Eur Arch Otorhinolaryngol (2012) 269:673–677
DOI 10.1007/s00405-011-1707-7

MISCELLANEOUS

# Influence of age and gender in the sensory analysis of balance control

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Received: 4 May 2011 / Accepted: 4 July 2011 / Published online: 26 July 2011


**Abstract** Postural control is achieved through the integration at the central nervous system level of information obtained by the visual, somatosensory and vestibular systems. Computerized dynamic posturography and the Sway Star system are both used to carry out sensory analysis. The purpose of this study was to determine the influence of sex and age on sensory analysis, measured with these two systems, and to compare their results. A prospective trial was conducted with 70 healthy individuals (average age: 44.9 years) uniformly distributed in seven age groups, who underwent postural study with both systems. We used SPSS 16.0 for statistical study: comparison of means test for influence of gender and age and Pearson's correlation test ($p < 0.05$). Gender variable had no influence. The influence of age in vestibular input was found to be significant with both posturography systems, while visual input was only found to be significant with the Sway Star. The results with the two systems were not comparable. Sensory contribution does not remain stable throughout life. Visual information decreases with age, reaching a minimum at 40–49 years, and may correspond to the deterioration of eyesight with age. Propioceptive information showed no statistically significant changes, and several forms of treatment might correct the deterioration of this system. Vestibular information reaches a maximum in the 40–49 years age group in an attempt to compensate for visual deterioration, and decreases again in subsequent decades. This may be due to aging of the vestibular system and the difficulty in its correction.

**Keywords** Dynamic posturography · Sway Star · Sensory analysis · Vestibular information

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## Introduction

Postural control is fundamental for the ability to carry out everyday activities. Its purpose is to maintain body balance, both at rest (static balance) and in movement (dynamic balance). This is achieved through the integration, at the central nervous system level, of the information obtained by the three main systems responsible for balance: visual, somatosensory and vestibular systems [1–3]. If this information is insufficient or inaccurate, owing to disease processes related to these systems or to the physiological deterioration associated with age [4], the regulation of postural control can be affected [5, 6].

A variety of posturography systems are available for clinical practice, such as computerized dynamic posturography (CDP) (conceived and developed by Nashner) [7] or the Sway Star system (developed by Allum) [8]. Both systems can perform sensory analysis that provides information on the capacity to use different types of sensory information, as well as the relative contribution of each to overall balance control.

The aim of the present study was to determine the influence of gender and age on sensory analysis in healthy subjects, evaluated by computerized dynamic posturography and the Sway Star system, as well as to identify any correlation between the parameters analyzed by both systems. The knowledge of this influence will allow us to make a more specific assessment of each patient and design a more individualized rehabilitation.

## Materials and methods

### Subjects

A prospective study was carried out with a sample of 70 healthy individuals, with an average age of 44.9 years (ranging from 16 to 81 years), uniformly distributed (five men and five women) in seven age groups: below 20 years of age, 20–29 years, 30–39, 40–49, 50–59, 60–69 and 70 years or older.

Inclusion criteria were the following: absence of any known pathology affecting balance control, no use of medication affecting the CNS, balance control or coordination, absence of clinical signs of balance disorder, vestibular pathology, neurological disorders, psychological disorders (including depression); no history of unexplained falls in the previous 6 months and normal vision (or corrected with eyeglasses).

The following were conducted: a detailed medical history (demographic and clinical data), a physical examination (height and weight), a basic otoneurology examination (otoscopy, examination of strength, sensitivity, cranial nerves, Bárány pointing test, cerebellum tests (finger–nose test and heel–knee test), absence of spontaneous or induced nystagmus by head-shaking test, absence of saccadic movements by Halmagyi test, Romberg's test and Unterberger test and a postural study.

