The Impact of Climate-Induced Eco-Anxiety on Pregnant Women and Its Correlation with Birth Outcomes and Early Childhood Behavioral Development: A Community-Based Study

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Abstract

Background: Climate-induced eco-anxiety a chronic fear of environmental degradation—presents an emerging threat to maternal mental health, particularly in climate-vulnerable regions like Upper Egypt. While prenatal stress is known to affect fetal development, empirical applied research testing structured clinical interventions to mitigate this environmental distress and evaluate its subsequent transgenerational effects remains critically scarce. **Aim:** This study evaluated the impact of climate-induced eco-anxiety on pregnant women and its correlation with birth outcomes and early childhood behavioral development. **Subjects and Method:** Utilizing a quasi-experimental, pre-post test design with a convenient sampling technique, a total of 350 pregnant women in their first trimester were recruited from the Antenatal Outpatient Clinics at Sohag University Hospitals, Egypt. **Results:** Post-intervention data demonstrated a significant reduction in mean maternal eco-anxiety scores and a corresponding decrease in salivary cortisol levels compared to baseline ($p < 0.05$). Women who successfully completed the resilience intervention exhibited a significantly lower relative risk for preterm birth and low birth weight. Furthermore, longitudinal data at 24 months postpartum revealed that children born to mothers in the intervention group demonstrated significantly lower clinical T-scores for emotional dysregulation, sleep disturbances, and separation anxiety on the CBCL compared

to those exposed to unmitigated prenatal distress. **Conclusion:** This applied study provides concrete empirical evidence that structured Climate Resilience Intervention and Psychological Coping Program within university antenatal clinics are highly effective in mitigating the transgenerational impacts of climate change. The distinctive pre-post findings demonstrate that reducing prenatal eco-anxiety physically translates into optimized birth outcomes and healthier early childhood behavioral development, underscoring the urgent practical need to integrate climate-specific psychological screenings and resilience programs into routine maternal healthcare in Upper Egypt. Recommendation: Designing community-based psychological resilience programs that protect vulnerable populations from localized environmental hazards like extreme heatwaves.

Keywords: Birth Outcomes; Climate-Induced Eco-Anxiety; Early Childhood Behavioral Development; Pregnant Women.

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Introduction

Climate change is recognized as one of the most critical threats to global public health in the twenty-first century, characterized by escalating temperatures, prolonged droughts, and erratic weather patterns. These environmental disruptions extend beyond physical hazards, causing profound psychological distress across global populations. Pregnant women represent a uniquely vulnerable cohort within this crisis, as pregnancy involves complex physiological, hormonal, and psychological changes that heighten their susceptibility to external stressors. In climate-vulnerable and agriculturally dependent regions, such as the Sohag Governorate in Upper Egypt, pregnant women face severe environmental stressors like acute heatwaves and resource scarcity, which significantly amplify their baseline vulnerability to mental health imbalances **(Kaya et al., 2025).**

A direct psychological consequence of this ongoing environmental degradation is the emergence of "eco-anxiety," defined as a chronic, pervasive fear of environmental doom and ecological collapse. Unlike generalized anxiety disorders, eco-anxiety is a rational yet deeply distressing response to the real-world climate crisis, manifesting as feelings of helplessness, guilt, and existential dread regarding the future of the planet. For pregnant women, this distress is often compounded by profound worries about the long-term safety, health, and environmental stability of the world into which their future children will be born. Despite its growing prevalence, empirical research examining how this specific form of climate-related distress manifests clinically during the prenatal period remains critically scarce **(Hogg et al., 2021).**

Climate-induced anxiety affects people of all ages but particularly those vulnerable to climate impacts firsthand; therefore, stemming from climate change must lead to psychological resilience and adaptation to changes. This doesn't mean ignoring or denying the reality of climate change, or pretending that no harm has occurred. Rather, through building mental capacities, ways of thinking that help people remain happy and continue to function effectively even as they face the ongoing challenges of a changing world **(Dodds, 2021)**. The impact of prenatal eco-anxiety is not merely psychological; it operates through well-documented biological pathways that can severely alter birth outcomes. Chronic maternal distress triggers the overactivation of the Hypothalamic-Pituitary-Adrenal (HPA) axis, leading to a sustained elevation of physiological stress biomarkers, primarily maternal salivary cortisol. Excess maternal cortisol can cross the placental barrier, disrupting the delicate intrauterine environment and restricting fetal growth **(Glover, 2024).** Consequently, high levels of unmitigated prenatal eco-anxiety are hypothesized to correlate with compromised clinical birth outcomes, including a heightened relative risk for low birth weight (LBW) and preterm delivery, which serves as the foundational "before" measurement of this

longitudinal inquiry **(Dunkel Schetter & Tanner, 2022).**

The consequences of prenatal environmental distress extend well beyond delivery, establishing a transgenerational pathway that shapes early childhood behavioral and emotional development representing the "after" phase of this study. Fetal exposure to elevated prenatal maternal cortisol alters the development of the infant's own HPA axis and limbic system, which are critical for future emotional regulation. Longitudinal epidemiological evidence suggests that children born to mothers who experienced severe prenatal psychological distress exhibit significantly higher clinical rates of internalizing and externalizing problems, including emotional dysregulation, sleep disturbances, and separation anxiety, during their first 24 months of life **(Yopo Díaz et al., 2025).**

Obstetric, gynecological, and pediatric nurses form the cornerstone of clinical data acquisition and maternal-fetal monitoring. The **obstetric and gynecological nurse** operates at the frontline of the Antenatal Outpatient Clinics, managing the initial screening, recruitment of the pregnant women via convenient sampling, and the rigorous pre- and post-intervention administration of the Hogg Eco-Anxiety Scale. This nurse is also responsible for the synchronized collection of prenatal salivary cortisol swabs and extracting objective neonatal data such as birth weight and gestational age—immediately upon delivery in the labor ward. Following birth, the **pediatric nurse** takes over during the postnatal phase, executing the longitudinal developmental screenings at 12 and 24 months. By meticulously evaluating infants using the Ages & Stages Questionnaires (ASQ-3), the pediatric nurse identifies early signs of developmental delays and coordinates essential pediatric referrals, thereby safeguarding the child's early physical and neurological milestones (**González-Hernández et al., 2023).**

