EFFECT OF POSITIONING OF THE FEET IN POSTUROGRAPHY

Seija Uimonen, * Kyösti Laitakari, * Martti Sorri, * Risto Bloigu, † and Antti Palva *

Departments of * Otolaryngology and † Applied Mathematics and Statistics, University of Oulu, Oulu, Finland
Reprint address: Seija Uimonen, MD, Department of Otolaryngology, University of Oulu, Box 22, SF-90221 Oulu, Finland

Abstract — Static posturography has been developed from a basic research test to a widely used clinical tool for evaluating dizzy patients. Before any actual standardization can be achieved, however, several aspects of the test situations have to be evaluated, including the position of the feet. The quantitative significance of the standing position in posturographic measurements was evaluated with healthy volunteers studied under visual and nonvisual conditions, using 4 foot positions: heels together with the toes 30° apart or at an angle of the volunteer's own choice, and the feet parallel and either 0 or 10 cm apart were studied separately. Each measurement was characterized in terms of 5 parameters (body sway velocity, vibration-induced shift of centre of force in anteroposterior and lateral directions, and maximum displacement of centre of force in the same directions). Body sway velocities were smallest when the feet were parallel and 10 cm apart. Although the position chosen by the subject was usually more stable than that with the toes 30 degrees apart, the difference was nonsignificant. According to our results, the standing position is not crucial in posturographic measurements provided that the distance between the heels is determined, and the subject can just as well choose the angle between the feet if the heels are kept together.

Keywords — postural control; statinometry; vestibulospinal examination; platform test.

Introduction

Apart from input–output tests of the sensory system that monitors human orientation in space, a growing need has become evident for measuring balance functions. Since an objective method for monitoring the postural control is needed, the use of a force platform system for diagnostic and follow-up purposes is increasing. Static posturography has proved a valuable tool for quantifying disequilibrium caused by disorders affecting the vestibulospinal system (1).

Static posturography has been recommended for the quantification of postural sway in normal and various pathological situations (2,3), but the comparison of posturographic data with those obtained by other authors is still hampered by differences in methods and recording techniques.

Since a standing position with the heels together may be too difficult for a vertiginous patient, the position with feet apart is the one mostly used. Different foot positions are recommended in the literature for posturographic measurements (4–6), but the angle between the feet is not always clearly defined. Only a few reports mention attempts to standardize the foot position (7,8). Different positions of the feet influence the body sway recorded in anteroposterior and lateral directions. As the inner distance between the feet increases from 0 to 10 cm, the lateral sway decreases, but anteroposterior sway does not change. Kollegger and colleagues recommend a position with the feet 10 cm apart (7). The present work was aimed at assessing the influence of different foot positions on body sway velocity and anteroposterior and lateral displacement of the centre of force and identifying the most reliably reproducible angle between the feet for the purpose of posturographic measurements.

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**Subjects**

The series comprised 17 healthy volunteers from among the hospital staff, 7 males and 10 females aged 22 to 35 years (median 30). The subjects had no history of vertigo, central nervous disorders, or ear disease.

**Methods**

**Recordings**

The equipment has been described in detail by Aalto and colleagues (9) and Enbom and colleagues (10), but the main features can be described as follows. A force platform technique based on the strain gauge principle was used. The equipment consisted of a force platform with 16 strain gauges for continuous detection of the changes in force. The signals \((x, y, z)\) from the strain gauges were amplified and passed through an analogue-digital converter to a Hewlett-Packard 300 microcomputer at a rate of 33.3 Hz. The test results are given as the average body sway velocity \((BSV = \text{length in cm of the path of the centre point divided by the time of measurement})\), the vibration-induced shift in the average centre of force in lateral \((\text{AVEX})\) and anteroposterior \((\text{AVEY})\) directions, and in terms of maximum displacement from the average position in the lateral directions \((\text{MAXX})\) and anteroposterior \((\text{MAXY})\) directions.

**Test Procedure**

During sequence 1 the subjects stand with their eyes open for the first 30 s with no vibration on the calf muscles, for recording of the basic body sway velocity. The second and third sequences comprise vibration to the calf muscles at frequencies of 40 and 80 Hz with constant amplitude lasting for 15 and 10 seconds, respectively. The fourth sequence is recorded after the last vibration. The whole set of measurements is repeated while the subject stands with the eyes closed (Figure 1).

