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Exploring associations between perinatal depression, anxiety, and urinary oxytocin levels in Latinas

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Abstract
Perinatal depression has been associated with lower oxytocin (OT) levels. However, few studies have explored this topic in relation to Latinas who are at high risk of perinatal depression. The objective of this study was to explore these associations in Latinas. A total of 108 Latinas in the third trimester of pregnancy participated in the study. Depression and urinary OT levels were assessed in pregnancy and 6 weeks postpartum. Nonparametric tests were implemented to test the proposed associations. Results revealed that 28% of the participants had probable depression in pregnancy, and 23% at 6 weeks postpartum. OT levels significantly decreased from prenatal to postpartum in the whole sample; however, participants with probable prenatal depression did not exhibit a significant change in OT levels. Participants who were depressed or anxious at 6 weeks postpartum exhibited persistently higher mean OT levels over time. A distinct pattern of higher levels of OT in depressed Latinas suggests that OT levels may be an important neuroendocrine factor contributing to depressive and anxious symptoms.

Keywords Latinas · Oxytocin · Prenatal depression · Postpartum depression · Breastfeeding

Introduction

Latinas exhibit higher rates of perinatal depression (PND) than the general population (Bogue 2011; Vidal de Haymes and Kilty 2007; Walmer et al. 2015) due to high exposure to psychosocial risk factors, such as poverty and adverse life events (Lara-Cinisomo et al. 2016; Linares 2014). PND, including both pre and postnatal depressive symptoms, can negatively affect mother-infant bonding, caretaking behaviors, and maternal well-being (Gress-Smith et al. 2011; Lefkovics et al. 2014; O'Hara and McCabe 2013; Provenzi et al. 2018); influence the likelihood of PND during future pregnancies and later depression (Chaudron et al. 2001; O'Hara and Swain, 1996;

Robertson et al. 2004); and is associated with altered physiological and hormonal profiles (Altemus et al. 2001; Bloch et al. 2003; Boufidou et al. 2009; Corwin et al. 2015). Approximately 6–9% of women experience major depression during pregnancy, with symptoms peaking in early pregnancy and declining over time into the postpartum period (Banti et al. 2011; Wu et al. 2010). However, the estimates for prenatal and postpartum depression in Latinas are substantially higher at 7–32% and 6–54%, respectively (Liu and Tronick 2013; Lucero et al. 2012). The reason behind these differences is unclear, but the role of varying neuroendocrine profiles related to postpartum depression, particularly those related to social bonding and maternal behaviors such as the prosocial hormone oxytocin (OT) may provide insights (Cox et al. 2015; Jobst et al. 2016).

Postpartum depression (PPD) is also associated with alterations in breastfeeding. Breastfeeding discontinuation and difficulties and negative experiences with breastfeeding have been associated with PPD (Dennis and McQueen 2009; Taveras et al. 2003). Although Latinas have high rates of breastfeeding initiation, their breastfeeding duration (both any and exclusive) falls short of the recommended levels (Ahluwalia et al. 2012; Eidelman 2012; Waldrop 2013; Wouk et al. 2016). Furthermore, US-born and more-acculturated Latinas are less likely to breastfeed than their immigrant and less-acculturated counterparts (Ahluwalia

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et al. 2012; Celi et al. 2005). Additional research is necessary to determine how other factors such as OT and depression may contribute to disparities in Latina mothers' breastfeeding practices.

Previous research suggests that PPD and early breastfeeding cessation may share a neuroendocrine mechanism involving OT (Cox et al. 2015; Stuebe et al. 2013). Studies suggest that depressive symptoms and diagnosis are associated with a dysregulated pattern of OT release and lower levels of plasma OT among women in the general population and in the perinatal period (Apter-Levy et al. 2013; Garfield et al. 2015; Massey et al. 2016; Moura et al. 2016; Skrundz et al. 2011; Stuebe et al. 2013). Higher levels of OT are contrastingly associated with exclusive breastfeeding (Grewen et al. 2010; Silber et al. 1991; Uvnas-Moberg et al. 1990). Furthermore, urinary OT has also been associated with stress in mothers (Feldman et al. 2011). However, few studies have examined OT levels and associations with PND in Latinas (Lara-Cinisomo et al. 2017), a population which is at a particular risk for psychosocial stressors (Lara-Cinisomo et al. 2016), PPD (Howell et al. 2005), and suboptimal breastfeeding duration and exclusivity (Waldrop 2013).

Several factors are associated with changes in OT levels, including circadian rhythms and stimuli-like stress (Cox et al. 2015; Lindow et al. 1996). OT concentrations vary considerably among women (Levine et al. 2007; Prevost et al. 2014) and have been found to be greater among pregnant women in their third trimester compared to non-pregnant controls (Altemus et al. 2004; Silber et al. 1991). However, findings on the distribution of OT levels throughout pregnancy and into the postpartum period are mixed (de Geest et al. 1985; Feldman et al. 2007; Jobst et al. 2016; Prevost et al. 2014). Variations in findings on the distribution of OT levels across the perinatal period may be partly due to the variations in how OT levels are measured. Alternatively, they may simply be due to the wide differences in OT concentrations between pregnant women (de Geest et al. 1985; Levine et al. 2007).

To further understand the relationship between OT and depressive symptomology in Latinas, we attempt to identify the degree to which OT levels relate to the observance of perinatal depressive symptoms, as well as identify other factors, which may be impacting their OT levels, such as breastfeeding. While Latinas are a heterogeneous group who trace their lineage to Latin America; self-identified as such regardless of race (Kim and Dee 2017) and have Cuban, Mexican, Puerto Rican, and South or Central American ancestry (Humes et al. 2011; Lopez et al. 2013); they are an important group to study because they are the prevailing ethnic minority group in the USA (Census 2013). They also have the highest fertility rate in the USA (Passel et al. 2013) and accounted for 24% of live births in the USA in 2010 (Livingston and Cohn 2012). However, they are understudied, particularly regarding the

role of hormones in PND (Lara-Cinisomo et al. 2015). Thus far, only one small pilot study has addressed and identified the role of OT and breastfeeding with postpartum depression in Latinas (Lara-Cinisomo et al. 2017). To address this gap, this study aims to develop a descriptive picture of Latinas' PND and OT profiles and to explore associations between maternal mood and OT levels.

