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Postural sway changes during pregnancy: A descriptive study using stabilometry☆

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ABSTRACT

Objective: This study aims to analyse changes in body sway over the course of pregnancy.
Study design: This is a descriptive study in which stabilometric tests were applied at three stages of pregnancy and with a combination of different visual conditions (eyes open/closed) and support base configuration (feet together/apart). Twenty healthy pregnant women participated in the study. Changes in postural control with pregnancy were analysed via the elliptical area of the stabilograms and spectral analysis of the displacements of the centre of pressure (COP) along the lateral and anterior/posterior directions.
Results: The elliptical area encompassing the COP significantly increased over the course of the pregnancy for the feet apart and eyes closed test protocols. The spectral analysis revealed a significant increase of COP oscillations along the anterior–posterior direction when subjects stood with the eyes open/feet together and feet apart. A reduction (significant) of the lateral oscillations of COP was observed for the eyes open/feet together protocol.
Conclusion: Pregnancy induced significant changes in the postural control when pregnant women stood with a reduced support base or with eyes closed.

1. Introduction

From a biomechanical perspective, progressive alterations in body shape, weight distribution and thus the average position of body centre of gravity (COG) during the course of the gestational period are documented [1,2]. The upright [3–5] and sitting postures [3,6] as well as joint moments and foot plantar pressure [7,8] during pregnancy are topics discussed in the literature. Nevertheless, the adaptations in the postural control at upright stance emerging throughout pregnancy have been marginally investigated so far [9,10].

Human postural control during quiet standing involves the integration of sensory information from body periphery, in particular from mechano receptors on the foot soles [11], and from specialised receptors coding body position and orientation with respect to the gravitational acceleration, the environment and the body segments [12]. Such sensory information is coordinated with precise modulations in ankle torque, possibly through fine adjustments in the length of plantar flexors [13], to compensate for the continuous and spontaneous sways of the body during quiet standing. In addition, passive elements (e.g. muscle–tendon connective tissues) seem to provide substantial contribution for the tonic ankle stiffness [14].

While the postural control mechanisms seem to be unaffected during pregnancy, the increased and asymmetric distribution of body mass and the posterior tilt observed over the pregnancy time course [7,8] could play an important role in modulating body sways amplitude and frequency, reflecting specific strategies for maintaining upright standing posture. On one hand, the increased mass in the anterior pelvic region in pregnant women would likely be compensated for with the increase of tonic activity of ankle plantar flexors and with the augment of ankle stiffness, under the inverted pendulum framework [15,16]. On the other hand, the time constant of body sways would also increase (e.g. the duration of body sways increases – [17]). Notwithstanding the larger degree of ankle tonic activity, women in the later stages of pregnancy would possibly compensate for the body sways with modulations of ankle torque at lower frequencies.

Stabilometry is a reliable method to quantify the position of body centre of pressure (COP – defined as the coordinates of the resultant force applied through the feet on the force-plate). Even though this method has been extensively used with normal subjects and patients, establishing normality ranges for classic

☆ This study was conducted in Rio de Janeiro, Brazil.

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stabilometric descriptors [18–20], only two studies seem to have focused on the assessment of changes in postural sways with pregnancy. By using temporal parameters of the stabilometric signal to assess the postural control, Butler et al. [9] observed a decline in balancing ability with pregnancy, which persisted for 6–8 weeks after delivery, and an increased reliance on visual cues to maintain balance during pregnancy. However, the effects of support base configuration on the stabilometric descriptors were not accounted for by these authors. Recently, Jang et al. [10] analysed the postural sways of pregnant women along both the medio-lateral (ML) and anterior–posterior (AP) directions, reporting an increased postural instability in the sagittal plane over the course of pregnancy. The lack of changes in COP sways along ML direction was attributable to the self-selection of support base configuration [10]. After all, the identification of postural strategies based on the interpretation of stabilometric data may be biased when anthropometric and biomechanical effects on stabilometric descriptors are overlooked [21,22].

The present study aims to detect and analyse possible changes in body sways, in both time and frequency domains, over the course of pregnancy in a sample of young and healthy women, accounting for possible effects of reducing the support base and suppressing the visual inputs. The following research questions are addressed in this study: (1) Are there changes in body sway during pregnancy when subjects stand with feet comfortably apart? (2) What are the effects induced by the reduction of support base and the suppression of visual input on the postural control with the course of pregnancy? The rationale for applying eyes open/closed and feet apart/together protocols is to investigate how the postural control of pregnant women adapts in response to the exposition to hazardous situations (e.g. standing in environments with scarce luminosity or standing on unstable supporting surface) throughout pregnancy.

2. Materials and methods

Twenty healthy pregnant women (28.7 ± 6.2 years, 158.2 ± 5.6 cm height) participated in this descriptive study. The subjects were attending pre-natal clinics at the Institute of Child Health of the Federal University of Rio de Janeiro, did not develop complications during their pregnancies and did not report a history of neurological or orthopaedic pathology. All subjects volunteered and gave informed consent for the study.