The subjects stand barefoot on the force platform, with the arms crossed over the chest and the knees locked. With this posture, when the joints are rigid and hands are in fixed position, a single link pendulum model can be

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**Figure 1.** Test procedure. Sequences of measurement: 1 to 4 eyes open, 5 to 8 eyes closed. The evaluation time is indicated with lines. It begins when the vibration starts and lasts for two seconds after the end of vibration.
Feet in Posturography

utilized. The posture was chosen in order to encourage ankle strategy and minimize hip strategy in postural control. The entire test lasts about 3 minutes.

Proprioceptive Perturbation

A mechanical vibrator is fixes on each gastrocnemius muscle with a self-fastening nonelastic strap to activate the underlying muscle spindles to elicit postural perturbation. The straps are tightened with a constant force of 1 kp (9.81 N) with the subject already positioned. Vibration is produced by two DC motors (Escap 16 M 11-205.1, Port Escap, Switzerland) combined with a 3-g brass eccentric weight inside 50- x 20-mm plastic tubular container. The vibrators are regulated by a custom-made electronic control unit.

Positions of the Feet

The first posturographic trial was performed with the toes 30° apart and the heels close together (position A), the second with the feet parallel, 10 cm apart (position B), and the third with the subject’s own choice of the angle but the heels close together (position C). The angle varied from 0° to 75° (median 50°) in the whole series and among the females, and from 40° to 75° (median 55°) among the males. The fourth measurement (position D) was performed with the feet parallel and together (Figure 2). This was done 18 months after the other tests.

Results

Each of the 8 sequences of the posturographic test was analyzed separately with regard to the 5 parameters BSV, AVEX, AVEY, MAXX, and MAXY and the 4 positions A, B, C, and D. Thus, the experiments with 17 subjects produced a total of 2720 posturographic measurements.

Effect of Foot Position on Body Sway Velocity

Position B was the most stable in BSV, being smaller than in the other positions in every sequence. The overall means and 95% confidence intervals are shown in Figure 3.

Statistics

A two-way analysis of variance was performed first to indicate the variation in the results between the different positions of the feet, in order to justify a detailed analysis. We then sought 95% confidence intervals for differences of the means by calculating paired measurements.

All of the tests were performed using software by SAS Institute Inc. (Cary, NC, U.S.A.).
Figure 3. Body sway velocity in positions A, B, C, and D. The overall means and 95% confidence intervals.

one sequence. Position D showed greater BSV in every sequence than C, but these differences were mostly nonsignificant. The results of the paired analyses are shown in Figure 4.

**Vibration-Induced Shift in the Average Centre of Force**

The vibration-induced shift in the average centre of force in terms of anteroposterior and lateral displacement was analyzed separately in each position. Sequences 1 and 2, 1 and 3, 5 and 6, and 5 and 7 were compared.

There were significantly larger shifts in an anteroposterior direction in sequences 6 and 7 (vibration of 40 and 80 Hz, eyes closed) in every foot position than in sequence 5 (basic stance, eyes closed), whereas the differences between sequences 2 and 3 (vibration of 40 and 80 Hz, eyes open) and sequence 1 (basic stance, eyes open) were significant only in position B (Figure 5). The shift in the centre of force was always backward, mean 0.6 to 0.8 cm. The average vibration-induced shift in the centre of force in a lateral direction did not differ at all between the sequences or between positions A, B, C, or D.

**Maximum Displacement of the Centre of Force in an Anteroposterior or Lateral Direction**

The maximum displacement of the centre of force in an anteroposterior direction did not vary significantly between the positions. Calculation of the differences between all the positions showed the maximum displacement to vary from 0.8 to 5.6 cm in an anteroposterior direction (Figure 6) and from 0.4 to 3.5 cm in a lateral direction, and to depend markedly on the foot position. The least displacement in a lateral direction was in position B, this difference being significant. The most marked difference was between positions B and D (Figure 7). The differences between positions B and C and B and A were significant in 7 sequences out of 8. A predominance of anteroposterior sway over lateral sway was seen in all positions.

**Discussion**

**Body Sway Velocity**

Just as the BSV was found to be smaller in every sequence here with the feet 10 cm apart
than in other foot positions, this same position had already been found to be more stable. Kollegger and colleagues (7) recommended that the feet should be 10 centimetres apart rather than 0, 4, or 20 cm because the values obtained with this foot position showed the lowest variance. In that work, no account was taken of disturbance in proprioceptive information. In fact, no other investigators have compared the BSV in different positions in earlier reports.

