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ORIGINAL ARTICLE

Subconstructs of the Edinburgh Postnatal Depression Scale in a multi-ethnic inner-city population in the U.S.

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Abstract The ten-item Edinburgh Postnatal Depression Scale (EPDS) is one of the most widely used self-report measures of postpartum depression. Although originally described as a one-dimensional measure, the recognition that depressive symptoms may be differentially experienced across cultural and racial/ethnic groups has led to studies examining structural equivalence of the EPDS in different populations. Variation of the factor structure remains understudied across racial/ethnic groups of US women. We examined the factor structure of the EPDS assessed 6 months postpartum in 515 women (29% black, 53% Hispanic, 18% white) enrolled in an urban Boston longitudinal birth cohort. Exploratory factor analysis (EFA) identified that a three-factor model, including depression, anxiety, and anhedonia subscales, was the most optimal fit in our sample as a whole and across race/ethnicity. Confirmatory factor analysis (CFA) was used to examine the fit of both the two- and three-factor models reported in prior research. CFA confirmed the best fit for a three-factor model, with minimal differences across race/ethnicity. "Things get on top of me" loaded on the anxiety factor among Hispanics, but loaded on the depression factor in whites and African Americans. These findings suggest that EPDS factor structure may need to be adjusted for diverse samples and warrants further study.

Keywords Edinburgh Postnatal Depression Scale · Postpartum depression · Anxiety · Anhedonia · Race/ethnicity · Factor analysis

This article belongs to the Topical Collection: The EPDS: Thirty Years On

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Introduction

The physiologic and social changes of the postpartum period for women create a window of heightened risk for psychopathology which has significant implications for maternal and child health (Schwab-Reese et al. 2016; Wisner et al. 2006). Our understanding of the etiology of postpartum depression (PPD), defined as moderate to severe depression in a mother following childbirth, continues to evolve with evidence suggesting that PPD may be mechanistically distinct from depression occurring in the non-pregnant state in a woman's life (Di Florio and Meltzer-Brody 2015; Pawluski et al. 2017). Moreover, symptom features may differ between PPD and depression outside the peripartum period (Hoertel et al. 2015). The burden of PPD among women in the USA is high, affecting up to 20% of women in some states in the USA according to self-reported symptoms (CDC 2008). Findings based on structured clinical interviews in the 3 months postpartum indicated that the rate of perinatal depression is as high as 19.2% for women in developed countries (Gavin et al. 2005).

There is also evidence that the occurrence of PPD is not evenly distributed across populations. For example, subgroups such as younger mothers, mothers with lower education levels, and mothers experiencing traumatic stress are at

higher risk of PPD or depressive symptoms (CDC 2008; Liu and Tronick 2013). Further, the prevalence of PPD varies regionally and across racial/ethnic groups (Halbreich and Karkun 2006). In an analysis of data from 13 US states, non-Hispanic white women had, on average, a significantly lower prevalence of postpartum depressive symptoms compared with women of other racial/ethnic groups (CDC 2008). Another analysis of 3748 women in New York City reported that the odds of PPD diagnosis was 1.5 (95% CI 0.9–2.7) times higher in the Hispanic group, compared to non-Hispanic whites (Liu and Tronick 2013).

PPD requires the presence of either depressed mood or anhedonia (APA 2013; Sibitz et al. 2010). Depressed mood is thought to reflect high negative affect whereas anhedonia reflects low positive affect with evidence that affective states vary by culture and race/ethnicity (Kanazawa et al. 2007). Some recent epidemiological data show that prevalence rates of depressed mood and anhedonia differ across race/ethnic groups underscoring the need to distinguish these components in PPD assessment (Liu and Tronick 2014). Moreover, morbidity studies suggest that PPD is likely to co-occur with other psychiatric disorders affecting women after birth, most commonly anxiety disorders (Le Strat et al. 2011; Miller et al. 2006), and anxiety might even be more common than depression in some postpartum populations (Giardinelli et al. 2012; Goodman et al. 2016; Matthey 2008; Woolhouse et al. 2009). A meta-analysis of international studies found that 8.5% of postpartum women experience one or more anxiety disorders as measured by diagnostic interviews (Goodman et al. 2016).

