Eur Arch Otorhinolaryngol (2015) 272:2201–2206
DOI 10.1007/s00405-014-3122-3

OTOLOGY

Is there a relationship between objective and subjective assessment of balance in elderly patients with instability?

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Received: 23 December 2013 / Accepted: 22 May 2014 / Published online: 12 June 2014

Abstract To assess whether a subjective questionnaire that measures the disability caused by balance disorders in daily life activities is correlated to objective assessment of balance in elderly patients with age-related instability. We included 37 subjects aged 65 years or more who presented balance disorders induced solely by age. Balance assessment was through the sensory organisation test and limits of stability of computerised dynamic posturography, the SwayStar system and the modified timed up and go test. The patients also completed the dizziness handicap inventory (DHI) questionnaire. The SwayStar balance control index (BCI) was most significantly correlated to the DHI score and the score of its different scales. When we divided the patients into subgroups according to DHI score, we only found statistically significant differences in the BCI and number of falls. In our population of elderly patients with instability, there is practically no correlation between the DHI and the static balance assessment. However, there is greater correlation with the BCI, which could show that dynamic balance is perceived as more disabling for these patients. In this case, when designing a rehabilitation protocol we should focus more on dynamic activities such as gait.

Keywords Dizziness handicap inventory · Computerised dynamic posturography · SwayStar · Balance · The elderly

Introduction

Balance becomes more precarious with age and balance disorders become more common. Their prevalence is difficult to calculate, as different factors affect its correct estimation, which is the reason for the shortage of reliable data in this population group [1]. Most prevalence studies were conducted in specific groups such as institutionalised or hospitalised patients, which cannot be extrapolated to the elderly population due to different functional and mental capacities.

In the published studies, balance disorders among the elderly patients who require medical care, need pharmacological treatment or limit activity show a prevalence ranging from 4 to 29 % [2–4]. When considering the prevalence of balance disorders in elderly patients in general, it rises to 37–61 % [5, 6], and is greater among women [5].

Accidental falls, especially in such elderly patients, represent one of the main social-healthcare problems in ageing western societies [7]. Nearly a third of all people who fall three or more times a year are hospitalised, admitted to a residential facility or die in the following year [8]. Repeated falls are therefore a prognostic factor for greater morbidity–mortality.

Falls also have significant social and psychological consequences, as patients tend to lose self-confidence, limiting their physical activity due to a fear of falling

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again. This generates isolation and interferes greatly with their daily life activities, significantly reducing their quality of life [9, 10].

There are questionnaires such as the dizziness handicap inventory (DHI) that have been shown to be useful for identifying specific functional, emotional or physical problems related to balance disorders [11]. It has also been translated into and adapted to Spanish, maintaining high reliability and internal consistence [12].

The objective of this study is to discover whether DHI score is related to assessment through objective balance-evaluation tests in elderly patients with instability in our setting.

Materials and methods

This study forms part of a research project funded by the National Institute of Health Carlos III (National R&D&I Plan 2008–2011, dossier PI11/01328) entitled "Reduction in falls by the elderly by the use of vestibular rehabilitation to improve balance". It is cross-sectional and was conducted in a tertiary university hospital.

Study population

The age of the study subjects was 65 years or more, and they presented balance disorders solely due to age. An otoneurological examination was performed to rule out other causes, including assessment for the absence of spontaneous or induced nystagmus with the head shake test, and the absence of saccades by the Halmagy test. The study was completed with videonystagmography, vestibular evoked myogenic potentials or imaging tests when necessary. They also presented a high risk of falling, meeting at least one of the following inclusion criteria:

- Having fallen at least once in the last 12 months.
- Taking more than 15 s, or needing support, in the modified timed up and go (TUG) test.
- Obtaining a score of less than 68 in the average score of the sensory organisation test (SOT) of the computerised dynamic posturography (CDP).
- Having fallen at least once during the SOT.

The study's exclusion criteria were:

- Cognitive decline that prevents the patient from understanding the examinations.
- Balance disorders caused by conditions other than age (neurologic, vestibular, etc.).
- Organic conditions that prevent standing, which is necessary for a complete postural assessment.

Study variables

We collected data about the number of falls by the patients in the 12 months prior to inclusion in the study.

Postural assessment was by the following tests:

- CDP. We used the Neurocom® Smart Equitest platform to perform the following tests:

(a) SOT. This posturograph consists of a moveable platform and screen, which can remain fixed or move in proportion to the force of the patient's feet; the patient stands on the platform and attempts to maintain his or her balance in the romberg position when sensorial conditions change [13]. The test assesses centre of gravity stability in six different sensorial conditions:

- Condition 1: fixed surface and visual surround, eyes open.
- Condition 2: fixed surface, eyes closed.
- Condition 3: fixed surface, eyes open, moving surround.
- Condition 4: moving surface, eyes open, fixed surround.
- Condition 5: moving surface, eyes closed.
- Condition 6: moving surface, eyes open, moving surround.

Each of these six conditions is repeated three times to calculate the average results obtained in each condition. The duration of each record is 20 s.