### Postural study

Postural study was performed for each patient. To carry out the postural study, first a *Smart Balance Master* posturography platform by *Neurocom*® was used. With this instrument, a sensory organization test was completed, which registered displacements of the center of pressure under six conditions [9]:

- Condition 1: eyes open, fixed visual environment and fixed platform.
- Condition 2: eyes closed and platform fixed.
- Condition 3: eyes open, moving visual environment and fixed platform.
- Condition 4: eyes open, moving visual environment and fixed platform.
- Condition 5: eyes closed and moving platform.
- Condition 6: eyes open, moving visual environment and moving platform.

Three recordings were made under each condition. Sensory analysis was determined by applying the following formulas:

$$\text{Somatosensorial information} = \frac{\text{averagescoreofcondition 2}}{\text{average score of condition 1}} \times 100$$

$$\text{Visual information} = \frac{\text{averagescoreofcondition 4}}{\text{average score of condition 1}} \times 100$$

$$\text{Vestibular information} = \frac{\text{averagescoreofcondition 5}}{\text{average score of condition 1}} \times 100$$

The second system used was the *Sway Star*® system model 2, which measures angular deviations of the trunk near the center of gravity (around L3–L5) in the anteroposterior and laterolateral planes [8]. A series of 14 tests (Table 1) proposed by the manufacturer were carried out to determine the sensory analysis using the balance control summary option (BCS). Unlike the calculation by dynamic posturography, this analysis provides a percent value for the contribution of each system to the overall balance by means of indexes obtained by applying the following formulas, where *V* corresponds to the velocity of movement of different tests and the abbreviations are explained in Table 1.

$$\text{Visual index: } CR_{VS} = \left[\frac{(V_{s2ecf} - V_{s2eof}) + (V_{s2ec} - V_{s2eo})}{(V_{s2eo} + V_{s2ec} + V_{s2eof} + V_{s2ecf})}\right] \times 100$$

$$\text{Somatosensory index: } CR_{SS} = \left[\frac{(V_{s2ecf} - V_{s2ec}) + (V_{s2eof} - V_{s2eo})}{(V_{s2eo} + V_{s2ec} + V_{s2eof} + V_{s2ecf})}\right] \times 100$$

$$\text{Vestibular index and others: } CR_{O} = 100 - CR_{VS} - CR_{SS}$$

### Statistical study

The SPSS 16.0 for Windows statistical package was used for the statistical study. In the first place, location measures from both posturography systems were analyzed; afterward, the statistical influence of gender and age variables was studied for each of the parameters by applying the comparison of means test (Student's *t* and ANOVA), after having compared variable normality with the Kolmogorov–Smirnov test. Significance was considered to be 5% ($p < 0.05$). Pearson's correlation test was used to analyze possible correlations between the dynamic posturography and Sway Star variables with a significance level of 5% ($p < 0.05$).

**Table 1** Protocol of tests for postural study with Sway Star

| | |
|---|---|
| 1. | Standing on 2 legs, eyes open on normal surface (s2eo) |
| 2. | Standing on 2 legs, eyes closed on normal surface (s2ec) |
| 3. | Standing on 1 leg, eyes open on normal surface (s1eo) |
| 4. | Standing on 1 leg, eyes closed on normal surface (s1ec) |
| 5. | Walking 8 tandem steps, eyes open on normal surface |
| 6. | Standing on 2 legs, eyes open on foam surface (s2eof) |
| 7. | Standing on 2 legs, eyes closed on foam surface (s2ecf) |
| 8. | Standing on 1 leg, with eyes open on foam surface (s1eof) |
| 9. | Walking 8 tandem steps, eyes open on foam surface. |
| 10. | Walking 3 m, pitching head |
| 11. | Walking 3 m, rotating head |
| 12. | Walking 3 m, eyes closed |
| 13. | Walking up and down stairs |
| 14. | Walking over barriers |

## Results

### Influence of gender

With respect to the influence of gender in sensorial analysis, applying the Student's *t* test, we found no significant difference ($p > 0.05$) between men and women for the mean of any contributions with either of the posturography systems, which is why we will proceed to present the overall results without differences for gender.

