ORIGINAL ARTICLE

Influence of Gender on the Sensory Organisation Test and the Limits of Stability in Healthy Subjects

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Keywords
Balance;
Effect of sex;
Healthy subjects

Abstract
Introduction: The sensory organisation test and the limits of stability are the gold standard for dynamic posturography. It is postulated that these measurements vary depending on age, activity of the subject and musculoskeletal system, emotional condition or other factors. The aim of this study was to determine the influence of gender on the above-mentioned analyses.
Material and methods: 70 healthy subjects (35 males and 35 females); mean age: 44.9 years. A clinical history was taken and a physical and otoneurological exploration was performed for each subject, along with a posturography study using the Neurocom SMART Balance Master platform model. The statistical study was carried out with the ANOVA test (P<.05).
Results: Condition 5 presented the lowest percentage of balance in both sexes (64.36%). The highest percentage of balance in males was in Condition 1 (P<.001) and the lowest in 3 (P=.030). There were no differences in the sensory analysis. The lowest employment of ankle strategy was in Condition 5 for both sexes (88.61%); women used the ankle strategy in Condition 4 more efficiently (P=.0129). There were also differences in the time of reaction towards the right (P=.022) and the mean (P=.011) (higher in females), and in the speed of movement backwards (P=.001) and towards the right (P=.04) (higher in males). In path length and directional control, there were no differences.
Conclusions: Gender differences should be taken into consideration for vestibular rehabilitation. Greater speed in conducting the tests does not lead to better balance control.

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PALABRAS CLAVE
Equilibrio;
Efecto del sexo;
Sujetos sanos

Resumen
Introducción: El test de organización sensorial y los límites de estabilidad son el test de referencia de la posturgografía dinámica. Se postula que estas mediciones pueden variar en función de la edad, actividad del sujeto y aparato locomotor o estados emocionales, entre otros. El objetivo de este trabajo es determinar la influencia del sexo sobre dichos análisis.

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Material y métodos: 70 individuos sanos (35 varones y 35 mujeres), edad media 44,9 años. Se realizó historia clínica, exploración física y otoneurológica básica y un estudio posturográfico con la plataforma posturográfica modelo Smart Balance Master® de Neurocom. Estudio estadístico con test de ANOVA (p < 0,05).

Resultados: La condición 5 presenta el menor porcentaje de equilibrio en ambos sexos (64,36%). Mayor porcentaje de equilibrio en varones en la condición 1 (p < 0,001) y menor en la 3 (p = 0,030). No hay diferencias en el análisis sensorial. Menor empleo de estrategía de tobillo en la condición 5 para ambos sexos (88,61%), las mujeres utilizan con mayor eficacia la estrategia de tobillo en la condición 4 (p = 0,0129). Diferencias en el tiempo de reacción hacia la derecha (p = 0,022) y el promedio (p = 0,011) (mayores en mujeres), y en la velocidad de movimiento hacia atrás (p = 0,001) y hacia la derecha (p = 0,04) (mayores en varones). En el recorrido y el control direccional no hay diferencias.

Conclusiones: Las diferencias entre sexos deben ser tenidas en cuenta para planificar la rehabilitación vestibular. Una mayor celeridad en la realización de las pruebas no lleva a un mejor control del equilibrio.

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Introduction

Posturography is the name given to the set of techniques that objectively study and quantify the postural control of an individual by motions of the centre of gravity (CoG), through the use of torque platforms. These techniques provide insight into a subject’s ability to use vestibular, visual and somatosensory information, and the relative contribution of each of them to overall balance; facilitate ascertaining a subject’s ability to adapt to sensory conflict situations; and allow knowing the functional status of a subject. This information aids in guiding medical treatment or rehabilitation, identifying sensory dysfunction.¹,²

Computerized dynamic posturography (CDP) was initially designed and developed by Nashner,³ clinically studied in collaboration with Black and Nashner⁴ and marketed in 1986 as EquiTest by Neurocom⁵ Inc. It measures body sway in the Romberg position with the subject under various sensory conflict situations.⁶ Since the CoG is not easy to measure, its near equivalent is used, the centre of pressure (CoP), according to a postural model that considers the subject’s oscillations similar to those of a pendulum in an inverted position.⁷-⁸

The sensory organisation test (SOT) is the reference test in dynamic posturography. It is not a study of the vestibulospinal reflex as such, since there is no specific vestibular stimulation, but it enables isolation of the components of the vestibular, visual and somatosensory information involved in maintaining balance. Tests of the voluntary control of centre of gravity movement comprise a set of tests that determine a patient’s ability to make voluntary movements of the CoG through the use of visual feedback. They include the determination of the limits of stability. The limit of stability is a 2-dimensional measure that defines the maximum angle of displacement of the CoG from the central position.⁹

We hypothesised that both the sensory organisation test and the limits of stability were not fixed but changed according to the conditions of the subject’s activity, location of the locomotor apparatus, the subject’s emotional states and aspects related to the environment.⁹ The aim of this study was to determine the influence of gender on the SOT and the limits of stability, since the existence of such differences should be taken into account both during a diagnostic phase and during the planning of vestibular rehabilitation.

