Change due to Aging in Equilibrium Function on Standing Posture; Sensory Organization Function and External Disturbance Stimulation due to Postural Deviation

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Abstract. For the clinical application of the Sensory Organization Test (SOT) in the Equi test system devised by L.M. Nashner, for the purpose of evaluating equilibrium function in the standing posture, we have conducted a basic analysis on SOT and prepared SOT databases. The subjects in this study were 19 healthy males and 26 healthy females between 20 to 85 years of age (average age: 46). We studied the characteristics of the sensory organization function of integrating vestibular sense information and inaccurate postural information in healthy persons by changing the sway gain of postural information input from bodily sense and visual sense, and by monitoring changes in equilibrium function due to aging. The results of this study, show that for elderly persons and patients with equilibrium function disorder, the condition of 1.0 sway gain (disturbance intensity), results in heavy psychological and physiological burdens and a danger of falling. Therefore we considered the optimum amount of disturbance stimulation to be 0.75 sway gain in all age groups. SOT using external disturbance stimulation caused by postural deviation reflected the aging alteration of equilibrium function, and it is a useful examination method for evaluating equilibrium disorder and the clinical conditions of elderly persons.

Key words: SOT (Sensory Organization Test), Aging, Equilibrium function.

(This article was submitted Apr. 10, 1997, and was accepted Jun. 10, 1997)

INTRODUCTION

In order to maintain a standing posture, it is necessary to integrate information from the somato-sensory system (somato) input from the skin and joints, information from the visual system (vision), and information from the vestibular sensory system (vest) through the inner ears. This integration of information is called the equilibrium function. Evaluating the equilibrium function in terms of sensory organizational function requires external disturbance stimulation. For the clinical application of the Sensory Organization Test (SOT) in the Equi test system devised by L.M. Nashner, for the purpose of evaluating equilibrium function in the standing posture, we have conducted a basic analysis on SOT and prepared SOT
databases. In SOT\textsuperscript{1)}, sensory information is operated and disturbed, and the postural deviation of the subject is used as external disturbance stimulation. In SOT, the subject is given inaccurate postural information of either controlled bodily sensory input (sway reference 1: stimulation by swaying the floor synchronously with the forward and backward sway of the body), or controlled visual sensory input (sway reference 2: stimulation by swaying an anterior visual field synchronously with the forward and backward sway of the body), or both (sway references 1 and 2). The integration function of integrating uncontrolled vestibular sensory information and inaccurate postural information is evaluated in SOT.

As a preliminary to the clinical application of SOT, we studied the characteristics of the sense-integration function of integrating vestibular sense information and inaccurate postural information in healthy persons by changing the sway gain of postural information input from bodily sense and visual sense, and by monitoring changes in equilibrium function due to aging.

**METHODS**

**Subjects**

The subjects in this study were 19 healthy males and 26 healthy females between 20 to 85 years of age (46 ± 19), and their heights were 158.7 ± 11.5 cm. They had no bone or joint disease or vestibular functional disorder.

**Measurement**

SOT (Sensory organization test) was performed using the Equi test system manufactured by Neuro Com International, USA. The subject was instructed to stand with bare feet on a standing stool fitted with a forceplate, Fig. 1. (The stance width was a certain distance between the right and left lateral ankles, depending on the subject’s height. The toe opening was 0–25° between the right and left toes; the distance between right and left lateral malleoluses was 22 cm for subjects 114–140 cm in height, 26 cm for those up to 165 cm in height, and 30 cm for those up to 203 cm in height). They were made to stand for 20 sec under four combination conditions (Fig. 2, four sensory conditions; A was inaccurate vision (eyes open), accurate vest and somato. B was inaccurate somato, accurate vest and vision (eyes open). C was inaccurate somato, accurate vest, and no vision (eyes closed). D was inaccurate somato and vision (eyes open), accurate vest.} selected from combinations of the following: 1) vestibular sensory input was accurate condition. 2) visual sensory condition; eyes open (visual surround, anterior visual field/eyes closed, 3) somato-sensory condition; inclination sway stimulation by the forceplate (support), synchronized with the forward and backward sway angle of the subject. For sway stimulation, both the standing stool and the front view were inclined at 10 degree from the ankle axis. Test conditions were combined with five kinds of sensory-information sway gain 0.00 (no control of postural sense), 0.25, 0.50, 0.75, and 1.00 (theoretically, no bodily or visual sensory information is given) corresponding to the forward and backward sway angle of the subject. Measurements were taken twice for each combination.

**EVALUATION**

The characteristics of equilibrium function were studied primarily based on the following two parameters obtained by the Equi test system.

1. Equilibrium Score (Fig. 3):

   The equilibrium score shows the degree of standing-posture equilibrium. A case in which there is no forward or backward sway and in which efficient integration of sensory information is seen is
2. Movement Strategy Score (Fig. 4):

This shows the reaction of a posture motion pattern for correcting forward and backward bodily sway. There are broadly two types of motion programs, ankle strategy and hip strategy\(^2\). Ankle strategy is a reaction for correcting forward and backward bodily sway by a postural motion pattern mainly using the ankles. Hip strategy is a reaction for correcting forward and backward bodily sway by a postural motion pattern primarily using the crotch and trunk. The forceplate is fitted with a forward and backward horizontal pressure sensor expressed as “100”. A case in which the forward and backward sway angle is 12.5° or over and in which theoretically the patient is clearly expected to fall is expressed as “0”. The degree of equilibrium is expressed in this range. At the subject’s gravity center measured by the forceplate, the inclination angle of the body (calculation of gravity center: set at 0.5572 of height) was calculated based on the forward and backward width (maximum change) and the subject’s height.