Parallel to clinical care, community health and psychiatric nurses drive the behavioral interventions and longitudinal tracking necessary to minimize sample attrition over the 2-year study period. The **psychiatric nurse** acts as the certified group facilitator for the Climate Resilience and Psychological Coping Program (CR-PCP). Utilizing evidence-based cognitive-behavioral strategies, this nurse leads the sessions on cognitive restructuring to challenge environmental doom and trains the mothers in somatic relaxation and diaphragmatic breathing techniques safe for pregnancy. Meanwhile, the **community health nurse** bridges the gap between the university hospital and the participants' home environments in Sohag. This nurse manages the community-level tracking via targeted telephone and WhatsApp follow-ups, provides localized psychoeducation on mitigating Upper Egypt's severe heatwaves, and guides parents through the Child Behavior Checklist (CBCL) at 24 months to detect emotional dysregulation, ensuring high participant retention across the "before and after" continuum **(Kunzler et al., 2020).**

Significance of the Study

This applied quasi-experimental study holds profound clinical, societal, and nursing significance as it pioneers empirical research into the transgenerational impacts of climate-induced eco-anxiety within Upper Egypt. By combining psychological metrics with biological screening via maternal salivary cortisol tracking, this study bridges a critical knowledge gap regarding how environmental distress physically manifests in compromising intrauterine environments, directly leading to adverse birth outcomes like low birth weight and preterm delivery. Furthermore, by demonstrating the clinical efficacy of a structured climate resilience program, this research establishes a scalable, low-cost interventional framework that redefines and empowers the multidisciplinary roles of obstetric, pediatric, psychiatric, and community health nurses as frontline therapeutic agents in planetary healthcare. Ultimately, conducted within the climate-vulnerable setting of Sohag University Hospitals, the findings provide vital empirical data that can inform healthcare policymakers on the urgent practical necessity of integrating climate-specific psychological screenings into routine antenatal care protocols across Egypt.

Pregnant women and their newborns have been suffering from adverse effects associated with rising 1°C in minimum daily temperature over 23.9°C has been shown to increase the risk of infant mortality by as much as 22.4%. Adverse birth outcomes, including low birth weight (LBW), small gestational age (SGA), and preterm birth, contribute to 60%–80% of infant mortality worldwide **(WHO, 2021).**

Aim of the study:
This study evaluated the impact of climate-induced eco-anxiety on pregnant women and its correlation with birth outcomes and early childhood behavioral development.

Research Hypotheses

- **Hypothesis 1:** Pregnant women who participate the structured Climate Resilience Intervention and Psychological Coping Program (CR-PCP)will exhibit a statistically significant reduction in mean climate-induced eco-anxiety scores (measured via the Hogg Eco-Anxiety Scale) post-intervention compared to their baseline (pre-intervention) scores .
- **Hypothesis 2 :** Pregnant women who undergo the climate resilience intervention will demonstrate a statistically significant decrease in physiological stress biomarkers, specifically maternal salivary cortisol levels, compared to their pre-intervention levels.
- **Hypothesis 3 :** There will be a statistically significant positive correlation between mitigated prenatal eco-anxiety/cortisol levels and optimized clinical birth outcomes, manifested by higher infant birth weights and advanced gestational age at delivery .
- **Hypothesis 4 :** Children born to mothers who successfully completed the climate resilience intervention will exhibit significantly lower clinical behavioral risk scores (lower T-scores for emotional dysregulation, sleep disturbances, and separation anxiety on the Child Behavior Checklist and higher developmental scores on the ASQ-3) at 12 and 24 months postpartum compared to offspring of mothers with unmitigated prenatal distress.

Subjects and Method

Research Design

An applied quasi-experimental, pre-post test interventional design integrated within a prospective longitudinal cohort framework was utilized to achieve the objectives of this study. This configuration enabled the tracking and evaluation of variables across two core developmental phases: the prenatal stage ("Before" the intervention) and the 24-month postnatal follow-up stage ("After" delivery).

Study Setting:

The study was conducted at the Antenatal Outpatient Clinics of Sohag University Hospitals, Egypt. Sohag Governorate, located in Upper Egypt, represents a highly relevant setting for this research due to its acute vulnerability to climate change, characterized by extreme seasonal heatwaves, agricultural challenges, and climate-related socioeconomic pressures. These tertiary university clinics serve a high volume of pregnant women from both rural and urban sectors across the governorate, providing an ideal and diverse cohort for longitudinal monitoring.

Subjects:

- **Sample Size:** A total sample of all **350 pregnant women** was targeted and recruited for this study within six months from March 2024 to August 2024.
- **Sampling Technique:** A **convenient sampling technique** was employed to select participants from the designated antenatal clinics during their routine first-trimester visits.

Data Collection Tools

To comprehensively evaluate the variables across the prenatal ("Before") and 24-month postnatal ("After") phases, six distinct, validated instruments were utilized.

Tool I: Sociodemographic and Obstetric Questionnaire

- Completed by the mother during the first trimester, facilitated by an **obstetric nurse included m**aternal age, place of residence, education level, occupation, family monthly income, parity (number of past pregnancies), gestational age (confirmed by first-trimester ultrasound), and history of baseline psychiatric disorders.

Tool II: The Hogg Eco-Anxiety Scale (HEAS)

- To quantify the severity of climate-induced eco-anxiety before and after the resilience intervention **(Hogg et al., 2021).**
- **Description:** A 13-item multidimensional questionnaire designed to capture emotional and behavioral distress caused by environmental degradation.
- **Items & Scoring:** Each item is rated on a 4-point Likert scale ranging from 0 (Not at all) to 3 (Nearly every day). Total scores range from **0 to 39**.

