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Perinatal food insecurity and postpartum psychosocial stress are positively associated among Kenyan women of mixed HIV status

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Abstract

Stress and food insecurity (FI) are associated with poor perinatal and HIV outcomes. We hypothesized that FI would increase postpartum stress among women in Kenya, and that the impact would be greater in women with HIV. Among 371 pregnant women, we identified latent FI trajectories across the perinatal period, and estimated their association with postpartum stress. Stress metrics included the Perceived Stress Scale (PSS) and hair cortisol concentrations (HCC). We identified two FI trajectories: persistent moderate FI and persistent mild FI. Moderate FI (vs. mild) was associated with higher PSS; this association was stronger among HIV-negative women. We observed a trend towards higher HCC associated with moderate FI, which did not differ by HIV status. HCC and PSS were not correlated. In summary, moderate FI (vs. mild) was associated

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CONFLICT OF INTEREST:
The authors declare that they have no conflict of interest.

with increased stress. The lack of PSS-HCC correlation could reflect different physiological pathways. Interventions to mitigate FI could alleviate postpartum stress.

RESUMEN

Hay una asociación entre el estrés y la inseguridad alimentaria en el hogar y resultados adversos para la salud perinatal y VIH. Nuestra hipótesis era que el estrés y la inseguridad alimentaria en el hogar incrementaría el estrés en el periodo de posparto entre mujeres en Kenia, y que el impacto seria mayor en aquellas mujeres con VIH. Identificamos trayectorias en materia del estrés y la inseguridad alimentaria en el hogar en estado latente y se estimo la asociación con el estrés en el periodo posparto entre 317 mujeres embarazadas. Se incluyeron la escala de estrés percibido (EEP) y la concentración de cortisol en las muestras de cabellos (CCC) recogidos como métricas de estrés. Identificamos dos trayectorias del estrés y la inseguridad alimentaria en el hogar, persistente moderada, y persistente liviana. Hay una asociación mayor entre EEP la trayectoria moderada del estrés y la inseguridad alimentaria en el hogar que la trayectoria liviana. Esta asociación es mayor entre las mujeres VIH-negativas. Observamos que hay una tendencia hacia un nivel mas alto de CCC y una asociación con la trayectoria moderada del estrés y la inseguridad alimentaria en el hogar, sin diferir entre estados de VIH. Las métricas CCC y EEP no están correlacionadas. En resumen, hay una asociación entre la trayectoria moderada del estrés y la inseguridad alimentaria en el hogar y un aumento del estrés. La falta de correlación entre CCC-EEP podría reflejar diferentes vías fisiológicas. Intervenciones destinadas para mitigar el estrés y la inseguridad alimentaria en el hogar podría aliviar el estrés en el periodo de posparto.

Keywords

Food insecurity; Stress; Psychological; Cortisol; Postpartum period; Pregnancy; HIV

INTRODUCTION

Psychosocial stress, hereafter referred to as “stress”, occurs when an individual perceives the environment as overwhelming or taxing on his or her ability to cope [1]. Stress is associated with an increased risk of chronic diseases such as gastrointestinal and autoimmune disorders, diabetes, and cardiovascular disease [2]. In the perinatal period (i.e., pregnancy and postpartum), a time of considerable transition, stress is associated with adverse pregnancy outcomes [3,4], postpartum depression [5], altered breastmilk quality [6], and poor infant health outcomes [7]. In persons living with HIV, stress is further associated with suboptimal adherence to antiretroviral treatment (ART) and disease progression [8].

Food insecurity, defined as uncertain access to nutritionally adequate, safe, or acceptable food, is highly prevalent in sub-Saharan Africa and is a leading cause of morbidity and mortality worldwide [9]. Prior studies have suggested that food insecurity is associated with depression [10], anxiety [11,12], and stress [13–16] in adults. However, data are limited from resource-limited settings during the critical perinatal period – when pregnant and breastfeeding women face increased demands [16–18] – and when patterns of food insecurity severity and frequency have been challenging to classify [16,19]. Moreover, few studies have examined the impact of perinatal food insecurity on stress in the context of highly prevalent HIV, despite evidence that food insecurity is associated with suboptimal treatment adherence during pregnancy and breastfeeding [20,21], potentially increasing the risk of perinatal HIV transmission [21,22].

