].

Walking, both for humans and other animals, is characterized, among others aspects, by the time interval between the heels contacting the ground two times with the same foot (two steps). We divide this rhythmic cycle into two components: the swing phase and phase-out. The first phase (62% of the cycle) occurs when the foot lifts up and starts to be projected forward with respect to the body. The second phase (38% of the cycle), when a foot is on the floor. Other walking study parameters include: gait speed, cadence, stride time, stride length, and single support (as percentage of stride time)[4].

In some neurological diseases the gait is so striking and stereotypical that even empirical diagnosis stands with little chance of error. In this regard, Gilles de la Tourette stated: "In normal gait it is the person who moves. In pathologic gait it is the disease that generates walking". The fact is that; in some diseases the walking is an adaptive response to the limitations imposed by the illness.

In the traditional neurologic examination (NE), gait analysis has always been more focused on the recognition of abnormal gait patterns like: myopathic, hemiplegic, *petits pas*, etc.[8]. However, the unarmed examination of the dynamic balance has developed and should not be restricted only to observations of the free walking. Examination of the gait together with examination of static balance may be better explored by the neurologist, produce reliable and reproducible data, and is an excellent opportunity to predict the possibility of fall risk, especially in elderly patients.

Two moments are of utmost importance in assessing dynamic balance. The first is during the rise – the gait study begins with the patient still seated – and the second is during the turn. The postural reflexes are much more stressed by rotating the body than when walking in a straight line[5]. Often, during a turn the balance disturbance and instability are first noticed. For example: in Parkinson's disease and in ataxias. The physician should note if the patient needs extra steps to turn the body, move excessively the feet to maintain balance, or if there is freezing.

A useful trick to sensitize the examination of dynamic equilibrium is asking patients to walk through a narrow passage or walk while performing another task (see timed up & go (TUG) manual and cognitive, below). A more challenging maneuver is to ask the examinee to make a 360° turn, first in the preferred direction and then in the opposite direction[9]. These clues can reveal subtle changes that are not seen during free walking. Curiously, walking backwards greatly improves the gait pattern of choreiform patients[2].

The purpose of this article is to encourage the gait examination using some very simple-to-perform bedside tests, which takes little time from the examiner, but may provide important information about the dynamic balance and also check the risk of falls in elderly patients.

Gait speed (preferred and maximum)

Examination of gait speed (preferred and maximum) is easy and fast to be executed and can help the clinician to assess the functional status of the patient. Gait velocity depends on three major systems: cardiopulmonary, neurological and skeletal muscle, and is an indicator of motor function, health status, as well as a prognostic factor for several diseases[3]. Slower gait speed is a risk factor for falls in old adults[10].

The test consists on check the time required for the individual to walk, in the most comfortable pace, a distance of six meters (the minimum distance to free gait assessment), first in preferred speed (PS), then at maximum speed (MS). It is necessary to measure the correct distance and use a stopwatch[11,12]. Gait velocity is calculated by dividing the distance (six meters) by time, in seconds. Table 1 shows some normative values.

Bohannon[13] consider that age, short stature, and little strength in the legs reduces the MS more than the PS. According to Swedish government standards, the functional state suitable for the elderly is to, among other things, walk comfortably 1.4 m/s. This speed was determined because it is considered the "normal" speed necessary for a pedestrian takes to cross an urban intersection[14].

Tandem gait

Asking the patient to walk heel to toe is part of routine neurological examination of many neurologists and represents a major challenge to patients, even those slightly ataxic, regardless the cause[5].

Instruct the examinee to keep eyes closed and arms folded across the chest while walking ten steps forward,

Table 1. Normative values for preferred and maximal gait speed (m/s).

20's years old	PS men: 1.09; women: 1.06 MS men: 1.95; women: 1.96
50's years old	PS men: 0.94; women: 1.09 MS men: 1.17; women: 1.49
At 70 years old (m/s).	PS men: 0.94; women: 0.85 MS men: 1.35; women: 1.19

Gait speed shown are Mean –2SD. PS: preferred speed; MS: maximum speed.

heel to toe, without hurrying. Observe the mistakes, not only by excessive balance, but also by the number of side steps. Normal individuals are able to execute tandem gait for at least ten steps without failures. Patients with acute or chronic vestibular dysfunction fail to accomplish 10 steps in this way. The side of the "out step", is an attempt to maintain balance, but is not a sure indicator in defining the side of the vestibular lesion[15].