### Influence of age

*Computerized dynamic posturography*

As a summary, in Table 2, we present the means of the sensory analysis for different age groups analyzed with dynamic posturography. Small variations could be seen in the somatosensory and visual information, but applying the ANOVA test no statistically significant differences were found ($p > 0.05$). However, significant differences were found between the different age groups for the mean values of the vestibular contribution ($p = 0.041$), which started increasing in the under-20 years group until it reached a maximum in the 30–39 years age group. This variable decreased gradually until the age of 60–69 years and then began to increase once again.

**Table 2** Results of sensory analysis for the different age groups

| Years | Somatosensorial information | Visual information | Vestibular information |
|---|---|---|---|
| <20 | 97.50 | 92.31 | 65.08* |
| 20–29 | 96.16 | 88.01 | 68.71* |
| 30–39 | 97.57 | 93.00 | 73.46* |
| 40–49 | 96.13 | 92.06 | 71.37* |
| 50–59 | 99.93 | 85.92 | 62.58* |
| 60–69 | 95.16 | 90.42 | 61.23* |
| ≥70 | 99.13 | 84.81 | 73.08* |

Percentage of use of different information

* The correlation is statistically significant at a 0.05 level of significance

*Sway Star system*

In Table 3, the mean sensory contribution values are shown for the different age groups regarding the Sway Star sensory analysis. With this posturography system, statistically significant differences were found both for visual ($p = 0.001$) and vestibular ($p = 0.004$) contribution. In Fig. 1, we can see how the relative importance of visual information gradually decreases with age, reaching a minimum with even negative values for the 40–49 years age group. The importance of this variable increases again in older age groups. In contrast, the relative importance of vestibular information increases steadily up to a maximum in the same 40–49 years age group and then decreases in older age groups.

### Correlations between the two posturography systems

By analyzing the correlation between the visual input provided by the computerized dynamic posturography and the Star Sway system, we obtain the Pearson correlation coefficient of −0.167 and significance of 0.168, indicating that there is no linear correlation between both variables. For the somatosensory contribution, a Pearson correlation coefficient of 0.165 and significance of 0.176 are obtained, indicating that there is no linear relationship. The same applies to the vestibular contribution: a Pearson correlation coefficient of 0.171 with significance of 0.158, indicating that there is no linear relationship.

**Table 3** Descriptive statistics for Sway Star sensory analysis

| Years | Visual index | Somatosensorial index | Vestibular and others index |
|---|---|---|---|
| <20 | 9.88* | 43.64 | 46.48* |
| 20–29 | 9.76* | 30.40 | 59.84* |
| 30–39 | 1.89* | 34.66 | 63.45* |
| 40–49 | −5.19* | 39.64 | 65.55* |
| 50–59 | 17.92* | 50.55 | 31.53* |
| 60–69 | 34.08* | 35.55 | 30.36* |
| ≥70 | 26.96* | 43.01 | 30.04* |

