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Digital Craniocorpography and Peripheral Vestibular Diseases

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Abstract: Peripheral vestibular diseases (PVDs) often produce many symptoms but few or no measurable signs. Tests that capture and measure signs permit the comparison between normal and vertiginous populations. The aim of our research was to find movement patterns that could identify PVD patients, using a motion analysis laboratory. The results from 21 asymptomatic volunteers who underwent the Unterberger-Fukuda stepping test were compared to those of 38 PVD patients. We established diagnosis after a complete otoneurological workup prior to the stepping test. The VICON 370 (Oxford Metrics Ltd, Oxford, UK) was used for digital capture and analysis of the stepping tests. Lateral sway, linear and total displacement, shoulder height oscillation, and torticollis angle were the same for individuals in both groups, but stepping time, body spin, and angular deviation were statistically greater in those in the patient group and might help in the diagnosis of PVDs.

Key Words: motion analysis; vestibular diseases; vestibular function tests

Equilibrium is maintained by means of a complex system that includes the cerebellum, brainstem, cerebrum, and sensory organs and their interconnections among other structures. Visual, vestibular, and proprioceptive inputs are constantly informing this system of the body's position in space. A disorder in one or multiple parts of this system may lead to various manifestations, from a sensation of dizziness to complete incapacity to stand upright.

One can study the influence of a diseased vestibule on the oculomotor nucleus through electronystagmography and on the vestibular pathways and cerebellum through vestibular evoked potentials and brain mapping. The direct result of a diseased vestibular organ or proprioceptive system on a patient's equilibrium should also be studied through body movement patterns [1].

Many authors have studied equilibrium and body movements in relation to peripheral vestibular diseases (PVDs). Unterberger, and later Fukuda, developed stepping tests for this purpose [2,3]. Claussen developed a method in which a patient's movement was photographed over polar coordinates during the Unterberger-Fukuda stepping test. His method—craniocorpography—established normal values for body movement patterns called *lateral sway*, *angular deviation*, *body rotation*, and *linear displacement* [4]. Movements, which are often very small, occur in three planes and in four dimensions, if time is included; therefore, stepping tests should be evaluated by precise systems that supply coordinates in three planes and running time [5]. Synchronization of distinct parts of the body during these movements should also be studied [1,6]. The aim of our research was to find movement patterns that could identify PVD patients, using computerized or digital craniocorpography (that is, the Unterberger-Fukuda test measured in a motion analysis laboratory), other than a statistically greater angular deviation in PVD patients found in a previous analysis [1].

SUBJECTS AND METHOD

Patients and Controls

Twenty-one normal individuals having no ear, nose, and throat or orthopedic complaints and having normal otoneurological examination and test results composed the control group. This group included 10 men and 11 women (ages, 19–34 years; average age, 25.48 years). The PVD group included 38 patients. Benign paroxysmal positional vertigo was the diagnosis in 11 patients,

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Ménière's disease in 7, metabolic vestibular disease in 12, vestibular neuritis in 2, chronic otitis media in 2, autoimmune vestibular disease in 1, idiopathic disease in 2, and otosclerosis in 1. This group was composed of 10 men and 28 women (ages, 18–77 years; average age, 43.92 years).

Preparation of Individuals

In this study, each individual received 10 markers. One marker was placed on each hallux, each epicondylus lateralis of the femur, each malleolus lateralis of the fibula, and the superior aspects of each acromion, as well as over the protuberantia mentalis and occipitalis, with the use of a mask that deprived the individuals of vision. Individuals then were isolated acoustically and set upright in the center of the test room, with their sport shoes completely in contact with the ground.