Therefore, to inform the development of interventions to avert stress-associated adverse perinatal outcomes, we first explored patterns of perinatal food insecurity in a region of Kenya with highly prevalent food insecurity and HIV by identifying latent trajectories with semi-parametric group-based trajectory modeling [23]. We then examined the relationship between food insecurity trajectories and postpartum stress, as indicated by self-reported stress and hair cortisol concentrations (HCC), an emerging biomarker reflecting chronic hypothalamic-pituitary-adrenal (HPA) axis activation, a major component of the physiologic stress response [24]. We hypothesized that more severe and frequent food insecurity, compared to mild or transient patterns, would be associated with higher subsequent postpartum stress. Additionally, we examined whether the impact of food insecurity on stress would be greater in women living with HIV compared to HIV-negative women, as was observed in Ghana prior to widespread access to antiretroviral treatment [16].

METHODS

Study design and population

Between August 2014 and February 2015, 371 pregnant women (<30 weeks gestation) from western Kenya were enrolled into a cohort study designed to explore the impact of food insecurity on maternal and infant health outcomes (NCT02974972) [25]. Quota sampling was used to include half HIV-positive and half HIV-negative, and, within HIV strata, equal numbers with no/low, moderate, and severe food insecurity at screening [26]. Study visits were timed to occur concurrently with standard clinical visits, including antenatally at study enrollment and 1 month later, and postpartum at 6 weeks, 3 months, and 9 months. Additionally, participants were phoned at 1 week and 6 months postpartum. Study procedures were approved by ethical review committees at Cornell University, Northwestern University, and the Kenya Medical Research Institute. All study participants provided written informed consent.

Primary exposure

Food insecurity was assessed at all visits using the Individually-focused Food Insecurity Access Scale (IFIAS), a 9-item instrument with total scores ranging from 0–27, which has been validated in pregnant women [26]. Higher scores represent greater food insecurity. We used this individual-level, rather than household-level, instrument to capture the experiences of pregnant and postpartum women who have increased nutritional demands and may face reduced income-generating capacity and unequal control of or access to resources [26].

Study outcomes

We measured self-reported stress in the prior 30 days with the 10-question Perceived Stress Scale (PSS), a standardized instrument with scores ranging from 0–40 [27]. Higher scores represent higher stress. The PSS has been validated in a wide range of populations [28–33], including resource-limited settings [30,31] and perinatal populations [31–33]. In our sample, Cronbach's alpha was 0.72 at enrollment and 0.79 at 9 months postpartum.

The HPA axis, which regulates cortisol release, is a central component of the stress response [34]. Cortisol is incorporated into hair as it grows, at a rate of approximately 1 centimeter per month [24]. A 3-centimeter hair sample therefore reflects cumulative HPA activity over the prior 3 months [35,36]. We collected 3-centimeter hair samples at 9 months postpartum following an established protocol [37] and cortisol concentrations were analyzed using validated methods [38]. Any sample with an assay coefficient of variation (standard deviation/mean) greater than 10% was rerun in triplicate and the median result was reported.

Potential covariates

We constructed a socio-economic status index with principal components analysis of household asset data collected at baseline [39]. Maternal education collected at 9 and 15 months postpartum in an extended follow-up study was used as a proxy for educational status at baseline; we used the 9-month measure preferentially. A household census at 9 months, including all household members' ages, was used as a proxy for baseline household size and dependency ratio (number of members <15 years or >64 years/number of members 15–64 years). At baseline and in follow-up, several questionnaires were administered, including: 1) a 10-item social support scale [40] adapted from the Duke-UNC Functional Social Support Questionnaire [41]; 2) the Center for Epidemiologic Studies Depression Scale (CES-D) [42]; and 3) the SF-8 Health Survey, to assess quality of life [43].

Statistical analyses

Food insecurity trajectories—We used group-based trajectory modeling [23,44,45], a semi-parametric method, to identify subgroups of participants with shared trajectories of food insecurity from enrollment through 6 months postpartum (Figure 1). Following published methods [44,45], we specified a censored normal distribution for IFIAS scores and examined models with 2–5 different trajectory groups; we believed 2–5 subgroups would allow for meaningful interpretation. We examined quadratic and cubic polynomials of IFIAS scores to describe changing severity within each trajectory. We determined the optimal number of trajectory groups to characterize our data, and the optimal polynomial form for each group, using Bayesian information criterion (BIC) [46]. To better understand the severity and frequency of food insecurity in each group, we then estimated the proportion of visits in which food insecurity was severe (IFIAS 19–27), moderate (10–18), mild (1–9), or not experienced (0), for each participant who completed the IFIAS on at least two visits.