Tandem walking with eyes open is mainly a test of cerebellar function due to the fact that vision compensates both the chronic vestibular and proprioceptive deficits[6]. Tandem gait with eyes closed seems to be a better test of vestibular function; the successful test indicates that cerebellar function and proprioceptive are intact[13]. The acute vestibular lesion, however, can prevent tandem gait, even with eyes open.

The test can be sensitized by asking the patient to walk on a narrow path high from the ground, but failure to perform this test is nonspecific and many individuals considered normal at any age, cannot run it.

Tandem walking not only assesses the dynamic balance on a narrow, but may also aid in the differential diagnosis of atypical parkinsonism (including: multiple system atrophy, progressive supranuclear palsy, and vascular parkinsonism), and Parkinson's disease[16]. More than two side steps aside while performing the task points towards an atypical parkinsonism[13]. Also, tandem walking was more sensitive (82%) and only slightly less specific (92%) in this differentiation than the "bicycle signal" (loss of the ability to cycle after disease onset, signaling the presence of atypical Parkinsonism), which had a sensitivity and specificity of 52% and 96% respectively[17,18].

Five-times-sit-to-stand test

Sitting and standing is a transitional movement which occurs many times a day. It is moderately correlated with walking speed, and has already been validated as a measure of leg strength[11,19]. The manner in which the individual organizes his body to rise illustrates an anticipatory postural response. The examiner observe the resources used by the patient to stand up: if the inclination of the body is adequate, if attempted several times, or if the examinee distributes his weight well on his feet. If he keeps his feet far apart as he sets up, it is often an indicator of instability, even when he holds the narrow base when standing[5].

Difficulty rising from a chair predicts a risk of falling. The five-times-sit-stand test (FTSST) was validated in patients with asymmetric vestibular function. The test showed 87% sensitivity and 84% specificity, in young adults, with a cutoff of ten seconds[20].

The only required resources for evaluation are a chair (43-46 cm tall, 47.5 cm deep) and a stopwatch. The patient should sit with arms folded across the chest and the back against the chair back. Request to the patient to lift (fully) and sit five times as fast as possible. The examinee should not lean back in the chair at each repetition. Begin timing when you say "up" and stop the stopwatch when the examinee sits on the chair after the fifth iteration[11].

The discriminative analysis showed that FTSST correctly identifies 65% of individuals with loss of balance (81% in examinees younger than 65 years). The optimal score (more sensitive and specific) for FTSST was ten seconds for individuals under 65 years and 14.2 seconds for older patients[20].

Dynamic gait index

The dynamic gait index (DGI) is a clinical test developed by Shumway-Cook[21] and has been validated in patients with known vestibular hypofunction, which makes it powerful to predict fall risk. This test considers eight different aspects of gait. The items include walking: freely; at different speeds; with head pointing up; with head pointing down; with head turned to the right side; with head pointing to the left; and then performing a 180° turn; around and over obstacles; and climbing a stair[20]. Regarding the last item, if there is not any stair available for the test, it is worth asking the patient how he would accomplishes the task.

Each value follows a pattern of pre-established responses[12]. The criteria summarized scores are as follows (Table 2).

We believe that the DGI should be used routinely by all neurologists interested in checking the dynamic balance of their patients as a validated and practical index of safety. The required resources are: a six meter distance mark, two cones (or something like), a shoe box, and a stopwatch. In general, with a little practice, the time spent evaluating the DGI does not exceed ten minutes.

Timed up & go

The TUG, is a very easy test to perform which measures in seconds the time required for the patient to rise from a chair (height of seat: 43-46 cm), walk as safely and

Table 2. Dynamic gait index test.

0	Severely impaired; can-not complete the test without assistance, large deviations and imbalances, insecure, staggers and tends to fall
1	Moderate impairment; abnormal gait pattern with slow speeds, with moderate walks, staggers but recovers
2	Mild impairment; needs support (e.g. cane) for walking, walks with variances, use short steps
3	Normal

Total points: 24. Scores below 19 points represents a risk of falling, especially in patients with vestibular dysfunction.

quickly as possible the distance of three meters, turn 180 degrees, walk back and sit down again. The complete test lasts less than one minute, can be performed in any environment (home or office), and requires only a chair with arms and a stopwatch.