Methods

Sample

Participants were screened, enrolled, and assessed in late pregnancy (35–36 weeks) and 6 weeks postpartum. As described in a previous publication (Pedersen et al. 2016), 325 prenatal women were screened for the parent study, 216 completed all waves, and 153 self-identified as either Hispanic or Latina. Of those 153, 108 had complete hormone data and were included in the present study. Participants provided written consent to participate in the study and to provide biological specimens.

Procedures

Participants were recruited during routine prenatal visits following medical record reviews. Participants completed two home visit interviews with a bilingual (English and Spanish) trained research assistant. Interviews were conducted in the participant's primary language. Self-reported demographic data collected at enrollment, including education, marital status, age, and health information are reported in Table 1. Each of the two home interviews included an assessment of depression and anxiety. Additionally, 24-hour urine samples were also collected to estimate OT levels.

Psychological assessment

Participants completed the Edinburgh Postnatal Depression Scale (EPDS; Cox et al. 1996), a valid screener during the prenatal period (Kozinszky and Dudas 2015) using a Spanish- or English-validated version of the measure. Scores range from 0 to 30 based on a 4-point scale, with a ≥ 10 cutoff for probable depression (Cox et al. 1996; Gaynes et al. 2005), which has been shown to be a reliable cut point for Latinas (Howell et al. 2012). Because PND is also often comorbid with anxiety (Bernstein et al. 2008), participants also completed the trait subscale of the Spielberger State-Trait Anxiety Inventory (STAI-T; Shahid et al. 2012) and were classified into high- and low-anxiety groups according to the recommended cutoff score of 40 (Dennis et al. 2013).

Table 1 Descriptive statistics of the sample ($N = 108$)

	Percent/mean (SD)
Age at enrollment	27.81 (5.37)
Education in years at enrollment	9.42 (3.37)
Pregnancy BMI[a]	32.65 (6.53)
Postpartum BMI[b]	26.93 (3.98)
Number of pregnancies	2.03 (1.52)
% Married or cohabitating	79%
% Employed at least part-time since becoming pregnant	47%
% Had C-section	17%
Breast or bottle when infant was born	
Breast fed only	61%
Bottle fed only	15%
Both breast and bottle fed	24%
Any breastfeeding when born	
No	15%
Yes	85%
Breast or bottle at 6 weeks postpartum	
Breast feeding only	19%
Bottle feeding only	19%
Both breast and bottle feeding	62%
Any breastfeeding at 6 weeks postpartum	
No	19%
Yes	81%
EPDS pregnancy score	6.67 (4.93)
EPDS postpartum score	5.67 (5.08)**
STAI Trait pregnancy score	35.99 (9.77)
STAI Trait postpartum score	32.90 (9.19)***
% Prenatal depression (EPDS ≥ 10)	28%
% Postpartum depression (EPDS ≥ 10)	23%
% Depressed prenatal and postpartum	18%
% High STAI Trait (≥ 40) anxiety prenatal	34%
% High STAI Trait (≥ 40) anxiety 6 weeks postpartum	24%

Note. ***$< .001$, **$p < .01$

[a] Based on 97 women

[b] Based on 103 women

Oxytocin assessment

OT levels were evaluated using 24-h urine samples collected by the participants. Research assistants trained participants on collection and storage procedures. Urinary OT samples were extracted with 1.5% trifluoroacetic acid, followed by 80% acetonitrile, dried, and reconstituted with assay buffer. OT levels were then measured using an assay kit and protocol from Enzo Life Sciences, Ann Arbor, MI. The hormone content (pg/ml) was determined by plotting the OT of each sample against a standard curve. The sensitivity of the assay was 2.9 pg/ml with a standard range of 4.7 to 312 pg/ml. The intra- and inter-assay variations were 4.8 and 8% respectively. Enzo Life Sciences reports cross-reactivity for similar neuropeptides found in mammalian sera at less than 0.001. To account for urine concentration and volume, creatinine was used to standardize OT levels across participants (Reyes et al. 2014). Urinary creatinine concentration levels were measured using an assay kit and protocol from R&D Systems, Minneapolis, MN. The sensitivity of the assay was 0.07 mg/dl with a standard range of 0.3 to 20 mg/dl. The intra- and inter-assay variation were 3.2 and 5.3%, respectively. Urinary OT levels are expressed as the ratio of OT to creatinine (pg OT/mg creatinine).

Analysis plan

The sample was characterized using descriptive statistics for continuous variables and percentages for categorical variables. Associations between demographic characteristics and probable depression (EPDS ≥ 10) and anxiety status (high versus low) were tested using chi-square tests and Fisher's exact tests with categorical variables and Kruskal-Wallis tests with continuous variables. Due to the non-normality of the data, Spearman's rank correlations were conducted for continuous variables (e.g., depressive symptoms, OT levels). Wilcoxon signed-rank tests were conducted to determine changes from pregnancy to postpartum in all continuous outcomes of interest, including depressive symptoms and anxiety scores as well as OT levels. We also conducted Kruskal-Wallis tests to assess differences in OT levels by breastfeeding status, probable depression status, and high versus low anxiety. Similar comparisons of subgroups by probable depression status were also conducted. The analyses were conducted using SPSS 23 (IBM Corp. 2015).

Results

Sample characteristics

The sample characteristics are presented in Table 1. At enrollment, close to a third of the sample (28%) met the EPDS cutoff for probable depression and 23% at 6 weeks postpartum. An examination of mean EPDS scores indicated that there was an average of one point decrease from prenatal to postpartum ($M = 6.67$, SD = 4.93 and $M = 5.67$, SD = 5.08, respectively). Results from the Wilcoxon signed-ranks test indicated that this change was statistically significant ($Z = -2.77$, $p = .006$). Of the participants, 18% had probable depression at enrollment and 6 weeks postpartum. There was a significant association between marital status and probable prenatal depression ($p = .014$). Just over a third of the sample (34%) met the STAI-T cutoff for high anxiety during the third trimester of pregnancy compared to 24% at 6 weeks postpartum; 19% had high anxiety at both time points. There was a

reduction in mean STAI-T scores of 3.08 over time, which was statistically significant ($Z = -4.06$, $p < .001$). No significant associations between demographic characteristics and anxiety status were observed.