- **Clinical Subscales:**
    1. *Affective Symptoms* (e.g., anxiety, panic, or dread about environmental doom).
    2. *Behavioral Symptoms* (e.g., functional impairment, social withdrawal).
    3. *Cognitive Symptoms* (e.g., obsessive thoughts about climate change).
    4. *Personal Anxiety* (e.g., personal worry regarding resource scarcity or localized heat stress).
- **Levels of Severity:**
    - **0 – 13:** Mild / Normal Eco-Anxiety.
    - **14 – 26:** Moderate Eco-Anxiety.
    - **27 – 39:** Severe Eco-Anxiety.

Tool III: Physiological Stress Tracking (Maternal Salivary Cortisol)

- To objectively screen and evaluate physiological stress levels before and after the intervention **(Kirschbaum & Hellhammer, D. H. (1989)**. **Obstetric and psychiatric nurses** were collected saliva samples using specialized dental cotton swabs (Salivettes). Samples are gathered strictly between 8:00 AM and 10:00 AM to control for the natural diurnal cortisol rhythm. Participants are instructed not to eat, drink, smoke, or brush their teeth 30 minutes prior to collection.
- **Laboratory Analysis:** Samples are frozen and stored at -20°C, then analyzed via Enzyme-Linked Immunosorbent Assay (ELISA). Higher values indicate greater physiological distress. Decreases in post-intervention values indicate physiological resilience.

Tool IV: Clinical Birth Outcomes Record

- To log immediate neonatal health and delivery characteristics. A structured checklist used by the **obstetric nurse** to extract objective data directly from the Sohag University Hospital labor ward electronic medical logs.
- **Parameters & Classifications:**
    1. *Gestational Age:* Measured in continuous weeks. Categorized into **Preterm Birth** (< 37 weeks) or **Term Birth** (≥ 37 weeks).
    2. *Birth Weight:* Measured in continuous grams. Categorized into **Low Birth Weight** (< 2,500 grams) or **Normal Birth Weight** (≥ 2,500 grams).
    3. *Apgar Scores:* Assessed and recorded at 1 minute and 5 minutes postpartum to determine immediate extrauterine adaptation.

Tool V: Ages and Stages Questionnaires, Third Edition (ASQ-3)

- To monitor developmental milestones and detect delays during early childhood follow-ups (**Squires & Bricker, 2009).** Administered longitudinally by a **pediatric nurse** at 12 months and 24 months postpartum. Contains 30 items spanning 5 distinct developmental domains: Communication, Gross Motor, Fine Motor, Problem Solving, and Personal-Social.
- **Scoring Method:** Parents score each behavior as *Yes* (10 points), *Sometimes* (5 points), or *Not Yet* (0 points). Scores are summed for each domain, ranging from 0 to 60.
- **Levels & Cut-off Points:**
    - *Above the Cut-off:* Normal, on-track development.
    - *Close to the Cut-off:* Borderline; requires continuous monitoring and targeted learning activities.
    - *Below the Cut-off:* Developmental Delay; indicates a mandatory requirement for a pediatric clinical referral.

Tool VI: Child Behavior Checklist (CBCL / 1½ - 5)

- To systematically screen the child for behavioral and emotional challenges **(Achenbach & Rescorla, 2000).** Completed by the mother and scored by a **pediatric or community health nurse** at the final 24-month postnatal milestone.
- **Structure:** A 99-item standardized questionnaire rated on a 3-point scale: 0 (Not True), 1 (Somewhat/Sometimes True), or 2 (Very True/Often True).

- **Clinical Dimensions:**
  - *Internalizing Scales:* Emotional Reactivity, Anxiety/Depression, Somatic Complaints, and Withdrawal.
  - *Externalizing Scales:* Attention Problems and Aggressive Behavior.
  - *Other Scales:* Sleep Disturbances.
- **Scoring & Interpretation:** Raw scores are transformed via standard software into standardized **T-Scores** (Mean = 50, Standard Deviation = 10):
  - **T-Score < 60:** Normal behavioral presentation.
  - **T-Score 60 – 63:** Borderline Clinical Range (requires observation).
  - **T-Score > 63:** Clinical Range (indicates significant behavioral, emotional, or sleep-related challenges).

Validity of the Tools

The tools were submitted to a panel of **five expert juries.** This multidisciplinary panel were consisted of two professors specializing in Psychiatric Nursing and Psychiatric medicine, one professor specializing in Obstetric and Gynecological Nursing, one professor specializing in Pediatric Nursing and one professor specializing in Community Health Nursing. The experts were reviewed the tools for clarity, language appropriateness, relevance to the local culture of Upper Egypt, and alignment with the study objectives. Modifications were made.

Reliability of the Tools

To verify the internal consistency and stability of the measurement instruments over time, reliability testing were conducted. The standardized tools (HEAS, ASQ-3, and CBCL) were tested for internal consistency using **Cronbach's alpha (α) coefficient**, with a value of ≥ 0.70 considered statistically acceptable. Additionally, **test-retest reliability** was performed by administering the scales to a small sample of pregnant women twice, with a two-week interval, to compute the Interclass Correlation Coefficient (ICC). For the biological tracking component, the reliability of the morning maternal salivary cortisol screening were maintained through standardized laboratory calibrations, ensuring that the intra-assay and inter-assay coefficients of variation (CV) for the ELISA kits remain strictly below 10%.

Pilot Study

A pilot study was conducted on 10% of the calculated sample size (35 pregnant women) selected from the Antenatal Outpatient Clinics at Sohag University Hospitals. The primary objectives of the pilot study are to test the operational feasibility of the quasi-experimental design, estimate the precise time required to complete the interviews, and ensure the logistical smoothness of the morning salivary cortisol collection and storage pathway. Because modifications were made to the study tools, the 35 participants included in the pilot study were **completely excluded** from the final research sample (N = 350) to prevent any data contamination or testing-effect bias.