Material and Methods

We selected a sample of 70 (35 men and 35 women) healthy (with no history of balance disorders, chronic or known degenerative disease) individuals, with a mean age of 44.9 years (range 16–81 years), evenly distributed by age groups.

Exclusion criteria were: known disease affecting balance (vestibular disease, neurological or psychological disorders including depression); use of medication affecting the central nervous system, balance or coordination; imbalance symptoms; history of unexplained falls in the last 6 months; vision alterations not corrected with mechanical systems (glasses, contact lenses, etc.); and presbyvertigo.

Each patient underwent a detailed medical history, a physical examination that collected height and weight, as well as a basic neuro-otological exploration. This included otoscopy, examination of strength, sensitivity, cranial nerves, Bárány indexes, cerebellar testing, verification of absence of spontaneous or induced nystagmus with the cephalic agitation test, absence of saccades through the Hallmagyi, Romberg and Unterberger tests and postural study.

The postural study was carried out using a posturography platform (Smart Balance Master® model from Neurocom®). We conducted a sensory organisation test, which recorded the movements of the CoP, with the patient in the Romberg position, barefoot and wearing a safety harness in 6 conditions: Condition 1: eyes open, fixed visual environment and fixed platform; Condition 2: eyes closed and fixed platform; Condition 3: eyes open, mobile visual environment and fixed platform; Condition 4: eyes open, fixed visual environment and mobile platform; Condition 5: eyes closed and mobile platform; and Condition 6: eyes open, mobile visual environment and mobile platform. In order to study the limits of stability patients were asked to shift their centre of pressure (represented by a pictogram on a screen in front of them) following the path of a circle which moved towards 8 points in space, always passing through the central position.
Influence of Gender on the Sensory Organisation Test and the Limits of Stability in Healthy Subjects

Table 1 Variables Analysed in the Study.

Sensory organisation test (SOT)
- Proportion of balance: the arithmetic mean of the percentage of balance achieved in each of the 3 records for each SOT condition
- Mean or composite global balance: the arithmetic mean of the percentage of balance obtained in each SOT condition
- Sensory analysis: contribution of each sensory system to the correct maintenance of balance: somatosensory, visual and vestibular information and visual conflict
- Analysis of the strategy: reports, through stability percentages, of the relative amount of ankle or hip movement which the patient uses to maintain balance in the sensory conditions tested

Limits of stability
- Response time: time elapsed since the signal moves until the start of patient movement
- Movement speed: average speed of movement of the centre of gravity
- Trajectory: trajectory from the initial position to the farthest distance reached by the centre of gravity
- Directional control: ability of a subject to control movement of the centre of gravity

The variables analysed in the study are shown in Table 1. The statistical analysis was carried out using the SPSS 16.0 software for Windows. The contrast of normality was done with the Kolmogorov–Smirnov test. The ANOVA test was used to establish the possible existence of differences between males and females (gender variable). The significance considered was 5%.

Results

Table 2 shows the descriptive statistics of percentages of balance for each of the conditions of the sensory and composite organisation test for the total population, males and females. As shown in this table, we can observe that as the difficulty of the conditions increased (sensory information was reduced or false sensory information was offered), the percentage of balance worsened. The lowest mean percentage was observed in Condition 5 (64.36%) and the lowest in Condition 6 (30%) for the total population. Males presented the lowest mean percentage (64.72%) and minimum (38%) in Condition 5. In the female population, the lowest mean percentage (63.99%) also appeared in Condition 5, but the minimum coincided with Condition 6 (30%). When comparing the male and female populations, we found statistically significant differences between the mean values of percentage of balance in Conditions 1 \( (P<.001) \) and 3 \( (P=.030) \), with the percentage of balance being significantly higher for males in Condition 1, while in Condition 3 it was higher for females.

Regarding the sensory analysis, Table 3 shows descriptive statistics for the general population and by gender. It shows that the mean value of the somatosensory, visual and vestibular contributions was slightly higher for males, while the average value of tolerance to visual conflict was greater in females; however, these differences were not statistically significant.

In the analysis of the strategy, as occurred with the mean percentage of balance, the mean percentage of ankle
Table 3  Descriptive Statistics for Sensory Analysis of the Total Population.

