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Romberg ratio in quiet stance posturography—Test to retest reliability

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ABSTRACT

We investigated test to retest reliability and intraindividual variability of Romberg ratios in quiet stance posturography. Thirty-six healthy young adults (17 males, 19 females aged 15–38 years) were divided into 3 groups with different time-intervals between consecutive trials (20 min, 3 h and 24 h respectively). Each group performed 5 posturography recordings in a randomized order of eyes open (EO) or closed (EC) + once after 3 months. We measured the torque variance in posturography and calculated Romberg ratios. Total postural sway as well as sway above and below 0.1 Hz was analyzed.
Results: Test to retest reliability was found to be poor for Romberg ratios (intraclass correlation coefficients (ICC) <0.4) despite that the individual EO and EC posturography recordings were consistent. For sway >0.1 Hz the Romberg ratios were found to be more consistent (fair to good, ICC 0.49–0.71). The variation between two consecutive tests (absolute difference (%)) was high when using the traditional Romberg ratio (EC/EO), but became less varied if an alternate formula that includes the total postural sway was used ((EC − EO)/(EC + EO) × 100).
Conclusion: In healthy young adults the evaluation of ratios from repeated quiet stance posturography show great intraindividual inconsistency. This questions the Romberg ratio as being a reliable tool for evaluation of postural performance and determination of sensory preference in postural control, at least in healthy controls. Whether test–retest reliability is acceptable in patient cohorts needs to be evaluated for proper validity of intervention and outcome studies and for detection of clinical relevance.

1. Introduction

Postural feedback and feed forward control is dependent on sensory input from vision, somatosensation and the vestibular organs. Within the central nervous system the inputs are processed, integrated and weighted dependent to their relative importance and to the context [1]. Assessment of the different contributions of the sensory systems, i.e. sensory weighting, and their changes has been made by the use of posturography measurements [2,3]. Although not originally intended for sensory weighting assessment, the Romberg test is frequently used in posturography by comparing postural sway in eyes open (EO) and eyes closed (EC) conditions. The ensuing Romberg ratio (EC/EO) is a set feature in the sensory organization test (SOT) in Equitest posturography [4], and it is interpreted as an indicator of proprioceptive contribution to postural stability. The same ratio has also been used to assess visual dependency in postural stability [3,5].

Posturography is frequently used to assess the efficiency of treatments of different balance disorders and in this context test to retest reliability is of utmost importance, i.e. intraindividual variability and stability. Reliability has been investigated for EO and EC in the context of SOT. Ford-Smith et al. [6] evaluated noninstitutionalized older adults on 2 occasions, 1 week apart, and found fair test–retest reliability (intraclass correlation coefficient (ICC) of 0.51 and 0.42 respectively, using the definition from Fleiss et al. [7]). Wrisley et al. [8] tested younger adults on 5 separate sessions and found overall a fair to good test–retest reliability of the six conditions of the SOT, though the lowest reliability was found for the easiest conditions, i.e. standing without any sensory interference with EO and EC. Neither of the above studies addressed test to retest reliability of the Romberg ratio. Since the Romberg ratio in the context of posturography measurements is a mathematical construction and small variations in the different conditions (EO/EC) could yield larger differences in the calculated ratio, it would be of great interest to examine whether this ratio is stable when repeatedly measured. If any conclusion could be

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drawn whether a subject has a proprioceptive or visual preference in regulating postural stability, then the ratio would have to be consistent. The present study aimed to assess whether the Romberg ratio is a consistent and reliable tool when performing repeated measurements in healthy subjects.

2. Material and method

Thirty-six healthy subjects were recruited (17 males, 19 females aged 15–38 years (mean 25 years, SD 4 years), weight 41–100 kg (mean 67.5 kg, SD 13.1 kg), and height 160–197 cm (mean 1.75 m, SD 0.09 m)), and divided into 3 groups (A, B and C). The subjects were originally recruited for a study on adaptation to repeated vibratory perturbation with different intervals [9], which was the basis for the group division. Each subject performed 5 trials; group A: with 20 min interval between each of the five trials, group B: with 3 h interval and group C: with 24 h interval. All subjects save 1 from group C returned for a follow-up posturography after 3 months. All subjects were naive concerning the study protocol and the methods employed. All subjects were healthy and had no history of any otoneurological, neurological, psychiatric, orthopedic or hearing disorders. Alcoholic beverages and sedative drugs were proscribed for 24 h preceding the testing, and none of the subjects were on any form of medication. Informed written consent was obtained from all the subjects and the experiments were done in accordance with the Helsinki Declaration of 1975 as revised in 2013, and approved by the local ethical committee.