The ten-item Edinburgh Postnatal Depression Scale (EPDS) (Cox et al. 1987) is one of the most widely used self-report measures for the assessment of PPD across diverse racial/ethnic and cultural groups including African Americans and Hispanics (Gibson et al. 2009; Hartley et al. 2014; Howell et al. 2012; Lau et al. 2010; Lee King 2012; Montazeri et al. 2007; Odalovic et al. 2015; Okano et al. 1996; Pop et al. 1992; Small et al. 2007; Toreki et al. 2014; Vivilaki et al. 2009). Although Cox et al. (1987) originally designed the EPDS as a one-dimensional measurement tool, the recognition that depressive symptoms can be differentially experienced across cultural and racial/ethnic groups has led to studies examining structural equivalence of the measure in different populations using factor analysis (Cunningham et al. 2015; Reichenheim et al. 2011). Some studies suggest that items from the EPDS cluster into two factors: one generally indicating "depression" and the other indicating "anxiety" (Astbury et al. 1994; Guedeney and Fermanian 1998; Hartley et al. 2014; Massoudi et al. 2013; Matthey 2008; Phillips et al. 2009; Toreki et al. 2014; Vivilaki et al. 2009), whereas other studies suggest three factors indicating depression, anxiety, and "anhedonia" (Chabrol and Teissedre 2004; Lee King 2012; Montazeri et al. 2007; Pop et al. 1992; Ross et al. 2003; Small et al. 2007). Notably, some of these factors were composed of different items across the different studies. It has been posited that variation in factor structures may in part be due to differences across languages and ethnic groups reflective of different underlying mental illness prevalence or how different cultural or socioeconomic groups interpret and respond to the questionnaire (Phillips et al. 2009), variable timing of administration, and the statistical methodology used to determine the factor structures.

Variation of the factor structure remains understudied across ethnic and racial groups in the USA. A recent study in Hispanic women drawn from a pediatric primary care setting identified a two-factor model (depression, anxiety) as the best fitting model (Hartley et al. 2014), whereas a study in postpartum African American women of low socioeconomic status showed that a three-factor model (depression, anxiety, and anhedonia) demonstrated the best fit (Lee King 2012). No studies to date have been large and diverse enough to permit direct multi-group analyses comparing factor structures across different race and ethnicities. In this study, we leveraged a lower-income, ethnically mixed US inner city birth cohort to examine the factor structure of the EPDS survey across non-Hispanic whites, Hispanics, and African Americans from the same geographical region.

Methods

Study participants

Between August 2002 and September 2009, English- or Spanish-speaking women ≥18 years old receiving prenatal care in mid- to late pregnancy (28.4 ± 7.9-week gestation) at the Brigham and Women's Hospital (BWH) and Boston Medical Center (BMC) and affiliated community health centers were recruited into the Asthma Coalition on Community, Environment, and Social Stress (ACCESS) project, a pregnancy cohort examining the effects of perinatal stress and other environmental factors on urban childhood asthma risk (Wright et al. 2008). Trained research coordinators approached women on select clinic days. Among pregnant women approached who were eligible, 989 (78.1%) agreed to enroll. Screening data showed that mothers who declined versus enrolled were slightly less likely to be ethnic minorities (78.9 and 81.5% Hispanic or African American, respectively) or to have <12 years of education (57.7 vs. 60.6%, respectively) and were slightly more likely to report an annual household income of <$20,000 (37.7 vs. 35.2%, respectively). Of those enrolled, 955 gave birth to a singleton infant and continued follow-up. Approximately half-way through recruitment, supplemental funding was obtained to examine determinants of PPD. Of $n = 598$ women still eligible for assessment of PPD in the first 6 months postpartum, $n = 515$ completed the depression survey and were available for analysis. Those providing

data on PPD did not differ significantly on key demographics when compared to all of those who were originally enrolled (Supplemental Materials, Table S1).