Analysing and comparing the responses to the different sensorial conditions, we can quantify the contribution of sensorial receptors to maintaining balance. The study analysed the following variables:

- Average balance score, obtained by weighting the means scores of each sensorial condition.
- Somatosensory input, which is the percentage value that results from the following formula: (mean score of condition 2/mean score of condition 1) ×100.
- Visual input, calculated as the result of: (mean score of condition 4/mean score of condition 1) ×100.
- Vestibular input, calculated as: (mean score of condition 5/mean score of condition 1) ×100.
- Visual preference, calculated as: [(mean scores of conditions 3 + 6)/(mean scores of conditions 2 + 5] × 100. It is a measure of the patient's reliance of visual information, even when that information is incorrect.

(b) Stability limits: the patient's ability to move his or her centre of gravity (CoG) to eight positions in a circle at a distance of 100 % of the theoretical greatest for the patient's age of the space represented on the posturograph's screen [13]. We analysed the following parameters:

Fig. 1 SwayStar mounted on belt at trunk level

- Reaction time: time from signal movement to start of patient movement.
- Mean velocity: mean speed of CoG movement as degrees per second.
- Endpoint excursion: distance travelled by CoG in first attempt to attain the target.
- Maximum excursion: longest distance travelled by CoG during the test. It can differ from the above if corrective movements are attempted because the first attempt fell short.
- Directional control: comparison between quantity of movement in the object's direction and the quantity of movement in another direction.
- SwayStar system (Fig. 1): it enables us to analyse and quantify the postural control during static, dynamic and gait tasks. It is based on measuring the angular deviations of the trunk in different sensorial conflict situations. The equipment is mounted on a belt on trunk level (around L3–L5) and has two angular velocity transducers. The transducers are oriented in roll and pitch planes. A software programme records and analyses the velocity and angle of trunk movements. The conditions in which this system was used were as follows:
- Static, standing (SS), eyes open, normal surface (NS).
- SS, eyes closed, NS.
- SS on one leg, eyes open, NS.
- SS on one leg, eyes closed, NS.
- 8 steps in tandem, eyes open, NS.
- SS, eyes open, foam surface (FS).
- SS, eyes closed, FS.
- SS on one leg, eyes open, FS.
- 8 steps in tandem, eyes open, FS.
- Walk 3 m, moving the head up and down.
- Walk 3 m, turning the head from side to side.
- Walk 3 m, eyes closed.

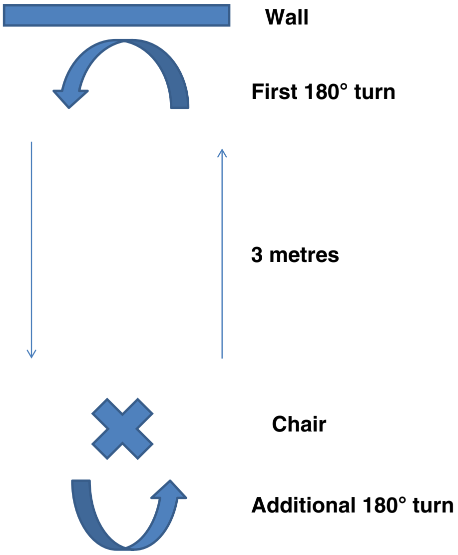

Fig. 2 Diagram of modified TUG (additional turn)

- Climb up and down two steps.

The balance control index (BCI) is used for the analysis. It is a summary value derived from the different stance and gait tasks [14].

- Modified TUG. In the standard test [15], the subject rises from a chair (without arm support), walks 3 m towards a wall, turns around and returns to sit on the chair. In the modified test [16], when the patient returns to the chair, he or she has to walk around it once before sitting (an additional 180° turn). We analyse the time taken to perform the test and the number of steps required (Fig. 2).

All the patients completed the Spanish version of the DHI [12]. It assesses the disability induced by balance disorders in daily life activities. It comprises 25 questions divided into three groups (9 on the functional scale, 9 on the emotional scale and 7 on the physical scale), with three possible answers: yes (four points), sometimes (two points) and no (zero points). The highest score (representing the greatest disability) is therefore 100. The resulting disability can be classified as mild (0–30), moderate (31–60) or severe (61–100) [17].

Statistical analysis

We first analysed the correlations between the different quantitative variables of the postural study with the DHI and its different scales (using Pearson's or Spearman's correlation test). It was then analysed whether there were different characteristics between the patients according to degree of disability identified by DHI (mild/

Table 1 Descriptive balance assessment results

Variable	Mean	Standard deviation
Average balance score	56.19	13.507
Somatosensory input	94.38	7.610
Visual input	64.51	24.406
Vestibular input	30.84	24.741
Visual preference	100.00	20.774
Reaction time	1.18	0.314
Mean velocity	2.27	0.740
Endpoint excursion	49.57	11.357
Maximum excursion	66.30	10.752
Directional control	66.86	13.280
BCI (SwayStar system)	767.92	179.548
Time (TUG)	20.15	6.824
Steps (TUG)	25.86	6.447

moderate/severe) using analysis of variance (ANOVA) or the Kruskal–Wallis test. We tested the hypothesis of normal distribution of the different variables with the Kolmogorov–Smirnoff test. The level of statistical significance in all the tests was $p < 0.05$. The SPSS 17.0 package for Windows was used for the statistical study.