Food insecurity and stress—We used multivariable linear regression to estimate the impact of food insecurity trajectories on stress. We first considered potential confounders of the association between food insecurity and stress with a directed acyclic graph (DAG, Supplementary Figure 1) [47,48]. The following minimally sufficient set was identified: age, socio-economic status, education, household size, dependency ratio, baseline PSS, baseline social support, and HIV status. We also explored whether HIV status modified the effect of food insecurity with an interaction term. We assessed whether variable transformations (e.g., polynomial forms, categorizations) of covariates improved model fit using the BIC as a guide [46].

HCC (pg/mg) was log transformed to approximate a normal distribution. To report results, we back-transformed regression coefficients to represent the percentage change in HCC associated with a unit change in each predictor, as follows: 100*(exp(coefficient)-1).[49] Four log-transformed HCC values were more than 3 standard deviations (SD) above the mean. In sensitivity analyses, we 1) excluded these observations, and 2) "Winsorized" these observations, i.e., replaced the value with the nearest value within 3 SD of the mean [50].

HCC and PSS—We assessed correlation between HCC and PSS visually with a scatter plot, and statistically with Pearson's correlation coefficient. We also assessed whether this correlation differed when stratified by food insecurity trajectories.

Missing data—At 9 months postpartum, HCC was measured in 203 participants, and PSS was measured in 271 (Figure 1). Thus, 45% and 27% of these outcomes were missing, respectively. Additionally, household size and the dependency ratio, both based on the household census, were missing in 31% of participants, and education was missing in 20%. All other covariates had 0–1% missing values. To minimize the bias that can be introduced in complete case analyses [51], we used multiple imputation, and assumed that data were conditionally missing at random (MAR) [52]. We used multivariate imputation by chained equations (MICE) to impute continuous variables with linear regression, binary variables with logistic regression, and, to prevent out-of-range values for the dependency ratio and the study outcomes (HCC and PSS), we used predictive mean matching. Imputation models included all variables in the analytic models and auxiliary variables which were associated either with a variable with a large portion missing or with missingness. Auxiliary variables included depression and quality of life at 6 weeks postpartum, and gravidity. We imputed 50 datasets to minimize sampling variability from the imputation process [51]. We report results from multiple imputation as our primary results, and also report analyses limited to observed outcomes and the complete case analyses.

All analyses were conducted in Stata version 15 (StataCorp LLC, College Station, TX).

RESULTS

Among 371 women, the median age was 24 (interquartile range [IQR]: 21–28) and 23% completed secondary education (Table 1). The median PSS at enrollment was 20 (IQR 17–23) and median depression score was 18 (IQR 12–23). Among 273 women who attended the 9-month visit, 271 (99%) completed the PSS and 232 (85%) provided hair samples; 29 samples were of insufficient quantity for analysis and thus 203 HCC results are included (Figure 1). Enrollment characteristics of those with and without HCC results were comparable, although social support was somewhat lower among those without HCC (data not shown).

Food insecurity trajectories

We identified two food insecurity trajectories (Figure 2). One group experienced persistent and primarily “moderate” food insecurity throughout follow-up (60% of participants) while the other experienced persistent and primarily “mild” food insecurity throughout. We did not observe trajectories with changing severity over time. No participants in this sample were consistently food secure throughout follow-up; 89% reported mild or more severe food insecurity at every visit. The median posterior probability of group membership was 1.00 in the moderate group (IQR 0.94–1.00), and 0.98 in the mild group (IQR 0.85–1.00), indicating good model fit [23]. To better understand the persistence and severity of food insecurity in each group, we estimated the proportion of visits in which food insecurity was severe, moderate, mild, or not experienced for each participant. Those in the “moderate” group reported severe food insecurity at a median of 17% of visits (IQR 0–33), moderate at 67% of visits (IQR 40–83), mild at 17% (0–33), and one participant was food secure at only one visit. In the “mild” food insecurity group, one participant reported severe food insecurity at one visit; otherwise, participants reported moderate food insecurity at a median of 33% of visits (IQR 15–50), mild at 67% (IQR 50–80) and none at 0% of visits (IQR 0–17).

