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Biomechanical analysis of breastfeeding positions and their effects on lumbopelvic curvatures and lumbar muscle responses

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ABSTRACT

This study aimed to analyze the position of the lumbopelvic region and lumbar muscle activity in the most common breastfeeding positions. We recorded the curvatures of the lumbar spine and pelvis by means of an electrogoniometer, and the muscle activation levels of the erector spinae with electromyography, in 34 women in erect standing and breastfeeding their children in several positions. Both side lying and clutch-hold positions showed a greater degree of lumbar spine flexion compared to standing. In all sitting postures it was observed that the pelvis was placed in retroversion when compared to standing and side lying. In muscle activity, it was observed that the activation intensity of the right erector in the right side-supported side lying position was significantly lower compared to the rest of breastfeeding postures and standing. Side lying may be a better position to avoid muscle fatigue.

1. Introduction

According to the World Health Organization, child nutrition during the first 6 months after birth should be based exclusively on breastfeeding. Despite the benefits that breastfeeding has to offer the child and mother, mothers are reported to breastfeed less and less worldwide (Engebretsen et al., 2007). One of the factors associated with low rates and early cessation of breastfeeding is pain during lactation (Hawley et al., 2015), which can be musculoskeletal in origin (Kam, 2016; Charette and Théroux, 2019; Rani et al., 2019; Afshariani et al., 2019). Musculoskeletal pain during lactation may affect different body regions, such as the pectoral region (Charette and Théroux, 2019), the neck (Rani et al., 2019) and the lower back (Rani et al., 2019; Afshariani et al., 2019). Low back pain affects more than 20% of lactating mothers (Rani et al., 2019), and has been related to the adoption of incorrect postures (Afshariani et al., 2019).

During lactation, women remain in certain positions several hours a day, especially in sitting. Prolonged sitting has been associated with the appearance of back pain (Park et al., 2018; Pope et al., 2002) and with the exacerbation of painful symptoms in most patients with low back pain (O`Sullivan et al., 2006). Milligan et al. (1996) found that breastfeeding in a sitting position caused greater levels of fatigue than the side lying position, and related this to the lower effort that the side lying position requires to hold the child. So a continuous muscular effort during sitting could also cause fatigue, and represent a risk factor for the discomfort of the mother and even the abandonment of breastfeeding (Chapman et al., 1985).

Mbada and Oyinlola (Mdaba and Oyinlola, 2012) in a survey of 383 lactating women found that 89.8% of women used the sitting position to breastfeed their newborn children, and that approximately 41% had low back pain. Likewise, 87.5% of the women who presented pain used a relaxed sitting position for breastfeeding. According to O`Sullivan et al. (2006), a relaxed sitting position is achieved by relaxing the thoracolumbar spine with a posterior rotation of the pelvis, with no active effort to extend the thoracolumbar spine or retract the shoulder blades.

Although the choice of one specific breastfeeding position depends on personal circumstances or preferences, inappropriate positions which could contribute to lower back pain should be avoided. Some clinical guidelines (National Collaborating Centre for Primary Care, 2006; International Lactation Consultant Association, 2005) collect some ergonomic advice: mothers should support their back properly and support their feet on the floor, and they may use pillows or footrests for greater comfort. However, biomechanical and ergonomic studies on sitting posture are focused on the general population within a working

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environment. Back pain during pregnancy has been related to spinal postural changes, especially increased lordosis, which alters the distribution of loads, causing increased tensions in lumbar structures (To and Wong, 2003; Östgaard et al., 1993). Afshariani et al. suggested that there may be a similar link between incorrect breastfeeding postures and low back pain, and even designed an ergonomic education intervention for breastfeeding mothers, which reduced significantly the incidence of low back pain among them (Afshariani et al., 2019). But to our knowledge there is no previous study which analyses the biomechanics of breastfeeding positions, to pinpoint those hypothetical "incorrect" aspects. Therefore, the aim of this study was to analyze the position of the lumbopelvic region and lumbar muscle activity in the most common breastfeeding positions. The hypothesis was that lumbopelvic curvatures and muscle activity patterns associated to the most frequent breastfeeding positions are not equal.

2. Materials and methods

2.1. Design

We designed a cross-sectional observational study, based on the kinematic and electromyographic analysis of breastfeeding postures on healthy mothers.