Establish a mark three meters away from the boundary of the previous chair. Allow the patient to use any assisted device (cane, crutch, or walker). The examinee does not need aid from the examiner. With the patient sitting with his back against the chair back and arms in armrest, the following statement is said: "Get up and walk comfortably and safely at my command to "Go". At this moment the examiner starts marking time and stops at the exact moment that the patient back sits on the seat[11,12]. The TUG already have standard values according to age (Table 3), and showed a good level of reliability and high levels of sensitivity and specificity for detecting risk of falling[1]. Times below ten seconds are considered normal. Times measured between 11 and 20 seconds are considered within normal limits, but only for the elderly, frail, or dependent on aid. A time over 14 seconds indicates a risk of falling. Score should be the time average of two trials[1].

Scores above 20 seconds are indicative of impairment of functional mobility, and more than 30 seconds indicates dependence in most activities of daily living[11]. In vestibular patients TUG show sensitivity (80%) and specificity (56%) for falls using a cut-off of 11.1 seconds[10].

Timed up & go divided attention

Walking is an automated rhythmic motor behavior that is mostly controlled by subcortical brain regions. Automaticity implies that gait can be performed without attention[22]. On the other hand, recent evidence suggests that the difficulty in performing dual tasks simultaneously, cognitive or manual, creates great difficulty in allocating attention to specific balance while walking and can contribute significantly to increase the risk of falls, which may not be apparent during conventional NE of older adults[23].

Timed up & go cognitive

Count the required time for the patient performing the TUG reciting aloud alternating letters of the alphabet (e.g., "a-c-e") or counting backward by threes from any number between 20 and 100.

Changes in gait patterns due to simultaneous performance of an attention-demanding task are interpreted as interference caused by competing demands for attention resources involving the cortical level in gait control[22]. Dual-task related gait changes are a new way to assess age-associated change in gait control or even normal pedestrians using mobile phones[24].

Table 3. Timed up & go (in seconds).

Age (years)	Male	Female
60-69	8	8
70-79	9	9
80-89	10	11

Table 4. Walking while talking (WWT) (12 meters) gait speed and risk of falling.

WWT	Over 18s at risk for falls
WWT simple	Over 20s at risk for falls
WWT complex	Over 33s at risk for falls

There is a dynamic interplay between the cognitive and motor tasks during divided attention tasks. Walking at a normal pace requires minimal cognitive involvement, and relies on automatic motor control processes. When additional cognitive demands are introduced during walking, attention resources have to be shared between both the cognitive and the motor tasks as suggested by decrements on gait performance[25].

Verghese et. al. [26] demonstrated a positive predictive value of 71% for falls in older adults undergoing TUG - cognitive, versus 42% for those undergoing TUG simple.

Timed up & go manual

The evaluation method is the same as the TUG. Count the time required for the standing individual, to walk, turn, and sit back taking a full glass of water in one hand. If the difference between the TUG manual and TUG is greater than 4.5 seconds, this indicates an increase risk of falls[11].

Walking while talking

The study of gait variability under dual-task walking while talking (WWT) represents a new challenge for the clinicians because high stride-to-stride variability is a powerful fall predictor in older adults[22].

WWT is a variant of cognitive TUG where it measures the time needed to walk comfortably at self-selected speed (without running) six meters per round (12 meters total) – the stages stand and sit are not taken into consideration.

In the WWT – simple, the subject walks the same round trip (12 meters total), and recites letters of the alphabet sequentially. Performing the test in over 18 seconds represents an increase risk of falling (Table 4).

Increasing the degree of difficulty in the cognitive task reciting alternate letters of the alphabet or counting serial 3 backward from any random number between 20 and 100 (WWT – complex), reduces gait velocity. Performing the test in over 33 seconds increases the risk of falling[12,23,25].

Lundin-Olsson et al.[27] showed that of twelve examinees that stopped walking when a conversation started, ten of them fell during the six-month follow-up. Besides that, with high specificity and low sensitivity, those who stopped walking when talking had a significantly less safe gait, performed basic mobility more slowly, and were more dependent in activities of daily living.

In conclusion, traditionally, unarmed observer walking is one of the most essential parts of the neurological examination. In recent decades, new methods of gait analysis, beyond simply observing the freely walking, arose from related specialties, like, for instance, neuro-otology and vestibular rehabilitation. We suggest that some of these bedside tests, which are very simple to be performed and interpreted, should become part of the routine neurological examination. In elderly patient exams, these tests also greatly facilitate the measurement of the risk of falling. Therefore, such additions can transform the traditional neurological examination in an assessment more useful, practical, and even prognostic.

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