Computerized Analysis of Established Craniocorpography

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Abstract: This study reports 21 patients who suffered from vertigo and underwent a complete otorhinolaryngological evaluation and otoneurological tests to establish a peripheral labyrinthine disorder. All patients were given the Unterberger stepping test in a motion analysis laboratory. Their results were compared to those of a population of 21 normal individuals who were analyzed in the same motion laboratory. A precise description of sway, angular deviation, and test duration was obtained from the VICON motion analysis program. As expected, angular deviation was statistically greater in the group with vestibular disorders.

Key Words: equilibrium; labyrinth; motion analysis

It is well-known that equilibrium is maintained through a complex system that involves 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 problem in one part or in 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 labyrinth on the oculomotor nucleus through electronystagmography and on the vestibular pathways and cerebrum through vestibular evoked potentials and brain mapping. The direct result of a diseased labyrinth or proprioceptive system on a patient's equilibrium should also be studied through body movements.

Many authors have studied equilibrium and body movements. Leitenstorfer [1] objectified muscular oscillations that keep individuals upright. Fischer and Wodak [2] described the rotation of the body after vestibular damage. Basler [3] stated that the body is kept upright owing to constant oscillations of the body's center of gravity. Unterberger [4] used cold-water irrigation of the ear canal and a stepping test to compare normal subjects with patients who complained of dizziness. Fukuda [5] submitted 500 normal individuals to Unterberger's stepping-in-place test and found that there is a limit to rotation and dislocation of the individual after 50 and 110 steps. Claussen [6] expanded this test, creating a method to render the Unterberger-Fukuda test more objective. His method consisted in photographing each individual's movement over polar coordinates and measuring lateral sway, angular deviation, body rotation, and linear displacement. This method, which was able to establish a normal value for each parameter, became known as *craniocorpography*.

Hattori and Fukuda [7], Claussen and Claussen [8], Claussen et al. [9], and Vaz Garcia et al. [10] contributed various methods for the automatic or computerized analysis of the Unterberger-Fukuda test. The use of ultrasonography and microphones to describe body movements electronically was introduced by Claussen et al. [11].

METHOD

The VICON 370 (version 2.01, Oxford Metrics Ltd, Oxford), developed for biomechanics, is a system for measurement and analysis of tridimensional movements. Six rings of infrared light–emitting diodes direct light reflected by glass-covered markers fixed to the parts of an individual being studied. The reflected light

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is captured by six charge-coupled device (CCD) cameras mounted on the walls of an infrared light–safe test room. The cameras are located in positions that permit the capture of all vertical and horizontal movements. The images are converted to binary values in the main computer. The main computer sends these values to the personal computer, which offers digital images of the movements and an Excel chart with *X*, *Y*, and *Z* values for each marked part of the body.

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 both superior aspects of the acromia, and one was placed over each side of the protuberantia mentalis with the use of a mask that also deprived the individual of vision. The individual then was isolated acoustically, set in the center of the cameras' focus, and ordered to take 80 steps over the same spot, with no specific velocity. At the end of the steps, coordinates for each marker, representing the movement of each marked part of the body during the test, were offered in an Excel chart. Through formulas, three parameters were calculated for each test.

Lateral sway was defined as the average sum of the distances between the rightmost point and the leftmost point occupied by the left acromion marker. The lowest right hallux position was used to define the rightmost right acromion position, and the highest right hallux position defined the leftmost right acromion position. Angular deviation was defined as the angle formed by the initial axis of the body and a line joining the middle point between the acromia in the beginning and end of the test. Test duration was defined as the amount of time it took from the first step to the eightieth step or first and eightieth hallux movement.

Twenty-one normal subjects with no ear, nose, and throat or orthopedic complaints and normal otoneurological examination and test results composed the control group (group 1). Each individual was submitted to two tests. This group included 10 men and 11 women whose ages ranged from 19 to 34 years. Their average age was 25.48 years. The other group (group 2) included 21 patients with peripheral labyrinthine disease diagnosed after an otoneurological workout. This group was composed of 5 men and 16 women, with ages ranging from 18 to 71 years. The average age in this group was 43.71 years. Each individual underwent at least two tests.

RESULTS

VICON presented coordinates for all the parts marked with reflecting markers. This permitted the calculation of all three parameters: test time, lateral sway, and angular deviation. The test lasted for 50.38 seconds ($\pm$8.41 seconds) for group 1 and 54.45 seconds ($\pm$11.81 seconds) for group 2, while the engineer took 35 to 55 seconds to evaluate the data.

For group 1, lateral sway was 79.37 mm, with a standard deviation of 26.49 mm; angular deviation was 22.39 degrees, with a standard deviation of 19.76 degrees. For group 2, lateral sway was 84.98 mm, with a standard deviation of 34.43 mm; angular deviation was 65.47 degrees, with a standard deviation of 24.01 degrees. The Student's *t*-test proved angular deviation to be greater in group 2 and lateral sway to be the same for both groups. Duration for the 80 steps presented a tendency to last longer in group 2, although this difference was not statistically significant.