Most baseline characteristics differed by trajectory group (Table 1). Those in the moderate food insecurity group were slightly older (median age 25 years, [IQR 21–29] vs. 24 [20–27], p=0.04); reported higher stress (median PSS 20 [IQR 18–23] vs. 19 [16–22], p=0.002) and depressive symptoms (median 19 [IQR 14–24] vs. 15 [10–20], p=0.0001); and reported lower quality of life (median 26 [IQR 23–30] vs. 31 [26–34], p=0.0001) and social support (median 25 [IQR 20–30] vs. 29 [23–33], p=0.0001).

Food insecurity and stress

At 9 months postpartum, median PSS was 19 (IQR 17, 21) among women with persistent moderate FI compared to 16 (IQR 13, 19) in those with mild FI (Table 2); when stratified by HIV status, we observed a larger difference in PSS by FI group among HIV-negative women (median 19, IQR 17, 21 in the moderate FI group vs 15, IQR 13, 18 in the mild FI group) compared to HIV-positive women (median 18, IQR 16.5, 21 in the moderate FI group vs 16, IQR 13.5, 20 in the mild FI group). In multivariable analysis, the association between food insecurity trajectory and PSS differed by HIV status, with borderline statistical significance (p=0.06 for the interaction term). Among HIV-negative women, those in the moderate food insecurity trajectory scored 3.6 points higher on the PSS (95% CI 2.2, 5.0; p<0.0001) compared to women in the mild trajectory (Table 3). Among women living with HIV, this association was attenuated (+1.6, 95% CI 0.0, 3.2, p=0.05). Analyses limited to observed outcomes and complete cases produced similar results.

Median HCC was 7.3 pg/mg (IQR 4.6, 12) in women with persistent moderate FI compared to 5.8 (IQR 4, 8.6) in those with mild FI (Table 2). This difference in unadjusted HCC distribution by FI group was similar when stratified by HIV status. In multivariable analysis, we observed a trend towards higher HCC among women in the moderate food insecurity trajectory compared to mild (+22%; 95% CI −7, 61; p=0.15; Table 3), which did not differ by HIV status (p=0.33 for the interaction term). When excluding or “Winsorizing” HCC outliers, the magnitude of this association increased (+25%, 95% CI 0, 56, p=0.05 and

+23%, 95% CI −3, 55, p=0.08, respectively). The magnitude of the association also was larger when the analysis was limited to observed outcomes (+26% including outliers; and +33% or +30% when outliers were excluded or Winsorized, respectively).

HCC and PSS

HCC (reflecting the prior 3 months) and PSS (reflecting the prior month) were not correlated with each other (r=0.095, p=0.18, Figure 3). When stratified by food insecurity trajectory, these results did not differ.

DISCUSSION

In a cohort of women from western Kenya followed through pregnancy and postpartum, we observed higher postpartum perceived stress among those who experienced persistent moderate food insecurity compared to those who experienced mild food insecurity. The magnitude of this association was stronger among HIV-negative women than among those living with HIV. We also observed a trend towards increased chronic HPA axis activation, measured in HCC, among those with persistent moderate food insecurity compared to those who experienced mild food insecurity. To our knowledge, this is the first assessment of the impact of food insecurity on HCC. Our results highlight the importance of chronic, persistent food insecurity, a modifiable condition, as a risk factor for psychosocial stress during this critical transition period in women’s lives.

Our identification of longitudinal trajectories of food insecurity builds on prior studies evaluating food insecurity across the perinatal period and self-reported stress [13–16]. A study from Ghana characterized postpartum women as persistently food insecure (mild or more severe at 4 visits, with the USDA Household Food Security Module) versus not persistent (at least one food-secure visit) in the first year postpartum [16], while another from North Carolina summarized food insecurity over the prior year with the USDA Module administered at 12 months postpartum [13]. Unlike these classifications of long-term food insecurity, group-based trajectory modeling allows for dynamic patterns to be revealed. Although we anticipated identifying trajectories with changing food insecurity severity over time, the best model fit identified two groups having fairly consistent moderate versus mild food insecurity throughout follow-up, reflecting the chronic, persistent challenge women face in this setting. Despite different approaches to characterizing longitudinal food insecurity, the studies from Ghana [16] and North Carolina [13] both found that food insecurity across the first year postpartum was associated with increased PSS, consistent with our findings.