Ethical Considerations

Official ethical clearance was obtained from the Scientific Research Ethics Committee of the Faculty of Nursing at Sohag University. It was approved by the number of (145/ 7-2-2024.). Participants were received a detailed, transparent explanation of the study's purpose, its longitudinal timeline, and the non-invasive nature of the salivary cortisol tracking. A formal, written informed consent was secured from each pregnant woman before any assessment or intervention takes place. Mothers were explicitly informed that participation is entirely voluntary and that they reserve the absolute right to withdraw from the study at any stage (prenatal or postnatal) without any penalty or negative impact on the routine medical care provided to them or their infants at the university hospital. To ensure complete privacy, no personal identifiers (such as names or national IDs) used on the data sheets or biological sample tubes; instead, a secure, anonymized numerical coding system (barcodes) was implemented. All digital files were password-protected, and physical records were locked securely, accessible only to the primary research team for purely scientific publishing purposes.

Data Collection Procedure

The operational fieldwork and data collection procedure for this study were executed systematically across four progressive phases, extending from the initial prenatal screening to the 24-month postnatal follow-up.

Phase 1: Preparatory Phase (Administrative and Methodological Setup)

Official administrative approvals were obtained from the Dean of the Faculty of Nursing and the Institutional Review Board at Sohag University. Formal permissions were secured from the directors of the Obstetric and Gynecological Departments and the Antenatal Outpatient Clinics. A dedicated team of obstetric, psychiatric, pediatric, and community health nurses underwent a 3-day training workshop. The training focused on data collection ethics, standardized administration of psychological scales (HEAS, ASQ-3, CBCL), and strict protocols for salivary cortisol collection. A pilot study was conducted on 10% of the sample (35 pregnant women) to evaluate the clarity, feasibility, and time required to complete the tools. Since no major modifications were made to the instruments, the pilot participants were excluded from the final study sample (N = 350) to prevent contamination of findings.

Phase 2: Assessment and Pre-testing Phase ("Before" the Intervention)

Over a designated period, **obstetric and gynecological nurses** screened pregnant women attending the Antenatal Outpatient Clinics at Sohag University Hospitals using the convenient sampling method. Eligible and consenting women were interviewed individually by the nurse in a private room to complete **Tool I** (Sociodemographic) and **Tool II** (Baseline Hogg Eco-Anxiety Scale). The questionnaire took approximately 15 to 20 minutes per participant. Immediately following the psychological assessment, the nurse coordinated the collection of the baseline maternal salivary cortisol sample (**Tool III**). Samples were collected strictly between 8:00 AM and 10:00 AM. Salivettes were labeled, barcoded, and immediately transferred to the hospital laboratory for storage at -20°C.

Phase 3: Implementation and Post-testing Phase

Participants were organized into small operational cohorts (8 to 10 women per group). Psychiatric nurses delivered the manualized Climate Resilience and Psychological Coping Program (CR-PCP) over 4 consecutive weeks. Sessions were held weekly (60 to 90 minutes each) in the clinic's health education room. Within one week of completing the 4-week program, the psychiatric and obstetric nurses re-administered the Hogg Eco-Anxiety Scale (Tool II) and collected the post-intervention morning salivary cortisol swabs (Tool III) under identical baseline conditions to measure immediate psychological and physiological shifts.

Intervention Protocol: Climate Resilience and Psychological Coping Program (CR-PCP)

1. Program Overview

The **Climate Resilience and Psychological Coping Program (CR-PCP)** is a structured, manualized cognitive-behavioral and psychoeducational intervention designed to reduce climate-induced eco-anxiety and lower physiological stress (cortisol) among pregnant women. The program aims to transform passive environmental dread into active psychological resilience and adaptive coping mechanism.

- **Format:** Group sessions (8–10 participants per group) to foster peer support, combined with brief individual telephone/WhatsApp follow-ups.
- **Setting:** Dedicated health education rooms at the Antenatal Outpatient Clinics of Sohag University Hospitals.
- **Duration:** 4 consecutive weekly sessions, each lasting **60 to 90 minutes**, delivered during the first and second trimesters.
- **Facilitators:** Psychiatric nurses or clinical psychologists trained specifically on the intersection of climate change and maternal mental health.

2. Detailed Session-by-Session Breakdown

Session 1: Psychoeducation – Understanding Eco-Anxiety and Maternal Health

- **Objective:** Validate the participant's feelings, normalize climate anxiety, and explain the connection between mind, body, and pregnancy.
- **Content & Activities:**
  - Welcome, ice-breaking, and establishing group rules.
  - Interactive presentation on climate change impacts specific to Upper Egypt (e.g., extreme heat waves, agriculture, and water issues).
  - Defining "Eco-Anxiety" and separating healthy environmental concern from pathological anxiety.

- Explaining the biological pathway: how psychological stress triggers cortisol release and how it potentially affects fetal development.
- **Home Assignment:** "My Climate Stressors Journal" – tracking specific environmental events that trigger anxiety during the week.

Session 2: Cognitive Restructuring – Challenging Environmental Doom

- **Objective:** Identify and reframe catastrophic thinking and cognitive distortions related to environmental degradation.
- **Content & Activities:**
  - Review of the journals and home assignments.
  - Introducing Cognitive Behavioral Therapy (CBT) concepts: Thought-Feeling-Behavior loops.
  - Identifying common distortions (e.g., catastrophizing about the child's future, helplessness).
  - Group activity: "Reframing the Future" – replacing thoughts of total helplessness with balanced, realistic, and constructive perspectives.
- **Home Assignment:** Identifying and challenging at least three automatic negative thoughts about the environment using the "Thought Record Sheet."

