

Systematic Review

The Role of the Home Environment in Perinatal Depression: A Systematic Review and Meta-Analysis of Observational Epidemiological Studies

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Abstract: Perinatal depression is a leading cause of maternal morbidity worldwide, impacting about one-third of all pregnant individuals. The indoor home environment plays a critical role in the mental health of pregnant individuals, as they spend a substantial amount of their day inside their homes. We conducted a systematic review and meta-analysis to identify, synthesize, and evaluate the available scientific literature on the association between home environment attributes related to stability, quality, and indoor exposures and perinatal depression. Comprehensive electronic searches were conducted in four major bibliographic databases. Dual independent screening, data extraction, and quality assessment were completed. Weighted Z-meta-analysis was conducted to synthesize the available evidence. The review included 27 observational epidemiological studies published between 2003 and 2024, involving 174,914 pregnant and/or postpartum individuals, which investigated the role of at least one home environment attribute in relation to perinatal depression. We found very strong evidence linking indoor air pollutants, particularly household tobacco smoke, to perinatal depression. We found strong evidence for the impact of housing instability on perinatal depression. In contrast, the evidence for associations involving housing quality and residential noise was weak. Our findings underscore the significance of incorporating home environment-focused initiatives in public health efforts to improve perinatal mental health. Further research is needed to identify common household attributes associated with poor perinatal mental health to inform future public intervention and policies.

Keywords: home environment; perinatal depression; pregnancy; indoor; systematic review



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1. Introduction

The home environment refers to indoor living contexts where individuals and families seek comfort, grow, and live. Interrelated housing characteristics (e.g., size, location, precarity, crowding), built environment features (e.g., physical spaces, structures, facilities) and biochemical exposures (e.g., mold, moisture, tobacco smoke, wood stove emissions,

disinfectants) are important determinants of health [1–4]. The home environment is an important consideration, especially for the mental health of pregnant individuals, as they spend a substantial amount of their day inside their homes (an average of 17.3 h/day) [5], resulting in prolonged and consistent exposures.

Previous research highlights the connections between housing characteristics and poor mental health outcomes [1,4,6,7]. A recent analysis showed that residential characteristics such as indoor lighting, safety, window views, and noise disturbance have a stronger influence on self-reported depression scores than sociodemographic and lifestyle behaviors [7]. Poor housing quality has been associated with moderate-to-severe depression, regardless of home size [1,6]. Pregnant individuals' perceptions of household air quality are linked with higher stress levels, potentially mediating the relationship between daily particulate matter (PM) 2.5 exposure and mental stress [8,9]. Furthermore, household air pollution sources, including environmental tobacco smoke and solid fuel use for cooking and heating, have been linked with depressive symptoms [9–13]. Hazardous exposures during pregnancy, such as residential noise, may also have long-term negative effects on mental health, contributing to an increased healthcare burden [14,15]. Findings from a longitudinal cohort study of 140,456 Canadian pregnant women revealed a higher risk of hospitalization for depression and other mental disorders among those exposed to nighttime noise over the 18-year follow-up period [15].

Perinatal depression impacts 1 in 4 women worldwide and is the leading cause of maternal morbidity [16,17]. Considering the detrimental mental health effects of adverse home exposures, it is critical to evaluate home environment factors linked with perinatal depression to guide prevention efforts. Despite the recognized importance of this area, no systematic review to date has comprehensively summarized the evidence on the relationship between home environment factors and depression in pregnant and postpartum populations. To address this gap, we conducted a systematic review to identify, synthesize, and evaluate the scientific literature on the association between home environment factors and perinatal depression. Notably, a standard definition or measure of the physical home environment is not available. Existing measures range from objective measures, such as housing size, ownership, indoor air quality, or residential noise, to subjective evaluations of perceived safety, comfort, pride, and satisfaction with the home and neighbourhood [1,6,7,18,19]. This review focuses specifically on measures related to the home environment's stability, quality and indoor conditions. The measures included: housing stability (relocation/frequent moves, housing affordability and homelessness), housing quality (ventilation, dampness, heating, type of housing [single/multifamily], ownership/rental/transitional living arrangement, household size, renovations), chemical and biological contaminants (indoor smoking, disinfectants/aerosols, incense, furnace/stove, synthetic chemicals, e.g., volatile organic compounds, pets, pest infestation, molds), and residential noise.

2. Methods

2.1. Literature Searches

The review was planned and conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), Meta-Analyses and Systematic Reviews of Observational Studies guidelines and the Cochrane Collaboration standards [20–22]. A protocol for the systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42023411656). Comprehensive literature searches were conducted by a health sciences librarian (LD) across four major bibliographic databases (Medline, Embase, Scopus and Web of Science) from database inception to June 2024. The search strategies were customized for each database, and no restrictions were

applied based on the year of publication, country of publication, or language. Reference lists of relevant literature reviews were manually searched (SA). The full search strategy is provided in Supplementary Table S1.