Percentage of contribution of each sensory systems to the global balance

* The correlation is statistically significant at a 0.05 level of significance

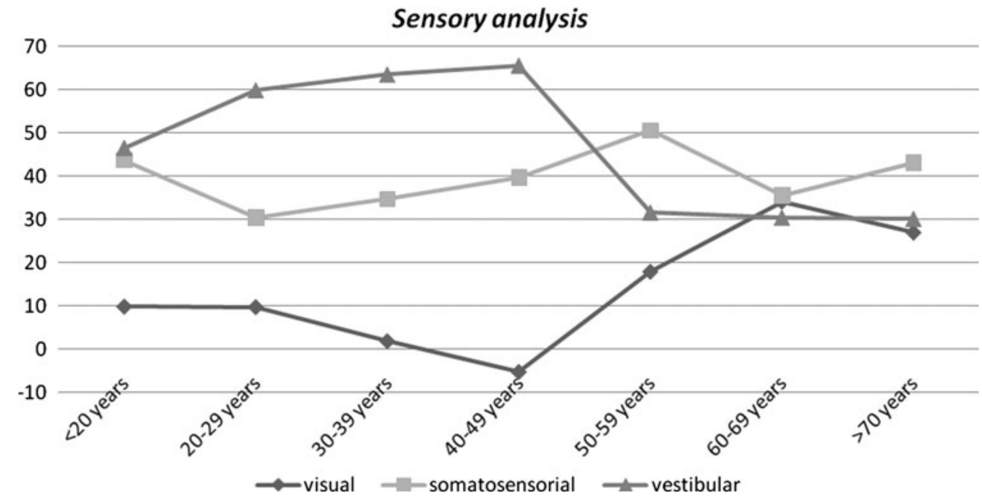


**Fig. 1** Graphic representation of Sway Star sensory analysis. The numbers along the *Y*-axis refer to the percent value for the contribution of each system

## Discussion

In the sensory analysis of the two posturography systems, we did not find differences associated with gender, as in other parameters of sensory organization test, such as percentage of balance (in condition 1 males have a higher percentage of balance than women, and in condition 3 the opposite occurs) or percentage of ankle strategy (in condition 4, women use more effectively the ankle strategy than men) [10].

The relative importance of visual information decreases with age, reaching a minimum in the 40–49 years age group, and increases again in later decades. We consider that the observed age-dependent reduction of visual input to the balance system may correspond to the progressive deterioration of eyesight with age, which in most cases can be corrected with glasses or surgery. For this reason, starting at the age of 50 years, when eyeglasses are usually introduced for the correction of presbyopia, the relative importance of visual contribution begins to recover again. Thus, in terms of percentage, visual contribution improves and other systems worsen [11, 12]. With respect to proprioceptive information, no statistically significant changes were found in the various age groups. Among older people, it represents the main stimulus for maintaining postural control [5]. Several forms of treatment are currently available that act on the proprioceptive system (prostheses, surgery). Although they do not provide an *ad integrum* recovery of the function (as does the correction of vision), they are useful for improving locomotion and reducing pain [13].

On the other hand, the relative importance of vestibular information continually increases until it too reaches a maximum in the 40–49 years age group in an attempt to compensate for visual deterioration up to that point. This parameter decreases again in subsequent decades. This may be due to aging of the vestibular system and the difficulty in its correction [14]; in fact, vestibular rehabilitation (as therapy for improving balance) is currently only used for individuals with pathology [15–17]. Another possible reason for the vestibular contribution changes among age, as opposed way to the visual information could be the way in which Sway Star does the calculation. By subtracting a 100 from the other two contributions, the decrease in vestibular contribution may simply be the result of a rise in visual contribution [18].

The lack of statistically significant correlation found between the sensory analysis of the two posturography systems may be due to a mathematical problem and to the difference in how the relative contributions of sensory afferents to overall balance are calculated [9]. While posturography yields absolute values, the Sway Star provides percentages (the afferences of the three sensory systems always add up to 100), such that if there is a decrease in one of the afferents the others increase automatically (hence, the variables are not independent) [4].

## Conclusions

1. According to the sensory analysis of computerized dynamic posturography, vestibular contribution is the only parameter that is altered with age, with a maximum contribution during middle age.
2. According to the sensory analysis by the Sway Star system, the contribution of the vestibular system changes in different age groups, reaching a maximum during middle age, unlike the visual system, which reaches a minimum at this age.
3. The values obtained by the two sensory analysis systems (computerized dynamic posturography and Sway Star) are not comparable because of the different methods of calculating the relative contributions of the sensory afferents to the overall balance.

**Acknowledgments** There is no financial relationship with the organization that sponsored the research.

**Conflict of interest** None.

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