Urinary OT levels, breastfeeding, and maternal mood

Mean urinary OT levels during pregnancy were 29.67 (SD = 36.69) and 21.75 (SD = 18.90) at 6 weeks postpartum. Results indicate that there was a significant decrease in OT levels from prenatal to postpartum ($Z = -3.15$, $p = .002$) in the whole sample. As Table 2 indicates, prenatal and postpartum depressed women as well as those classified as having high anxiety using the STAI-T exhibited higher mean OT levels at both time points compared to non-depressed or low-anxiety women. However, these differences were not statistically significant. Women whose depression persisted from the prenatal to the postpartum visit exhibited higher mean OT in pregnancy and postpartum ($M = 44.39$, SD = 77.15 and $M = 28.71$, SD = 27.78, respectively) compared to women who were never depressed ($M = 27.14$, SD = 19.78 and $M = 20.15$, SD = 17.18, respectively) or depressed at one-time point ($M = 23.91$, SD = 15.74 and $M = 20.77$, SD = 11.89, respectively), though these differences were not statistically significant. Additional analyses revealed a similar pattern in women with high anxiety (STAI-T ≥ 40) at both time points who had higher mean OT ($M = 41.92$, SD = 74.03 and $M = 28.27$, SD = 26.72, respectively) than women whose anxiety was never high ($M = 27.03$, SD = 20.73 and $M = 19.46$, SD = 16.59, respectively) or was high only once ($M = 25.73$, SD = 11.30 and $M = 22.43$, SD = 15.50, respectively). Again, these differences were not statistically significant.

There were observed variations in prenatal OT levels by breastfeeding status after birth and at 6 weeks postpartum (Table 3). With the exception of any breastfeeding at 6 weeks postpartum, mean postpartum OT levels were higher among those who did not report breastfeeding. However, the differences were not statistically significant.

When comparing changes in urinary OT levels between depression subgroups (i.e., splitting the analysis by probable depression status), results revealed that participants who were

Table 2 Mean (SD) urinary oxytocin levels by probable depression status using the EPDS and anxiety level using the STAI ($N = 108$)

	Prenatal		Postpartum		Prenatal		Postpartum	
	Depressed ($N = 30$)	Non-depressed ($N = 78$)	Depressed ($N = 25$)	Non-depressed ($N = 83$)	High anxiety ($N = 37$)	Low anxiety ($N = 71$)	High anxiety ($N = 26$)	Low anxiety ($N = 82$)
Prenatal oxytocin (pg/mg)	36.81 (62.24)	26.92 (19.59)	39.57 (67.92)	26.69 (19.17)	35.23 (56.30)	26.77 (20.07)	38.35 (66.70)	26.92 (19.32)
Postpartum oxytocin (pg/mg)	26.52 (23.26)	19.91 (16.74)	25.95 (25.07)	20.49 (16.59)	25.65 (22.86)	19.72 (16.28)	27.28 (24.48)	20.00 (16.55)

Table 3 Mean (SD) urinary oxytocin levels by breastfeeding status ($N = 108$)

	Any breastfeeding after birth		Only breastfeeding after birth		Any breastfeeding 6 weeks postpartum		Only breastfeeding 6 weeks postpartum	
	Yes ($N = 92$)	No ($N = 16$)	Yes ($N = 66$)	No ($N = 42$)	Yes ($N = 87$)	No ($N = 21$)	Yes ($N = 20$)	No ($N = 88$)
Prenatal oxytocin (pg/mg)	26.04 (18.85)	50.55 (83.07)	25.34 (14.47)	36.47 (55.71)	27.71 (19.29)	37.76 (74.27)	26.98 (16.35)	30.28 (39.93)
Postpartum oxytocin (pg/mg)	20.86 (17.32)	26.87 (26.37)	21.39 (19.31)	22.32 (18.46)	22.08 (19.79)	20.37 (15.00)	20.79 (24.30)	21.97 (17.61)

classified as having probable prenatal depression ($n = 30$) did not exhibit a significant change in OT levels over time ($Z = -.79$, $p = .43$) compared to the non-depressed group ($n = 78$; $Z = -3.28$, $p = .001$). Though there was a general decrease in OT levels from prenatal to postpartum among women classified as PPD at 6 weeks, these women exhibited persistently higher mean OT levels over time ($n = 25$, $Z = -1.01$, $p = .31$). In contrast, non-depressed postpartum women exhibited a significant decrease in OT levels over time ($n = 83$; $Z = -3.10$, $p = .002$). Significant differences in OT levels by breastfeeding status were observed when splitting the data by probable depression subgroups. There was a significant difference within those with probable prenatal depression, with those who reported any breastfeeding immediately after birth ($n = 25$) exhibiting significantly lower mean prenatal, ($Z = 6.32$, $p = .012$), and postpartum ($Z = 5.86$, $p = .015$) OT levels ($M = 23.57$, SD $= 15.23$ and $M = 21.53$, SD $= 16.80$, respectively) compared to depressed women who did not report any breastfeeding ($n = 5$; $M = 102.99$, SD $= 141.87$ and $M = 51.46$, SD $= 36.00$, respectively). Similarly, women with probable postpartum depression who reported any or only breastfeeding immediately after birth exhibited significantly ($Z = 6.32$, $p = .012$ and $Z = 5.16$, $p = .023$, respectively) lower mean postpartum OT levels ($M = 19.59$, SD $= 17.53$ and $M = 19.53$, SD $= 18.71$, respectively) compared to those who did not ($M = 51.42$, SD $= 36.04$ and $M = 39.60$, SD $= 32.29$, respectively).

Discussion

It is not clear why Latinas with postpartum or persistent depression, or anxiety exhibited higher levels of OT compared to their counterparts in this study. This raises important questions about potential contributing factors to high urinary OT levels that might be protective in women with depression or anxiety.

