

RESEARCH NOTE

Open Access



Measurement invariance analysis of the Postpartum Specific Anxiety Scale - Research Short Form in mothers of premature and term infants

Semra Worrall^{1*} , Paul Christiansen¹ , Asma Khalil^{2,3} , Sergio A. Silverio^{4,5†}  and Victoria Fallon^{1†} 

Abstract

Objective Mothers of premature infants are more likely to develop anxiety during the first postpartum year than mothers of term infants. However, commonly used measures of anxiety were developed for general adult populations and may produce spurious, over-inflated scores when used in a postpartum context. Although perinatal-specific tools such as the Postpartum Specific Anxiety Scale [PSAS] offer a promising alternative form of measurement, it is not clear whether the measure performs similarly in mothers of premature infants as it does in mothers of term infants. The objective of the current study was to identify whether items on the Postpartum Specific Anxiety Scale - Research Short Form (PSAS-RSF) are being interpreted in the same manner in mothers of term infants and mothers of premature infants. Mothers (N = 320) participated in an international on-line survey between February 2022 and March 2023 (n = 160 mothers of premature infants, n = 160 mothers of term infants) where they completed the PSAS-RSF. Data were analysed using a measurement invariance analysis to assess whether constructs of the PSAS-RSF are performing in a similar manner across the two groups.

Results Whilst the PSAS-RSF achieved configural invariance and so retains its four-factor structure, metric invariance was not reached and so items are being interpreted differently in mothers of premature infants. Items concerning infant-separation, finance, and anxieties surrounding infant health are potentially problematic. Future research must now modify the PSAS-RSF for specific use in mothers of premature infants, to ensure measurement of anxiety in this population is valid.

Keywords Gestational age, Preterm birth, Postpartum anxiety, Psychometric measurement, Measurement invariance

[†]Sergio A. Silverio and Victoria Fallon joint senior authors.

*Correspondence:

Semra Worrall
Semra.Worrall@liverpool.ac.uk

¹Department of Psychology, Institute of Population Health, University of Liverpool, Liverpool, UK

²Fetal Medicine Unit, Liverpool Women's NHS Foundation Trust, Liverpool, UK

³Fetal Medicine Unit, St. George's University Hospitals NHS Foundation Trust, University of London, London, UK

⁴Department of Women & Children's Health, School of Life Course & Population Sciences, King's College London, London, UK

⁵School of Psychology, Faculty of Health, Liverpool John Moores University, Liverpool, UK



© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

Introduction

Whilst many women report the transition to motherhood positively, for some, it can present psychological, social, physical, and emotional challenges. The transition to motherhood has been suggested as a potential period of psychological vulnerability [1], with anxiety and depression often highlighted as examples of poor mental health in the postnatal period.

Preterm birth represents a significant public health issue. The World Health Organization [WHO] estimate that over 13 million infants were born too early in 2020, with preterm birth now the leading cause of child mortality worldwide [2]. Adverse consequences include respiratory diseases [3], and increased likelihood of neuro-developmental delay comparative to term infants [4].

Research consistently shows mothers who give birth prematurely are more likely to develop depression [5], post-traumatic stress disorder [6], and anxiety [7], when compared to mothers of term infants. Postpartum anxiety in particular, may be exacerbated in mothers of premature infants compared to mothers of term infants, perhaps due to the sudden and unexpected nature of the birth [8], and uncertainty surrounding infant health [9].

Postpartum anxiety can be characterised by excessive, irrational worries occurring during the postpartum. From an evolutionary perspective, some anxieties after childbirth are adaptive, so there is a need to evaluate the presence of anxieties occurring after birth that may be considered maladaptive [10], through effective screening and identification. Despite high prevalence rates (up to 40%) [11], postpartum anxiety remains under-recognised and under-diagnosed [12]. This may perhaps be, in part, due to the lack of appropriate measurement tools for postpartum women. Most studies measuring postpartum anxiety use tools validated in general adult populations, which have been extrapolated for use in mothers as there has historically been no suitable alternative [13]. This can lead to spurious findings which may be unreliable [14].

Recently, the Postpartum Specific Anxiety Scale [PSAS] has been developed for research purposes and validated as a 51-item long-form [15], and as 16-item (PSAS-RSF) [16], and 12-item (PSAS-RSF-C) [17] short-forms. The PSAS has not been widely used in mothers of premature infants; to date only one study has investigated preterm birth and anxiety using the measure [7]. It is hypothesised however, some items contained within the PSAS may not be interpreted in the same manner in mothers of premature infants as with mothers of term infants. Items particularly pertinent to mothers of preterm infants may produce inflated findings given the increased likelihood of health concerns in this population [18], irrespective of anxiety. Similarly, items assessing anxieties surrounding infant development and maternal self-efficacy may also

be elevated, given these are common anxieties for mothers of premature infants [19, 20].

