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ORIGINAL ARTICLE

Value of dynamic postural control tests on elderly people with vestibulopathy

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KEYWORDS
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Abstract
Introduction and objectives: The stability limits and rhythmic weight shift tests study the functional capacity to achieve voluntary postural control of movement in the standing position. The objectives of this paper are to know the interest of these tests in the evaluation of elderly people with vestibular disorders and their relation with the number of falls suffered during the year prior to the study.
Material and methods: Sixty elderly people (65-80 years old) with vestibular disorders (patients) and 60 healthy subjects (control group) of similar age were selected. According to videonystagmographic and clinical criteria, the patients group was divided into compensated and decompensated. All the subjects in the sample performed the stability limits and rhythmic weight shift tests with the NedSVE/IBV system. The number of falls of each subject was determined by a meticulous anamnesis.
Results: Compensated patients, decompensated patients, and the control group had similar scores in this instrumental functional evaluation, without any statistically significant differences. None of the parameters assessed in this study correlated statistically with the subjects' number of falls during the year prior to the study.
Conclusions: The stability limits and rhythmic weight shift tests are of little utility in the functional evaluation of the elderly with vestibular disorders and in the detection of patients with greater risk of falls.

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PALABRAS CLAVE
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Caídas

Valor de las pruebas de control postural dinámico de la posturografía en ancianos con vestibulopatía

Resumen

Introducción y objetivos: Las pruebas de los límites de estabilidad y de control rítmico direccional estudian la capacidad funcional para el control postural voluntario del movimiento en bipedestación. En este trabajo se pretende conocer el interés de estas pruebas en la valoración de estabilidad; los ancianos con vestibulopatía y la relación con el número de caídas que sufrieron durante el año anterior al estudio.
Material y métodos: Se seleccionó a 60 ancianos de 65-80 años con trastornos del sistema vestibular (pacientes) y 60 sujetos sanos (grupo control) de similar edad. El grupo de pacientes se dividió en compensados y descompensados, según criterios videonistagmográficos y clínicos. Todos los sujetos de la muestra realizaron las pruebas de los límites de estabilidad y de control rítmico y direccional mediante el sistema NedSVE/IBV. Se determinó el número de caídas de cada sujeto mediante una minuciosa anamnesis.
Resultados: Las puntuaciones obtenidas en esta valoración funcional instrumental por los pacientes compensados y descompensados y los sujetos del grupo control fueron muy similares, sin diferencias estadísticamente significativas. Ninguno de los parámetros valorados en este estudio se correlacionó de forma significativa con el número de caídas de los sujetos durante el año anterior al estudio.
Conclusiones: Las pruebas de los límites de estabilidad y de control rítmico-direccional tienen escasa utilidad en la valoración funcional de los ancianos con trastornos vestibulares y en la detección de pacientes con mayor riesgo de caídas.

Introduction

Postural control refers to the regulation of the integral body position (posture) in space with the goal of keeping it in balance at rest (static balance) or moving (dynamic balance).[1] It could also be defined as the ability to maintain the body's centre of gravity within the base of support during static sitting and standing positions and during movement. Ultimately, postural control is the ability of an individual to acquire and maintain the desired position spontaneously and in response to external disturbances, and to ensure stability during the performance of body movements.

In falls among the elderly, there are usually diverse causal factors involved to a greater or lesser extent, both from the individual and also related to the environment.[2] Aging leads to a set of changes in the body which increase their emergence. In addition, there are many diseases that contribute to the higher incidence of these events in the elderly.[3] Among these, the diseases and disorders of the vestibular system deserve special attention as they are characterized by a postural disorder manifesting itself during movement and the activities of daily living[4] and may predispose to falls.[5] Therefore, it is important to study postural control in elderly people suffering from these diseases and its relation to falls.

Studies of postural control through posturography systems have typically focused on static posturography tests and sensory organization tests using computerized dynamic posturography, in which the subject must maintain the upright position in situations of sensory restriction. However, there are fewer studies analyzing the stability limit tests (SL) and the rhythm-direction control of movement (RDC), which study voluntary (not reflex) dynamic postural control while standing, without external imbalance or sensory restriction.