This research was approved by the local Corporate Ethics Committee

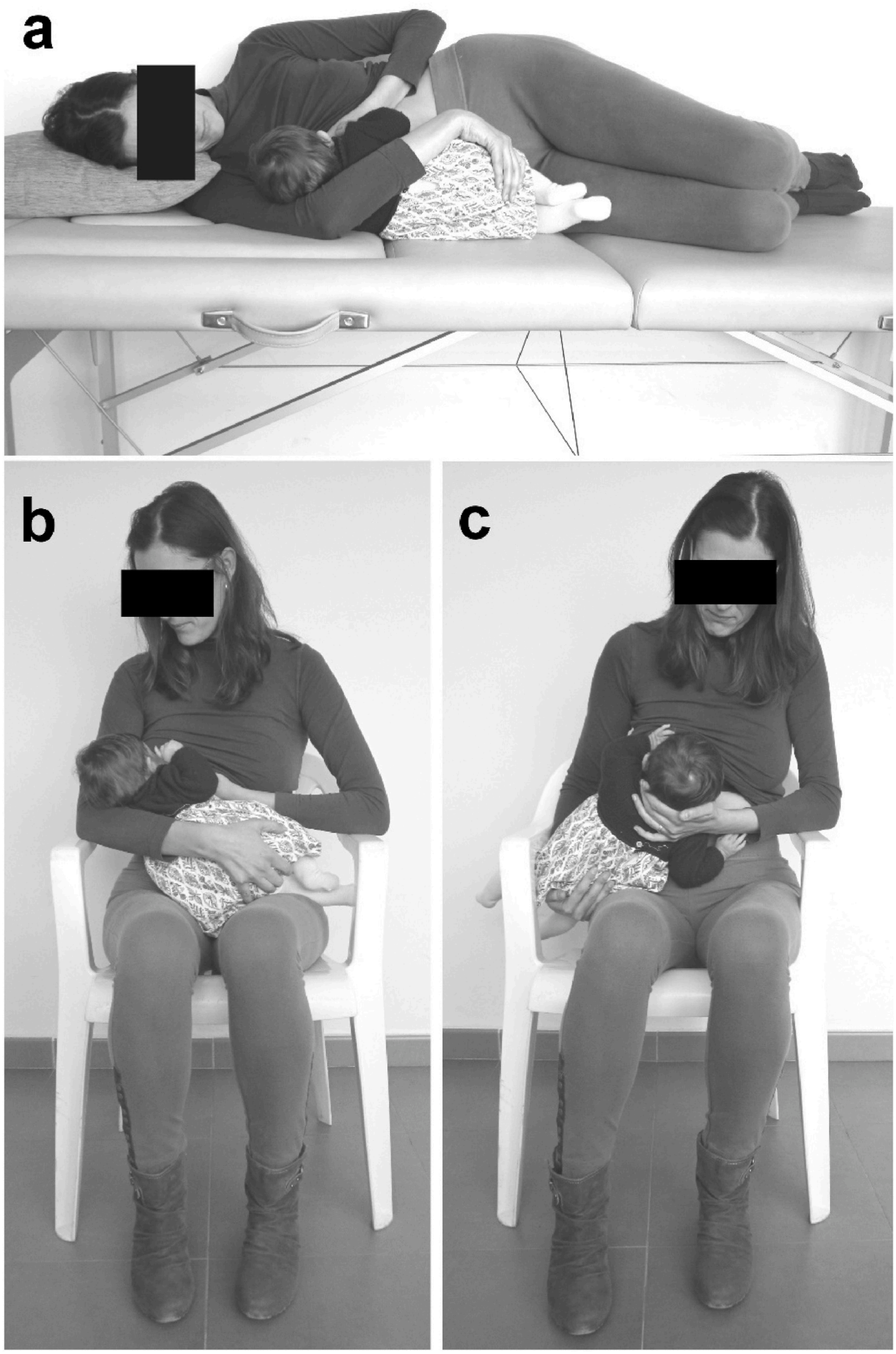

Fig. 1. Breastfeeding positions: (a) side-lying position, (b) cradle hold, and (c) clutch or football hold. Photograph taken by the authors, with full written consent of the participant for publishing.

for Clinical Research in Primary Care (GESTALUMAB), and the University Ethics Committee on Human Research (H1385706839672). All the procedures were conducted in accordance with the principles of the World Medical Association's Declaration of Helsinki and all participants provided their written informed consent.

2.2. Setting

The recordings were carried out in a biomechanics university laboratory, while the mothers breastfed their children in the three positions recommended by the American Academy of Pediatrics (Fig. 1) (New Mother's Guide to Breastfeeding, 2011).

a) Side-lying position: the participants lay in right lateral decubitus on a stretcher, with a cushion under their heads. The baby was on his side, close to and facing his mother. The mother placed her right arm under the child's head.
b) Cradle hold: the participants were seated on a chair, with their backs resting on the backrest. The right forearm of the mother supported the baby's back, and she cupped his bottom or upper thigh with her hand. The participant then rotated her forearm so the baby's entire body turned toward her. The baby's pelvis was up against the mother's abdomen, his chest against her chest, and his mouth lined up with her nipple.
c) Clutch or football hold: the participants were seated on a chair, with their backs resting on the backrest. The child was placed with the head at the level of the right breast and the body held between the right forearm of the mother and right side of her trunk. The mother held the child's head and neck with their opposite hand.