Data collection

Women completed the Edinburgh Postnatal Depression Scale (EPDS) questionnaire, a ten-item self-evaluation measure (Cox et al. 1987), at 6 months postpartum in a face-to-face interview. In short, the ten items include "1: able to laugh," "2: looking forward (with enjoyment to things)," "3: self-blaming," "4: worrying," "5: scared," "6: things get on top of me (overwhelmed)," "7: difficult to sleep," "8: feeling sad," "9: crying," and "10: the thought of self-harming." Participants rated each item on the severity based on four levels ranging from never to very often (scored from 0 indicating the most favorable condition to 3 indicating the least favorable condition for each item). Sociodemographic information was also collected at the time of interview. Procedures were approved by human studies committees at the BWH and BMC, and the written consents were obtained in participants' primary language.

Data analysis

We performed an exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to evaluate the underlying structure of the EPDS in our cohort as a whole, as well as stratified by race/ethnicity categories in the 515 women with EPDS data.

EFA and CFA approaches, in contrast to dimensional reduction techniques such as principal component analysis (PCA), seek to identify latent factors that organize relationships among the variables studied, consistent with the goals of this study, and to test their utility in explaining patterns of variance in the data. Factors were extracted with the ordinary least squares (OLS) procedure, which Briggs and MacCallum (2003) found more sensitive than the commonly applied maximum likelihood approach (Costello and Osborne 2005), although both techniques were applied in preliminary analyses and yielded materially similar results in this sample (Supplemental Materials, Table S2). To determine the optimal number of factors to be included in the EFA, we first examined the scree plot, variance plot, and eigenvalue of the variables to identify the cutoff point where minimal incremental variance is added with additional factors. We additionally used chi-squared goodness-of-fit tests to confirm that the number of factors inferred from the scree tests was sufficient to model the observed correlation matrix. We then conducted EFA using the suggested numbers of factors with varimax (orthogonal) rotations to draw the factor structures based on the standardized loadings, though we also explored a promax (oblique) rotational strategy which yielded essentially identical results (Supplemental Materials, Table S2), suggesting that these results are not sensitive to the correlations among the factors extracted. CFA was then performed based on the dimensional scrutiny suggested by the EFA, as well as the factors suggested by previous literature as recent literature suggests that the number of factors (either a two- or three-factor model) may vary between different target populations (Cunningham et al. 2015). As report of item 10 "thought of self-harming" was rare (0.8% for quite often), all analyses were conducted without this item (i.e., using the other nine items) to avoid the calculation of potentially negative eigenvalues, yielding not positive definite matrices (Wothke 1993). As a result, our sample size yielded a subject-to-variable (STV) ratio ranging from 57.2 in the overall group to 10.2 in the non-Hispanic white subgroup, with STVs for African American and Hispanic subgroups of 16.4 and 30.5, respectively. These are in line with the widely used "rule of 10" for sample size guidelines in conducting EFA, suggesting that STVs exceeding 10 can achieve good reproducibility (MacCallum et al. 1999; Velicer and Fava 1998). Further, empirical simulation studies (Arrindell and van der Ende 1985; MacCallum et al. 1999; Preacher and MacCallum 2002) have reported reliable and generalizable effects in datasets with even smaller samples and smaller STV ratios than those from our analyses.

Goodness of fit of CFAs was evaluated using the indices suggested by previous literature (Bollen and Long 1993), including indices of absolute fit, relative fit, and fit with a penalty function for lack of parsimony. Specifically, we examined the traditional overall chi-squared test of model fit (which should not be statistically significant), root mean square error of approximation (RMSEA; a good fit is generally defined as RMSEA <0.08), comparative fit index (CFI; a CFI ≥ 0.95 is generally considered an excellent fit), and the standardized root-mean-square residual (SMSR; which should be ≤ 0.05) (Brown 2015; Hartley et al. 2014; Hu and Bentler 1999). These procedures reflect the most commonly applied approaches in the literature and should thus generalize well (Briggs and MacCallum 2003; Costello and Osborne 2005). Analyses were done using SAS (version 9.4, SAS Institute, Inc., Cary, NC) and the packages "stats," "psych," and "lavaan" in R (version 3.2.3) (Revelle 2016; Revelle and Condon 2015; Rosseel 2012).