<table>
<thead>
<tr>
<th></th>
<th>Somatosensory</th>
<th>Visual</th>
<th>Vestibular</th>
<th>Visual Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>97.37</td>
<td>89.51</td>
<td>67.93</td>
<td>104.45</td>
</tr>
<tr>
<td>M</td>
<td>97.47</td>
<td>89.53</td>
<td>68.19</td>
<td>103.35</td>
</tr>
<tr>
<td>F</td>
<td>97.27</td>
<td>89.49</td>
<td>67.67</td>
<td>105.56</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>97.41</td>
<td>90.28</td>
<td>68.90</td>
<td>103.72</td>
</tr>
<tr>
<td>M</td>
<td>96.91</td>
<td>90.53</td>
<td>69.42</td>
<td>103.34</td>
</tr>
<tr>
<td>F</td>
<td>97.87</td>
<td>90.03</td>
<td>67.03</td>
<td>104.74</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>4.80</td>
<td>8.68</td>
<td>10.93</td>
<td>8.53</td>
</tr>
<tr>
<td>M</td>
<td>5.65</td>
<td>8.94</td>
<td>11.29</td>
<td>7.10</td>
</tr>
<tr>
<td>F</td>
<td>3.85</td>
<td>5.55</td>
<td>10.71</td>
<td>9.74</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>126.39</td>
<td>106.02</td>
<td>87.23</td>
<td>135.22</td>
</tr>
<tr>
<td>M</td>
<td>126.39</td>
<td>106.02</td>
<td>85.42</td>
<td>124.87</td>
</tr>
<tr>
<td>F</td>
<td>107.14</td>
<td>98.21</td>
<td>87.23</td>
<td>135.22</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>87.37</td>
<td>51.28</td>
<td>40.00</td>
<td>86.56</td>
</tr>
<tr>
<td>M</td>
<td>91.11</td>
<td>53.13</td>
<td>40.00</td>
<td>86.51</td>
</tr>
<tr>
<td>F</td>
<td>87.37</td>
<td>51.28</td>
<td>40.29</td>
<td>86.56</td>
</tr>
</tbody>
</table>

F: females; M: males.

strategy decreased as sensory stimuli were suppressed. We found the lowest percentage of ankle strategy in Condition 5, both for the total population (88.61%) and for both genders. Regarding the minimum value, this also corresponded to Condition 5 in the 3 populations (Table 4). Using the ANOVA test, we found significant differences between the means of the strategy employed in Condition 4 (P=.012), with females showing a higher percentage of ankle strategy (90.1%).

As for the limits of stability, in terms of reaction time there was a significant difference in reaction time to the right (P=.022) and mean (P=.011) between males and females, with both being higher for females. We also found significant differences in the speed of backwards movement (P=.001) and right movement (P=.04). Both speeds were higher for males. There were no differences in distance and directional control between genders, so the results expressed in Table 5 are those of the total population.

Discussion

Computerized dynamic posturography is a technique used to analyse the balance of subjects, adaptation to changes in posture and the use of different sensory information which contributes to stabilise the centre of gravity. With regard to

Table 4  Descriptive Statistics of Each Strategy for the Total Population.

<table>
<thead>
<tr>
<th></th>
<th>Strategy 1</th>
<th>Strategy 2</th>
<th>Strategy 3</th>
<th>Strategy 4</th>
<th>Strategy 5</th>
<th>Strategy 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>97.30</td>
<td>96.56</td>
<td>96.91</td>
<td>88.61</td>
<td>79.45</td>
<td>81.62</td>
</tr>
<tr>
<td>M</td>
<td>97.20</td>
<td>96.20</td>
<td>96.83</td>
<td>87.11*</td>
<td>77.80</td>
<td>80.74</td>
</tr>
<tr>
<td>F</td>
<td>97.40</td>
<td>96.91</td>
<td>96.99</td>
<td>90.10*</td>
<td>81.10</td>
<td>82.50</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>98.00</td>
<td>98.00</td>
<td>97.67</td>
<td>89.67</td>
<td>80.83</td>
<td>82.33</td>
</tr>
<tr>
<td>M</td>
<td>98.00</td>
<td>97.00</td>
<td>97.33</td>
<td>88.33</td>
<td>78.67</td>
<td>80.33</td>
</tr>
<tr>
<td>F</td>
<td>98.00</td>
<td>98.00</td>
<td>97.67</td>
<td>90.67</td>
<td>82.33</td>
<td>85.33</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>2.31</td>
<td>4.08</td>
<td>1.69</td>
<td>5.01</td>
<td>7.88</td>
<td>7.35</td>
</tr>
<tr>
<td>M</td>
<td>2.36</td>
<td>5.30</td>
<td>1.83</td>
<td>5.52</td>
<td>8.16</td>
<td>6.20</td>
</tr>
<tr>
<td>F</td>
<td>2.29</td>
<td>2.34</td>
<td>1.57</td>
<td>3.99</td>
<td>7.33</td>
<td>8.34</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>99.00</td>
<td>99.00</td>
<td>99.00</td>
<td>95.33</td>
<td>90.67</td>
<td>91.33</td>
</tr>
<tr>
<td>M</td>
<td>99.00</td>
<td>99.00</td>
<td>99.00</td>
<td>94.33</td>
<td>90.33</td>
<td>90.00</td>
</tr>
<tr>
<td>F</td>
<td>99.00</td>
<td>99.00</td>
<td>99.00</td>
<td>95.33</td>
<td>90.67</td>
<td>91.33</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>85.00</td>
<td>67.00</td>
<td>91.67</td>
<td>71.33</td>
<td>48.00</td>
<td>54.67</td>
</tr>
<tr>
<td>M</td>
<td>87.00</td>
<td>67.00</td>
<td>91.67</td>
<td>71.33</td>
<td>48.00</td>
<td>65.67</td>
</tr>
<tr>
<td>F</td>
<td>85.00</td>
<td>86.00</td>
<td>92.33</td>
<td>76.00</td>
<td>50.67</td>
<td>54.67</td>
</tr>
</tbody>
</table>