OT plays a role in the promotion of maternal behavior (Febo et al. 2005; Pedersen et al. 2006; Strathearn et al. 2009), which is often impaired in women with maternal depression (Lovejoy et al. 2000). Previous studies assessing plasma OT indicated higher maternal-fetal attachment scores in women whose OT levels rise from early to late pregnancy relative to women whose OT levels remained constant or decreased (Levine et al. 2007). However, a drop in plasma OT levels from pregnancy to postpartum (Jobst et al. 2016) as well as lower prenatal OT levels alone (Skrundz et al. 2011) are both associated with increased postnatal depressive symptoms. In the current study, urinary OT levels decreased in all the participants; however, OT levels were consistently higher in women with probable depression or high anxiety relative to non-depressed and non-anxious Latinas. While this finding seems contrary to findings from the general population, previous studies have mainly used one-time plasma measures of OT. The current study used a 24-h urine sample of OT, which captured the circadian rhythms of OT as well as continual release over an extended period of time. This work is consistent with other studies that have found ethnic differences in prenatal physiology above and beyond other demographic factors. This includes differences in cortisol and corticotropin-releasing factor in the Latina and Black population relative to their White counterparts (Glynn et al. 2007; Harville et al. 2009) and large incidences in preterm birth (Goldenberg et al. 2008; Pearl et al. 2018) and maternal mortality (Creanga et al. 2015; Gyamfi-Bannerman et al. 2018) among Black women. One likely interpretation is that ethnicity and/or race are proxies for class, opportunity, life experiences, and stressors that different groups face that may shape physiology relevant for perinatal outcomes and long-life disease (i.e., allostatic load) (Chambers et al. 2018; Glynn et al. 2007; Kuzawa and Sweet 2009; McEwen and Gianaros 2010). As such, aspects of Latino culture may be protective against the stressful effects of depression or anxiety and preserve high levels of OT or work to combat stress (Grippo et al. 2012).

The decrease in postnatal depressive symptoms in Latinas exhibited in the present study has been replicated in other studies (Lara-Cinisomo et al. 2017), but studies in the general population show both increases (O'Hara and Swain 1996) and decreases in depressive symptoms (Banti et al. 2011) across the perinatal period. Human and animal models have also demonstrated improved anxiety in the postpartum period relative to gestation (Heron et al. 2004; Lonstein 2005). Researchers speculate that tactile and other interactions with offspring might account for those changes. In Latinas, improved mood may also be associated with the strong cultural significance of

motherhood. Motherhood is revered in Latino culture and considered a traditional gender role for women (Guendelman et al. 2001; Raffaelli and Ontai 2004). Adhering to traditional cultural value of gender roles is protective against the deleterious effects of acculturative stress on maternal depressive symptoms in pregnant Mexican-American women (D'Anna-Hernandez et al. 2015). Due to strong cultural family ties, social and/or intergenerational support is strong among Latina postpartum women (Campos et al. 2008; Negron et al. 2013). Interestingly, interactions between social support and OT are associated with coping with stress (Chen et al. 2011; Heinrichs et al. 2003). Given the cultural importance of motherhood and childrearing, even though depressed or anxious, mothers could still be interacting with their infants in ways associated with high-OT levels. Bonding with infants could be a strong compensatory mechanism associated with the Latino culture. Unfortunately, mother-child interactions were not quantified in this sample, but this hypothesis should be addressed in future work.

This is one of the first studies to address urinary OT and perinatal depressive and anxious symptoms in Latinas. The only other previously published study similarly found low levels of OT in Latinas with postpartum depression who had ceased breastfeeding (Lara-Cinisomo et al. 2017) supporting a distinct lower OT profile in depressed Latinas. Other studies on non-pregnant minority populations have suggested ethnic differences in OT in response to stress as well (Grewen et al. 2008). For example, African-American women exhibited lower OT and greater pain sensitivity in a stress paradigm of acute ischemic pain compared with Whites (Grewen et al. 2008). In addition, among ethnic minorities with HIV, higher OT was associated with increased stress and a healthy immune system (Fekete et al. 2011). Others have also demonstrated an association between generalized social anxiety disorder and elevated OT levels compared to healthy controls (Hoge et al. 2008). However, there are limitations to the current work. First, the sample is relatively small, and while the sample is composed mainly of Latinas of Mexican descent due to the location of the study, there is no information available on other Latina subgroups. These differences between subgroups may play a role in the heterogeneity of health and birth outcomes among Latinas (Matthews et al. 2015; Vega et al. 2009) and should be addressed in future studies. Second, data on acculturation, changes in cultural values, beliefs, and behavior as a result of cultural contact (Berry 2003; Sam and Berry 2010) were not collected in the current study. Acculturation has been shown to play a role in maternal depressive symptoms in some (Heilemann et al. 2004; Martinez-Schallmoser et al. 2003), but not all studies (Beck 2006; Beck et al. 2005; D'Anna-Hernandez et al. 2015). Given that motherhood plays such a critical role in the Latino culture, parts of acculturation or cultural values may be more important during this perinatal

period. Future work should explore adherence to cultural values and beliefs surrounding childbearing. Related, psychosocial stressors (e.g., low-socioeconomic status, lack of social support due to migration, and other stressors) should be assessed to help explain why, despite the protective role of culture, high rates of postpartum depression persist among Latinas and to assess their association with OT levels during the perinatal period. Third, mother/child interactions were not addressed in the current study and may have had relationships with OT levels. Fourth, the OT levels collected in this study were via 24-h urine while other studies were one-time plasma measures, which may account for many of the differences observed between the current and other studies. However, in the current study, urinary OT collection was a strength because OT is pulsatile, and a 24-h urine measure is likely a better summation of diurnal OT activity. Fifth, the exclusive use of urinary OT without a comparison to plasma OT or OT in breastmilk limits our interpretations of the results. Correlations between urinary and plasma OT are equivocal (Amico et al. 1987; Feldman et al. 2011). Additionally, urinary OT levels have not been correlated with OT levels in breastmilk, which could be influenced by breastfeeding status. Therefore, subsequent studies should assess both forms to provide a definitive answer and advance our understanding of how OT is associated with PPD. It is important to note that urinary OT has also been associated with stress in mothers and breastfeeding practices, which are relevant in the context of depression (Feldman et al. 2011). Finally, while breastfeeding has been associated with higher OT (Grewen et al. 2010; Silber et al. 1991; Uvnas-Moberg et al. 1990), it is unclear why women in our study who had probable depression and breastfed had lower mean OT levels than women with probable depression who did not breastfeed. While our subgroup sample sizes were small and trends in OT levels by breastfeeding status mirror those found in the whole group, results should be interpreted with caution. Thus, future studies should include a larger sample of depressed Latinas with varying breastfeeding practices.