Results

Participant characteristics

Analyses were performed on the total sample ($n = 515$) and also on subsets of participants reporting their race/ethnicity as African American ($n = 148$), Hispanic ($n = 275$), or non-Hispanic white ($n = 92$). The characteristics of the participants in the sample as a whole and by race/ethnicity are presented in

Table 1 Participant characteristics

	All		African American		Hispanic		White	
Sample size (*n*, %)	515	100	148	28.7	275	53.4	92	17.9
Education level (*n*, %)								
>12 years	181	35.1	69	46.6	61	22.2	51	55.4
≤12 years	334	64.9	79	53.4	214	77.8	41	44.6
Enrollment age (mean, SD)	27.0	5.8	26.7	6.09	27.1	5.56	27.3	6.08
Total EPDS score (mean, SD)	5.24	5.94	5.99	5.84	4.58	5.58	6.01	6.90

Table 1. In our data, Hispanic mothers on average had lower total EPDS scores compared to African American ($p = 0.02$) or non-Hispanic white mothers ($p = 0.04$).

Exploratory factor analysis

We first used the scree plots to identify how many factors would be optimal to explain variability of the EPDS across our total sample and when stratified by race/ethnicity. While previous studies have suggested either a two-factor or a three-factor model for EPDS scores, scree plots generated in our sample demonstrated some ambiguity in the optimal selection of two- or three-factor models (Supplemental Materials, Fig. S1). That is, while the initial "elbow" of the scree plots was localized on the second factor, the shallow slope and comparable eigenvalues for the third factor were suggestive of a three-factor model, particularly in race-stratified models. Given this ambiguity, we explored factor loadings in both two- and three-factor models in EFA, and followed with CFA to determine which model provided the best fit. The results of the EFA are summarized in Table 2. The three-factor model generally suggested a similar structure in the overall and race-stratified analyses, with minimal loading differences (Table 2). The three factors identified in our data generally referred to items related to depression (items 7–9: difficult to sleep, sad, cry), anxiety (items 3–5: self-blaming, scared, worry), and anhedonia (items 1–2: able to laugh, looking forward), with the item 6 (overwhelmed) on the border of depression and anxiety dependent on race/ethnicity. Notably, the two-factor models generally differentiated anhedonia-type items (items 1–2) from other items.

Confirmatory factor analysis

CFA was conducted to examine the fit of the structural models, using both two-factor and three-factor models based on the EFA, among different race/ethnicity groups. Examination of the fit indices (chi-square, RMSEA, CFI, and SRMR) confirmed that the three-factor models of depression, anxiety, and anhedonia provided a better fit to our data, as compared to two-factor models, for all mothers and race/ethnicity-stratified analyses. Table 3 presents the results from three-factor models with corresponding fit indices among each subgroup. Interestingly, for African American and non-Hispanic white groups, the item 6 (overwhelmed) fit best with items 7–9, which are generally considered depression-type responses. In the Hispanic group, on the other hand, item 6 fit best with items 3–5, which are generally considered anxiety-type responses.

Discussion

To our knowledge, this is the largest sample used to examine the factor structure and psychometric properties of the EPDS among ethnically mixed postpartum women in an urban US population. Overall, a three-factor model consisting of item clusters corresponding to postpartum symptoms including depressed mood, anhedonia, and anxiety provided the best fit, similar to those reported in Tuohy and McVey (2008), Petrozzi and Gagliardi (2013), and Coates et al. (2016). In our ethnically mixed sample, the groupings differed slightly for the Hispanic subgroup compared to the African American or non-Hispanic white subgroups by one item (overwhelmed) that clustered with anxiety-type items in the former rather than depression-type items in the African Americans and whites. The results of this study further support the call for broadening the definition of postpartum distress to include other subconstructs in addition to depressive disorders (Goodman et al. 2016).