2.2. Study Selection

Studies were included if they were: (a) primary observational epidemiological studies (i.e., prospective or retrospective cohort, case-control, or cross-sectional studies), (b) assessed at least one home environment domain, and (c) reported on perinatal depression. The home environment domains included housing instability (e.g., moves, eviction, homelessness), housing quality (e.g., ventilation, heating, ownership, household size, renovations), household chemical exposures (e.g., indoor smoking, aerosol/disinfectants, incense, stove/heating fuel, furniture, volatile organic compounds), biological exposures (e.g., pets, pest infestation, moulds), and residential noise. The primary outcome of interest was perinatal depression, defined as a mood disorder during pregnancy (antepartum) and up to a year after birth (postpartum).

The titles and abstracts identified through database searches were independently assessed by at least two reviewers (SA, MV, SB). Full-text articles deemed potentially relevant were retrieved for detailed assessment against the eligibility criteria. For duplicate publications, only the most recent version was included. Any disagreement during the selection process were resolved through discussion among the reviewers until consensus was reached. Study selection and screening were managed using Covidence, a web-based review management platform (Veritas Health Innovation, Melbourne, Australia).

2.3. Risk of Bias Assessment

Two reviewers (SA, MV) independently assessed the risk of bias (RoB) of included studies using tools adapted to their respective study designs [23,24]. The quality criteria included representativeness of the study sample, comparability among groups, adjustment of potential sociodemographic covariates and prior history of mental disorders, measurement of home environment attributes (objective vs. subjective), and validity of perinatal depression measures.

We used the Newcastle-Ottawa Scale (NOS) for the RoB assessment of cohort and case-control studies across three domains: study selection (selection bias), comparability among groups (confounding bias) and exposure/outcome assessment (measurement bias). Each study received a score of 1 for meeting the quality criterion, for a maximum possible score of 9. Studies were categorized as low, unclear and high RoB based on their overall quality score. Low RoB was defined as a NOS score of 3–4 for study selection, 1–2 for comparability, and 2–3 for outcome assessment; unclear RoB a score of 2–3 for study selection, 1–2 for comparability, and 1–2 for outcome assessment; and high RoB a score of 0–1 for study selection, a score of 0 for comparability, and a score of 0–1 for outcome assessment.

For cross-sectional studies, a tool designed for prevalence studies was used to evaluate RoB across nine categories assessing selection and measurement biases. Studies were classified as follows: Low RoB: high-risk classification in 0–3 categories; Unclear RoB: high-risk classification in 4–6 categories; High RoB: high-risk classification in 7–9 categories. Similar rating criteria have been used in previously published reviews of observational studies [25,26]. Disagreements in RoB appraisals were resolved by discussion and consensus (SA, MV). Individual study ratings in RoB domains were presented in a RoB table.

2.4. Data Extraction and Synthesis

Two reviewers (SA, MV) independently extracted and verified data using Microsoft Excel™ Version 16.95.1 (Microsoft Corporation, Santa Rosa, CA, USA). Data were extracted on study characteristics, author, year of publication, sample size, study duration, home

environment measures, perinatal depression estimates, probability values and 95% confidence intervals (where available), and analytical methods. Discrepancies in data extraction were resolved through consensus. An effect direction plot and summary tables were used to summarize review results.

A traditional Mantel–Haenszel meta-analysis using random effects was initially planned. However, due to substantial heterogeneity in study design, methodology, measurement of home environment factors, and effect estimates, pooling of observational data can be difficult. An alternate approach using a weighted Z-test meta-analysis was conducted. This approach has been used in previously published reviews on built environments to pool heterogeneous studies with variations in exposure-outcome assessment across studies [27,28]. We used Stouffer’s Z-score method to pool Z-scores derived from two-tailed *p*-values and weighted by sample size and study RoB [27–29]. We assigned the Z-score of 1.96 for statistically significant (two-tailed *p*-value at 0.05) findings in the expected direction, -1.96 for significant findings in the unexpected direction, and 0 for non-significant findings. The expected direction of association was defined based on prior knowledge (e.g., exposure to household aerosols is expected to increase the risk of perinatal depression).

Each study was assigned a cumulative weight based on its RoB rating and sample size. Studies rated as low RoB were assigned a weight of 7, unclear RoB 5 and studies with high RoB were assigned a weight of 3. This approach has been used previously [27]. Based on the sample size, the following weightage was assigned: 0.25 for ≤ 100 participants; 0.50 for 101–300 participants; 1.00 for 301–500 participants; 1.25 for 501–1000 participants; 1.50 for 1001–2500 participants; and 1.75 for >2500 participants. The cumulative weight for each study was calculated as the sum of the RoB and sample size weights. This weighting approach has been used in prior research [27]. We calculated the weighted Z value by dividing the sum of weighted z-scores by the square root of the sum of squared weights. A two-tailed *p*-value was derived to interpret the strength of the evidence based on Bland’s approach for interpreting probability values, i.e., $p < 0.001$: very strong evidence; $p < 0.01$ strong evidence; $p < 0.05$ weak evidence, and $p > 0.05$ no statistical significance/null evidence [30]. If an association was reported by four or fewer studies, the strength of evidence was downgraded to account for limited data. Publication bias assessment using funnel plots was planned for meta-analysis including at least 10 studies [22]. Data analysis was conducted using Microsoft Excel™ (Microsoft Corporation, USA).