Given the vast social, economic, and psychological consequences of preterm birth, it is essential to investigate if using a postpartum-specific tool performs in a similar manner in mothers of premature infants as it does in mothers of term infants to ensure accurate measurement. This study therefore aims to undertake a measurement invariance analysis [21], to assess if anxiety has the same meaning across groups, using the PSAS-RSF in an English-speaking population of mothers of preterm and term infants in the first postpartum year.

Materials and methods

The current study forms part of a wider survey investigating postpartum anxiety and gestational age. The present analysis comprises datasets from two studies, which received full ethical approval from the University of Liverpool Institute of Population Health Research Ethics Committee (Study 1 ref:- 10606; Study 2 ref:- 3616). Written informed consent was gained via an electronically signed consent form, and participants received a full debrief upon completion.

Participants were recruited on-line, via social media and by word-of-mouth. Participants who were under 18 years of age, whose infant was born <24 week's gestation, or who were currently in the Neonatal Intensive Care Unit [NICU], were not eligible to participate. Participants were eligible to take part in the study if they were over the age of 18, had an infant born >24 week's gestation. If participants had an infant in the NICU, they had to have been discharged and well for at least three months to take part. Study 1 data were collected at two separate time points: February to August 2022 and November 2022 to March 2023. Study 1 data were combined with Study 2 data, which had been collected between January and February 2023, rendering 320 participants total. This allowed for the creation of two groups of equal number (premature [$n=160$]; and term [$n=160$]). There is no specific power calculation for measurement invariance, but the sample size was determined following the rule of 10 cases per item [22], rendering 160 participants for each group as there are 16 items on the PSAS-RSF. Participants completed demographic questions and psychometric scales including the PSAS-RSF [16].

Measures and analysis plan

Demographics

Several demographic questions, including age, ethnicity, and educational attainment were asked. Infant demographics, including gestational age (week of birth), and birth order were also gathered.

Postpartum Specific Anxiety Scale - Research Short Form (PSAS-RSF)

The PSAS-RSF [16] is a 16-item scale developed in 2021 measuring the frequency of maternal-and-infant anxieties occurring during the previous seven days, scored on a Likert scale from 1 (not at all) to 4 (almost always). The scale can be used in mothers of infants from 0 to 12 months of age. It features four subscales, consisting of four items each, scored separately: Maternal Competence and Attachment Anxieties, Practical Infant Care Anxieties, Infant Safety and Welfare Anxieties, and Psychosocial Adjustment to Motherhood. The scale has excellent reliability in the current study (McDonald's $\omega_h=0.75$).

Method of analysis

All data analyses were conducted in R version 4.2.1, using lavaan [23], dplyr [24], corrplot [25], semTools [26], semTables [27], and psych [28] packages. Measurement invariance of the scale was tested across the two groups (mothers of term and mothers of premature infants). Diagonally weighted least squares estimation was used as individual responses on the PSAS-RSF are ordinal, scored on a scale of one-to-four [29].

Configural invariance was tested to investigate if the factor structure held across the two groups, with a random effect of group in the model. Model fit was assessed using several indices. The Tucker-Lewis Index [TLI] and Comparative Fit Index [CFI] were computed, with values of ≥ 0.95 considered excellent [30]. A Root Mean Square Error of Approximation [RMSEA] was also computed, with values of < 0.05 considered good, and values of 0.08 considered fair [30, 31]. Finally, the Standardised Root Mean Square Residual [SRMR] was also computed, with values of < 0.08 considered good [30].

The configural model was then compared to a metric invariance model. The model structure remained the same, but factor loadings across groups are fixed, which allows interpretation as to whether each individual item on the scale performs in the same way across the two groups. The validity of this model was tested using CFI differences ($\Delta CFI < 0.01$), RMSEA differences ($\Delta RMSEA < 0.015$), and SRMR differences ($\Delta SRMR < 0.03$) as cut-offs [32]. If problematic, that is: values are above these figures, loadings across items were allowed to vary, to attempt to reach metric invariance. Problematic items were identified by assessing differences in standardised regression coefficients between the two groups.

The metric model is then compared to the scalar invariance model whereby factor loadings and intercepts are assumed to be equal across the two groups, so means of factor loadings can be compared. The cut-offs remain the same as the metric invariance model, but the SRMR cut-off is stricter ($\Delta SRMR < 0.015$).

Results

Participants

Mothers in both the premature ($n=160$) and term ($n=160$) groups were predominantly from the United Kingdom of Great Britain and Northern Ireland and the Republic of Ireland (52% vs. 59%), married (63% vs. 81%), primiparous (66% vs. 76%); with both groups demonstrating similar levels of education to either undergraduate or equivalent degree level (34% vs. 39%). See Tables 1 and 2 for full demographic characteristics.