Others have similarly found that the EPDS was best characterized by a tri-dimensional structure consisting of depressed mood, anhedonia, and anxiety symptoms in the postpartum period. Our findings are most consistent with the results in a study of Italian women (measured 2–3 days postpartum) identified by EFA with oblique rotation (Petrozzi and Gagliardi 2013) and a population-based study of women living in southwest England (measured at 18- and 32-week gestation and 8 weeks and 8 months postpartum) identified by EFA with oblique rotation and CFA with maximum likelihood estimation (Coates et al. 2016), both suggesting a three-factor structure including depression (items 7–10), anxiety (items 3–6), and anhedonia (items 1–2). Another study conducted via an internet survey measured at approximately 6.5 months postpartum also found a similar three-factor structure (items 7–10 for depression; items 3–5 for anxiety; items 1–2 for

Table 2 Factor loadings of exploratory factor analysis (EFA) of EPDS for two- and three-factor models, stratified by race/ethnicity [a]

	EPDS items	Three-factor model			Two-factor model	
		F1	F2	F3	F1	F2
All (n = 515)						
1	Able to laugh	0.00	0.07	*0.63*	0.02	*0.68*
2	Look forward	0.00	−0.02	*1.00*	0.00	*0.94*
3	Self-blame	0.13	*0.48*	0.00	*0.58*	−0.04
4	Worry	−0.07	*0.89*	0.02	*0.74*	−0.04
5	Scared	0.12	*0.65*	−0.05	*0.73*	−0.12
6	Overwhelmed	0.24	*0.47*	0.05	*0.69*	0.00
7	Difficult to sleep	*0.51*	0.18	0.12	*0.67*	0.12
8	Sad	*0.85*	0.04	−0.02	*0.79*	0.03
9	Cry	*0.86*	−0.04	0.02	*0.73*	0.08
African American (n = 148)						
1	Able to laugh	−0.04	*0.99*	0.03	−0.01	*0.78*
2	Look forward	0.27	*0.61*	−0.06	0.05	*0.84*
3	Self-blame	0.33	0.01	*0.43*	*0.65*	−0.08
4	Worry	−0.03	0.02	*0.98*	*0.64*	−0.15
5	Scared	0.28	−0.03	*0.42*	*0.62*	−0.14
6	Overwhelmed	*0.48*	−0.08	0.28	*0.67*	−0.07
7	Difficult to sleep	*0.63*	0.13	0.08	*0.65*	0.17
8	Sad	*0.83*	0.00	0.02	*0.75*	0.09
9	Cry	*0.90*	0.01	−0.05	*0.74*	0.13
Hispanic (n = 275)						
1	Able to laugh	−0.01	−0.04	*0.74*	−0.01	*0.72*
2	Look forward	0.00	0.01	*0.85*	0.03	*0.85*
3	Self-blame	*0.54*	−0.07	0.07	*0.51*	−0.01
4	Worry	*0.64*	0.14	0.13	*0.75*	0.06
5	Scared	*0.88*	−0.04	−0.10	*0.80*	−0.16
6	Overwhelmed	*0.66*	0.07	0.09	*0.71*	0.02
7	Difficult to sleep	0.31	*0.32*	0.18	*0.62*	0.12
8	Sad	−0.02	*0.99*	−0.02	*0.78*	0.01
9	Cry	0.25	*0.51*	0.13	*0.71*	0.09
White (n = 92)						
1	Able to laugh	−0.03	*0.76*	0.01	0.02	*0.71*
2	Look forward	0.03	*0.92*	0.00	0.01	*0.96*
3	Self-blame	0.38	−0.10	*0.43*	*0.80*	−0.15
4	Worry	−0.01	0.04	*0.98*	*0.80*	−0.02
5	Scared	0.29	0.10	*0.44*	*0.71*	0.02
6	Overwhelmed	*0.48*	0.05	0.24	*0.72*	0.00
7	Difficult to sleep	*0.60*	0.08	0.19	*0.75*	0.06
8	Sad	*0.81*	0.07	0.05	*0.79*	0.09
9	Cry	*0.90*	0.02	−0.11	*0.71*	0.07