3. Results

3.1. Search Results

We identified 6462 records through database searches. After deduplication, 2911 titles and abstracts were screened. Of these, 61 full-text articles were assessed for eligibility, of which 27 were included in the review. A detailed account of study inclusion and exclusion process is presented in Figure 1. The complete list of excluded studies is available upon request.

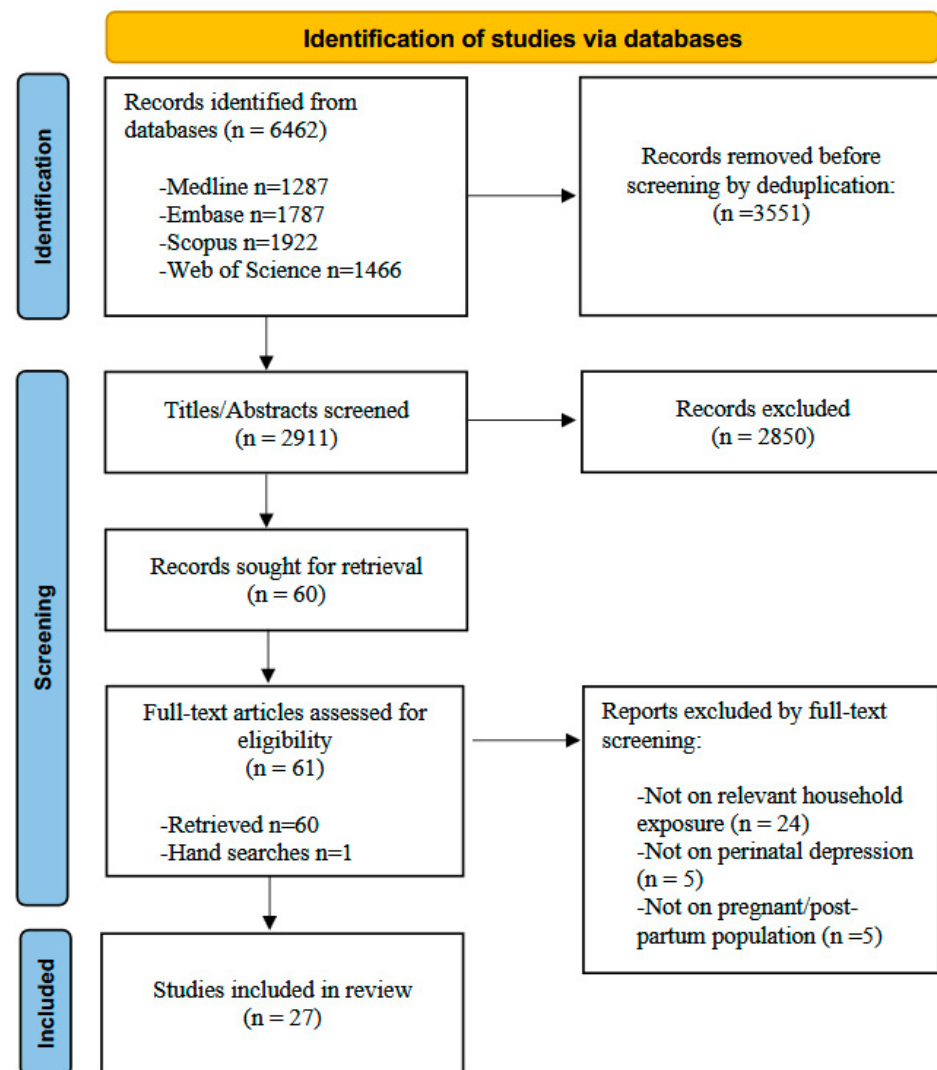


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study flow diagram.

3.2. Characteristics of Included Studies

The 27 included studies were conducted across six countries and published between 2003 and 2024 [31–57]. Most studies (n = 20) were published after 2015, with the United States contributing the largest number (n = 13), followed by China (n = 9). Sample sizes ranged from 139 to 80,814 pregnant/postpartum individuals. A majority of studies (n = 22) recruited pregnant individuals with singleton, uncomplicated pregnancies. Five studies focused on unique sub-populations: minority groups (n = 2) [42,46], pregnant individuals with substance use disorders (n = 1) [53], and women with twin pregnancies (n = 2) [36,55]. Participants' ages ranged from 15 to 45 years. Most included studies were cohort studies (n = 20), followed by cross-sectional (n = 7) and case-control (n = 1) designs. More than half (n = 17) were nested in larger longitudinal studies. The most frequently studied home environment domain was indoor air pollutants (n = 8), followed by household insecurity (n = 5) and exposure to persistent chemicals (n = 5). Perinatal depression was commonly assessed using screening tools such as the Edinburgh Postnatal Depression Scale (EPDS n = 14) and the Center for Epidemiologic Studies Depression (CES-D) scale (n = 6). Detailed study characteristics are presented in Table 1.