### Fig. 2.  The Sensory Condition of Sensory Organization Test

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<th>C</th>
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### Fig. 3. Equilibrium Score

The theoretical sway stability limit is 12.5°. A score near 10 shows strongly equilibrium, a score near 0 shows poorly equilibrium or falling.

\[ \text{Equilibrium Score} = \{12.5^\circ - (\text{sway max degree} - \text{min})/12.5^\circ\} \times 100 \]
in addition to a vertical pressure sensor. Gravity at the time of measurement (data obtained by measurement for two seconds or longer is used) is corrected, and the Strategy Score is calculated from the amount of forward and backward horizontal force against the forceplate surface. The Strategy Score was obtained according to a certain calculation formula based on the sum of forward and backward maximum horizontal forces. The action of correcting bodily sway using only a leg motion pattern was expressed as a Strategy Score of “100”, and the action of correcting it using only a crotch and trunk motion pattern was expressed as a Strategy Score of “0”. The postural motion pattern was expressed in this range.

In analyses, all data were analyzed using a Stat View software program (J-4.5, Abucus). ANOVA (two-way classification, p<0.05) and correlation analysis (p<0.05) were used for the effects of sway gain aging on each parameter, and correlation analysis (p<0.05) was used to compare the Equilibrium Score and Strategy Score.

**RESULTS** (Table 1, Fig. 5)

1. Effects of sway gain on Equilibrium Score

With an increase in sway gain, the Equilibrium Score decreased {in B (r= - 0.69, p<0.01), C (r=...
2. Effects of aging on Equilibrium Score

With an increase in aging, the Equilibrium Score decreased in all conditions \{A (r=-0.36, p<0.01), B (r=-0.32, p<0.01), C (r=-0.27, p<0.01), D (r=-0.24, p<0.01)\}.

3. Correlation between Equilibrium Score and Strategy Score

There was a high correlation between Equilibrium Score \(y\) and Strategy Score \(x\) \((r=0.78, y=1.37x - 35.7, p<0.01)\). It was confirmed that, following forward and backward bodily sway, a strong equilibrium reaction by the postural motion pattern to correct bodily sway primarily using crotch and trunk motion occurred. In young subjects, the Strategy Score in the eye open/closed standing posture at rest was 87.4 ± 2.5. The equilibrium reaction primarily involved the use of the legs.

4. Visual and Somato sway gain for elderly persons

Two persons (average age: 71) under conditions of a sway gain of 1.0 (Condition C, D) fell during measurement, and the measurement was stopped.

**DISCUSSION**

Many studies\(^{3-5}\) have been conducted on the measurement and examination of adjustment functions in the standing posture of elderly persons and Parkinsonian patients given external disturbance. In such studies, disturbance stimulation is applied 1) by applying a physical external force directly from the outside, and 2) by using the bodily inclination of the subject, as in this study. In evaluating
the sensory organization function as in this study, it is necessary to use disturbance stimulation using the bodily inclination of the subject\(^6\). With regard to safety in measurement and easy adjustment of stimulation intensity, this measurement method of swaying the standing stool and using the bodily inclination of the subject is suitable for elderly persons. In the Equi test system (SOT), only a database of 1.0 sway gain (disturbance intensity) is maintained. Thus, for elderly persons and patients with equilibrium function disorder, this sway gain results in heavy psychological and physiological burdens and a danger of falling. Based on the results of this study, we considered the optimum amount of disturbance stimulation to be 0.75 sway gain in all age groups.

Horak et al.\(^7\) have studied the relationship between the size of the gravity center and strategy in healthy persons and elderly persons. When the ankle strategy is used, healthy persons can maintain a standing posture up to 8 degree forward sway and 4 degree backward sway, but elderly persons depend on the hip strategy to maintain a posture even with low-intensity disturbance because elderly persons cannot generate sufficient ankle torque to maintain posture due to damage to the peripheral nerve, peripheral motion disorder, and a decrease in inferior limb muscle force, and because the hip strategy is activated as a compensatory function. Bohannon et al.\(^8\) investigated changes in the balancing ability of healthy persons accompanying aging. They claim that a one-leg balance test both with eyes open and closed is an effective screening method for evaluating a decrease in balancing ability due to aging. The muscle force of the inferior limbs decreases with age, a highly efficient joint torque cannot be generated, and the elderly must depend on the hip strategy to compensate for lowered balancing ability and to maintain posture. The results of this study show that, as it becomes difficult to maintain equilibrium, not only elderly persons but also patients suffering from lowered equilibrium function due to sense integration disorder perform sway correction with a low-frequency and large-amplitude hip strategy.

The Sensory Organization Test using external disturbance stimulation caused by postural deviation is a useful examination method for evaluating equilibrium disorder and the clinical conditions of elderly persons. It is necessary to create a more complete database of 0.75 sway gain for the clinical application of SOT.

**REFERENCES**