DISCUSSION

Movements occur in three planes and in four dimensions, if we include time; therefore, a test should be evaluated by a system that supplies coordinates in three planes and running time [12]. Many authors have recognized the synchronization of distinct parts of the body during stepping [11,13].

Group 1 included healthy young adults, the probable reason why all individuals completed the test without leaving the boundaries of the area covered by the cameras. Conversely, some patients in group 2 who had the symptom of dizziness quickly exited the test area, owing to their disequilibrium with eyes closed. The heights of some patients were above the reach of the cameras in the test area. This was owing to the fact that the VICON system was not meant to study the Unterberger-Fukuda test. Adaptations for marker placement, camera positioning, and separate calculations were necessary to obtain results. The inclusion of this test in the VICON program would make analysis quicker and easier.

In this study, patients with peripheral vestibular disease demonstrated an angular deviation greater than that described by the normal subjects in group 1. Lateral sway and angular deviation found among the normal subjects in this study showed no statistical difference as compared to the normal standards established by Claussen [14]. Normal subjects had a tendency to complete the test faster than did the patients from group 2. This difference was almost significant ($p = .08$). A larger population of patients with disequilibrium could possibly prove test duration in this group to be slower, once they express greater difficulty in maintaining equilibrium with eyes closed.

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 Unterberger-Fukuda test and calculated the coordinates for all the parameters. Just as with ultrasonographic craniocorpography, the system promoted a three-dimensional study in relation to time, which permitted the analysis of height-related movements. Markers instead of emitters with cables permitted the study of movements displayed by all the external parts of the body chosen in this survey. Parameters that include these and other parts of the body and interrelationships between these parts should be developed.

CONCLUSION

Peripheral labyrinthopathy patients present a lateral sway within the normal range. The angular deviation presented by the peripheral labyrinthopathy patients was greater than the angular deviation found in the normal population. The values obtained for test duration suggest that patients with disequilibrium have a tendency to march more slowly than do normal individuals.

REFERENCES

1. Leitenstorfer H. *Das militarische Trainig auf physiologischer and praktischer Grundlage*. Stuttgart: F. Enke, 1897.
2. Fischer MH, Wodak E. Prinzipielle Betractungen zum Probleme des Ziegerversuches. *Acta Otolaryngol* 10:24–51, 1927.
3. Basler A. Zur Physiologie des Hockens. *Z Biol* 88:524, 1929.
4. Unterberger S. Neue Objectiv Registrierbare Vestibularis-Körper Drehreaktion erhalten durch Treten auf der Stelle. Der Tretversurch! *Archiv Ohren Nasen Kehlkopjheilkunde* 145:478–492, 1938.
5. Fukuda T. *Statokinetic Reflexes in Equilibrium and Movement*. Tokyo: Igaku Shoin, 1957:62–71.
6. Claussen C-F. Die Cranio-Corpo-Graphie (CCG), eine einfache Photooptische Registriennethode für Vestibulospinale Reaktionen. *Zeitschr Laryngol Rhinol* 49:634–639, 1970.
7. Hattori T, Fukuda T. Automated Analysis of Fukuda's Stepping Test. In M Igarashi, FO Black (eds), *Vestibular and Visual Control of Posture and Locomotor Equilibrium*. Seventh Symposium of the International Society of Posturography. Basel: Karger, 1988:80–88.
8. Claussen C-F, Claussen E. Objective and quantitative vestibulospinal testing by means of computer-videocraniocorpography. *Adv Otorhinolaryngol* 42:43–49, 1988.
9. Claussen C-F, Schneider D, Marcondes LG, Patil NP. A computer analysis of typical CCG patterns in 1021 Neurootological patients. *Acta Otolaringol (Stockh)* 468:235–238, 1989.
10. VazGarcia F, Tavares J, Tavares L, Dias Ferreira A. Craniocorpo-graphy: Informatic Treatment of the Unterberger Test. In CF Claussen, MV Kirtane, D Schneider (eds), *Proceedings of the Neurootological and Equilibriometric Society,* vol 21. Hamburg: Werner Rudat & Co, 1995:455–461.
11. Claussen C-F, Claussen E, Heindl E. Recent Developments in the Computer Evaluation of Cranio-Corpo-Graphy. In CF Claussen, E Sakata, A Itoh (eds), *Vertigo, Nausea, Tinnitus and Hearing Loss in Central and Peripheral Vestibular Diseases*. Amsterdam: Elsevier Science, 1995:287–292.
12. Claussen C-F. Neck flexion, extension and rotation test. *Int Tinnitus J* 7(2):84–96, 2001.
13. Norre ME. Head stabilization in peripheral vestibular syndromes. *Clin Otolaryngol* 21(2):151–157, 1996.
14. Claussen C-F, Claussen E. *Forschungsbericht Cranio-Corpo-Graphie (CCG)—Ein einfacher, objektiver und quantitativer Gleichgewichtstest für die Praxis*. St. Augustin, Germany: Schriftenreihe des Hauptverbandes der gewerblichen Berüfsgenossenschaften e.V., 1986:60.