Table 1. Characteristics of included studies.

Study, Year	Country	Study Design	Study Population	Sample Size (N)	Housing Factors Examined (Method of Assessment)	Perinatal Depression (Screening Tool Used, Timepoint(s))
Agostini, 2015 [33]	Italy	Prospective Cohort	- Pregnant individuals with singleton pregnancy and fluent in Italian - 18 to 45 year	404	- Moved house - Housing difficulties (self-reported)	Edinburgh Postnatal Depression Scale (EPDS); third trimester
Aung, 2023 [34]	USA	Retrospective Cohort	- Pregnant individuals in the second trimester with singleton pregnancy and fluent in English or Spanish - Mean age: 30.7 years	517	Per- and poly-fluoroalkyl substances (PFAS) (serum samples collected in the second trimester)	Center for Epidemiological Studies Depression Scale (CES-D); second trimester
Butler, 2003 [51]	New Zealand	Cross-Sectional	- Individuals six weeks postpartum, where the child has at least one parent of Pacific Island ethnicity and is a permanent resident of New Zealand - Mean age: 27 years	1376	- Dampness in the home - Cold in the home (self-reported)	EPDS; six weeks after birth
Chilukuri, 2024 [53]	USA	Prospective Cohort	- Pregnant and postpartum individuals with substance use disorder - 18 to 43 years	494	Housing Insecurity (self-reported)	EPDS; timepoint not reported (NR)
Farrow, 2003 [47]	UK	Prospective Cohort	- Pregnant individuals residing in Avon, UK - Mean age: NR	13,971	- Air freshener - Aerosol (self-reported)	EPDS; 9 months postpartum
Foster, 2024 [52]	USA	Prospective Cohort	- Pregnant individuals presenting in their second trimester with proficiency in English with deliveries after 35 weeks' gestation - Mean age: 32.1 years - 19–44 years	718	Organophosphates (house dust collected at 3–4 months postpartum)	CES-D; 18- and 36-weeks' gestation, 6 and 12 months postpartum
Hu, 2024 [55]	China	Prospective Cohort	- Married individuals presenting in the first trimester with twin pregnancies - Mean age: 30.4 years	150	Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) (maternal whole blood samples collected at each of three clinic visits)	Chinese CES-D; early pregnancy and followed-up either 1 or 6 months postpartum
Hu, 2024 [56]	China	Prospective Cohort	- Pregnant women presenting in the first trimester - Mean age: 31 years	2166	Noise exposure (self-reported)	EPDS; one of three trimesters
Hu, 2022 [35]	China	Prospective Cohort	- Pregnant individuals presenting in the first trimester - Mean age: NR	2166	Perceived indoor air quality (PIAQ) (self-reported)	EPDS; each trimester
Hu, 2023 [36]	China	Prospective Cohort	- Wuhan city residents presenting at <16 weeks' gestation with twin pregnancies - Mean age: 30.7 ± 3.9	432	- Bisphenols - Parabens - Phthalates (urine samples in the first, second, and third trimesters)	Chinese version of EPDS; early pregnancy, 1 and 6 months postpartum

Table 1. Cont.