The current results suggest that OT levels may be one of the many neuroendocrine factors contributing to depressive and anxious symptoms in Latinas. It is possible that the OT system could be reorganized according to culture, which may account for the higher levels of OT seen in women with postpartum depression or anxiety, and should be directly tested in future research.

Compliance with ethical standards

Ethical approval   All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the University of North Carolina at Chapel Hill Institutional Review Board.

Informed consent   Informed consent was obtained from all individual participants included in the study.

Conflicts of interest   The authors declare that they have no conflict of interest.

References

Ahluwalia IB, D'Angelo D, Morrow B, McDonald JA (2012) Association between acculturation and breastfeeding among Hispanic women: data from the pregnancy risk assessment and monitoring system. J Hum Lact 28:167–173

Altemus M, Redwine L, Leong Y, Frye C, Porges S, Carter C (2001) Responses to laboratory psychosocial stress in postpartum women. Psychosom Med 63:814–821

Altemus M, Fong J, Yang R, Damast S, Luine V, Ferguson D (2004) Changes in cerebrospinal fluid neurochemistry during pregnancy. Biol Psychiatry 56:386–392. https://doi.org/10.1016/j.biopsych.2004.06.002

Amico JA, Ulbrecht JS, Robinson AG (1987) Clearance studies of oxytocin in humans using radioimmunoassay measurements of the hormone in plasma and urine. J Clin Endocrinol Metab 64:340–345

Apter-Levy Y, Feldman M, Vakart A, Ebstein RP, Feldman R (2013) Impact of maternal depression across the first 6 years of life on the child's mental health, social engagement, and empathy: the moderating role of oxytocin. Am J Psychiatry 170:1161–1168. https://doi.org/10.1176/appi.ajp.2013.12121597

Banti S, Mauri M, Oppo A, Borri C, Rambelli C, Ramacciotti D, Montagnani MS, Camilleri V, Cortopassi S, Rucci P, Cassano GB (2011) From the third month of pregnancy to 1 year postpartum. Prevalence, incidence, recurrence, and new onset of depression. Results from the Perinatal Depression–Research & Screening Unit study. Compr Psychiatry 52:343–351

Beck C (2006) Acculturation: implications for perinatal research. MCN Am J Matern Child Nurs 31:114–120. https://doi.org/10.1097/00005721-200603000-00011

Beck C, Froman R, Bernal H (2005) Acculturation level and postpartum depression in Hispanic mothers. MCN Am J Matern Child Nurs 30:299–304

Bernstein IH, Rush AJ, Yonkers K, Carmody TJ, Woo A, McConnell K, Trivedi MH (2008) Symptom features of postpartum depression: are they distinct? Depress Anxiety 25:20–26

Berry J (2003) Conceptual approaches to acculturation. Acculturation: advances in theory, measurement and applied research. APA Press, Washington, DC

Bloch M, Daly RC, Rubinow DR (2003) Endocrine factors in the etiology of postpartum depression. Compr Psychiatry 44:234–246

Bogue DJ (2011) Contraception, attitude-practice, and fertility differentials among US Hispanic, African–American and white women. J Popul Res 27:275–292. https://doi.org/10.1007/s12546-011-9052-7

Boufidou F, Lambrinoudaki I, Argeitis J, Zervas IM, Pliatsika P, Leonardou AA, Petropoulos G, Hasiakos D, Papadias K, Nikolaou C (2009) CSF and plasma cytokines at delivery and postpartum mood disturbances. J Affect Disord 115:287–292

Campos B, Schetter CD, Abdou CM, Hobel CJ, Glynn LM, Sandman CA (2008) Familialism, social support, and stress: positive implications for pregnant Latinas. Cult Divers Ethn Minor Psychol 14:155–162. https://doi.org/10.1037/1099-9809.14.2.155

Celi AC, Rich-Edwards JW, Richardson MK, Kleinman KP, Gillman MW (2005) Immigration, race/ethnicity, and social and economic factors as predictors of breastfeeding initiation. Arch Pediatr Adolesc Med 159:255–260. https://doi.org/10.1001/archpedi.159.3.255

Chambers BD, Baer RJ, McLemore MR, Jelliffe-Pawlowski LL (2018) Using index of concentration at the extremes as indicators of structural racism to evaluate the association with preterm birth and infant mortality—California, 2011–2012. J Urban Health:1–12

Chaudron LH, Klein MH, Remington P, Palta M, Allen C, Essex MJ (2001) Predictors, prodromes and incidence of postpartum depression. J Psychosom Obstet Gynecol 22:103–112

Chen FS, Kumsta R, von Dawans B, Monakhov M, Ebstein RP, Heinrichs M (2011) Common oxytocin receptor gene (OXTR) polymorphism and social support interact to reduce stress in humans. Proc Natl Acad Sci 108:19937–19942

Corwin E, Pajer K, Paul S, Lowe N, Weber M, McCarthy D (2015) Bidirectional psychoneuroimmune interactions in the early postpartum period influence risk of postpartum depression. Brain Behav Immun 49:86–93

Cox JL, Chapman G, Murray D, Jones P (1996) Validation of the Edinburgh Postnatal Depression Scale (EPDS) in non-postnatal women. J Affect Disord 39:185–189. https://doi.org/10.1016/0165-0327(96)00008-0