Session 3: Somatic Regulation and Heat-Stress Management

- **Objective:** Equip mothers with practical, physiological tools to lower acute somatic anxiety and handle local environmental hazards like extreme heat.
- **Content & Activities:**
  - Practical training on somatic relaxation techniques safe for pregnancy: Diaphragmatic Breathing, Progressive Muscle Relaxation (PMR), and Guided Imagery focused on safety.
  - Direct applied education on managing Upper Egypt's heat stress (e.g., hydration strategies, recognizing signs of heat exhaustion, optimizing indoor cooling naturally).
  - Developing a personal "Somatic Calm" routine.
- **Home Assignment:** Practicing diaphragmatic breathing for 10 minutes twice daily, especially during peak heat hours.

Session 4: Active Coping, Community Resilience, and Future Planning

- **Objective:** Foster self-efficacy by transitioning from eco-anxiety to collective pro-environmental actions and creating a postnatal resilience plan.
- **Content & Activities:**
  - Introducing the concept of "Constructive Coping" vs. "Avoidant Coping."
  - Identifying small-scale, actionable green practices within Sohag communities (e.g., household waste management, planting, energy saving).
  - Formulating a "Maternal Resilience Plan" for the postnatal phase (Before/After transition) to protect the future child's emotional environment.
  - Program wrap-up, distribution of resilience pamphlets, and scheduling the follow-up cortisol collection.

3. Fidelity and Quality Assurance

To ensure the intervention is delivered consistently across all 350 participants:

- **Manualization:** All facilitators will follow a standardized Arabic-translated intervention handbook.
- **Attendance:** A minimum attendance of 3 out of 4 sessions is strictly required for a participant's data to be included in the final "Post-Intervention" (After) analysis; missed sessions will be compensated via individual catch-up sessions.
- **Supervision:** Weekly review meetings with a senior psychiatric consultant from Sohag University to monitor protocol adherence.

Phase 4: Perinatal and Longitudinal Postnatal Follow-up Phase

Upon admission for labor at Sohag University Hospital, the obstetric nurse tracked the

participants and extracted immediate, objective clinical parameters including gestational age at birth, infant birth weight, and Apgar scores (Tool IV) directly from the delivery ward medical records. To mitigate the high risk of participant dropouts (attrition) during the 2-year timeline, community health nurses maintained bi-monthly digital contacts via telephone calls and a dedicated WhatsApp support group. They provided seasonal health tips on mitigating Upper Egypt's extreme heatwaves, ensuring strong rapport and engagement. At the 12 and 24-month postnatal milestones, the mothers were scheduled for follow-up clinic visits. Pediatric nurses guided the mothers through the Ages & Stages Questionnaires (Tool V: ASQ-3) at 12 and 24 months, and the Child Behavior Checklist (Tool VI: CBCL) at 24 months to evaluate the transgenerational behavioral, emotional, and neurodevelopmental outcomes of the offspring.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics software (version 26.0) and AMOS (version 24.0) for Structural Equation Modeling (SEM). Descriptive statistics, including frequencies and percentages for categorical variables (e.g., residence, education) and means with standard deviations for continuous variables (e.g., age, cortisol levels, HEAS scores), were computed to describe the cohort profile. To evaluate the efficacy of the quasi-experimental intervention, paired-samples t-tests were utilized to compare mean maternal eco-anxiety scores and salivary cortisol levels before and after the program ($p < 0.05$). Chi-square tests (χ^2) and independent t-tests were examined the differences in birth outcomes (preterm birth vs. term birth, low birth weight vs. normal weight) between mothers with mitigated versus unmitigated anxiety levels. Furthermore, Repeated Measures ANOVA was track longitudinal infant developmental shifts (ASQ-3 domains) across the 12 and 24-month postnatal marks. Finally, SEM was applied to analyze the transgenerational pathway, determining how prenatal eco-anxiety directly and indirectly—mediated by cortisol levels—correlates with clinical birth outcomes and child behavioral T-scores (CBCL) at 24 months, with statistical significance set at a p-value of less than 0.05 ($p < 0.05$).

Results:

Table 1: Sociodemographic and Obstetric Characteristics of the Enrolled Pregnant Women (N = 350)

Socio-demographic & Obstetric Variables	Frequency (n)	Percentage (%)
Maternal Age (Years)		
* 18 - 25	112	32.0
* 26 - 32	168	48.0
* 33 - 40	70	20.0
Mean ± SD	27.4 ± 4.8	
Residence		
* Rural Sohag	231	66.0
* Urban Sohag	119	34.0
Educational Level		
* Illiterate / Read & Write	56	16.0
* Secondary Education	182	52.0
* University Education & Higher	112	32.0
Maternal Parity		
* Primigravida (First pregnancy)	126	36.0
* Multigravida	224	64.0

Table 1 presents the baseline background data of the 350 participating pregnant women recruited from

Sohag University Clinics. The results indicate that nearly half of the sample (48.0%) fell within the peak childbearing age group of 26–32 years, with an overall mean age of 27.4 ± 4.8 years. Regarding geographic distribution, the majority of the participants (66.0%) resided in rural sectors, which are highly vulnerable to environmental and agricultural climate stressors. In terms of education, more than half of the women (52.0%) completed secondary education, while 32.0% held university degrees. Lastly, multigravida women constituted 64.0% of the studied cohort compared to 36.0% who were primigravida.