The SL is the maximum angle measured from the vertical at which an individual can lean without changing the base of support.[6] It is estimated to be 12.5° in the anteroposterior direction (8.25° anterior and 4.25° posterior) and 16° in the mediolateral direction (8° to the right and 8° to the left).[7] It could also be defined as the border of an area of space where the body position can be maintained without changing the position of the feet. These limits can be altered by factors related to the individual (pathological processes, task performed) or related to the environment (poor lighting, uneven flooring, etc).[8] If at any time the vertical projection of the centre of gravity of the body (CGB) is outside the SL, the subject will need to move a foot to prevent a fall (step strategy).

The objectives of this work are: *a)* to ascertain whether the elderly with vestibular diseases have an altered voluntary dynamic postural control when standing compared to a control group of subjects without vestibular disorder, and *b)* to determine if there is a relationship between the number of falls in the sample studied and the results of the instrumental study conducted.

Material and method

We studied 60 patients with balance disorders (peripheral vestibular diseases or central disorders) and 60 subjects without any known postural control abnormalities, who formed the control group. The minimum age of the subjects studied was 65 years and the maximum was limited at 79 years, to make it conform to that of the subjects making up the normalcy database of the Institute of Biomechanics in Valencia.[9]

Subjects with symptomatic disorders of the musculoskeletal apparatus and known neurological disorders which could affect postural control were excluded from the study; subjects who were taking vestibular sedatives, antidepressants, anxiolytics, or other central action drugs were also excluded.

We performed a detailed clinical history for all subjects in which we collected the number of falls experienced during the year preceding the study. We evaluated all patients by caloric and rotary tests, conducted by videonystagmography (VNG) (Ulmer v. 1.4, Synapsis®, Marseilles).

In order to evaluate the status of vestibular compensation in patients with peripheral vestibular disease, we used clinical and videonystagmographic criteria. We considered as decompensated those patients who presented positioning nystagmus caused by the Dix-Hallpike or McClure manoeuvres and those who met any of the videonystagmographic criteria described by Eisenmann et al.[10]

Instrumental study

We used the NedSVE/IBV posturography system.[9] The assessment of voluntary dynamic postural control in standing position included the determination of the SL and analysis of the RDC. The SL test analyzes the voluntary movement of the centre of gravity of an individual in 8 directions (anterior, anterior-right, right, posterior-right, posterior, posterior-left, left, and anterior-left), and offers a comprehensive assessment. Once the subject was on the platform (standing with the heels together and the toes separated at an angle of 30°),[11] a cursor was shown on a monitor which reflected the position of the centre of gravity. For 8 seconds the subject had to move and try to keep the centre of gravity within each target, the position of which depended on the age and size of the individual, the factors by which the database for normalcy of the Institute of Biomechanics in Valencia[9] is segmented. The anterior target was the first, following the order of movement clockwise. The calculated parameters for each of the 8 stability limits were as follows: *a)* maximum displacement (%): percentage reached regarding the normal pattern (segmented by gender, age, and height) of the maximum displacement reached in each direction; *b)* reaction time (s): time spent by each individual to reach the limits of stability; *c)* directional control (%): linearity of the path followed by the subject to reach each limit of stability; *d)* success (%): stability of the subject after reaching the target in each of the limits of stability; and *e)* confinement time (s): time elapsed since the start of the test until the projection of the centre of gravity left the central target. The score of each SL was based on the following weighting of the parameters studied: maximum displacement (55%), reaction time (10%), directional control (25%), success (5%) and confinement time (5%), with respect to patterns of normalcy. An evaluation of 100% reflected normality and different ratings expressed discrepancies with respect to it. The final SL score obtained was an average of the scores obtained in each of the 8 limits.