In addition, the position of the lumbar spine and the activity of the erector spinae muscles were recorded with the participants in a neutral standing position, without carrying the baby, with the hands hanging freely at the sides. This was used as a reference for an unloaded position with low muscle activity levels.

For the cradle and for the clutch hold we used a conventional plastic chair, as shown in the figure. The chair had armrests and a straight backrest, which got to the level of the shoulder blades. The cradle hold and the clutch hold were recorded in two different ways: (1) with both feet resting on the floor, and (2) with the left foot resting on the floor, and the right foot resting on a step 14 cm high. We used a standard and commercially available wooden step, bought from a supplier of physiotherapy equipment (Ecopostural step, Herycor, Elx, Spain). The mothers adapted to each required posture and started nursing their children: when they said that they were stable, comfortable and relaxed, the recording started. The recording of each posture lasted 1 min. All tests were performed at least 2 h after the women had gotten out of bed in order to minimize diurnal variations in the mechanics of the spine (Adams et al., 1990).

2.3. Sample

31 women participated in the study (age: 35 ± 1), two months after childbirth (8 ± 3 weeks postpartum). Exclusion criteria were: (1) a history of low back pain, with enough intensity to cause loss of workdays at some point, (2) any kind of diagnosed spine disorders, such as vertebral fractures, discal herniation, scoliosis, vertebral tumors, etc, (3) a significant difference in the length of both legs and/or (4) a history of surgery in the low back region. All participants had vaginal births, and none of the infants showed abnormalities in palatal development or any issues with latching.

2.4. Measurement

The positions of the lumbar spine and the pelvis were recorded using a Liberty 240/16 motion analysis device (Polhemus Inc., Colchester, USA). This electrogoniometer uses a low frequency magnetic field generated by an electromagnetic source located on a plastic platform of adjustable height at the level of the coxofemoral joint of each participant. It has a sampling frequency of 240 Hz. Two sensors were used, one on the spinous process of the first lumbar vertebra (L1) for the displacement in the sagittal plane of the trunk as a whole, and another on the first sacral vertebra (S1) for pelvic sagittal motion (Fig. 2).

An EMG100C Biopac module (Biopac Systems, Inc., Goleta, CA) was used to record the electromyographic (EMG) activity of the erector spinae muscles, with pre-gelled disposable silver-silver chloride (Ag/AgCl) surface electrodes, with a diameter of 2 cm. Following the recommendations of the Surface Electromyography for Non-Invasive Assessment of Muscles (SENIAM) project (Hermens et al., 2000), two pairs of recording electrodes were placed 3 cm to the right and left of the third lumbar spinous process (Fig. 2), with another neutral electrode over the sternum. After carefully cleaning and lightly abrading the skin with an alcohol pad, the recording electrodes were attached bilaterally, parallel to the underlying muscle fibers, with a center-to-center distance of 2 cm. The EMG activity recorded from each posture was expressed as a percentage of a submaximal normalization contraction, obtained by means of a Biering-Sorensen maneuver in a horizontal roman chair, as described in Biviá-Roig et al. (2019a).

2.5. Data analysis

An a priori analysis of the intensity of the effect and the sample size was carried out to obtain a statistical power of 90%. Effect size was

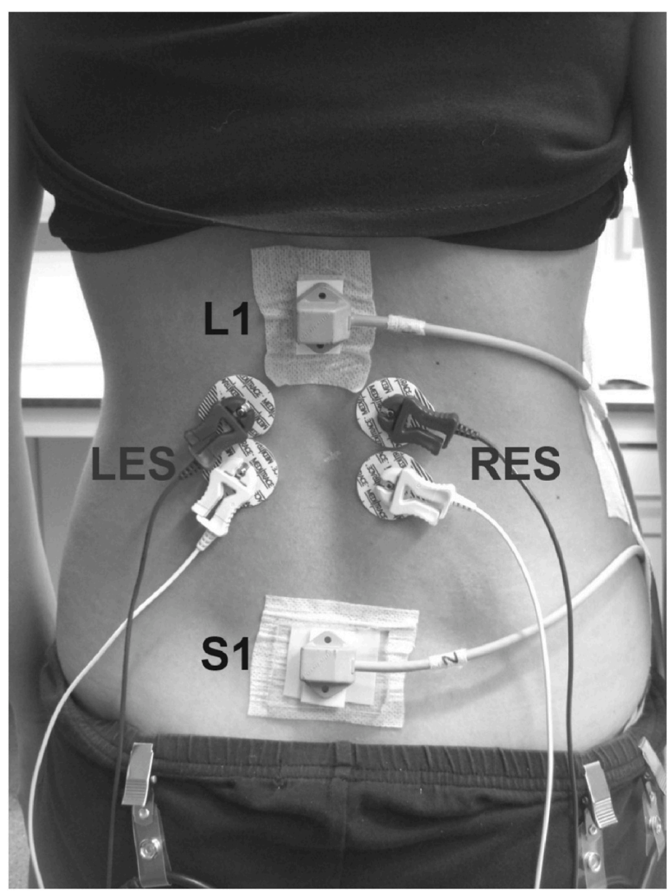

Fig. 2. Location of the erector spinae EMG electrodes and the lumbopelvic position sensors. RES: right erector spinae EMG electrodes, LES: left erector spinae EMG electrodes, L1: position sensor at the level of the first lumbar vertebra, S1: position sensor at the level of the first sacral vertebra. Photograph taken by the authors, with full written consent of the participant for publishing.