The experimental protocol consisted in the application of 30 stabilometric tests in each of the following standing conditions: (1) eyes open with feet comfortably apart (EO/FA); (2) eyes closed with feet comfortably apart (EC/FA); (3) eyes open with feet together (EO/FT); and finally (4) eyes closed with feet together (EC/FT). Two-minute rest periods were interposed between each test. Stabilometric exams were applied during the first (to be referred to as G1), second (G2) and third (G3) trimesters of pregnancy. Subjects were allowed to choose their preferred foot position over the force-plate during the protocols with feet comfortably apart, and the size of their support base, defined as the distance between the mid-points of the long axis of each foot (from hallux to the middle of the heel), was measured. For the three exams, Table 1 shows mean and standard deviation of the parameters body mass, abdominal girth and the size of the support base over the course of pregnancy.

The deflections of the centre of pressure (COP) along the lateral (x) and anterior/posterior (y) axes were recorded (sampling rate: 50 Hz) with a custom force platform, developed in accordance with the specifications provided by the French Association of Posturology [23] and Bizzo et al. [24]. The area (*area*) encompassed by the COP was analytically evaluated as an ellipse (ca. 85% of COP samples are within the ellipse), whose principal axes were estimated through PCA – Principal Component Analysis [18,25]. Spectral analysis was applied for each stabilometric test in both x and y direction by using Burg's autoregressive method [19,26], with order 100 and decimation to 10 Hz. The total power (*TP*) was calculated separately for each direction, AP and ML, to obtain a global measure of COP sways, which corresponds to its variance. Only the frequencies encompassed in the band 0–2 Hz were included in *TP* calculation, since very little activity was observed above this limit.

To investigate the variations in *area* and *TP* with the gestational period, a 3 × 2 × 2 multivariate analysis of variance (MANOVA) design was applied (gestational trimesters × eyes open/closed × feet apart/together). Orthogonal contrasts were used for post hoc pair-wise comparisons and results were considered significant at $p < 5\%$.

Table 1
Description of the sample (mean ± standard deviation, $N = 20$ subjects) over the three trimesters of pregnancy.

Trimester	G1	G2	G3
Time of exam (week into pregnancy)	15.1 ± 1.8	24.0 ± 2.4	34.5 ± 2.5
Mass (kg)	59.8 ± 8.8	64.9 ± 8.2	69.1 ± 9.1*
Abdominal girth (cm)	86.1 ± 9.0	95.4 ± 6.7	102.2 ± 5.3**
Size of support base (cm)	14.2 ± 3.4	13.5 ± 2.6	13.9 ± 2.1

Statistically significant differences among the three trimesters *$p = 0.01$, **$p = 0.00$.

3. Results

The relative gain in body mass from the first to the third trimester was 16.2 ± 7.9% with an increase of abdominal girth of 15.4 ± 8.6% (mean ± standard deviation). In contrast, the size of preferred configuration of the support base did not change significantly with pregnancy (Table 1).

Although the elliptic area of COP sways progressively increased with pregnancy, except for the eyes open and feet apart condition, it reached statistical significance only in the second ($p = 0.018$) and third ($p = 0.003$) trimesters, in comparison to the early stage of pregnancy (Fig. 1).

Significant changes in the postural control with development of pregnancy were observed in EC/FA and EO/FT conditions. The total power of COP sways along ML direction significantly increased when pregnant women stood with feet apart and eyes closed during the second and third gestational periods, with respect to the same standing protocol applied within the first 3 months of pregnancy (Fig. 2a). Interestingly, *TP* in the frontal plane decreased

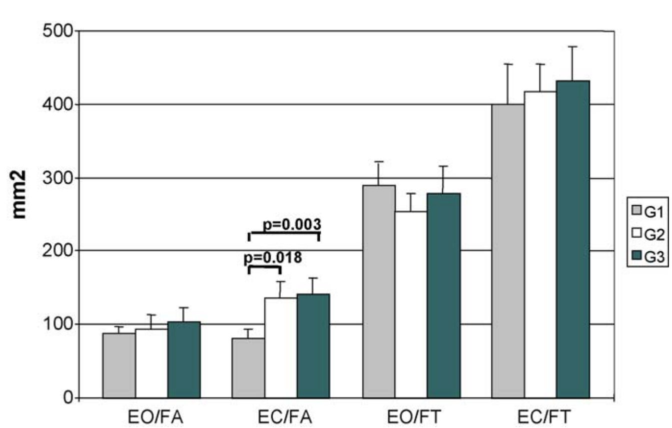

Fig. 1. Mean area of the stabilograms (in mm^2) and standard errors (error bars) over the three trimesters of pregnancy (G1, G2 and G3) for each of the four test protocols. The brackets indicate statistically significant change over the course of pregnancy. EO = eyes open; EC = eyes closed; FA = feet apart; FT = feet together.