Configural invariance

The model showed a good fit for the data (CFI=0.99, TLI=0.98, RMSEA=0.03 [90%CI 0.000 to 0.048], SRMR=0.07), showing the factor structure was consistent across groups.

Metric invariance

The PSAS-RSF did not reach cut-offs for metric invariance ($\Delta RMSEA=0.01$, $\Delta CFI=0.02$, $\Delta SRMR=0.01$). Problematic items were identified by assessing differences in standardised regression coefficients between groups in the configural model (see Table 3).

Metric invariance was reached after the slope for one item was allowed to vary (*I have felt frightened when my baby is not with me*; $\Delta RMSEA=0.01$, $\Delta CFI=-0.01$, $\Delta SRMR=0.06$). This model was also tested for scalar invariance, with loadings and intercepts for the problematic item being free to vary, and this was achieved ($\Delta RMSEA=0.009$, $\Delta CFI=-0.015$, $\Delta SRMR=0.006$).

However, it is also notable that a comparison of the regression slopes between groups for three items with high differences in standardised regression coefficients were significant: *I have worried I will not know what to do when my baby cries* ($p < .001$); *I have worried about my baby being accidentally harmed by someone or something else* ($p < .001$); *I have worried more about my finances than before my baby was born* ($p = .023$), indicating these items may also be problematic.

Discussion and conclusions

The aim of this study was to conduct a measurement invariance analysis to assess the performance of the PSAS-RSF in mothers of premature and term infants. Results demonstrate the PSAS-RSF achieves configural invariance, and so retains the original four-factor structure. However, it is clear there are several problematic items in the current version of the PSAS-RSF, which are being answered differently in mothers of premature infants.

The item "*I have felt frightened when my baby is not with me*" is being interpreted differently in mothers of premature infants on the PSAS-RSF. Extended periods of maternal-infant separation are relatively commonplace

Table 1 Maternal demographic characteristics, split by the premature and term groups

Maternal Characteristic	Value		Maternal Characteristic		Value	
	Premature (N = 160)	Term (N = 160)	Current Diagnosis of Clinical Anxiety (N%)	Timing of Anxiety Diagnosis ^b (N%)	Premature (N = 160)	Term (N = 160)
<i>Maternal Age (M ± SD)</i>	30.76 ± 5.74	29.31 ± 4.22	<i>Current Diagnosis of Clinical Anxiety (N%)</i>			
<i>Country of Residence (N%)</i>	United Kingdom of and Great Britain and Northern Ireland and Ireland		Yes		84 (52.50%)	59 (36.90%)
	United States		No		72 (45.00%)	101 (63.10%)
	Other European		Prefer Not to Say		4 (2.50%)	0 (0.00%)
<i>Ethnic Origin (N%)</i>	Other Non-European		<i>Timing of Anxiety Diagnosis^b (N%)</i>			
	White		Before Pregnancy		44 (27.50%)	46 (28.70%)
	Black Caribbean and Black African		During Pregnancy		7 (4.40%)	4 (2.50%)
<i>Marital Status (N%)</i>	Indian		Postpartum		33 (20.60%)	9 (5.60%)
	Other		<i>Taking Prescribed Medication for Anxiety^b (N%)</i>			
	Prefer Not to Say		Yes		44 (27.50%)	7 (4.40%)
	Married		No		39 (24.40%)	52 (32.50%)
	Living with Partner		Declined to Answer		1 (1.19%)	0 (0.00%)
<i>Occupation (N%)</i>	Separated		<i>Current Diagnosis of Clinical Depression (N%)</i>			
	Single		Yes		60 (37.50%)	14 (8.80%)
	Managers, Directors and Senior Officials		No		99 (61.90%)	146 (91.30%)
	Professional Occupations		Prefer not to Say		1 (0.60%)	0 (0.00%)
<i>Educational Attainment (N%)</i>	Completed Postgraduate Education, or equivalent		<i>Timing of Depression Diagnosis^b</i>			
	Completed Postgraduate Education, or equivalent		Before Pregnancy		29 (18.10%)	11 (6.90%)
	Completed Postgraduate Education, or equivalent		During Pregnancy		5 (3.10%)	3 (1.90%)
	Completed Postgraduate Education, or equivalent		Postpartum		26 (16.30%)	14 (8.80%)
	Completed Postgraduate Education, or equivalent		<i>Taking Prescribed Medication for Depression^b</i>			
	Completed Postgraduate Education, or equivalent		Yes		38 (23.80%)	7 (4.40%)
	Completed Postgraduate Education, or equivalent		No		21 (13.10%)	7 (4.40%)
	Completed Postgraduate Education, or equivalent		Declined to Answer		1 (1.67%)	0 (0.00%)
	Completed Postgraduate Education, or equivalent		<i>Maternal Anxiety on PSAS-RSF (M ± SD)</i>			
	Completed Postgraduate Education, or equivalent		Maternal Competence and Attachment Anxieties		7.85 ± 2.80	6.95 ± 2.06
Completed Postgraduate Education, or equivalent		Infant Safety and Welfare Anxieties		11.49 ± 3.11	8.98 ± 2.52	
Completed Postgraduate Education, or equivalent		Practical Infant Care Anxieties		10.78 ± 2.86	8.24 ± 2.46	
Completed Postgraduate Education, or equivalent		Psychosocial Adjustment to Motherhood		11.52 ± 2.82	9.25 ± 2.36	
Completed Postgraduate Education, or equivalent		PSAS-RSF Total		41.64 ± 9.04	33.41 ± 6.46	