estimated by calculating Cohen's d statistic (Cohen, 1998) from the results of previous studies that compared pregnant and non-pregnant women with similar dependent variables: the EMG of the trunk extensors (Sihvonen et al., 1998) or the lumbopelvic position in the sagittal plane (Gilleard et al., 2002). Based on the values of the Cohen's d statistic, the sample size was estimated using the G*Power 3 software (Faul et al., 2007), with a minimum estimated sample size of 30 participants.

In order to study spinal and pelvic positions, data obtained in the sagittal plane were used, considering the vertical as the 0° position. All the measurements provided by the sensors had the electromagnetic source as the origin of the coordinates. S1 sensor data represented by themselves pelvic anteversion/retroversion values. The position of the lumbar spine in the sagittal plane was obtained by subtracting the S1 sensor data from the L1 sensor data (curvature in the sagittal plane of the trunk as a whole, pelvis and lumbar spine) (Biviá-Roig et al., 2018, 2019b; Neblett et al., 2003).

The raw EMG signal was initially processed with a band-pass filter (cutoff frequencies: 10 Hz high pass, 500 Hz low pass) and amplified (input impedance greater than 100 MΩ, common mode rejection ratio of 110 dB at 60 Hz, overall gain of 1000). EMG signals were A/D converted at a sampling frequency of 1000 Hz with a 16-bit data acquisition system (model MP150; Biopac Systems Inc.), and their noise level was smoothed by calculating the root mean square of the data with a window of 0.02 s. A specific data processing application was developed using MATLAB® software (The MathWorks, Inc., Natick, MA USA).

2.5.1. Statistical procedures

Normality was checked for each dependent variable and each study group by means of the Shapiro-Wilk test, with all study groups showing compliance with the assumption of normality.

To compare the mean values of lumbopelvic position and muscular activity of the erector spinae obtained during the 1-min recording of the different breastfeeding postures, a one-way repeated measures analysis of variance (ANOVA) was carried out, with the type of lactation posture as the independent variable. Compliance with the sphericity assumption was verified by the Mauchly sphericity test. Sphericity was not met for any of the comparisons, so a multivariate (MANOVA) approach was used as an alternative for calculating the main effects for each of the dependent variables. Left-right differences in erector spinae EMG activation were analyzed using paired t-tests. For the specific comparisons between pairs of measures, the Bonferroni test was used as post-hoc. A significance level of 0.05 was used for all comparisons. SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA) software was used for all statistical calculations.

3. Results

Table 1 shows the age, weight, height and body mass index of the participants. The average weight of the children held by the mothers during the breastfeeding postures was 3.1 ± 0.4 kg. All the participants were right-handed.

Regarding lumbopelvic position, the results showed a greater degree of lumbar spine flexion both in side lying ($p < 0.001$) and in the two clutch-hold positions (with and without step, $p = 0.007$ and $p = 0.012$, respectively), compared to standing. No significant differences were found in the degree of flexion of the lumbar spine between standing and the two cradle positions, with and without step.

Table 1
Age, weight, height and body mass index of the participants.

Age (years)	35.0 ± 1
Weight (kg)	62.1 ± 8.7
Height (cm)	163.2 ± 6.7
Body mass index (kg/m2)	24.8 ± 9.8

Values presented as mean ± SD.
Main effects were statistically significant for the type of lactation posture, either for lumbar position ($p < 0.001$, $F = 32.931$), pelvic position ($p < 0.001$, $F = 23.670$), right erector spinae EMG activation ($p < 0.001$, $F = 6.979$) and left erector spinae EMG activation ($p < 0.001$, F = 8,785).

On the other hand, in all sitting postures it was observed that the pelvis was placed in retroversion when compared to standing and side lying (all p-values <0.001), during which the pelvis was in anteversion. There were no significant differences in the degree of retroversion of the pelvis between sitting postures.

Fig. 3a and b shows the degrees of lumbar and pelvic inclination obtained in each posture, expressed in negative (lumbar extension/pelvis retroversion) or positive degrees (lumbar flexion/pelvis anteversion) with respect to the vertical.