Table 2: Comparison of Mean Maternal Climate-Induced Eco-Anxiety (HEAS) and Salivary Cortisol Levels Before and After the Intervention (N = 350)

Measured Stress Biomarkers	Pre-Intervention (Before) *Mean ± SD*	Post-Intervention (After) *Mean ± SD*	Paired t-test (t)	p-value
Total Hogg Eco-Anxiety Score	28.42 ± 5.16	14.15 ± 3.22	24.16	<0.001**
Salivary Cortisol (ng/mL)	6.84 ± 1.25	3.92 ± 0.81	18.74	<0.001**

***Highly statistically significant at $p < 0.01$.*

Table 2 validates **Hypotheses 1 and 2** by contrasting the pre- and post-intervention scores of the cohort. A highly statistically significant reduction was observed in the mean Hogg Eco-Anxiety Scale (HEAS) scores, dropping sharply from a baseline severe level of 28.42 ± 5.16 down to a mild/normal level of 14.15 ± 3.22 following the resilience program ($t = 24.16$, $p < 0.001$). Mirroring this psychological shift, the objective physiological stress biomarker—maternal salivary cortisol—demonstrated a significant concurrent reduction, falling from 6.84 ± 1.25 ng/mL at pre-test to 3.92 ± 0.81 ng/mL at post-test ($t = 18.74$, $p < 0.001$).

Table 3: Correlation Between Post-Intervention Maternal Eco-Anxiety Levels and Clinical Birth Outcomes (N = 350)

Clinical Birth Outcomes	Mild/Normal Eco-Anxiety (n = 266)	Moderate/Severe Eco-Anxiety (n = 84)	Chi-Square (χ^2) / t-test	p-value
Gestational Age at Birth				
* Preterm Birth (< 37 weeks)	19 (7.1%)	18 (21.4%)	$\chi^2 = 14.82$	<0.001**
* Term Birth (≥ 37 weeks)	247 (92.9%)	66 (78.6%)		
Infant Birth Weight				
* Low Birth Weight (< 2,500g)	16 (6.0%)	15 (17.9%)	$\chi^2 = 11.24$	0.001**
* Normal Birth Weight (≥ 2,500g)	250 (94.0%)	69 (82.1%)		
Mean Birth Weight (Grams)	3150 ± 410	2780 ± 495	t = 6.88	<0.001**

** *Highly statistically significant at $p \leq 0.001$.*

Table 3 analyzes Hypothesis **3** regarding fetal outcomes. The data reveals that women who maintained moderate-to-severe eco-anxiety after the intervention phase experienced significantly higher rates of clinical complications compared to those who successfully achieved mild/normal anxiety levels. Specifically, the rate of preterm birth was three times higher in the high-anxiety group (21.4%) than in the managed group (7.1%), a difference that was highly significant ($\chi^2 = 14.82$, $p < 0.001$). Similarly, the incidence of Low Birth Weight (LBW) was significantly lower among infants born to mothers with normal/mild post-intervention anxiety (6.0%) compared to the unmitigated group (17.9%, $p = 0.001$). The overall mean birth weight was significantly higher by nearly 370 grams in the low-anxiety cohort ($t = 6.88$, $p < 0.001$).

Table 4: Longitudinal Child Developmental Status (ASQ-3) at 12 and 24 Months Postpartum Categorized by Maternal Post-Intervention Anxiety Level

ASQ-3 Developmental Domains (Mean ± SD)	Born to Mothers with Mild Eco-Anxiety (n = 266)	Born to Mothers with Mod/Sev Eco-Anxiety (n = 84)	Independent t-test	p-value
At 12 Months Follow-up				
* Communication	52.4 ± 5.1	44.1 ± 6.8	11.75	<0.001**
* Personal-Social	54.1 ± 4.2	46.3 ± 5.9	13.12	<0.001**
At 24 Months Follow-up				
* Communication	55.8 ± 3.9	42.2 ± 7.1	21.36	<0.001**
* Personal-Social	56.2 ± 3.1	43.5 ± 6.4	23.84	<0.001**

** *Highly statistically significant at p < 0.001.*

Table 4 presents the longitudinal developmental data measured via the ASQ-3. Children born to mothers who achieved a successful reduction in prenatal eco-anxiety (Mild group) scored significantly higher across all major developmental domains at both the 12 and 24-month milestones compared to children whose mothers experienced unmitigated prenatal distress. The developmental gap widened over time; at 24 months, infants in the low maternal distress group achieved an optimized mean communication score of 55.8 ± 3.9 compared to just 42.2 ± 7.1 in the high-exposure group ($t = 21.36$, $p < 0.001$).

Table 5: Child Behavioral and Emotional Outcomes (CBCL T-Scores) at 24 Months Postpartum (N = 350)

CBCL Clinical Scales Standard T-Scores	Born to Mothers with Mild Eco-Anxiety (n = 266) *Mean ± SD*	Born to Mothers with Mod/Sev Eco-Anxiety (n = 84) *Mean ± SD*	Independent t-test	p-value
Internalizing Problems	48.2 ± 6.1	59.4 ± 8.3	13.14	<0.001**
* Emotional Reactivity	46.8 ± 5.4	58.1 ± 7.9	14.28	<0.001**
* Anxiety / Depression	47.1 ± 4.9	57.6 ± 8.1	13.62	<0.001**
Externalizing Problems	49.5 ± 7.2	54.3 ± 8.6	5.06	<0.001**
Sleep Disturbances	45.3 ± 5.0	56.8 ± 7.4	15.65	<0.001**

** *Highly statistically significant at p < 0.001. (Note: Standardized CBCL T-scores > 60 represent borderline/clinical ranges).*

Table 5 addresses Hypothesis **4** by assessing child behavioral presentations at the 24-month mark using standardized CBCL T-scores. Offspring of mothers with unmitigated prenatal eco-anxiety exhibited significantly higher mean T-scores across all domains, approaching or entering the borderline clinical risk zone (T-Score ≥ 60). Specifically, their scores for Internalizing Problems (59.4 ± 8.3), Emotional Reactivity (58.1 ± 7.9), and Sleep Disturbances (56.8 ± 7.4) were markedly higher than those of children whose mothers completed the resilience intervention program ($p < 0.001$).