Table 1 (continued)

Maternal Characteristic	Value		Maternal Characteristic		Value	
	Premature (N = 160)	Term (N = 160)	Premature (N = 160)	Term (N = 160)	Premature (N = 160)	Term (N = 160)
Completed Undergraduate Education, or equivalent	55 (34.40%)	63 (39.40%)				
Completed A-Levels, or equivalent	29 (18.10%)	47 (29.40%)				
Completed GCSEs, or equivalent	17 (10.60%)	28 (17.50%)				
No Qualifications	7 (4.40%)	1 (0.60%)				
Other	14 (8.80%)	2 (1.30%)				
<i>Housing Situation (N/%)</i>						
Own your Own Home	89 (55.6%)	120 (75.00%)				
Rent Privately	50 (31.30%)	28 (17.50%)				
Rent from the Local Authority	13 (8.10%)	7 (4.40%)				
Live with Parents	3 (1.90%)	3 (1.90%)				
Other	5 (3.10%)	2 (1.30%)				
<i>Occupant Number, inc. Participant (N/%)</i>						
Two	10 (6.30%)	5 (3.1%)				
Three	86 (53.80%)	115 (71.90%)				
Four	38 (23.80%)	22 (13.8%)				
Five or more	26 (16.25%)	18 (11.30%)				

N/B.

^a This option was not presented to participants in the term group.

^b This item was only presented to participants who answered 'Yes' to the current clinical diagnosis question. Participants were free not to answer the questions.

^c Participants (n=15) from the second dataset were not presented with these questions. N/percentages are therefore representative of the n=145 participants who were presented these questions.

Table 2 Infant demographic characteristics, split by the premature and term groups

Infant Characteristic	Value	
	Premature (N = 160)	Term (N = 160)
Infant Age (M ± SD)	21.54 ± 14.86	20.37 ± 12.92
Multiple Birth (N%)		
Yes	18 (11.30%)	3 (1.90%)
No	142 (88.80%)	157 (98.1%)
Birth Order		
First	106 (66.30%)	122 (76.30%)
Second	33 (20.60%)	22 (13.8%)
Third	11 (6.90%)	14 (8.80%)
Fourth or after	10 (6.25%)	2 (1.30%)
Week of birth (M ± SD)	31.48 ± 3.06	39.45 ± 1.70
Infant in the NICU ^{a,c}		
Yes	135	N/A
No	10	N/A
Duration of NICU Stay in Weeks (N%) ^{a,b}		
< 1 week	1 (0.69%)	N/A
1 to 4 weeks	67 (46.21%)	N/A
5 to 10 weeks	45 (31.03%)	N/A
11 to 15 weeks	16 (11.03%)	N/A
16 or more weeks	6 (4.14%)	N/A

N/B.

^a This option was not presented to participants in the term group.^b Participants (n=15) from the second dataset were not presented with these questions. N/percentages are therefore representative of the n=145 participants who were presented these questions.

with premature infants, particularly at or shortly after the point of birth [33], and may contribute to feelings of anxiousness when separated. Admission to the neonatal intensive care unit [NICU] can contribute feelings of physical separation from the infant [34]. It may also

be the environment of the NICU itself leads to feelings of separation, with parents often reporting the physical space around the infant is dominated by medical equipment, meaning they find it difficult to remain close to the infant [35]. Furthermore, the constraints of hospital policies mean mothers can feel further apart from their new baby [36]. This is important as prolonged separation, particularly considering the NICU, can lead to impairments in attachment and bonding [37, 38], which can increase anxiety [39].