Study, Year	Country	Study Design	Study Population	Sample Size (N)	Housing Factors Examined (Method of Assessment)	Perinatal Depression (Screening Tool Used, Timepoint(s))
Huang, 2017 [32]	China	Cross-Sectional	- Pregnant women at ≥ 28 weeks of gestation - Mean age: NR	2176	- Second-hand smoke in homes (self-reported)	CES-D; during pregnancy
Jacobson, 2021 [37]	USA	Prospective Cohort	- Individuals at < 18 weeks' gestation - Mean age: 30.8 ± 5.8 - 26 to 34 years	139	- Bisphenols - Phthalates (urine samples in early and mid-pregnancy)	Patient Health Questionnaire (PHQ-9) and EPDS; each trimester of pregnancy and 4 months postpartum
Jacobson, 2023 [57]	USA	Prospective Cohort	- Individuals from cohorts with data on urinary chemical concentrations from at least 1-timepoint in pregnancy - 16 to greater than 35 years	2174	- Phenols (bisphenols and triclosan) - Phthalates - Parabens - Triclocarban (prenatal urine samples)	EPDS and CES-D; 2 weeks and 12 months postpartum
Jigeer, 2022 [38]	China	Cross-sectional	- Pregnant individuals residing in Shanghai	2018	Noise (land use regression model based on participant's residence)	Chinese version of CES-D; late pregnancy
Kawasaki, 2017 [39]	Japan	Retrospective Cohort	- Pregnant individuals living in one of seven prefectures on Kyushu Island in southern Japan or in Okinawa prefecture - Mean age: 31.2	1745	- Smoking status - pack years of smoking - secondhand smoke exposure at home (self-reported)	Japanese version of CES-D; between the 5th and 39th weeks of pregnancy
Khan, 2015 [40]	USA	Retrospective Cohort	- Individuals who gave birth in the last 2–6 months - Age: NR	6884	Second-hand smoke (self-reported)	Two questions from the Pregnancy Risk Assessment Monitoring System; between 2nd and 6th months postpartum
Matsumura, 2022 [31]	Japan	Prospective Cohort	- Pregnant individuals - Mean age: 30.9 ± 4.93	80,814	Pets (self-reported)	EPDS and Kessler Psychological Distress Scale; first trimester, second/third trimester, 1 month, 6 months and 1 year postpartum
McGovern, 2023 [54]	USA	Prospective Cohort	- Individuals that had delivered between 1998 and 2000 - 15 to over 35 years	4898	Neighborhood rent burden (administrative data)	Composite International Diagnostic Interview Short Form (CIDI-SF); after giving birth, one-year post-partum
Messer, 2012 [41]	USA	Prospective Cohort	- Individuals with singleton pregnancies, English fluency and between 18- and 28-weeks gestation - 18 to > 35 years	723	Housing damage (self-reported)	CES-D; timepoint NR

Table 1. Cont.

Study, Year	Country	Study Design	Study Population	Sample Size (N)	Housing Factors Examined (Method of Assessment)	Perinatal Depression (Screening Tool Used, Timepoint(s))
Mutic, 2021 [42]	USA	Retrospective Cohort	- African American individuals with singleton pregnancies with English proficiency residing in the urban Georgia area - 18 to 35 years - Mean age: 24.2	193	Polybrominated diphenyl ethers (PBDEs) - PBDE 47 - PBDE 99 - PBDE 100 (maternal serum)	EPDS; 8–14 weeks gestation
Peltier, 2022 [43]	USA	Case–control	- Pregnant individuals with singleton pregnancies with English or Spanish proficiency - Mean age: 31.2 years	367	PBDE 47 (plasma samples)	International Classification of Diseases (ICD-10 codes), year after delivery
Sandel, 2018 [44]	USA	Retrospective Cohort	- Individuals living with their children of less than 48 months with proficiency in English, Spanish, or Somali - Mean age: between 26 and 28 years	22,324	- Multiple moves (≥ 2 in the past 12 months) - Homelessness (self-reported)	3-item screening test developed for maternal depression, NR
Suglia, 2011 [45]	USA	Retrospective Cohort	- Postpartum individuals with English or Spanish proficiency - Mean age: 24.8 years	2104	- Housing deterioration - Housing instability (self-reported)	CIDI-SF; 12- and 36-month post-partum
Tan, 2011 [46]	USA	Cross-Sectional	- Black, African American, or Hispanic individuals with singleton pregnancies with English proficiency seeking care at one of three prenatal sites in Washington, DC	929	Household environmental tobacco smoke exposure (self-reported)	Back Depression Inventory (BDI) Fast Screen; second or third trimester
Wang, 2018 [48]	China	Cross-sectional	- Women who delivered in February, May, August, or November 2014 - Mean age: 28 years	973	Third-hand smoke exposure (self-reported)	EPDS; post-partum
Wang, 2023 [49]	China	Retrospective Cohort	- Married individuals intending to deliver at the recruitment hospital - Mean age: 28.5 years	2741	PFAS (blood samples)	EPDS; 6 weeks postpartum
Wei, 2023 [50]	China	Retrospective Cohort	- Chinese residents of Guangzhou who can understand Mandarin or Cantonese at <20 weeks of gestation - Mean age of 30.2 years	21,306	Incense burning (self-reported)	Self-Rating Depression Scale (SDS); early and late pregnancy

CES-D = Center for Epidemiological Studies Depression Scale; EPDS = Edinburgh Postnatal Depression Scale; NR = not reported, PFAS = Perfluoroalkyl and Polyfluoroalkyl Substances.

3.3. RoB Assessment

All included studies adjusted for potential confounders such as maternal demographics (age, race/ethnicity, education, employment, marital status), obstetric complications, measurement time, household income, and prenatal care. However, only five studies adjusted for prior history of mental disorders in their analyses [31,39,52–54]. Overall, 14 studies were assessed as having low RoB, while 13 were rated as having unclear RoB. Table 2 shows the summary of RoB assessment for individual studies.

Table 2. Risk of Bias (RoB) assessment for included studies.