Test Procedure

The VICON 370 (version 2.01, Oxford Metrics Ltd, Oxford, UK), developed for biomechanics, is a system for measurement and analysis of tridimensional movements. After the individuals were prepared for the stepping test, they were ordered to take 80 steps over the same spot, with no specific velocity, in front of the VICON cameras. During the test, six rings of infrared light–emitting diodes directed light, which was continually reflected by glass-covered markers fixed to the parts of each individual being studied. The reflected light was captured by six charged coupled-device cameras mounted on the walls of an infrared light–safe test room. The cameras were located in positions that permitted the capture of all vertical and horizontal movements. The VICON program converted images into binary values that could be seen as digital images of the movements or X, Y, and Z values for each marked part of the body on an EXCEL chart (Microsoft Corp., Redmond, WA).

Each individual underwent two tests. Through formulas, the following eight parameters representing movement patterns were calculated for each test:

- *Lateral sway*: the average sum of the distances between the rightmost point and the leftmost point occupied by the left acromion marker
- *Angular deviation*: the angle formed by the initial axis of the body and a line joining the middle point between the acromia at the beginning and end of the test
- *Test duration*: the amount of time it took from the first step to the eightieth step or first and eightieth hallux movement
- *Body spin*: the angle formed between the body axis at the beginning and end of the test
- *Linear displacement*: the distance from the initial position of the right hallux to its position at the end of the test
- *Total displacement*: the sum of the distances between the point occupied by the right hallux at the beginning and end of each step
- *Torticollis angle*: the angle formed between the line that joins the acromia and the one that joins the head markers
- *Shoulder height oscillation*: the average value of the differences between the maximum and minimum height of the left acromion during the last 10 steps

RESULTS

VICON presented coordinates for all the parts marked with reflecting markers, which permitted the calculation of all eight parameters. The Student's t-test was used in the comparison of test results. Average values and standard deviations are presented in Table 1.

Table 1. Values from the Unterberger-Fukuda Stepping Test Results Analyzed by the VICON 370

	Lateral Sway (mm)	Angular Deviation (deg)	Test Duration (sec)	Body Spin (deg)	Linear Displacement (mm)	Total Displacement (mm)	Torticollis Angle (deg)	Shoulder Height Oscillation (mm)
Controls								
AV	79.37	22.39	50.38	6.79	937.41	1,290.17	3.14	−2.98
SD	± 26.49	± 19.76	± 8.41	± 49.23	± 492.68	± 462.54	± 10.22	± 3.84
PVD patients								
AV	87.57	17.49	56.78	−31.08	1,075.13	1,355.24	−0.52	−1.37
SD	± 34.27	± 67.05	± 13.49	± 50.20	± 470.72	± 520.22	± 5.39	± 6.49
	$p = .151$	$p = .037$*	$p = .003$*	$p < .001$*	$p = .140$	$p = .508$	$p = .169$	$p = .106$

AV = average values; PVD = peripheral vestibular diseases; SD = standard deviation.
*$p \leq .05$.
Note: Results from 21 asymptomatic volunteers (control) and 38 patients with peripheral vestibular disease.

DISCUSSION

In this study, patients with PVDs demonstrated a movement pattern described by the parameters angular deviation and body spin (i.e., a tendency to deviate to the left or right). These results agree with the findings of Claussen [7,8]. Stepping time was also statistically greater for PVD patients, probably owing to the greater difficulty these individuals have in moving with their eyes closed. This was also observed in PVD patients who submitted to other motion analysis methods [9]. Though the VICON permitted the study of vertical movements, shoulder height was not a sensitive parameter in the study of PVD patients. Linear and total displacement and torticollis angle were not statistically different from the results in asymptomatic patients probably because of a tighter proprioceptive control of these movements in PVD patients [10] or a diminished influence of vestibular input in the control of vertical movements of the body.

The VICON system was still slow and expensive in relation to other computer-based programs for analysis of the Unterberger-Fukuda test. However, the VICON system was easily adapted to the test and calculated the coordinates for all parameters.

CONCLUSION

PVD patients present lateral sway, linear and total displacement, shoulder height oscillation, and torticollis angle within the normal range, whereas stepping time, body spin, and angular deviation are statistically greater than the norm. Peripheral vestibulopathy should be considered in patients who experience dizziness and who present results that are statistically greater than the norm in certain parameters, as outlined previously, when subjected to digital craniocorpography.

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