Parental concerns for preterm infants also extend beyond their baby's physical health. Financial concerns following the birth of a preterm baby are inversely associated with gestational age [40], and financial burdens of caring for a preterm baby are further exacerbated if the infant is in hospital for a prolonged period after birth, and can lead to a reliance on support networks [41]. Notwithstanding the financial burdens associated with hospital care immediately after birth, significant costs can persist right across the first year postpartum. For example, infants with severe health complications as a result of their birth may require heightened medical care once at home, including specialised equipment required to further support development, and follow-up appointments, which may lead to time off work extending beyond parental leave [42]. Furthermore, the NICU has been associated with significant out-of-pocket expenses, including childcare for other siblings, and direct medical costs which cause significant concern even in mothers who have paid parental leave [43]. It is also important to consider, as this study was international, the cost of healthcare may also be a contributing factor. For example, estimates suggest privately insured families in the

Table 3 Standardised regression coefficients for the premature and term group

PSAS-RSF Factor	Item	Premature Group	Term Group	Difference
Psychosocial Adjustment to Motherhood	I have felt that I have had less control over my day than before my baby was born (PSAS-RSF 7)	0.67	0.52	0.15
	I have felt unable to juggle motherhood with other responsibilities (PSAS-RSF 2)	0.73	0.50	0.23
	I have worried that I am not going to get enough sleep (PSAS-RSF 12)	0.64	0.59	0.05
	I have worried more about my finances than before my baby was born (PSAS-RSF 10)	0.43	0.15	0.28
Practical Infant Care Anxieties	I have worried about my baby's milk intake (PSAS-RSF 5)	0.57	0.51	0.06
	I have worried about my baby's weight (PSAS-RSF 11)	0.56	0.48	0.08
	I have worried about the length of time my baby sleeps (PSAS-RSF 1)	0.58	0.60	-0.02
	I have worried about getting my baby into a routine (PSAS-RSF 14)	0.76	0.60	0.16
Maternal Competence and Attachment Anxieties	I have felt that my baby would be better cared for by someone else (PSAS-RSF 9)	0.56	0.40	0.16
	I have had negative thoughts about my relationship with my baby (PSAS-RSF 4)	0.72	0.49	0.23
	I have worried I will not know what to do when my baby cries (PSAS-RSF 16)	0.64	0.29	0.35
Infant Safety and Welfare Anxieties	I have worried that my baby is picking up on my anxieties (PSAS-RSF 3)	0.80	0.63	0.17
	I have repeatedly checked on my sleeping baby (PSAS-RSF 8)	0.63	0.65	-0.02
	I have worried that my baby will stop breathing whilst sleeping (PSAS-RSF 6)	0.71	0.70	-0.01
	I have felt frightened when my baby is not with me (PSAS-RSF 13)	0.71	0.23	0.48
	I have worried about my baby being accidentally harmed by someone or something else (PSAS-RSF 15)	0.72	0.40	0.32

United States may still incur out-of-pocket costs relating to NICU care in excess of \$10,000 [44]; and in the UK, costs can reach approximately £75,000 for the earliest preterm infants, with all of this cost absorbed to the National Health Service [NHS] [45].

Anxieties surrounding infant health and accidental harm, as well as concerns surrounding infant care may also be increased in women with babies in NICU. They have already been found to be more prevalent for mothers with the earliest preterm infants [7]. The environment and constraints of the NICU, including handing over routine care of the infant to medical professionals can lead mothers to feel powerless and disconnected from their infant [19], which can further contribute to anxiety, leading mothers to feel uncertain about their parental role. This can lead to feelings of over-protection towards the infant [45], including fears regarding accidental harm and health. Mothers often feel uncertain about their parental role [46], and so may feel unsure and alone when the environment of the NICU is removed [47].

Limitations

This study is the first to conduct a measurement invariance analysis of the PSAS-RSF across mothers of term and premature infants. However, the sample were predominantly White, married women from the United Kingdom of Great Britain and Northern Ireland and the Republic of Ireland. Future research should make a concerted effort to recruit women from diverse backgrounds, particularly as anxiety levels amongst mothers of premature infants can differ by race [48], and women from minority ethnic groups are less likely to engage with perinatal mental health services [49]. The results of the current study can inform modification of the current version of the PSAS-RSF for use in mothers of premature infants. Adaptation of the scale can be further informed by stakeholders and mothers of premature infants, before ensuring validity and reliability of any new measure.

Conclusion

We conducted a measurement invariance analysis of the PSAS-RSF across mothers of term and premature infants. Results support the retention of the four-factor structure found in other variations of the PSAS as the measure achieved configural invariance, however, potentially problematic items include those around infant care, safety, and psychosocial adjustment to motherhood. Future research should now modify the PSAS-RSF for use in this specific population of mothers of premature infants.

Abbreviations

WHO	World Health Organization
PSAS	Postpartum Specific Anxiety Scale
PSAS-RSF	Postpartum Specific Anxiety Scale Research Short Form

PSAS-RSF-C	Postpartum Specific Anxiety Scale Research Short Form for Global Crisis
NICU	Neonatal Intensive Care Unit
TLI	Tucker Lewis Index
CFI	Comparative Fit Index
RMSEA	Root Mean Square Error of Approximation
SRMR	Standardised Root Mean Square Error of Approximation

Acknowledgements

None.