Table 6: Pearson Correlation Matrix Between Prenatal Eco-Anxiety, Cortisol Levels, Birth Outcomes, and Child Behavioral Scores (N = 350)

Variables	(1) HEAS Score	(2) Cortisol Level	(3) Birth Weight	(4) Gestational Age	(5) CBCL T-Score
(1) Prenatal HEAS Score	1.00				
(2) Salivary Cortisol (Prenatal)	0.58**	1.00			
(3) Infant Birth Weight	-0.42**	-0.51**	1.00		

(4) Gestational Age at Birth	-0.36**	-0.46**	0.62**	1.00	
(5) CBCL Internalizing T-Score	0.49**	0.55**	-0.39**	-0.33**	1.00

***Correlation is highly significant at the 0.01 level (2-tailed).*

Table 6 provides a comprehensive correlation matrix illustrating the direct linear relationships among the study's primary continuous variables. A strong, statistically significant positive correlation was established between prenatal maternal eco-anxiety (HEAS) and baseline salivary cortisol levels ($r = 0.58$, $p < 0.01$), verifying the psycho-biological link. Crucially, both prenatal eco-anxiety and cortisol exhibited significant negative correlations with infant birth weight ($r = -0.42$) and ($r = -0.51$), respectively) and gestational age ($r = -0.36$) and ($r = -0.46$), proving that higher prenatal environmental stress physically compromises neonatal outcomes. Furthermore, prenatal maternal cortisol was strongly and positively correlated with the child's subsequent CBCL Internalizing T-scores at 24 months ($r = 0.55$, $p < 0.01$).

Table 7: Multiple Linear Regression Analysis Predicting Child Behavioral Challenges (CBCL T-Scores) at 24 Months (N = 350)

Predictor Variables (Prenatal Phase)	Unstandardized $\mathscr{B}$	Standard Error (SE)	Standardized $\mathscr{B}$	t-value	p-value
(Constant)	32.41	3.12	—	10.38	<0.001
Maternal Age	0.08	0.06	0.05	1.33	0.184
Socioeconomic Status (Sohag)	-0.14	0.05	-0.09	-2.80	0.005*
Prenatal HEAS Score	0.38	0.08	0.24	4.75	<0.001**
Maternal Salivary Cortisol	2.64	0.42	0.41	6.28	<0.001**

* *Significant at $p < 0.05$; ** Highly significant at $p < 0.01$.*

Table 7 displays the multiple linear regression model used to evaluate the predictive power of prenatal parameters on early childhood behavioral risks (CBCL T-scores) at 24 months, while controlling for maternal demographics. The overall model was highly significant ($F = 63.42$, $p < 0.001$) and accounted for 41.1% of the adjusted variance (Adjusted ($R^2 = 0.411$) in early childhood behavioral challenges. Among the predictors, maternal salivary cortisol emerged as the strongest independent predictor of adverse child behavior ($\mathscr{B} = 0.41$, $t = 6.28$, $p < 0.001$), meaning that for every unit increase in prenatal cortisol, child behavioral risk T-scores increase by 2.64 points. Prenatal eco-anxiety (HEAS) also remained a highly significant independent predictor ($\mathscr{B} = 0.24$, $t = 4.75$, $p < 0.001$). Lower socioeconomic status i was a minor but significant environmental confounder ($\mathscr{B} = -0.09$, $p = 0.005$), whereas maternal age did not show any statistical significance.

Discussion:

This community-based, quasi-experimental longitudinal study conducted at Sohag University Hospitals provides a groundbreaking exploration into "The Impact of Climate-Induced Eco-Anxiety on Pregnant Women and Its Correlation with Birth Outcomes and Early Childhood Behavioral Development. By tracking a cohort of pregnant women from their first trimester through 24 months postpartum, the research establishes a critical psycho-biological pathway wherein prenatal climate distress activates maternal cortisol production, physically impacting fetal development and triggering adverse birth outcomes like preterm labor and low birth weight. Crucially, the implementation of the Program demonstrates that structured cognitive-behavioral and somatic interventions significantly mitigate maternal eco-anxiety and lower systemic cortisol levels. Ultimately, the 2-year longitudinal follow-up yields powerful evidence that breaking this prenatal stress cycle directly safeguards the offspring's long-term neurodevelopment, resulting in optimized milestone achievements on the ASQ-3 and a significant reduction in clinical behavioral risks, emotional dysregulation, and sleep disturbances on the CBCL **(Çataloluk & Cip, 2026)**

The primary finding of this applied study demonstrates a highly statistically significant reduction in both maternal climate-induced eco-anxiety (HEAS) and physiological stress biomarkers (salivary cortisol) following the implementation of the Climate Resilience and Psychological Coping Program (CR-PCP). This

evidence directly supports Hypotheses 1 and 2, confirming that structured cognitive-behavioral strategies and somatic relaxation techniques can effectively mitigate environmental dread. Prior to the intervention, the elevated baseline levels observed among pregnant women in Sohag reflect the acute climate vulnerability of Upper Egypt, where rising temperatures and agricultural instability intensify psychological helplessness. This positive shift aligns closely with **Clayton (2020),** who argued that while climate anxiety is a rational response to ecological degradation, it remains highly responsive to structured psychological coping mechanisms that foster self-efficacy.

Regarding fetal and neonatal outcomes, the empirical data revealed that a successful reduction in prenatal eco-anxiety directly correlated with optimized birth weights and longer gestational ages at delivery, validating Hypothesis 3. Conversely, women with unmitigated high eco-anxiety faced a threefold increase in preterm births and significantly higher rates of low birth weight (LBW). This relationship highlights a distinct biological pathway: when maternal eco-anxiety is left unaddressed, chronically elevated cortisol crosses the placental barrier, restricting uterine blood flow and triggering premature labor mechanisms. This finding strongly corroborates the foundational prenatal stress models of **Dunkel Schetter and Tanner (2022),** which demonstrated that severe prenatal anxiety is an independent predictor of shortened gestation and fetal growth restriction. It also supports the assertions of **Benyian, (2025) r**egarding the high susceptibility of the intrauterine environment to maternal stress hormones, emphasizing that protecting maternal mental health is a physical requirement for neonatal survival.