Cox EQ, Stuebe A, Pearson B, Grewen K, Rubinow D, Meltzer-Brody S (2015) Oxytocin and HPA stress axis reactivity in postpartum women. Psychoneuroendocrinology 55:164–172. https://doi.org/10.1016/j.psyneuen.2015.02.009

Creanga AA, Berg CJ, Syverson C, Seed K, Bruce FC, Callaghan WM (2015) Pregnancy-related mortality in the United States, 2006–2010. Obstet Gynecol 125(1):5–12

D'Anna-Hernandez KL, Aleman B, Flores A-M (2015) Acculturative stress negatively impacts maternal depressive symptoms in Mexican-American women during pregnancy. J Affect Disord 176:35–42. https://doi.org/10.1016/j.jad.2015.01.036

de Geest K, Thiery M, Piron-Possuyt G, Vanden Driessche R (1985) Plasma oxytocin in human pregnancy and parturition. J Perinat Med 13:3–13

Dennis CL, McQueen K (2009) The relationship between infant-feeding outcomes and postpartum depression: a qualitative systematic review. Pediatrics 123:e736–e751. https://doi.org/10.1542/peds.2008-1629

Dennis C-L, Coghlan M, Vigod S (2013) Can we identify mothers at-risk for postpartum anxiety in the immediate postpartum period using the State-Trait Anxiety Inventory? J Affect Disord 150:1217–1220

Eidelman AI (2012) Breastfeeding and the use of human milk: an analysis of the American Academy of Pediatrics 2012 Breastfeeding Policy Statement. Breastfeed Med 7:323–324

Febo M, Numan M, Ferris CF (2005) Functional magnetic resonance imaging shows oxytocin activates brain regions associated with mother–pup bonding during suckling. J Neurosci 25:11637–11644

Fekete EM, Antoni MH, Lopez C, Mendez AJ, Szeto A, Fletcher MA, Klimas N, Kumar M, Schneiderman N (2011) Stress buffering effects of oxytocin on HIV status in low-income ethnic minority women. Psychoneuroendocrinology 36:881–890. https://doi.org/10.1016/j.psyneuen.2010.12.003

Feldman R, Weller A, Zagoory-Sharon O, Levine A (2007) Evidence for a neuroendocrinological foundation of human affiliation: plasma oxytocin levels across pregnancy and the postpartum period predict mother-infant bonding. Psychol Sci 18:965–970. https://doi.org/10.1111/j.1467-9280.2007.02010.x

Feldman R, Gordon I, Zagoory-Sharon O (2011) Maternal and paternal plasma, salivary, and urinary oxytocin and parent–infant synchrony: considering stress and affiliation components of human bonding. Dev Sci 14:752–761

Garfield L, Giurgescu C, Carter CS, Holditch-Davis D, McFarlin BL, Schwertz D, Seng JS, White-Traut R (2015) Depressive symptoms in the second trimester relate to low oxytocin levels in African-American women: a pilot study. Arch Women's Mental Health 18: 123–129. https://doi.org/10.1007/s00737-014-0437-4

Gaynes BN, Gavin N, Meltzer-Brody S, Lohr KN, Swinson T, Gartlehner G, Brody S, Miller WC (2005) Perinatal depression: prevalence, screening accuracy, and screening outcomes. Evid Rep Technol Assess (Summ) (119):1–8

Glynn LM, Schetter CD, Chicz-DeMet A, Hobel CJ, Sandman CA (2007) Ethnic differences in adrenocorticotropic hormone, cortisol and corticotropin-releasing hormone during pregnancy. Peptides 28(6):1155–1161

Goldenberg RL, Culhane JF, Iams JD, Romero R (2008) Epidemiology and causes of preterm birth. Lancet 371(9606):75–84. https://doi.org/10.1016/S0140-6736(08)60074-4

Gress-Smith JL, Luecken LJ, Lemery-Chalfant K, Howe R (2011) Postpartum depression prevalence and impact on infant health, weight, and sleep in low-income and ethnic minority women and infants. Matern Child Health J 16:887–893. https://doi.org/10.1007/s10995-011-0812-y

Grewen KM, Light KC, Mechlin B, Girdler SS (2008) Ethnicity is associated with alterations in oxytocin relationships to pain sensitivity in women. Ethn Health 13:219–241. https://doi.org/10.1080/13557850701837310

Grewen KM, Davenport RE, Light KC (2010) An investigation of plasma and salivary oxytocin responses in breast- and formula-feeding mothers of infants. Psychophysiology 47:625–632. https://doi.org/10.1111/j.1469-8986.2009.00968.x

Grippo AJ, Pournajafi-Nazarloo H, Sanzenbacher L, Trahanas DM, McNeal N, Clarke DA, Porges SW, Sue Carter C (2012) Peripheral oxytocin administration buffers autonomic but not behavioral responses to environmental stressors in isolated prairie voles. Stress 15:149–161

Guendelman S, Malin C, Herr-Harthorn B, Noemi Vargas P (2001) Orientations to motherhood and male partner support among women in Mexico and Mexican-origin women in the United States. Soc Sci Med 52:1805–1813. https://doi.org/10.1016/S0277-9536(00)00296-3

Gyamfi-Bannerman C, Srinivas SK, Wright JD, Goffman D, Siddiq Z, D'Alton ME, Friedman AM (2018) Postpartum hemorrhage outcomes and race. Am J Obstet Gynecol 219:185.e1–185.e10

Harville EW, Savitz DA, Dole N, Herring AH, Thorp JM (2009) Stress questionnaires and stress biomarkers during pregnancy. J Women's Health 18(9):1425–1433

Heilemann M, Frutos L, Lee K, Kury F (2004) Protective strength factors, resources, and risks in relation to depressive symptoms among childbearing women of Mexican descent. Health Care Women Int 25:88–106. https://doi.org/10.1080/07399330490253265

Heinrichs M, Baumgartner T, Kirschbaum C, Ehlert U (2003) Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. Biol Psychiatry 54:1389–1398. https://doi.org/10.1016/S0006-3223(03)00465-7

Heron J, O'Connor TG, Evans J, Golding J, Glover V (2004) The course of anxiety and depression through pregnancy and the postpartum in a community sample. J Affect Disord 80:65–73