Ethical aspects

The study was conducted according to the Declaration of Helsinki and all the patients granted their consent to participate in the study in writing. The study protocol was approved by our regional committee on research ethics.

Results

The study sample comprised 37 patients with a mean age of 74.39 ± 4.626 years, 29 of them women and 8 men. Their mean height was 154.36 ± 7.654 cm, their mean weight was 73.90 ± 9.252 kg and the mean BMI was 30.80 ± 3.318 kg/m^2.

The patients presented a mean of 19.24 ± 61.367 falls in the last 12 months. Thirty of them presented at least one or more falls in the period.

Table 1 shows the descriptive results of the different postural study tests.

The mean DHI score was 52.76 ± 25.300. 24.32 % of the patients presented mild disability (0–30), 40.54 % moderate disability (31–60) and 35.14 % severe disability (61–100).

When analysing the global DHI score with the results of the postural assessment, we found the following statistically significant correlations:

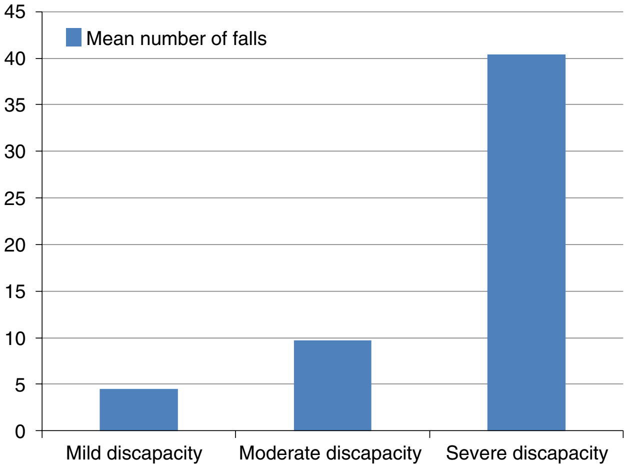

Fig. 3 Mean number of falls per year according to degree of disability (mild/moderate/severe) measured by DHI

- In relation to the CDP, we only found a weak negative correlation between the somatosensory input of the SOT and the physical scale (−0.362, $p = 0.027$; Spearman's correlation).
- The SwayStar BCI shows a moderate correlation with global DHI score (0.432, $p = 0.008$; Pearson's correlation) and the functional scale (0.406, $p = 0.013$; Pearson's correlation). The correlation was weak with the physical (0.370, $p = 0.024$; Pearson's correlation) and emotional (0.368, $p = 0.025$, Pearson's correlation) scales.
- In relation to the modified TUG, we found weak correlations between global DHI score (0.362, $p = 0.028$, Pearson's correlation) and the emotional scale (0.368, $p = 0.025$, Pearson's correlation).
- Relative to number of falls in previous year, we found a weak correlation between DHI emotional scale and number of falls (0.332, $p = 0.045$; Spearman's correlation).

When we divided the patients into subgroups according to DHI score, we only found statistically significant differences in the BCI ($p = 0.014$, ANOVA) and number of falls ($p = 0.016$, Kruskal–Wallis test). Figure 3 shows the mean number of falls in each subgroup.

Discussion

Correlation between DHI and SOT in different patient groups varies according to the study [18–22]. Specifically in our population of elderly patients with instability, correlations are practically non-existent with this test, which assesses static balance, other than with the use of somatosensorial information, which shows a weak relationship. This could indicate two things:

- Poor use of proprioceptive information is very disabling in these patients. Indeed, another study shows that proprioceptive control deficiency is of key importance in these patients' falls [23].
- In daily life activities, these patients do not usually face the most complex conditions of the SOT (moving surface or visual surround) so they are not correlated with their disability.

To a certain extent, we are surprised to find that the DHI is not correlated with LOS, as when the latter are diminished the risk of falling would appear to be greater [24]. However, we did find a correlation between number of falls and the emotional scale of the DHI, confirming the psychological consequences of such falls [9, 10].

The correlation between the DHI and TUG time is weak, consistent with other studies [17, 20]. The results do not therefore show that slower walking speed is more disabling in our patients.

Of the variables analysed in the postural study, the most closely related to the DHI is the BCI, which could show that poor dynamic balance is a disabling factor in daily life activities. Indeed, nearly half of the falls in this group of patients occurred when walking [25]. This could have important clinical implications, particularly when it comes to designing a vestibular rehabilitation protocol, which should focus more on dynamic activities such as gait.

Finally, objective and subjective assessments are always complementary, and the latter can also help to choose the most appropriate treatment for each patient, according to his or her disability. In fact a complete balance study in elderly patients with falls will allow us for the implementation of rehabilitation programmes which is the final objective of the present study.

Acknowledgments This study was supported by a grant of the National Institute of Health Carlos III (National R&D&I Plan 2008–2011, dossier PI11/01328).

Conflict of interest The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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