F: females; M: males.

* P<.05.
the percentage of balance, as expected, the scores obtained on the different conditions of the sensory organisation test in normal subjects diminished as the sensory difficulty of the registers increased.\textsuperscript{10-12} In our study, the worst scores for both the total population and for males and females separately were obtained in Condition 5. This coincides with other Spanish studies, such as that published by Oliva Domínguez et al.\textsuperscript{13} in 2005. However, it differs from other foreign studies, such as that by Hirabayashi and Iwasaki\textsuperscript{14} in 1995, in which the worst scores were obtained in Condition 6. The differences are a striking aspect found (significant from a statistical point of view) for Conditions 1 and 3 between males and females. In particular, in Condition 1, males performed better than females; on the other hand, in Condition 3, it was females who obtained the highest scores. Other studies also observed significant differences between genders; Matheson et al.\textsuperscript{15} in a 1998 publication, stated that old males had a poorer postural control than females in terms of visual and vestibular conflict, without finding a precise cause to justify this fact. Hirabayashi and Iwasaki\textsuperscript{16} highlighted these differences between genders for Condition 5, in children aged 7 and 8, supporting this on the fact that vestibular function has a late development, which may be slower in males.

With respect to the analysis of strategies, we noted in our study an increased use of ankle strategy over hip strategy in healthy subjects. This is consistent with the works published by Karlsson and Lanshammar\textsuperscript{17} or Baydal-Bertomeu et al.\textsuperscript{18} As in the case of percentage of balance, we found that the lowest scores (which implied less ankle strategy and more hip strategy) corresponded to Condition 5. This is logical, since more difficult sensory conditions cause greater instability of the centre of gravity and therefore lead to the employment of other strategies, such as the hip strategy. With regard to gender analysis, there were differences for Condition 4, with females using more ankle strategy. One possible explanation for this fact could be the use of high heels, since the use of this type of footwear includes a reduction in body support surface. The body must become accustomed to this situation to prevent falling and does this through the stabilisation of the ankle joint. An exposure to this situation over the years means training in the management of ankle strategy, a training which for obvious reasons, males do not acquire.

Analysis of the stability limits quantifies the characteristics of movement associated with the ability of a patient to voluntarily change spatial position and maintain stability in that position. With regard to reaction time, there were differences between males and females, with males having a shorter reaction time. These differences were mainly related to the mean reaction time and to the rightwards direction. The speed of movement, as well as reaction time, also showed differences between males and females, with males being faster than females. These differences related mainly to the speed of movement when moving backwards. Unlike for reaction time and speed, there were no differences by gender with respect to trajectory. Neither did we find differences in the analysis of directional control. This leads us to believe that more celerity (less time and higher speed) in conducting the tests does not lead to more effective results.

Conclusions

Regarding the sensory organisation test, we observed that in Condition 1 (eyes open, fixed visual surroundings and fixed platform) males had a higher percentage of balance than females; in Condition 3 (eyes open, mobile visual environment and fixed platform) the opposite occurred. In Condition 4 (eyes open, fixed visual surroundings and mobile platform), females used the ankle strategy more effectively than males. These results should be taken into account when planning vestibular rehabilitation. For females, it should focus on the training of the hip strategy, since they usually use the ankle strategy; while in males it should work on the tolerance to visual conflict, to which they are less habituated on a global scale.

The limits of stability showed that males have a lower reaction time and faster speed than females in postural changes of the limits of stability. However, the trajectory and directional control were identical for both genders, implying that more celerity in the tests did not lead to a better balance control.

Conflict of Interests

The authors have no conflicts of interest to declare.