Design: Cohort *							
Author, Year	Selection			Comparability	Outcome Assessment		
	Representativeness of Study Sample	Ascertainment of Exposure	Outcomes Not Present at Outset	Study Controls for Confounders	Assessment of Outcome	Follow-Up Adequacy	RoB Rating **
Agostini, 2015 [33]		?		?	?		Unclear
Aung, 2023 [34]		?		?	?		Unclear
Chilukuri, 2024 [53]		?		⊕	⊕		Unclear
Farrow, 2003 [47]		?		?	⊕		Unclear
Foster, 2024 [52]		?		⊕	⊕		Unclear
Hu, 2022 [35]		⊕		?	⊕		Low
Hu, 2023 [36]		⊕		?	⊕		Low
Hu, 2024 [55]		⊕		?	⊕		Low
Hu, 2024 [56]		⊕		?	⊕		Low
Jacobson, 2021 [37]		⊕		?	⊕		Low
Jacobson, 2023 [57]		⊕		?	⊕		Low
Kawasaki, 2017 [39]		?		⊕	?		Unclear
Khan, 2015 [40]		?		?	⊕		Unclear
Matsumura, 2022 [31]		?		⊕	⊕		Unclear
McGovern, 2023 [54]		⊕		⊕	⊕		Low
Messer, 2012 [41]		⊕		?	?		Unclear
Mutic, 2021 [42]		?		?	?		Unclear
Peltier, 2022 [43]		⊕		?	?		Unclear
Sandel, 2018 [44]		?		?	?		Unclear
Suglia, 2011 [45]		⊕		?	⊕		Low
Wang, 2023 [49]		⊕		?	⊕		Low
Wei, 2023 [50]		⊕		?	⊕		Low
Design: Cross-sectional +							
Author, Year	External Validity			Internal Validity			RoB Rating ++
Butler, 2003 [51]	⊕⊕⊕⊕			⊕⊕⊕⊕⊕⊗			Low
Huang, 2017 [32]	⊕⊕⊕⊕			⊕⊕⊕⊕⊕⊕			Low

Table 2. Cont.

Design: Cross-sectional +			
Author, Year	External Validity	Internal Validity	RoB Rating ++
Jigeer, 2022 [38]	⊕⊕⊗⊕	⊕⊕⊕⊕⊗	Low
Tan, 2011 [46]	⊕⊕⊕⊕	⊕⊗⊕⊕⊕⊕	Low
Wang, 2018 [48]	⊕⊕⊕⊗	⊕⊕⊕⊕⊕⊕	Low

* For cohort studies: ⊕ = score of 3–4 in study selection/2 in comparability/2–3 in outcome assessment; ? = score of 2–1 in study selection/1 in comparability/1 in outcome assessment; ⊗ = score of 0 in study selection/comparability outcome assessment. ** Low RoB: score of 3–4 for study selection, 1–2 for comparability, and 2–3 for outcome assessment; unclear RoB: score of 2–3 for study selection, 1–2 for comparability, and 1–2 for outcome assessment; high RoB: score of 0 in any domain. + For cross-sectional studies: each ⊗ represents a high-risk score; each ⊕ represents a low-risk score, ++ Low RoB: high risk in 0–3 categories, unclear Rob: high-risk classification in 4–6 categories, high RoB = high risk classification in 7–10 categories.

3.4. Summary of Findings

Home environment attributes with potentially similar mechanistic pathways were grouped in weighted Z-meta-analyses to obtain pooled estimates. For example, persistent chemicals like per- and poly-fluoroalkyl substances (PFAS) and polybrominated diphenyl ether (PBDE) were analyzed together, as they potentially impact mental health via similar endocrine disruption mechanisms [34,42,55]. A summary of the main review findings is presented in Table 3.

Table 3. Summary of main findings for the association between home environment domains and perinatal depression.

Home Environment Domains	Sample Size (Number of Studies)	Direction of Effect *	Overall Risk of Bias (RoB)	Weighted Z-Score (p-Value) **	Strength of Evidence +
General Housing Characteristics					
• Housing instability	30,224 (5)	↑ (3/5 studies)	Unclear with concerns in study selection and confounding	2.8 ($p = 0.003$)	Strong
• Poor housing quality	4203 (3)	≅ (2/3 studies)	Low	1.2 ($p = 0.218$)	Null evidence
Chemical Contaminants					
• Indoor air pollutants	50,162 (8/8)	↑ (8/8 studies)	Low	5.5 ($p < 0.001$)	Very Strong
○ Household smoking	12,719 (5)	↑ (5/5 studies)	Low	4.3 ($p < 0.001$)	Very Strong
• Persistent chemicals	4536 (5)	↑ (3/5 studies)	Unclear with concerns in study selection, exposure assessment and confounding bias	2.2 ($p = 0.025$)	Weak
○ Poly and perfluoroalkyl substances (PFAS)	3258 (2)	≅ (1/2 studies)	Unclear with concerns in representativeness and confounding	1.2 ($p = 0.231$)	Null evidence
○ Polybrominated Diphenyl Ethers (PBDE)	560 (2)	↑ (2/2 studies)	Unclear with concerns in participant selection and confounding bias	2.8 ($p = 0.005$)	Weak (downgraded because of small number of studies)

Table 3. Cont.