The RDC test is based on voluntary tracking with the centre of gravity of a moving target that the subject sees on a monitor placed to the front at eye level. The study consisted of two parts: in one the target moved rhythmically and horizontally on the screen, and the subject had to move his or her centre of gravity from left to right and vice versa to track the movement. In the other, the target was moving rhythmically and vertically on the screen, and the subject had to move his or her centre of gravity from front to back and vice versa, to follow it. In each of them the target was moving at 3 different speeds: slow for the first 14 s, continuing at intermediate speed during 10 s, and finally, at a faster pace for 6 s. The targets moved up to 60% of the maximum anteroposterior and mediolateral distances achieved by the subject in the SL test. We calculated the following parameters: *a)* ability (%): quantifies the tightness of movement of the centre of gravity of the subject, with respect to the direction of motion of the moving target, and *b)* control and efficiency (%): estimates the monitoring carried out by the subject with his or her centre of gravity in the direction perpendicular to the movement of the target.

Statistical analysis

We employed the statistical package SPSS v.13. In the comparative analysis, we applied Levene's homogeneity test of variances and the Kolmogorov-Smirnov test to assess the degree of normality of continuous variables. To compare independent quantitative variables we used the analysis of variance (ANOVA) and post hoc tests to compare each group with the others. To establish the relationship between quantitative variables we used the Pearson correlation coefficient. Sample differences were considered statistically significant when $P<.05$ and highly significant when $P<.01$.

Results

The group of patients (n=60) comprised 4 sub-groups: *a)* 13 subjects diagnosed with benign paroxysmal positional vertigo (BPPV); *b)* 18 who had suffered a single neuritis-type vestibular crisis (VUC); *c)* 17 who had several peripheral vertigo crises of Ménière type or benign recurrent vertigo (BRV); and *d)* 12 who were suffering from balance disorders of central origin. Of the total 48 patients with peripheral vestibular disease, it was considered that 30 were decompensated and the remaining 18 were compensated.

Table 1 shows the general characteristics of the sample studied (distribution by gender, age and anthropometric characteristics), as well as the number of falls in the groups studied.

Of the total 120 subjects studied, only 115 could carry out this instrumental study (59 from the control group and 56 patients), due to difficulties in understanding and carrying out the tests.

The descriptive and comparative results with respect to the control group (post hoc tests) in the test of stability limits (anterior, posterior, right, and left limits) and rhythmic and directional control are shown in Tables 2 and 3, respectively.

Table 1 General characteristics and number of falls in the sample studied

	Males/females	Age	Height, cm	BMI	Falls, n
Control group (n=60)	17/43	71.92 (3.29)	158.07 (8.400)	28.17 (3.46)	0.23 (0.50)
Group of patients (n=60)	17/43	71.28 (4.39)	157.87 (9.260)	28.8 (5.01)	1.67 (3.94)
Peripheral (n=48)	14/34	70.97 (4.06)	157.92 (8.750)	28.06 (3.98)	1.71 (4.21)
Decompensated (n=30)	8/22	71.2 (3.68)	157.47 (9.420)	27.39 (3.61)	1.8 (5.00)
Compensated (n = 18)	6/12	70.61 (4.70)	158.67 (8.280)	29.18 (4.60)	1.56 (2.91)
Central (n=12)	3/9	72.5 (5.58)	157.67 (10.43)	31.78 (7.22)	1.5 (2.06)

BMI indicates body mass index.
The data present the average (standard deviation)

Table 2 Descriptive and comparative results (with respect to the control group) in the test for the stability limits (anterior, posterior, right, and left limits)

	Stability limits			
Clinical conditions and stages	Anterior [P*]	Posterior [P*]	Right [P*]	Left [P*]
Normal (n=59)	90.92 (12.87)	89.63 (12.29)	83.32 (14.9)	84.22 (13.56)
SVC (n=17)	93.47 (4.77) [0.591]	90.5 (10.79) [0.806]	86.18 (8.8) [0.414]	84.65 (15) [0.756]
RVC (n=16)	96.19 (2.85 [0.306]	86.44 (15.55 [0.649]	86.38 (15.48) (0.461]	83 (9.43) [0.796]
BPPV (n=12)	95.58 (3.17) [0.461]	89.75 (12.27) [0.915]	82.92 (12.53) [0.849]	85.42 (16.19) [0.728]
Central (n=11)	90.09 (11.94) [0.898]	83.73 (25.18) [0.128]	78.27 (22.12) [0.347]	80.09 (15.01) [0.219]
Decompensated (n=28)	95.04 (3.77) [0.369]	87.46 (14.16) [0.799]	85.89 (9.74) [0.615]	84.11 (13.31) [0.776]
Compensated (n=17)	94.94 (4.17) [0.408]	91.24 (10.42) [0.855]	84.53 (15.97) [0.799]	89.56 (7.76) [0.281]