Values are shown as mean (bars) and standard deviation (error bars), in degrees. †significant difference $p < 0.01$; *significant difference $p < 0.05$; SL = side lying, a = differences with SL; FHF = clutch/football hold with foot step, b = differences with FHF; FHnF = clutch/football hold with no foot step, c = differences with FHnF; CHF = cradle hold with foot step, d = differences with CHF; CHnF = cradle hold without foot step, e = differences with CHnF; S = standing, f = differences with standing.

In erector spinae EMG activity, it was observed that the activation intensity of the right erector spinae in the side lying position (supported on the right side) was significantly lower compared to the rest of breastfeeding postures and standing (p-values ranging from less than 0.001 to 0.014) (Fig. 4a). In the left erector spinae there were no significant differences between any of the breastfeeding postures, although all of them showed greater activity on the left side than the standing position (p-values ranging from less than 0.001 to 0.009) (Fig. 4b). Regarding the differences in activation between the right and left erector spinae, greater activity was observed on the left side in all postures of lactation (p-values ranging from less than 0.001 to 0.035). This difference between the left and right side was not observed in standing.

Values are shown as mean (bars) and standard deviation (error bars), in percentage of submaximal activation. †significant difference $p < 0.01$; *significant difference $p < 0.05$; SL = side lying, a = differences with SL; FHF = clutch/football hold with foot step, b = differences with FHF; FHnF = clutch/football hold with no foot step, c = differences with FHnF; CHF = cradle hold with foot step, d = differences with CHF; CHnF = cradle hold without foot step, e = differences with CHnF; S = standing, f = differences with standing.

4. Discussion

Our participants displayed retroversion of the pelvis in all sitting postures, unlike the pelvic anteversion observed in standing. This is a well-known general feature of sitting postures, and agrees with the results showed by previous studies which dealt with sitting postures in the general population (Nairn et al., 2013; Yasukouchi, A., & Isayama, 1995).

With regard to lumbar curvature, some authors have observed an increased lumbar flexion in both sitting (Keegan, 1953; Frey and Tecklin, 1986; Claus et al., 2009) and side lying (Keegan, 1953) compared to standing. Keegan (1953) carried out a radiographic study of lumbar curvatures in different positions. This study showed that in side lying there was an increase in lumbar flexion and a flattening of the lumbar lordosis without reversing the curvature when the hips reached 45 degrees of anteversion. It was when hip anteversion reached 90° that the lumbar spine adopted a kyphotic curvature. This observation coincides with our results about the side lying position: in our case, women were placed with their lower limbs in semi-flexion, forming an angle of about 45° while they nursed the child, keeping it close with their arms. In line with the results of Keegan, in our study breastfeeding in the side lying position also produced an increase in lumbar flexion, but without completely rectifying the lumbar lordosis.