Hoge EA, Pollack MH, Kaufman RE, Zak PJ, Simon NM (2008) Oxytocin levels in social anxiety disorder. CNS Neurosci Ther 14: 165–170

Howell EA, Mora PA, Horowitz CR, Leventhal H (2005) Racial and ethnic differences in factors associated with early postpartum depressive symptoms. Obstet Gynecol 105:1442–1450

Howell EA, Balbierz A, Wang J, Parides M, Zlotnick C, Leventhal H (2012) Reducing postpartum depressive symptoms among black and Latina mothers: a randomized controlled trial. Obstet Gynecol 119:942–949

Humes KR, Jones NA, Ramirez RR (2011) Overview of race and Hispanic origin: 2010. Retrieved on July 30, 2018 from https://www.census.gov/prod/cen2010/briefs/c2010br-02.pdf

IBM Corp. (2015) IBM SPSS statistics for windows, version 23, 23rd edn. IBM Corp., Armonk

Jobst A, Krause D, Maiwald C, Härtl K, Myint AM, Kästner R, Obermeier M, Padberg F, Brücklmeier B, Weidinger E, Kieper S, Schwarz M, Zill P, Müller N (2016) Oxytocin course over pregnancy and postpartum period and the association with postpartum depressive symptoms. Arch Women's Mental Health 19:571–579

Kim Y, Dee V (2017) Self-Care for health in rural Hispanic women at risk for postpartum depression. Matern Child Health J 21:77–84

Kozinszky Z, Dudas RB (2015) Validation studies of the Edinburgh Postnatal Depression Scale for the antenatal period. J Affect Disord 176:95–105

Kuzawa CW, Sweet E (2009) Epigenetics and the embodiment of race: developmental origins of US racial disparities in cardiovascular health. Am J Hum Biol 21(1):2–15. https://doi.org/10.1002/ajhb.20822

Lara-Cinisomo S, Wisner KL, Meltzer-Brody S (2015) Advances in science and biomedical research on postpartum depression do not include meaningful numbers of Latinas. J Immigr Minor Health 17: 1593–1596. https://doi.org/10.1007/s10903-015-0205-1

Lara-Cinisomo S, Girdler SS, Grewen K, Meltzer-Brody S (2016) A biopsychosocial conceptual framework of postpartum depression risk in immigrant and US-born Latina mothers in the United States. Womens Health Issues 26:336–343

Lara-Cinisomo S, McKenney K, Di Florio A, Meltzer-Brody S (2017) Associations between postpartum depression, breastfeeding, and oxytocin levels in Latina mothers. Breastfeed Med 12:436–442

Lefkovics E, Baji I, Rigo J (2014) Impact of maternal depression on pregnancies and on early attachment. Infant Ment Health J 35: 354–365. https://doi.org/10.1002/imhj.21450

Levine A, Zagoory-Sharon O, Feldman R, Weller A (2007) Oxytocin during pregnancy and early postpartum: individual patterns and maternal–fetal attachment. Peptides 28:1162–1169

Linares AM (2014) Screening for postpartum depression in Chilean women with the Postpartum Depression Screening Scale, Spanish version. In: Perinatal depression among Spanish-speaking and Latin American women. Springer, pp 51–63

Lindow SW, Newham A, Hendricks MS, Thompson JW, van der Spuy ZM (1996) The 24-hour rhythm of oxytocin and beta-endorphin secretion in human pregnancy. Clin Endocrinol 45:443–446. https://doi.org/10.1046/j.1365-2265.1996.8290840.x

Liu CH, Tronick E (2013) Rates and predictors of postpartum depression by race and ethnicity: results from the 2004 to 2007 New York City PRAMS survey (Pregnancy Risk Assessment Monitoring System). Matern Child Health J 17:1599–1610. https://doi.org/10.1007/s10995-012-1171-z

Livingston G, Cohn DV (2012) U.S. birth rate falls to a record low; decline is greatest among immigrants. vol Book, Whole

Lonstein JS (2005) Reduced anxiety in postpartum rats requires recent physical interactions with pups, but is independent of suckling and peripheral sources of hormones. Horm Behav 47:241–255

Lopez MH, Gonzalez-Barrera A, Cuddington D (2013) Diverse origins: the nation's 14 largest Hispanic-origin groups Washington, DC: pew Hispanic center. Retrived on July 30, 2018 from http://www.pewhispanic.org/files/2013/06/summary_report_final.pdf

Lovejoy MC, Graczyk PA, O'Hare E, Neuman G (2000) Maternal depression and parenting behavior. Clin Psychol Rev 20:561–592. https://doi.org/10.1016/S0272-7358(98)00100-7

Lucero NB, Beckstrand RL, Callister LC, Sanchez Birkhead AC (2012) Prevalence of postpartum depression among Hispanic immigrant women. J Am Acad Nurse Pract 24:726–734. https://doi.org/10.1111/j.1745-7599.2012.00744.x

Martinez-Schallmoser L, Telleen S, Macmullen NJ (2003) The effect of social support and acculturation on postpartum depression in Mexican American women. J Transcult Nurs 14:329–338. https://doi.org/10.1177/1043659603257162

Massey SH, Backes KA, Schuette SA (2016) Plasma oxytocin concentration and depressive symptoms: a review of current evidence and directions for future research. Depress Anxiety 33:316–322. https://doi.org/10.1002/da.22467

Matthews T, MacDorman M, Thoma M (2015) Infant mortality statistics from the 2013 period linked birth/infant death data set. National vital statistics reports vol 64. National Center for Health Statistics, Hyattsville

McEwen BS, Gianaros PJ (2010) Central role of the brain in stress and adaptation: links to socioeconomic status, health, and disease. Ann N Y Acad Sci 1186(1):190–222. https://doi.org/10.1111/j.1749-6632.2009.05331.x

Moura D, Canavarro MC, Figueiredo-Braga M (2016) Oxytocin and depression in the perinatal period—a systematic review. Arch Women's Mental Health 19:561–570. https://doi.org/10.1007/s00737-016-0643-3