BPPV, benign paroxysmal positional vertigo; RVC indicates recurrent vestibular crisis; SVC, single vestibular crisis.
The data present the average (standard deviation).
*Comparison of the different subgroups with the normal group.

Table 3 Descriptive and comparative results (with respect to the control group) in the rhythm and directional control test

	Parameters			
Clinical conditions and stages	MLA [P*]	MLCE [P*]	APA [P*]	APCE [P*]
Normal (n=59)	88.52 (16.42)	96.01 (9.6)	93.62 (13.29)	86.1 (20.48)
SVC (n=17)	93.47 (11.38) [0.237]	100 (0) [0.096]	94.94 (12.28) [0.698]	90.77 (11.09) [0.341]
RVC (n=16)	86.83 (14.84) [0.693]	99.83 (0.55) [0.119]	97.44 (7.12) [0.272]	94.22 (11.66) [0.107]
BPPV (n=12)	92.08 (12.62) [0.476]	97.41 (6.07) [0.623]	94.91 (11.25) [0.75]	92.24 (14.31) [0.294]
Central (n=11)	85.33 (15.08) [0.523]	94.14 (15.42) [0.509]	91.73 (13.08) [0.640]	86.95 (19.66) [0.884]
Decompensated (n=28)	89.83 (13.82) [0.773]	99.98 (0.79) [0.518]	96.18 (9.73) [0.632]	95.8 (8.08) [0.241]
Compensated (n=17)	92.11 (12.09) [0359]	98.19 (11.99) [0.791]	91.28 (2.74) [0.591]	86.98 (15.1) [0.875]

APA, anteroposterior ability; APCE indicates anteroposterior control and effectiveness; BPPV, benign paroxysmal positional vertigo; MLA: mediolateral ability; MLCE, mediolateral control and effectiveness; RVC, recurrent vestibular crises; SVC, single vestibular crisis.
The data present the average (standard deviation).
*Comparison of the different subgroups with the normal group.

Table 4 shows the comparison (ANOVA) of results in the instrumental study and the number of falls between the different study groups (controls versus patients, and decompensated versus compensated). There were no statistically significant differences in any studied parameter of the instrumental study. The number of falls in the group of patients was significantly higher than that of subjects without balance disorders (P=.006). However, no significant differences were found between patients with vestibular disorders according to their vestibulo-ocular compensation status (P=.851).

The correlation between scores obtained in the SL and RDC tests and the number of falls by the studied subjects during the year preceding the survey is shown in Table 5. No correlation with statistical significance was found in any parameter analyzed.

Discussion

It is estimated that approximately 30% of subjects over 65 years of age suffer at least one fall annually, and half of these have several.[12]. It is believed that the frequency of these events in patients with unilateral peripheral vestibular disease is similar to that of the general population, but lower than in patients with bilateral vestibular deficits.[13] In our sample, the average number of falls in the group of normal subjects during the year preceding the posturography was 0.23, while the group with pathologies had an average of 1.67. The comparative study documented that patients with vestibular diseases suffered more falls than the control group.

The "classic" static posturography only studies the patient in a position of standing erect, so it does not provide information on the dynamic aspects of postural balance. The limits of stability and the voluntary control of postural changes of a subject report their ability to perform movements safely. When the first are altered or the adjustment of displacements of the centre of gravity is inadequate, it is easier for an eventual fall to take place.

The SL can be affected for different reasons: they are worse in patients with hip prosthetics,[14] Parkinson patients in *off* phase,[15] and when the subject carries a burden on the upper body.[16] By contrast, the increase in quadriceps strength, a balance training program in patients with Parkinson's disease[17] and the intensive practice of Tai Chi[18] are all related to an improvement in the SL.