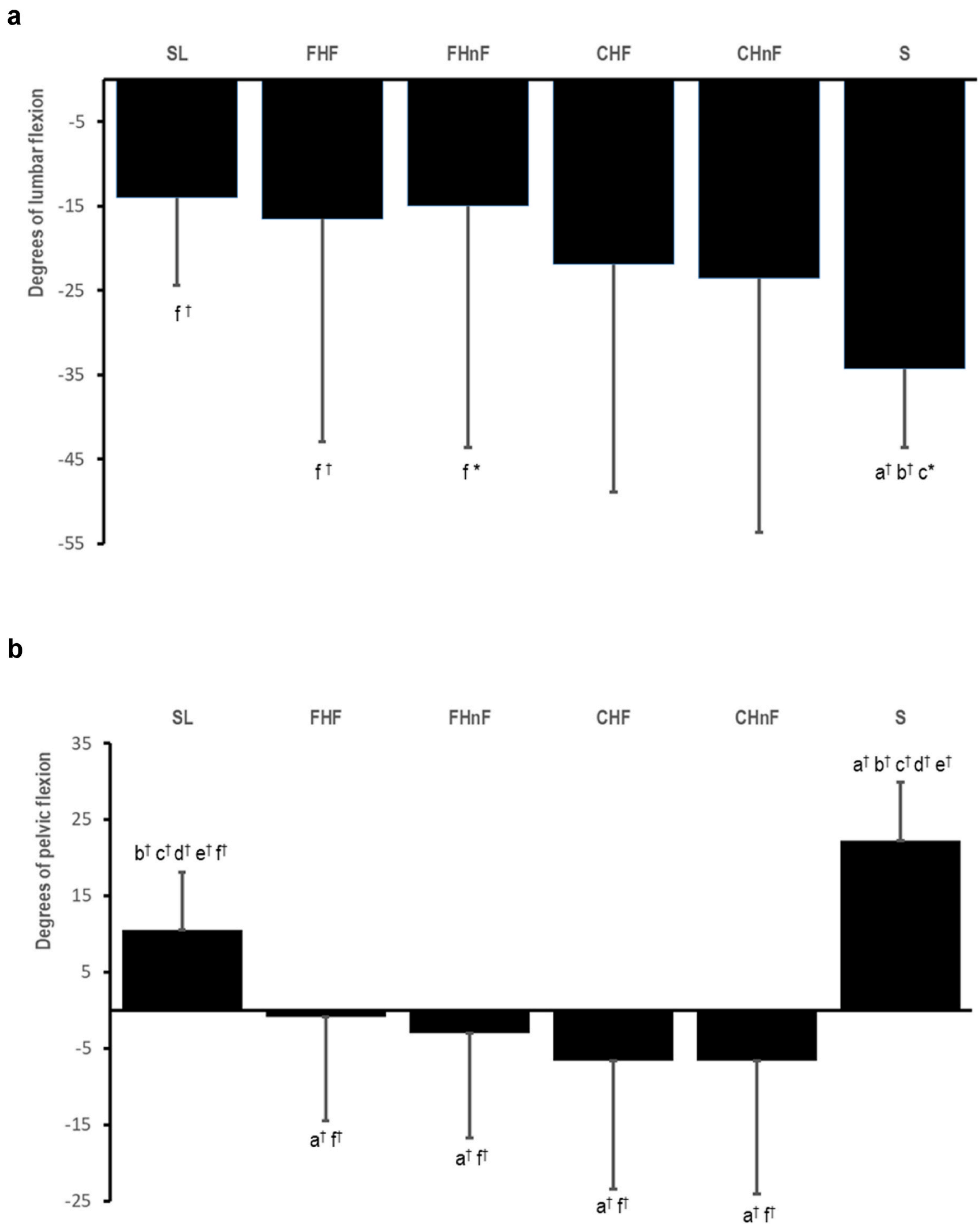

Fig. 3. Lumbar (a) and pelvic (b) inclination in the standing position and the postures of breastfeeding.

Our results showed that the clutch hold increases lumbar flexion, while in the cradle hold there were no changes compared to the standing position. Previous studies have compared different kinds of sitting postures: erect and relaxed sitting (Keegan, 1953), with or without support (Adams et al., 2002; Frey and Tecklin, 1986; Keegan, 1953) or with a support with different inclinations (Nairn et al., 2013). Even the studies which, as we did, employed backed chairs show considerable methodological differences from ours. For example, Frey and Tecklin (1986) used a conventional chair with a backrest, but during the recordings participants were placed with the trunk leaning forward, while performing a task on a desk. However, in the present study the position adopted during the cradle hold was completely different, since the participants were instructed to sit with their backs straight, leaning on the back while nursing the child.

It should be emphasized that a greater lumbar flexion was observed in the clutch hold with respect to standing and the cradle hold. These differences may be explained by how the mothers hold their child's weight in each position. In the cradle hold the mother holds the child with her forearm, but the weight falls on the mother's abdomen, whereas in the clutch hold the child's body and limbs are between the