Author contributions

Conceptualisation: [SW, VF, SAS, PC, AK]; Methodology: [VF, SW, PC]; Software: [SW]; Validation: [PC, AK, SAS, VF]; Formal Analysis: [SW, PC]; Investigation: [SW, VF, SAS]; Resources: [VF, SAS]; Data Curation: [SW]; Writing-Original Draft: [SW]; Writing-Review and Editing: [SAS, PC, VF, AK]; Visualisation: [SW]; Supervision: [VF, SAS, PC, AK]; Project Administration: [SW].

Funding

This study received no specific funding.

Data availability

The dataset analysed for this study is not publicly available. However, reasonable requests for data can be sent to the corresponding author.

Declarations

Ethics approval and consent to participate

The study received full ethical approval from the University of Liverpool Institute of Population Health Research Ethics Committee (ref:-10606; ref:-3616). All participants provided written informed consent via an electronically signed form, and were made aware of their right to withdraw. All aspects of the study were performed in accordance with the latest version of the Declaration of Helsinki.

Consent for publication

All participants were fully informed and their informed consent for publication has been obtained that their data would be used for the publication of this study, and consented to their anonymized data being published.

Competing interests

Miss. Semra Worrall's PhD is supported financially by the University of Liverpool; however, the institution has no influence over research design, data collection, analysis, write-up, or the decision to submit. All other authors declare no known competing financial interests or personal relationships which could have appeared to influence the work reported in this article.

Received: 29 September 2023 / Accepted: 8 March 2024

Published online: 14 March 2024

References

1. Kuipers YJ, van Beeck E, Cijssouw A, van Gils Y. The impact of motherhood on the course of women's psychological wellbeing. *J Affect Disorders Rep.* 2021;6:100216. <https://doi.org/10.1016/j.jadr.2021.100216>.
2. Preterm birth [Internet]. World Health Organization. 2023 [cited 2023 Sept 5]. Available from: <https://www.who.int/news-room/fact-sheets/detail/preterm-birth>.
3. Gallini F, Coppola M, De Rose DU, Maggio L, Arena R, Romano V, Cota F, Ricci D, Romeo DM, Mercuri EM, Vento G. Neurodevelopmental outcomes in very preterm infants: the role of severity of Bronchopulmonary Dysplasia. *Early Hum Dev.* 2021;152:105275. <https://doi.org/10.1016/j.earlhumdev.2020.105275>.
4. Chung EH, Chou J, Brown KA. Neurodevelopmental outcomes of preterm infants: a recent literature review. *Translational Pediatr.* 2020;9(Suppl 1):S3. <https://doi.org/10.21037/tp.2019.09.10>.
5. de Paula Eduardo JA, de Rezende MG, Menezes PR, Del-Ben CM. Preterm birth as a risk factor for postpartum depression: a systematic review and meta-analysis. *J Affect Disord.* 2019;259:392–403. <https://doi.org/10.1016/j.jad.2019.08.069>.