Subjects in the control group and the different clinical sub-groups studied had similar scores in the SL test. The comparative study found no significant differences between the results obtained by the control group and that of the patients. However, the number of falls was higher in patients than in subjects without balance disorders (P=.006), so this posturography parameter does not seem to be clearly related to the number of falls in the sample studied.

The scores obtained in this instrumental test by compensated and decompensated patients was similar, without statistically significant differences, so the state of vestibular compensation in the sample studied did not influence their limits of stability.

Owings et al[19] noted that different measures of postural stability, including the SL, are of little use in identifying healthy elderly people with repeated falls. In the same sense, Brauer et al[20] in a study by posturography to predict falls in elderly people, found that the stability limits test had little ability to predict them, pointing to its multifactorial origin in the elderly population.

In our sample we found no statistically significant correlation between the total score of the stability limits and the number of falls during the year preceding the posturography, so its study was of limited value in assessing these events in the population studied.

However, Girardi et al[21] noted that this test was the most important part of the dynamic posturography to identify patients with falls, so they consider it a good predictor. In their work, which included patients with multisensorial deficiency, the average number of annual falls was 3.5, but in our sample it was 0.95. This difference could be due to the fact that our study excluded patients with other concomitant sensory disorders.

Table 4 Comparison of the results of the instrumental study and the falls in the groups studied

	Patients versus the control group	Decompensated versus compensated
SL	0.572	0.508
MLA	0.565	0.684
MLCE	0.224	0.076
APA	0.775	0.788
APCE	0.467	0.052
Falls	0.006*	0.851

APA, anteroposterior ability; APCE indicates anteroposterior control and effectiveness; MLA, mediolateral ability; MLCE, mediolateral control and effectiveness; SL, stability limits.
*P<.01.

Table 5 Correlation between the results of the instrumental study and the number of falls during the year prior to the posturography

Test	PC	P	n
SL	0.160	0.087	115
MLA	−0.166	0.077	115
MLCE	0.016	0.966	115
APA	0.064	0.497	115
APCE	0.069	0.468	115

APA, anteroposterior ability; APCE indicates anteroposterior control and effectiveness; MLA, mediolateral ability; MLCE, mediolateral control and effectiveness; PC, Pearson correlation; SL, stability limits.

Although the descriptive study of the study sample indicated that the group of patients obtained better scores than the subjects in the control group in the RDC tests, the comparative analysis found no statistically significant differences; therefore the rhythmic and direction control test does not seem to be useful to discriminate between healthy elderly and those with vestibulopathy. These results could be due to the fact that vestibular disorders do not significantly alter the control of voluntary rhythmic movement while standing.

The results obtained by the compensated and decompensated patients in the 4 parameters studied of the RDC were similar. The comparative study found no differences in any of them between these 2 groups, so it is possible that the lack of vestibulo-ocular compensation has not affected the voluntary control of the mediolateral and anteroposterior displacement of the centre of gravity in the patients studied.

Delbaere et al[22] found a worse result in the test of anteroposterior rhythm and direction control in the elderly with falls with respect to those who had not suffered any. However, in our sample, the comparative study of the parameters studied and number of falls during the year preceding the posturography did not find any correlation with statistical significance. This lack of correlation could be due to the fact that many falls occur while walking, in unexpected situations, and usually when the limits of stability are exceeded, whereas in this test the moving target only moved up to 60% of the maximum distance reached by the test subject in the SL.

Conclusions

The results of voluntary dynamic postural control tests while standing (limits of stability and control of direction and rhythm) were similar in elderly people with decompensated and compensated vestibular disorders and in the control group, so these tests have little relevance to the functional assessment of elderly people with this disease.

No correlation was found between the results of these tests and the number of falls of the sample studied during the year preceding the survey; therefore they are not useful for discriminating the elderly with increased risk of falls with respect to those who do not suffer these events.

Conflict of interests

The authors have indicated there is no conflict of interest.

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