[a] Factors identified by ordinary least squares (OLS) with varimax (orthogonal) rotation. The highest loading of each variable among the factors is shown in italic

anhedonia) by EFA with direct quartimin rotation (Tuohy and McVey 2008). These subconstructs were similar to our sample measured at 6 months postpartum, except (i) item 6 (overwhelmed) was suggested to be aligned with either depression (for African American or non-Hispanic white subgroups) or anxiety (for Hispanics) in our sample and (ii) item 10 (self-harming) was excluded in our analysis due to extremely low rate of positive response. These analyses suggest that item 6 (overwhelmed) may be related to different or even multiple subconstructs depending on different population characteristics. Compared to our sample (mean age 27.0 years, mean total EPDS score = 5.24), the Italian sample (Petrozzi and Gagliardi 2013) was older (mean age 32.3 years) with a similar mean total EPDS score (mean = 5.3), the UK sample (Coates et al. 2016) was similar in age (approximately 28 years old) with similar total EPDS score (median = 5), and women in the internet survey study (Tuohy and McVey 2008) were older (mean age 30.2 years) with a higher average total EPDS score (mean = 9.5). A study of women in Brazil (mean age = 25.3 years) that also reported a three-factor structure has identified item 6 as being most relevant to anhedonia (items 7–10 for depression; items 3–5 for anxiety; items 1, 2, 6 for anhedonia) by CFA and an exploratory structural equation model using geomin oblique rotation (Reichenheim et al. 2011).

While some have argued for the continued use of the EPDS as a uni-dimensional scale (Reichenheim et al. 2011), a growing number of studies demonstrate that a three-factor solution may be most optimal, including three related factors of depression, anhedonia, and anxiety similar to our population (Coates et al. 2016; Cunningham et al. 2015; Zhong et al. 2014). In addition to differences in sample characteristics that may influence the structure of the EPDS, it has been suggested that timing of administration may also play a role. A recent study by Coates et al. (2016) examined the structure of the EPDS at different time points (prenatal, 8 weeks, and 8 months postnatally) and found that a three-factor solution was most optimal at all time points including depression (items 7–10), anhedonia (items 1 and 2), and anxiety (items 3–6); these authors also found similar factor loadings across all time points. As Coates et al. (2016) pointed out, studies finding the three-factor solution tend to have a larger sample size ($n > 400$), suggesting that as correlation patterns become more stable with a larger sample, items separate into depression and anhedonia subconstructs, in addition to the anxiety subconstruct. These findings coupled with epidemiological data showing that prevalence rates of depressed mood and anhedonia differ across racial/ethnic groups support the need to distinguish these components in PPD assessment (Liu and Tronick 2014). Moreover, different dimensions (e.g., depressive symptoms, anhedonia, anxiety) may have variable antecedents or risk factors.

On the other hand, some studies reporting a three-factor structure find different item groupings. For example, Chabrol and Teissedre (2004) identified items 3, 4, 5, 6, and 7 as one subconstruct in a French population and Montazeri

Table 3 Confirmatory factor analysis (CFA) of EPDS, stratified by race/ethnicity

Race/ethnicity	Model	Factor structure	χ^2	*df*	*p*	CFI	RMSEA	SRMR
All (n = 515)	3-factor model	F1: 7,8,9 F2: 3,4,5,6 F3: 1,2	93.3	24	<.0001	0.97	0.07	0.03
African American (n = 148)	3-factor model	F1: 6,7,8,9 F2: 1,2 F3: 3,4,5	57.4	24	<.0001	0.94	0.10	0.06
Hispanic (n = 275)	3-factor model	F1: 3,4,5,6 F2: 7,8,9 F3: 1,2	75.4	24	<.0001	0.95	0.09	0.04
White (n = 92)	3-factor model	F1: 6,7,8,9 F2: 1,2 F3: 3,4,5	25.0	24	0.41	0.97	0.02	0.03