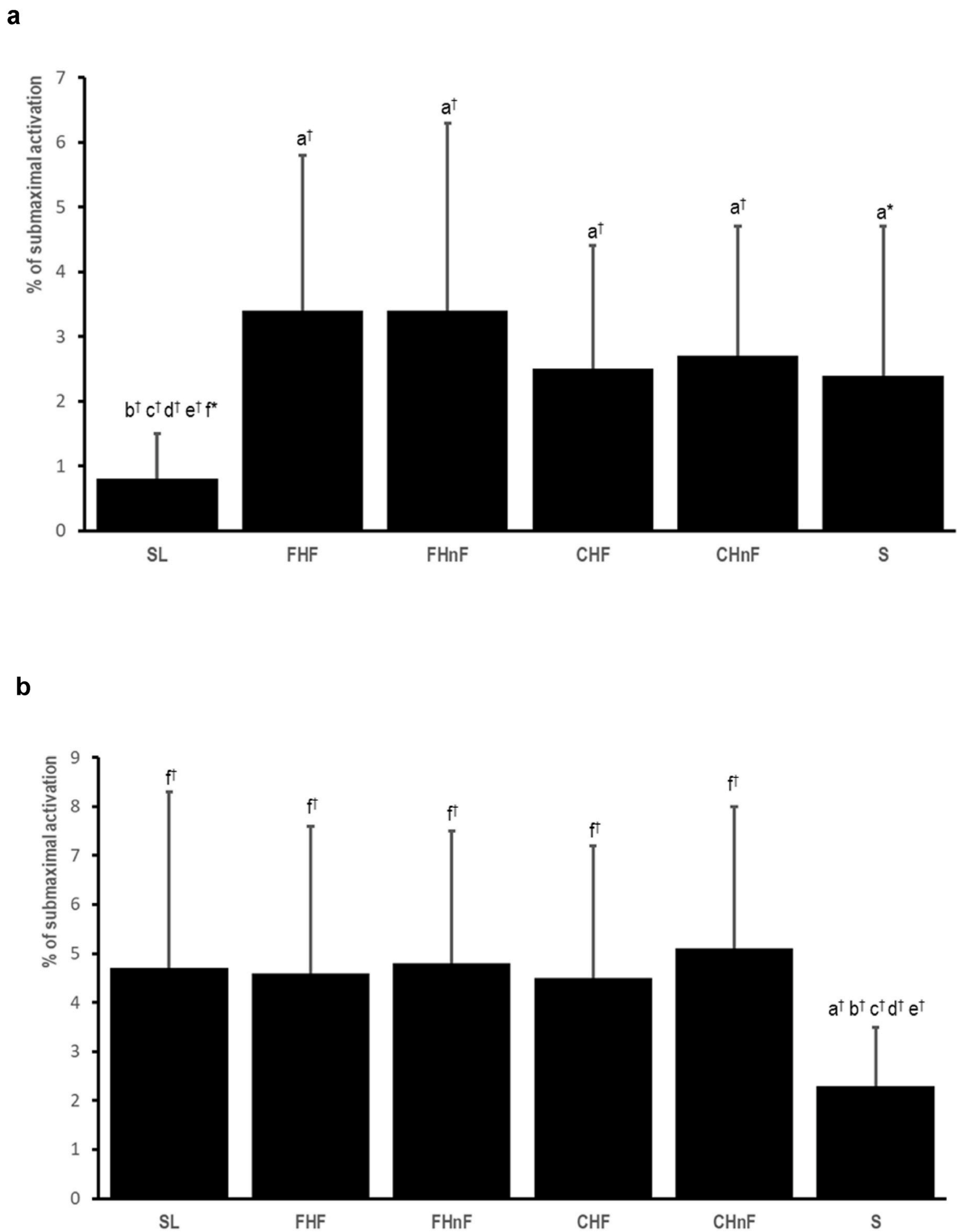

Fig. 4. EMG activity of the right (a) and left (b) erector spinae in the standing position and the postures of breastfeeding.

side of the trunk and the forearm of the mother. Mothers are probably increasing their lumbar flexion in the clutch hold in order to provide more space between their trunk and the back of the chair to place the body and limbs of the child, adopting, at the same time, a more comfortable position to support the child's weight. Bending moment during spine flexion is the main source of damage to spinal connective structures (Adams et al., 2002) and increases as forward flexion progresses. In fact, low back pain patients have been observed to reduce the time during which maximum lumbar flexion ranges are kept, as a protective mechanism (Sánchez-Zuriaga et al., 2015). So the clutch hold, given that it causes an increase in lumbar flexion values, could be less advisable as a breastfeeding position. But the differences with the rest of the breastfeeding postures and neutral standing, although statistically significant, are not great: there is not even a complete rectification of the lumbar lordosis during the clutch hold. With the differences observed in the present study, it is difficult to make recommendations based solely in lumbopelvic position data.

On the other hand, the use of a step to support one foot in activities involving prolonged sitting or standing positions is a widespread recommendation in ergonomics manuals (Malińska et al., 2012; Whistance et al., 1995). The use of a step is supposed to reduce lumbar lordosis (Nairn et al., 2013; Yasukouchi, A., & Isayama, 1995). Some authors argue that supporting one foot on a step causes pelvic retroversion, which helps to avoid an excessive lumbar lordosis and in turn decreases stress on the intervertebral discs (White and Panjabi, 1978). This recommendation about the use of a foot rest also extends to breastfeeding postures: a 2002 cohort intervention study (Ingram et al., 2002) proposed as a basic point of a good breastfeeding technique that the mother should be able to place the feet on a footrest if necessary, to keep the child at the level of her lap. Despite these recommendations, we have found no study dealing with the relationship between the use of an elevated foot support and changes in lumbar curvature in sitting. Our results showed no differences in any of the two sitting positions (cradle and clutch hold) between keeping both feet on the ground and supporting one of them on a step. In standing, some authors have observed that the use of a 20 cm step to elevate one foot produces a greater degree of pelvic retroversion than keeping both feet on the ground (Whistance et al., 1995). We have not observed such changes in sitting: this may be related to the fact that the sitting position causes by itself pelvic retroversion. It is possible that the height of the step used in this study (14 cm) was insufficient to generate a significant increase in said retroversion. Anyhow, the use of a foot step could be more related to a subjective feeling of comfort of the mother than to real changes in the lumbopelvic curvatures.