Home Environment Domains	Sample Size (Number of Studies)	Direction of Effect *	Overall Risk of Bias (RoB)	Weighted Z-Score (p-Value) **	Strength of Evidence +
Chemical Contaminants					
• Non-persistent chemicals	2745 (3)	≅ (2/3 studies)	Low	1.1 ($p = 0.277$)	Null evidence
Biological Exposure					
• Presence of pets (cat) at home	80,814 (1)	↑ (1/1 studies)	Unclear with concerns in comparability and outcome assessment	-	-
• Presence of pets (dog) at home	80,814 (1)	↓ (1/1 studies)	Unclear with concerns in comparability and outcome assessment	-	-
Noise	4184 (2)	↑ (2/2 studies)	Low	2.7 ($p = 0.005$)	Weak (downgraded because of small number of studies)

* ↑ = majority of studies show a positive association, ↓ = majority of studies show a negative association, ≅: null evidence. ** Z-scores are weighted for sample size and risk of bias of included studies. + $p < 0.001$ signifies very strong evidence, $p < 0.01$ strong evidence, $p < 0.05$ indicates weak evidence, $p > 0.05$ no statistical significance.

3.5. Housing Instability

Five longitudinal studies [33,44,45,53,54] explored the relationship between housing instability and perinatal depression. A variety of definitions were used to measure housing instability, which included housing difficulties, difficulty paying rent, frequent moves, and homelessness. After accounting for sample size and RoB, strong evidence was found for a positive association between housing insecurity and perinatal depression ($n = 5$, p -value: 0.004).

3.6. Housing Quality

Three studies [41,45,51] assessed housing quality, focusing on attributes such as housing damage, disarray, deterioration, indoor heating and dampness (cohort $n = 2$, cross-sectional = 1). We did not find a significant association between housing quality attributes and perinatal depression ($n = 3$, p -value: 0.218).

3.7. Indoor Air Quality

Eight studies assessed the impact of household air pollutants on perinatal depression [32,35,39,40,46–48,50]. Household smoking was the most frequently assessed air pollutant ($n = 5$), followed by air fresheners or aerosol use ($n = 1$), incense burning ($n = 1$) and general indoor air quality ($n = 1$). Meta-analysis shows very strong evidence for the positive association between overall indoor air pollutant exposure ($n = 8$, $p < 0.001$), household smoking ($n = 5$, p -value < 0.001) and perinatal depression.

3.8. Household Chemicals

Five studies [34,42,43,49,52] assessed the relationship between persistent chemical exposure (PFAS $n = 2$, PBDE $n = 2$, and organophosphates $n = 2$) during pregnancy and perinatal depression. Weak evidence was observed for the association between persistent chemicals ($n = 5$, p -value: 0.03), specifically PBDE ($n = 2$, p -value: 0.005) and perinatal depression. There was null evidence for an association between PFAS exposure ($n = 2$, p -value: 0.231) and perinatal depression. Three studies [36,37,57] assessed non-persistent

chemicals (i.e., bisphenols, phthalates, parabens) and found no significant association ($n = 3$, $p = 0.277$).

3.9. Biological Exposures

One longitudinal study explored the association between the presence of cats and dogs at home and perinatal depression [31]. The study found that cat ownership was linked with increased odds of perinatal depression, while an inverse association was observed for dog ownership and odds of perinatal depression.

3.10. Noise

Two studies examined the association between residential noise exposure and perinatal depression [38,56]. Definitions of higher noise exposure included daily exposure to unwanted sounds for 15 min and noise levels ≥ 65 decibels. Weak evidence supported an association between higher noise exposure and perinatal depression ($n = 2$, p -value: 0.005).

4. Discussion

This systematic review of 27 observational studies published between 2003 and 2024 critically evaluated the current evidence on the relationship between physical home environment attributes and perinatal depression. Using a weighted Z-score meta-analytic approach, we accounted for the sample size and RoB of individual studies, providing a robust assessment of the strength of evidence. The review found evidence of positive associations between antenatal exposure to indoor air pollutants (particularly household cigarette smoke), housing instability, persistent organic chemicals, residential noise, and depression during pregnancy and/or postpartum. The biological pathways between housing precarity, adverse housing conditions and poor mental health are not well understood. Potential mechanisms include immune dysfunction, elevated levels of pro-inflammatory cytokines, hypothalamic–pituitary–adrenal (HPA) axis dysregulation, and gut microbiome dysbiosis [12,34,58–62]. Recognizing risk factors and mechanistic pathways to perinatal depression is essential to guide effective intervention.