Negron R, Martin A, Almog M, Balbierz A, Howell EA (2013) Social support during the postpartum period: mothers' views on needs, expectations, and mobilization of support. Matern Child Health J:1–8

O'Hara MW, McCabe JE (2013) Postpartum depression: current status and future directions. Annu Rev Clin Psychol 9:379–407. https://doi.org/10.1146/annurev-clinpsy-050212-185612

O'Hara M, Swain AM (1996) Rates and risk of postpartum depression– a meta-analysis. Int Rev Psychiatry 8:37–55

Passel JS, Livingston G, D'Vera C (2013) Explaining why minority births now outnumber white births. http://www.pewsocialtrends.org/2012/05/17/explaining-why-minority-births-now-outnumber-white-births/

Pearl M, Ahern J, Hubbard A, Laraia B, Shrimali BP, Poon V, Kharrazi M (2018) Life-course neighbourhood opportunity and racial-ethnic disparities in risk of preterm birth. Paediatr Perinat Epidemiol

Pedersen C, Vadlamudi S, Boccia M, Amico J (2006) Maternal behavior deficits in nulliparous oxytocin knockout mice. Genes Brain Behav 5:274–281

Pedersen C, Leserman J, Garcia N, Stansbury M, Meltzer-Brody S, Johnson J (2016) Late pregnancy thyroid-binding globulin predicts perinatal depression. Psychoneuroendocrinology 65:84–93

Prevost M, Zelkowitz P, Tulandi T, Hayton B, Feeley N, Carter CS, Joseph L, Pournajafi-Nazarloo H, Yong Ping E, Abenhaim H, Gold I (2014) Oxytocin in pregnancy and the postpartum: relations to labor and its management. Front Public Health 2. https://doi.org/10.3389/fpubh.2014.00001

Provenzi L, Guida E, Montirosso R (2018) Preterm behavioral epigenetics: a systematic review. Neurosci Biobehav Rev 84:262–271. https://doi.org/10.1016/j.neubiorev.2017.08.020

Raffaelli M, Ontai LL (2004) Gender socialization in Latino/a families: results from two retrospective studies. Sex Roles 50:287–299

Reyes TL, Galinsky AM, Hoffmann JN, You HM, Ziegler TE, McClintock MK (2014) Social peptides: measuring urinary oxytocin and vasopressin in a home field study of older adults at risk for dehydration. J Gerontol B Psychol Sci Soc Sci 69:S229–S237

Robertson E, Grace S, Wallington T, Stewart DE (2004) Antenatal risk factors for postpartum depression: a synthesis of recent literature. Gen Hosp Psychiatry 26:289–295. https://doi.org/10.1016/j.genhosppsych.2004.02.006

Sam DL, Berry JW (2010) Acculturation: when individuals and groups of different cultural backgrounds meet. Perspect Psychol Sci 5:472–481. https://doi.org/10.1177/1745691610373075

Shahid A, Wilkinson K, Marcu S, Shapiro CM (2012) State-Trait Anxiety Inventory (STAI). Springer New York, New York, pp 367–368. https://doi.org/10.1007/978-1-4419-9893-4_90

Silber M, Larsson B, Uvnas-Moberg K (1991) Oxytocin, somatostatin, insulin and gastrin concentrations vis-a-vis late pregnancy, breastfeeding and oral contraceptives. Acta Obstet Gynecol Scand 70:283–289

Skrundz M, Bolten M, Nast I, Hellhammer DH, Meinlschmidt G (2011) Plasma oxytocin concentration during pregnancy is associated with development of postpartum depression. Neuropsychopharmacology 36:1886–1893. https://doi.org/10.1038/npp.2011.74

Strathearn L, Fonagy P, Amico J, Montague PR (2009) Adult attachment predicts maternal brain and oxytocin response to infant cues. Neuropsychopharmacology 34:2655–2666

Stuebe AM, Grewen K, Meltzer-Brody S (2013) Association between maternal mood and oxytocin response to breastfeeding. J Women's Health (2002) 22:352–361. https://doi.org/10.1089/jwh.2012.3768

Taveras EM, Capra AM, Braveman PA, Jensvold NG, Escobar GJ, Lieu TA (2003) Clinician support and psychosocial risk factors associated with breastfeeding discontinuation. Pediatrics 112:108–115

U. S. Census US (2013) Hispanics by the Numbers. Retrieved from http://www.infoplease.com/spot/hhmcensus1.html. Accessed 21 July 2018

Uvnas-Moberg K, Widstrom AM, Werner S, Matthiesen AS, Winberg J (1990) Oxytocin and prolactin levels in breast-feeding women. Correlation with milk yield and duration of breast-feeding. Acta Obstet Gynecol Scand 69:301–306

Vega WA, Rodriguez MA, Gruskin E (2009) Health disparities in the Latino population. Epidemiol Rev 31:99–112. https://doi.org/10.1093/epirev/mxp008

Vidal de Haymes M, Kilty KM (2007) Latino population growth, characteristics, and settlement trends: implications for social work education in a dynamic political climate. J Soc Work Educ 43:101–116. https://doi.org/10.5175/JSWE.2007.200400493

Waldrop J (2013) Exploration of reasons for feeding choices in Hispanic mothers. MCN Am J Matern Child Nurs 38:282–288

Walmer R, Huynh J, Wenger J, Ankers E, Mantha AB, Ecker J, Thadhani R, Park E, Bentley-Lewis R (2015) Mental health disorders subsequent to gestational diabetes mellitus differ by race/ethnicity. Depress Anxiety 32:774–782. https://doi.org/10.1002/da.22388

Wouk K, Lara-Cinisomo S, Stuebe AM, Poole C, Petrick JL, McKenney KM (2016) Clinical interventions to promote breastfeeding by Latinas: a meta-analysis. Pediatrics 137(1):e20152423. https://doi.org/10.1542/peds.2015-2423

Wu YP, Selig JP, Roberts MC, Steele RG (2010) Trajectories of postpartum maternal depressive symptoms and children's social skills. J Child Fam Stud 20:414–423. https://doi.org/10.1007/s10826-010-9407-2