df degree of freedom, *CFI* comparative fit index, *RMSEA* root-mean-square error of approximation, *SRMR* standardized root-mean-square residual

et al. (2007) identified items 3, 4, 5, and 8 as one subconstruct in Iranian/Persian women, albeit these two studies also identified items 1–2 as another one of the three subconstructs as in our study. Further, a few studies categorized some items in more than one subconstruct. For example, a study in Dutch women reported that items 6 and 8 might belong to two of the three factors (F1: 7, 8, 9, 10; F2: 3, 4, 5, 6; F3: 1, 2, 6, 8) (Pop et al. 1992), and another study in Canada reported that items 2, 6, and 7 might also belong to two of the three factors (F1: 1, 2, 6, 7, 8, 9; F2: 3, 4, 5, 6, 7; F3: 2, 10) (Ross et al. 2003). These findings imply that while various datasets support multifactorial structures of the EPDS, the composition of each subconstruct may be dependent on the social constituents and cultural norms for different racial/ethnic groups. It is also possible that the inconsistent subconstructs identified across different studies may in part be due to the use of different statistical methodologies. If there is variation by racial/ethnic or SES groups, it would imply that these subconstructs may not meet measurement invariance, meaning that the instrument could be measuring different constructs across groups and therefore comparisons across groups need to be made with caution (Cunningham et al. 2015). Notably, almost all items in our analysis showed no evidence of cross-loadings in both two- and three-factor models, with just one exception in the race-stratified model—in Hispanics, we observed similar loadings for item 7 ("difficult to sleep") across the first (depression-related) and second (anxiety-related) factors in the three-factor model (Table 2). Therefore, we had reasonable robustness of the identified factor structures across three different racial/ethnic groups living in the same geographical area.

To our knowledge, only two studies to date have examined the factor structure of ethnic and racial subgroups in the USA. Lee King et al. (2012) used a CFA approach with a sample of African American women (n = 169) in the Midwestern USA recruited from a Medicaid or similar prenatal care coordination program through local health departments. Their postpartum survey data fit best with a three-factor model as identified by Tuohy and McVey (2008) as described above, which is similar to our findings in the same racial group. Notably, the socioeconomic characteristics in our sample were similar to the sample in Lee King et al. (2012). On the other hand, Hartley et al. (2014) examined a sample of Hispanic women (n = 220) in the Southeastern USA recruited from their child's pediatric primary care clinic in a large pediatric hospital using CFA, and found that a two-factor model of depression and anxiety was the structure that demonstrated best fit. The difference in the findings between our study and Hartley et al. (2014) for Hispanics could be partly due to geographic differences in the populations (Northeastern USA vs. Southeastern USA) or other factors that were not examined such as country of origin and length of time in the USA.

While our ethnically diverse sample allowing for the comparison of the EPDS factor structure across race/ethnicity subgroups is a strength, we also note some limitations. First, our study population consists of a majority of women with high school education level or less, potentially limiting the generalizability of our findings to other populations with higher socioeconomic status. Second, given that our goal was to compare model fits across racial sub-groups, our analysis did not include within-group cross-validation steps, in that both EFA and CFA procedures were conducted on the same participants. Ideally, these procedures would be done on independent random subsamples, but the sample size of some racial sub-groups, particularly non-Hispanic white women, would not allow for this. Further, the inconsistency between

the factor structures identified in the Hispanic women in our study compared to the other US Hispanic study of Hartley et al. (2014) warrants further investigation in this ethnic group.

In summary, these analyses support the need to consider the EPDS as a multi-dimensional scale in this ethnically mixed postpartum sample of women. Future epidemiological studies in ethnically mixed samples should consider EPDS subconstructs in addition to the conventionally used total score, as these subconstructs could have different risk factors and may be related to different behavioral or functional outcomes in both mothers and their children followed longitudinally.

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Conflict of interest The authors declare they have no competing interests.

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