Housing instability emerged as an important factor linked to perinatal depression. However, assessing housing instability is challenging due to the absence of standardized measures or a universally accepted definition [63–65]. The included studies used varied terms such as housing difficulties, housing instability, housing insecurity, precarious housing, and homelessness. The recent literature has conceptualized housing instability as a spectrum of housing difficulties, forced moves, and evictions, with homelessness being the severest form [63,64]. All the included studies treated housing instability as a binary variable, which fails to capture the dynamic and multidimensional nature of housing instability, complicating measurement. Housing instability is often intertwined with other stressors, such as financial challenges, food insecurity, and limited social support, which collectively exacerbate mental health challenges [53,66–69]. Despite these measurement challenges, our findings are consistent with prior research that links housing instability to adverse perinatal outcomes such as complicated delivery, preterm birth, and other adverse birth outcomes [63,64,70]. Findings from our meta-analysis add to this body of evidence and reveal a positive association between housing instability and perinatal depression.

Housing quality refers to both structural and functional attributes of a dwelling that directly impact on health. Previous research has linked housing deterioration, inadequate heating, and household size with depression, stress, anxiety and affective disorders [1,4,69,71]. The association between adverse housing conditions such as disrepair, overcrowding, inadequate heating, dampness and poor mental health is well established in the literature [1,4,71,72]. However, our review found no significant association between

housing quality and perinatal depression. These findings are based on a small sample size and merit further investigation. Additionally, we noted a lack of studies examining the influence of household type, ownership, house size, and renovations on perinatal depression which highlights a gap in comprehensive assessments of housing characteristics and the built environment attributes in the context of perinatal mental well-being.

Antenatal exposure to indoor air pollutants was significantly associated with perinatal depressive symptoms, with household tobacco smoke exposure emerging as a key risk factor. This finding aligns with existing evidence linking passive tobacco smoke exposure during pregnancy to obstetric complications such as placental dysfunction, fetal growth restriction, and preterm birth [73–75]. Interventions to reduce environmental smoke exposure among pregnant individuals often emphasize avoidance, which may not be feasible in crowded and limited spaces [76]. Multi-sectoral approaches focused on engaging partners, providing family-centric smoking cessation support, and implementing tobacco-free households policies for pregnant individuals, are critical to promoting healthier environments and potentially reducing perinatal depression. Further research on other sources of indoor air pollution, such as aerosols, disinfectants, candles/incense, and fuel used for cooking and heating, is warranted to better understand the impact of indoor air quality on maternal mental health.

We found weak evidence for the association between persistent organic chemicals such as PBDE, residential noise and perinatal depression. Evidence for the relationship between biological contaminants in homes and perinatal depression was scarce. It is critical to identify all potentially modifiable household factors that contribute to poor maternal mental health. Rigorous epidemiological research is needed to elucidate the relationship between understudied indoor home environment attributes and perinatal mental health.

This systematic review has several strengths. We conducted comprehensive literature searches across major bibliographic databases to retrieve available evidence on the association between home environment factors and perinatal depression. We followed Cochrane guidelines and conducted a dual independent assessment, extraction and RoB assessment of retrieved articles. We assigned conservative z-scores to reported associations and accounted for sample size and RoB of studies in meta-analysis. This approach enhanced the validity of our conclusions and allowed for the synthesis of heterogeneous exposure measures.

Our review, however, has some limitations that merit attention. As the included studies were observational, causal relationships cannot be established. Variability in definitions and measurements of indoor home environment attributes, combined with reliance on self-reported data to assess housing stability, quality, environmental tobacco smoke exposure, and noise, may have introduced bias and limited generalizability. Development of standardized measures of home environment attributes is needed to better understand their impact on perinatal health outcomes. The majority of the included studies used a variety of screening tools to assess perinatal depression. Screening tools have a potential for underreporting and misclassification as they may fail to capture atypical cases and cultural sensitivities and are prone to self-reported bias [77]. Changes were made to the study protocol after publication to add further details to the synthesis methods. However, these changes were made before analysis and did not influence data analysis and interpretation. We used weighted z-score meta-analysis, which allowed the pooling of heterogeneous data. However, this approach tests for overall significance and lacks effect size estimation, which may limit the public health relevance of observed associations. This approach is sensitive to reported *p*-values and lacks quantification and addressing heterogeneity among included studies. All the included studies were conducted in high and middle-income countries,

which limits the application of our inferences to low-income regions due to variations in home environment structures, policies, and cultural and socioeconomic circumstances.

5. Conclusions

The systematic review and meta-analysis of observational studies identified associations between housing instability and hazardous household exposures (i.e., indoor air pollutants, household tobacco, persistent chemicals, and residential noise), and perinatal depression. Further research is warranted to develop comprehensive measures of the home environment and identify common household attributes contributing to poor perinatal mental health, which can inform the development and implementation of targeted preventive strategies. A multisectoral approach integrating housing planning and policy, healthy home environment initiatives and awareness programs regarding potentially avoidable ubiquitous household exposures may help reduce the incidence of perinatal depression.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/environments12040112/s1>, Table S1: Search Strategy.

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