All of the positions with heels together gave similar results regarding body sway velocity, and no significant differences emerged between positions A, C, or D. BSV seemed a better measuring unit than the MAXX or MAXY, because it could discriminate better between the positions of the feet.

Vibration definitely increases body sway and instability, and nonsignificant differences in BSV between B and the other positions appeared only when the vibration disturbed the proprioceptive receptor system. The differences between the positions usually became nonsignificant with the more forceful 80-Hz vibration effect, and more clearly so in nonvisual situations (sequence 7). The measuring sequence after 80 Hz vibration (sequences 4 and 8) also gave this misleading information. Correction of the body position takes place at this moment, and the effect may have reached beyond the sequence measured.

MAXY and MAXX

In keeping with the results of others (7,8), position B did not differ from others in the MAXY. MAXX changed significantly with position. Lateral sway showed a tendency to diminish in position B, which was the only position with open legs. Differences between all other positions showed no marked changes.

Visual Control

Vision has a stabilizing effect on balance, as recognized since the observations of Romberg in 1853 as stated by the Manual of Nervous Disease of Man (12). However, visual control of stance becomes less important when the feet are placed apart, as reported earlier (7), and this was shown here by the results for position B, in which the BSV was smallest when the subjects had their eyes closed.
Positions with Heels Together

Positions A (30° between the feet) and C (own choice of angle between the feet) did not differ significantly in terms of BSV, MAXX, or MAXY values, apparently because of the small actual difference in the angles used, as the angles chosen by the volunteers were on average 50° (females) to 55° (males). No notable differences in body sway velocity were seen between positions A, C, and D, in all of which the heels were together and only the angle between the toes varied. Position D was less stable than A or C, but not significantly so.

Vibration-Induced Shift

The differences in mean values for vibration-induced shift in an anteroposterior direction were significant between sequences 6 and 5 and between sequences 7 and 5. This was seen in all of the foot positions examined. Even the smaller vibration of 40 Hz was great enough to produce a significant difference in mean values for shift with eyes closed, whereas with eyes open, between sequences 2 and 1 and between 3 and 1, the only differences were found in position B. The destabilizing effect of vibration seemed to be most pronounced when the foot position chosen was associated with a high initial stability. Position B was more stable than the others, and this may be the reason why even a small shift in the centre of force emerged more clearly. No differences were found in a lateral direction between positions A, C, and D.

Stimulation of the calf muscles produced a backward body sway, as reported by Pyykkö and colleagues (5). A forward oscillation in body position stretches the triceps surae muscle. To prevent falling, the calf muscles must be activated synchronously with the oscillation.
of the centre point of force. These authors suggest that vibration of calf muscles seems to inform the body's postural system about the stretching of the muscle, which is followed by activation of the motor nerves of the muscle, causing a backward body sway (11).

The difficulty of the task depends on the test situation and condition of the subject. When examining patients, the test should include several levels of difficulty. Our test arrangement consisted of 6 situations; eyes open or closed, basic stance without any perturbation or with vibration of 40 or 80 Hz. This misleading information supplied to the sensory systems was needed to disturb the control of posture. BSV is clearly induced even

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**Figure 6.** Differences in maximal anteroposterior displacement in positions A, B, C, and D.

**Figure 7.** Differences in maximal lateral displacement in positions A, B, C, and D.
by 40 Hz vibration, and the influence increases with frequency, although the amount of vibration was not of great importance in our results.

It is essential to observe measurement that is the most informative when examining patients repeatedly. The preferred parameter for testing body vibration is the BSV, and it was this that was the most sensitive in distinguishing between the positions investigated. BSV, vibration-induced shift in the average centre of force in the anteroposterior and lateral directions, and maximum body sway displacement in the anteroposterior and lateral directions did not differ significantly between the foot positions, provided that the heels were together (A, C, D). The use of healthy test subjects probably reduced interindividual dispersion in the results. According to our results, posturographic measurements are reliable when the subject is allowed to choose the angle between the feet, provided that the heels are kept together. However, if a more stable position is needed, a position with the feet 10 centimeters apart could be used.

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REFERENCES