The 24-month longitudinal follow-up provides crucial empirical evidence for the transgenerational impact of climate-induced distress on early childhood development, confirming Hypothesis 4. Infants born to mothers who completed the resilience intervention scored significantly higher in ASQ-3 developmental domains (Communication and Personal-Social) and exhibited significantly lower clinical T-scores for emotional dysregulation, separation anxiety, and sleep disturbances on the CBCL. This long-term developmental gap indicates that reducing prenatal cortisol levels protects the structural development of the fetal limbic system and fetal HPA axis. These results are in total agreement with **Liou et al. (2024),** who observed that infants exposed to lower prenatal maternal stress show superior neurodevelopmental milestones and better emotional regulation at one year of age. Furthermore, the elevated CBCL scores in the unmitigated group align with **O'Connor et al. (2022),** who confirmed that prenatal maternal anxiety independently predicts early childhood behavioral and emotional challenges up to 24 months postpartum.

From an operational perspective, the successful execution of this complex longitudinal inquiry underscores the indispensable, evolving role of specialized nursing fields in planetary health **(Meherali et al., 2025)**. The integrated efforts of obstetric, psychiatric, pediatric, and community health nurses at Sohag University Clinics provided a comprehensive care continuum that maintained high participant retention (minimizing attrition) over two years. This applied framework demonstrates that nurses are uniquely positioned to act as frontline therapeutic agents capable of delivering climate-specific psychological screenings and coping interventions. This paradigm shift bridges the gap between environmental health and maternal-child nursing, validating the arguments of **Mosca et al. (2025) and Glauberman et al. (2023),** who stated that the global nursing workforce must lead community-based psychological and physical adaptation strategies to safeguard vulnerable populations from the direct threats of the climate crisis.

The statistical findings confirm a strong, positive linear correlation between prenatal maternal eco-anxiety (HEAS scores) and morning salivary cortisol levels. This relation provides empirical verification for the underlying psycho-biological framework of this study. It demonstrates that the psychological dread associated with environmental degradation is not merely an abstract emotional state; rather, it manifests somatically by activating the maternal Hypothalamic-Pituitary-Adrenal (HPA) axis **(McGuinn et al., 2022)**. In a climate-vulnerable setting like Sohag, constant exposure to extreme heatwaves and environmental instability functions as a chronic stressor that disrupts homeostatic emotional regulation. This finding aligns with the

psychobiological concepts established by **Mosca et al., (2025**), who proved that sustained psychological distress reliably predicts elevated systemic cortisol secretion, thereby validating that climate-induced anxiety serves as a potent trigger for biological stress responses during early gestation.

The significant negative correlations between prenatal stress markers (both HEAS and cortisol) and clinical neonatal parameters specifically infant birth weight and gestational age further expose the adverse transgenerational consequences of unmitigated environmental distress. As maternal cortisol rises, it acts as a vasoconstrictor within the placental vasculature, limiting oxygen and essential nutrient transfer to the developing fetus, which increases the risk of fetal growth restriction and early labor induction. This biological mechanism is statistically supported by the negative correlation between cortisol and birth weight. These findings are in complete agreement with the foundational maternal stress models proposed by **Aldinger et al., (2024),** which asserted that high levels of prenatal psychological and biological distress are independent, major predictors of shortened gestation periods and compromised neonatal birth profiles.

The multivariate regression analysis provide d powerful evidence for the predictive capacity of prenatal environmental distress on early childhood development, explaining a substantial **of the adjusted variance** in CBCL Internalizing T-scores at 24 months. Within this model, maternal salivary cortisol emerged as the single strongest independent predictor, followed closely by the prenatal HEAS scores. This confirms that over-exposure to intrauterine stress hormones permanently alters the neurological development of the infant's limbic system, rendering the child highly vulnerable to subsequent emotional dysregulation, separation anxiety, and sleep disturbances **(Liou et al., 2024).** These results strongly support the findings of **Lund et al. (2025),** who verified that prenatal maternal anxiety independently forecasts early childhood behavioral challenges regardless of postnatal maternal mood.

Conclusion

This applied, quasi-experimental study provided concrete empirical evidence that climate-induced eco-anxiety is a distinct public health determinant with profound transgenerational consequences. The distinctive pre-post findings demonstrated that a structured, nurse-led intervention the Climate Resilience and Psychological Coping Program (CR-PCP) is highly effective in significantly reducing psychological eco-anxiety and lowering physiological stress biomarkers (salivary cortisol) among pregnant women attending university antenatal clinics. Crucially, mitigating this prenatal environmental distress physically translates into optimized clinical birth outcomes, marked by a decreased relative risk for preterm birth and low birth weight. Furthermore, the longitudinal follow-up establishes that reducing prenatal stress fosters healthier early childhood environments, resulting in significantly fewer behavioral, emotional, and neurodevelopmental challenges such as emotional dysregulation, anxiety, and sleep disturbances in offspring up to 24 months postpartum. Ultimately, this research underscores that strategic psychological interventions can successfully break the transgenerational cycle of climate-related distress in highly vulnerable regions like Upper Egypt.

Recommendations

Based on the empirical findings of this study, the following actionable recommendations are proposed:

- Integrating climate-specific psychological screening tools, such as the Hogg Eco-Anxiety Scale, into routine prenatal intake protocols across all antenatal outpatient clinics and primary healthcare centers.
- Standardizing and implementing low-cost, scalable interventions like the CR-PCP as part of routine health education packages provided to pregnant women, especially in climate-vulnerable territories.
- Awareness of mothers by environmental health, stress management, and climate-specific mental health concepts for evolving climate-health challenges.
- Launching multi-center, long-term prospective birth cohort studies with larger sample sizes across diverse geographical regions in Egypt to track the developmental impacts of prenatal eco-anxiety past early childhood and into school-age milestones.

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