6. Anderson C, Cocola P. Implications of preterm birth for maternal mental health and infant development. *MCN: Am J Maternal/Child Nurs.* 2017;42(2):108–14. <https://doi.org/10.1097/NMC.0000000000000311>.
7. Worrall S, Silverio SA, Fallon VM. The relationship between prematurity and maternal mental health during the first postpartum year. *J Neonatal Nurs.* 2023;29(3):511–8. <https://doi.org/10.1016/j.jnn.2022.10.002>.
8. Blackburn C, Harvey M. We weren't prepared for this: parents' experiences of information and support following the premature birth of their infant. *Infants Young Child.* 2019;32(3):172–85. <https://doi.org/10.1097/IYC.0000000000000142>.
9. Lasiuk GC, Comeau T, Newburn-Cook C. Unexpected: an interpretive description of parental traumas associated with preterm birth. *BMC Pregnancy Childbirth.* 2013;13(1):1–0. <https://doi.org/10.1186/1471-2393-13-S1-S13>.
10. Lorenzo LS. Beyond the 'normal' worries: detection and treatment of perinatal anxiety and anxiety disorders. *BJPsych Adv.* 2023;29(3):187–97. <https://doi.org/10.1192/bja.2022.9>.
11. Field T. Postnatal anxiety prevalence, predictors and effects on development: a narrative review. *Infant Behav Dev.* 2018;51:24–32. <https://doi.org/10.1016/j.infbeh.2018.02.005>.
12. Rai S, Pathak A, Sharma I. Postpartum psychiatric disorders: early diagnosis and management. *Indian J Psychiatry.* 2015;57(Suppl 2):S216. <https://doi.org/10.4103/0019-5545.161481>.
13. Overview. Antenatal and Postnatal Mental Health: Clinical Management and Service guidance: Guidance [Internet]. 2020 [cited 2023 Sept 5]. Available from: <https://www.nice.org.uk/guidance/cg192>.
14. Swallow BL, Lindow SW, Masson EA, Hay DM. The use of the General Health Questionnaire (GHQ-28) to estimate prevalence of psychiatric disorder in early pregnancy. *Psychol Health Med.* 2003;8(2):213–7. <https://doi.org/10.1080/1354850031000087591>.
15. Fallon V, Halford JC, Bennett KM, Harrold JA. The postpartum specific anxiety scale: development and preliminary validation. *Arch Women Ment Health.* 2016;19:1079–90. <https://doi.org/10.1007/s00737-016-0658-9>.
16. Davies SM, Christiansen P, Harrold JA, Silverio SA, Fallon V. Creation and validation of the postpartum specific anxiety scale research short-form (PSAS-RSF). *Arch Women Ment Health.* 2021;24(6):957–69. <https://doi.org/10.1007/s00737-021-01114-7>.
17. Silverio SA, Davies SM, Christiansen P, Aparicio-García ME, Bramante A, Chen P, Costas-Ramón N, de Weerth C, Della Vedova AM, Infante Gil L, Lustermans H. A validation of the Postpartum specific anxiety scale 12-item research short-form for use during global crises with five translations. *BMC Pregnancy Childbirth.* 2021;21(1):1–2. <https://doi.org/10.1186/s12884-021-03597-9>.
18. Cherián S, Morris I, Evans J, Kotecha S. Oxygen therapy in preterm infants. *Paediatr Respir Rev.* 2014;15(2):135–41. <https://doi.org/10.1016/j.prrv.2012.12.003>.
19. O'Donovan A, Nixon E. Weathering the storm: mothers' and fathers' experiences of parenting a preterm infant. *Infant Mental Health J.* 2019;40(4):573–87. <https://doi.org/10.1002/imhj.21788>.
20. Valipour S, Estebarsari F, Nasiri M, Vasli P. Predictors of readiness for discharge in mothers of preterm infants: the role of stress, self-efficacy and perceived social support. *Asian Pac J Reprod.* 2022;11(6). <https://doi.org/10.4103/2305-0500.356845>.
21. Putnick DL, Bornstein MH. Measurement invariance conventions and reporting: the state of the art and future directions for psychological research. *Dev Rev.* 2016;41:71–90. <https://doi.org/10.1016/j.dr.2016.06.004>.
22. Nunnally J. *Psychometric theory.* (No Title). 1994.
23. Rosseel Y. lavaan: An R Package for Structural Equation Modeling. *J. Stat. Soft.* [Internet]. 2012 May 24 [cited 2023 Sep. 13];48(2):1–36. Available from: <https://www.jstatsoft.org/index.php/jss/article/view/v048i02>.
24. Wickham H, François R, Henry L, Müller K, dplyr. *A Grammar of Data Manipulation.* R package version 0.7.6. Computer software]. <https://CRAN.R-project.org/package=dplyr>. 2018.
25. Wei T, Simko V. R package corplot: Visualization of a Correlation Matrix [Internet]. 2017. Available from: <https://github.com/taiyun/corplot>.
26. Jorgensen TD, Pornprasertmanit S, Schoemann AM, Rosseel Y, Miller P, Quick C, Garnier-Villarreal M, Selig J, Boulton A, Preacher K, Coffman D. Package 'semtools'. Website: <https://cran.r-project.org/web/packages/semTools/semTools.pdf>. 2016 Oct 22.
27. Johnson P, Kite B, semTable. Structural equation modeling tables. Website: <https://cran.r-project.org/web/packages/semTable/index.html>. 2020 Apr 29.
28. Revelle W. *Psych: procedures for psychological, psychometric, and personality research* (R package version 1.9.12). Evanston, IL: Northwestern University; 2019.
29. Mindrilić D. Maximum likelihood (ML) and diagonally weighted least squares (DWLS) estimation procedures: a comparison of estimation bias with ordinal and multivariate non-normal data. *Int J Digit Soc.* 2010;1(1):60–6. <https://doi.org/10.20533/ijds.2040.2570.2010.0010>.
30. Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct Equation Modeling: Multidisciplinary J.* 1999;6(1):1–55. <https://doi.org/10.1080/10705519909540118>.
31. MacCallum RC, Browne MW, Sugawara HM. Power analysis and determination of sample size for covariance structure modeling. *Psychol Methods.* 1996;1(2):130. <https://doi.org/10.1037/1082-989X.1.2.130>.
32. Chen FF. Sensitivity of goodness of fit indexes to lack of measurement invariance. *Struct Equation Modeling: Multidisciplinary J.* 2007;14(3):464–504.
33. Førelund AM, Engesland H, Kristoffersen L, Fegran L. Postpartum experiences of early skin-to-skin contact and the traditional separation approach after a very preterm birth: a qualitative study among mothers. *Global Qualitative Nurs Res.* 2022;9:23333936221097116. <https://doi.org/10.1177/23333936221097116>.
34. Treherne SC, Feeley N, Charbonneau L, Axelin A. Parents' perspectives of closeness and separation with their preterm infants in the NICU. *J Obstetric Gynecologic Neonatal Nurs.* 2017;46(5):737–47. <https://doi.org/10.1016/j.jogn.2017.07.005>.
35. Flacking R, Ewald U, Nyqvist KH, Starrin B. Trustful bonds: a key to becoming a mother and to reciprocal breastfeeding. Stories of mothers of very preterm infants at a neonatal unit. *Soc Sci Med.* 2006;62(1):70–80. <https://doi.org/10.1016/j.socscimed.2005.05.026>.
36. Aija A, Toome L, Axelin A, Raiskila S, Lehtonen L. Parents' presence and participation in medical rounds in 11 European neonatal units. *Early Hum Dev.* 2019;130:10–6. <https://doi.org/10.1016/j.earlhumdev.2019.01.003>.
37. Lebel V, Campbell-Yeo M, Feeley N, Axelin A. Understanding factors associated with emotional closeness in parents with a preterm infant in the neonatal intensive care unit. *Early Hum Dev.* 2022;173:105664. <https://doi.org/10.1016/j.earlhumdev.2022.105664>.
38. Mäkelä H, Axelin A, Feeley N, Niela-Vilén H. Clinging to closeness: the parental view on developing a close bond with their infants in a NICU. *Midwifery.* 2018;62:183–8. <https://doi.org/10.1016/j.midw.2018.04.003>.
39. Lutkiewicz K, Bieleninik L, Cieślak M, Bidzan M. Maternal–infant bonding and its relationships with maternal depressive symptoms, stress and anxiety in the early postpartum period in a Polish sample. *Int J Environ Res Public Health.* 2020;17(15):5427. <https://doi.org/10.3390/ijerph17155427>.
40. Cheah IG. Economic assessment of neonatal intensive care. *Translational Pediatr.* 2019;8(3):246. <https://doi.org/10.21037/tp.2019.07.03>.
41. Lomotey AY, Bam V, Diji AK, Asante E, Asante HB, Osei J. Experiences of mothers with preterm babies at a Mother and Baby Unit of a tertiary hospital: a descriptive phenomenological study. *Nurs Open.* 2020;7(1):150–9. <https://doi.org/10.1002/nop2.373>.
42. Greenfield JC, Klawetter S. Parental leave policy as a strategy to improve outcomes among premature infants. *Health Soc Work.* 2016;41(1):17–23. <https://doi.org/10.1093/hsw/hlv079>.
43. Lakshmanan A, Song AY, Belfort MB, Yieh L, Dukhovny D, Friedlich PS, Gong CL. The financial burden experienced by families of preterm infants after NICU discharge. *J Perinatol.* 2022;42(2):223–30. <https://doi.org/10.1038/s41372-021-01213-4>.
44. Chua KP, Fendrick AM, Conti RM, Moniz MH. Out-of-pocket spending for deliveries and newborn hospitalizations among the privately insured. *Pediatrics.* 2021;148(1). <https://doi.org/10.1542/peds.2021-050552>.
45. Yang M, Campbell H, Pillay T, Boyle EM, Modi N, Rivero-Arias O. Neonatal health care costs of very preterm babies in England: a retrospective analysis of a national birth cohort. *BMJ Paediatrics Open.* 2023;7(1). <https://doi.org/10.1136/bmjpo-2022-001818>.
46. Pisoni C, Spairani S, Manzoni F, Ariaudo G, Naboni C, Moncecchi M, Balottin U, Tinelli C, Gardella B, Tziella C, Stronati M. Depressive symptoms and maternal psychological distress during early infancy: a pilot study in preterm as compared with term mother–infant dyads. *J Affect Disord.* 2019;257:470–6. <https://doi.org/10.1016/j.jad.2019.07.039>.
47. Granero-Molina J, Medina IM, Fernández-Sola C, Hernández-Padilla JM, Lasserrotte MD, Rodríguez MD. Experiences of mothers of extremely preterm infants after hospital discharge. *J Pediatr Nurs.* 2019;45:e2–8. <https://doi.org/10.1016/j.pedn.2018.12.003>.
48. Fabiya C, Rankin K, Norr K, Shapiro N, White-Traut R. Anxiety among black and Latina mothers of premature infants at social-environmental risk.

Newborn Infant Nurs Reviews. 2012;12(3):132–40. <https://doi.org/10.1053/j.nainr.2012.06.004>.

49. Pilav S, De Backer K, Easter A, Silverio SA, Sundaresh S, Roberts S, Howard LM. A qualitative study of minority ethnic women's experiences of access to and engagement with perinatal mental health care. *BMC Pregnancy Childbirth*. 2022;22(1):1–3. <https://doi.org/10.1186/s12884-022-04698-9>.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.