In terms of muscle activation of the right erector spinae, our results showed no significant differences between the different positions of breastfeeding and standing, excepting the right erector spinae in the side lying position. Some studies have analyzed the differences in muscle activation between an upright sitting position and a relaxed sitting position (Park et al., 2018; O'Sullivan et al., 2006). With regard to erect sitting, some authors have observed that without a backrest the EMG activity of the erector spinae is greater than in standing (Kippers and Parker, 1985) whereas the use of a backrest decreases muscle activity (Bennett et al., 1989). In the present study, however, right erector spinae activity while lactating in an upright sitting position with a backrest was similar to that obtained in the unloaded, neutral standing position. This difference with respect to the results obtained in the aforementioned previous studies could be due to the fact that in our study the mothers were holding the child in their arms, which implies an additional load anterior to the trunk that could be increasing the demands of the posterior trunk extensor muscles. It should also be noted that breastfeeding is not a static activity, and requires constant interaction between the mother and the child. Although the participants in our study maintained their backs on their backrests at all times, this interaction between the mother and the child requires continuous postural adjustments which could cause an increase in muscle activity.

Regarding the differences in the activation of the right and left erector spinae, greater activity was observed on the left side in all the postures of lactation. In sitting postures this could be due to the fact that the participants held the child between their trunk and right arm, so that the left erector spinae was probably increasing its activity to compensate for the lateral imbalance that the child's weight poses to the trunk.

In the side lying position, a lower level of activation was observed at the right erector spinae compared to the other positions. This differences were not observed at the left side. In this position the mothers brought their child closer and held the head to her chest with her left arm, which could be increasing the demands on the left erector spinae muscle. The lower activation observed on the right side could be due to the fact that the women were placed in lateral decubitus resting on their right side, so that the position itself could be allowing greater relaxation on the support side.

Milligan et al. (1996) analyzed the relationship between fatigue levels and breastfeeding positions during the first three postpartum months. In this study fatigue symptoms were measured using the Modified Fatigue Symptoms Checklist, a list of perceived symptoms of fatigue, with established reliability and validity. Their results showed that women experienced a lower level of fatigue after breastfeeding the child in the side lying position compared to sitting. The authors attributed this decrease to the lower effort that the side lying position requires to hold the child. The lower levels of muscle activation in the side lying position on the side resting on the stretcher that we have observed could be related to the lower level of fatigue observed by Milligan et al. This result could be important, since there are many women who, in view of the physical demands of breastfeeding and newborn care, also show symptoms of physical fatigue that can lead, in many cases, to the abandonment of breastfeeding (Chapman et al., 1985).

A Cochrane systematic review showed that health professionals trained in breastfeeding techniques should give women early practical advice on correct positioning to reduce problems and increase breastfeeding duration (Balogun et al., 2016). In addition, other studies conclude that prenatal education, information and advice were associated with increased breastfeeding duration (Piro and Ahmed, 2020; Sikosrki and Renfrew, 2000), particularly in the first 2 months postpartum (Piro and Ahmed, 2020). In this line, with the results of the present study it is difficult to provide biomechanical evidence useful to offer objective recommendations to mothers about the less harmful breastfeeding postures for the lumbopelvic region: with our results, it is difficult to recommend categorically one position over another. The lower muscle activation observed in side lying could make this position more advisable. However, these results should be considered with caution, since differences observed between positions are of small magnitude.

4.1. Limitations

Mothers kept the different postures of breastfeeding while breastfeeding their own children, which is a source of variability among the participants in terms of weight and size of the load they carry. However, this allows us to study an actual breastfeeding situation. This is important for the validity of the study, since breastfeeding involves a constant interaction between mother and child. Our intention to achieve a realistic and representative breastfeeding task also made us not to control all the aspects of the postures of the mothers which went beyond the actual description of each position provided by the American Academy of Pediatrics, which were left to the natural preferences of the participants. This may represent another source of variability, in aspects such as the degree of hip and knee flexion during the side-lying position. Another limitation of the experimental setting was the step added to the clutch and cradle hold positions, which was a commercially available product not adaptable to the height or the leg length of the participants. This was done again to create a more realistic setting, similar to everyday conditions, when mothers do not have access to adjustable steps.

5. Conclusions

Only the positions of side lying and clutch hold (with and without step) showed an increased lumbar flexion which, nevertheless, did not cause a reversion of the lordotic curvature. This is to say, the differences in the position of the lumbopelvic region between the different breastfeeding postures and standing were small.

Lumbopelvic position and muscular activation showed no differences in any of the sitting positions (cradle and clutch hold) between keeping both feet flat on the ground, or the support of one of them on a step.

The results of muscle activation showed a lower EMG activity in the right erector spinae in the right side lying position. This could make this position more recommendable than the rest, although the magnitudes of the differences are small.

Our results could be a starting point for future studies on breastfeeding postures, which focus on additional measures and populations. The recording of motion data from the transverse and frontal planes, as well as subjective perception measures about the mothers' comfort, could be useful to further assess each posture. We also believe it would be of great interest to study the differences in subjective perception, postural and muscle activation variables of healthy women and women with low back pain during breastfeeding.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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