Postural control was evaluated during 30 s standing on a force platform (400 × 400 × 75 mm) equipped with six strain-gauge sensors. The custom built force platform recorded torques and sheer forces with six degrees of freedom using force transducers with an accuracy better than 0.5 N. Data were sampled at 50 Hz by a computer equipped with a 12-bit AD converter. After the recording of 30 s quiet stance, all subjects were subjected to vibratory calf stimulation, the results of which were presented in a previous report [9]. After information about the test procedure the subjects were instructed to stand erect but not at attention, with arms crossed over the chest and feet at an angle of about 30 degrees open to the front and the heals approximately 3 cm apart. All tests were performed by the same examiner and thus received the same instructions prior to each test. Two tests were conducted at each trial occasion, EO and EC. In the EO condition, subjects were fixating on mark on the wall at a distance of 1.5 m at eye level. The test order, EO/EC, was randomized. In order to minimize any external disturbances or cues for the test subjects, the recordings were performed while the test subjects listened to classical music relayed through headphones. The music sequence was repeated and the same through all tests. Romberg test can be measured also in tandem stance and standing on foam, we used the above-described method since it is the most used method.

We measured torque and analyzed the variance of the torque values. Postural stability during quiet stance is commonly analyzed using force platforms and the movements of the centre of pressure (CoP), i.e., the point of application of the ground reaction force. Torque correspond to Centre of Pressure (CoP); torque τ is calculated from the formula $\tau = \text{CoP} \times Fz$; where $Fz \approx m \times g$; where m = the assessed subjects mass (in kg) and g = gravitational constant 9.81 (m/s^2). Hence, changes in recorded torque are equivalent to changes in CoP [10], however, the information is here presented in the form of energy used towards the support surface to maintain stability [10,11], which in turn corresponds to the efficiency of standing [12]. Changes in recorded torque from the force platform correspond well to the actual body movements and posture changes induced by vibratory stimulus [13]. The formula for variance is given by

$$\bar{\tau} = \sum_{i=1}^{n} \frac{\tau(i)}{n}$$

$$\text{var}\,\tau \frac{1}{n-1} \sum_{i=1}^{n} (\tau(i) - \bar{\tau})^2$$

where i = sample, n = number of samples recorded during an analyzed period.

The torque variance values were normalized to account for anthropometric differences between the subjects, using the subject's squared height and squared mass, as height and mass are key factors influencing the body sway recorded by a force platform [11,14]. The squared nature of the variance algorithm made it necessary to use normalization with squared parameters to achieve unit agreement.

In the data analysis, the variance of torque was divided into three categories, total, low frequency (<0.10 Hz), and high frequency (>0.10 Hz). A fifth-order digital finite duration impulse response (FIR) filter [15], with filter components selected to avoid aliasing was used for spectral separation. The frequency cut-off level of 0.1 Hz was based on fast Fourier transformation (FFT) analysis of the sway composition under EO and EC conditions [16]. The frequency limit at 0.1 Hz was also based upon empirical tests on recorded body sway, which have shown that this frequency limit is efficient when separating between fast corrective movements to maintain balance, and the smooth corrective changes in the overall stance [17].

The Romberg ratio was calculated in the traditional manner, i.e. EC/EO. A value exceeding 1.0 would indicate a greater amount of postural sway during eyes closed.

We also analyzed another Romberg ratio according to the following formula [3]:

$$\frac{\text{Eyes Closed (EC) torque} - \text{Eyes open (EO) torque}}{\text{EC torque} + \text{EO torque}} \times 100$$

A ratio close to zero or negative indicates that the magnitude of body sway was similar or smaller in the condition with EC than with EO, i.e. visual information was less important for postural control. This formula considers the total amount of body sway during both visual conditions (EO and EC).

3. Data analysis

Test to retest reliability was assessed in three different ways:

(1) Intraclass correlation coefficients (ICCs, mixed model evaluating consistency) were estimated for each trial and each parameter, i.e. torque variance for EC and EO, and for both Romberg ratios. The ICCs were also estimated according to the interval between the tests (minutes, hours, 1 day) and to the frequency of the sway (total, low frequency, high frequency sway). Test to retest reliability was assessed according to the Fleiss criteria where an ICC of <0.4 indicates poor, 0.4–0.75 fair-to-good, and >0.75 excellent reliability [18]. If the confidence interval (CI) in the analysis ranged below zero, it would mean that the test–retest measurements were unreliable. The CI also gives information about the limits of uncertainty surrounding the estimated ICCs.

(2) The absolute difference between the Romberg ratios was calculated between each consecutive trial, i.e. between the 1st and 2nd, 2nd and 3rd etc. ((Ratioday2–Ratioday1). This