In Ghana, the impact of food insecurity on stress was greater among women living with HIV than among HIV-negative women [16]. In contrast, we observed an attenuated association among women living with HIV. Important differences in study populations may explain these divergent results. First, the Ghana study was conducted before ART was available, when only single-dose nevirapine was offered for prevention of perinatal transmission at delivery. Baseline stress in women living with HIV could be much greater in this context, given the high risk of breastfeeding transmission in the absence of ART. This vulnerability and baseline stress could impair one’s ability to cope, leading to a larger stress response to new negative stimuli such as food insecurity. In our study, all HIV-positive women were on ART receiving regular adherence counselling. This ongoing support from the clinic may have bolstered women's coping skills, resulting in an attenuated stress response to other negative stimuli, compared to HIV-negative women who have less interaction with healthcare providers. Second, 11% of the Ghana cohort was persistently food insecure whereas 89% of our cohort reported some degree of food insecurity at every visit. Third, background HIV prevalence was higher in our sample, and finally, we used an individually-focused measure of food insecurity, versus household-level metrics. Nonetheless, in both studies, greater food insecurity was associated with increased stress for both HIV-positive and HIV-negative women overall.

We did not observe a difference in the association between food insecurity and HCC by HIV status. Importantly, HIV infection negatively impacts the immune system, which is tightly integrated with the HPA axis; immune responses thereby affect HPA activity and vice versa [53,54]. While some studies in persons living with HIV have reported elevated baseline cortisol but blunted cortisol responses to stress, the impact of HIV disease progression and ART on HPA dysregulation remains poorly understood [53,54]. While HIV infection likely influenced cortisol release in our sample, the impact of HIV and ART on cumulative cortisol levels over 3 months requires further investigation.

Although moderate persistent food insecurity was positively associated with perceived stress, and the association with HCC was in the same direction despite wide confidence intervals, these metrics were not correlated with each other. One reason may be that the recall period for the PSS was the prior one month, while HCC represented HPA axis activity in the prior three months. Still, a recent meta-analysis reported no consistent associations between PSS scores and HCC across 26 studies (including one among pregnant women [55]), with some studies applying these metrics to the same time periods [24]. The authors noted that most studies were conducted in low-stress populations, and low variability in stress could limit power to detect associations; this would not apply to our sample with average PSS scores at the mid-point of the scale. While increased HPA axis activity is a natural function of late pregnancy, this generally returns to pre-pregnancy levels shortly after delivery [36] and as such would not impact our 9-month postpartum measures. Notably, increased cortisol release is not the only physiologic response to stress. HPA axis dysregulation could lead to altered diurnal patterns of cortisol release [56], insufficient release [57] or blunted responses as observed in persons living with HIV [53,54]. Identification of such patterns are not reflected in cumulative HCC. Food insecurity, particularly long-term persistent food insecurity, could lead to physiological stress pathways other than increased cortisol release.

Given the high-cost and invasive nature of biological sample collection, the low-cost and widely validated PSS remains an important clinical and research tool. To further understand the pathways by which perceived stress leads to HPA dysregulation and poor health outcomes, research incorporating short-term and long-term biomarkers of stress combined with self-report is warranted. Longitudinal measures are of particular importance in the perinatal period, when women face hormonal and physical changes, changes in physical activity, and new responsibilities and routines, all of which may differentially impact perceived stress and physiologic stress responses.

Our study has some limitations. First, we did not measure baseline HCC and were only able to adjust for baseline differences in PSS. Other unknown or unmeasured confounders could explain some of the association we observed. Second, by 9 months postpartum, transfers out and loss to follow-up led to significant missing data on outcomes, which we addressed with multiple imputation. Further, while hair collection has been highly acceptable in some settings in Kenya [58], in our sample, a number of participants expressed reservations, and ultimately 15% declined. However, our primary results using multiple imputation were comparable to analyses limited to observed outcomes.

CONCLUSIONS

In conclusion, we observed higher postpartum stress among women who experienced persistent moderate food insecurity throughout the perinatal period compared to those who experienced mild food insecurity. Further research with longitudinal stress metrics is needed to understand the impact of stress during the perinatal period on maternal, infant, and early child outcomes. The mitigation of food insecurity could alleviate postpartum stress and associated poor perinatal and HIV outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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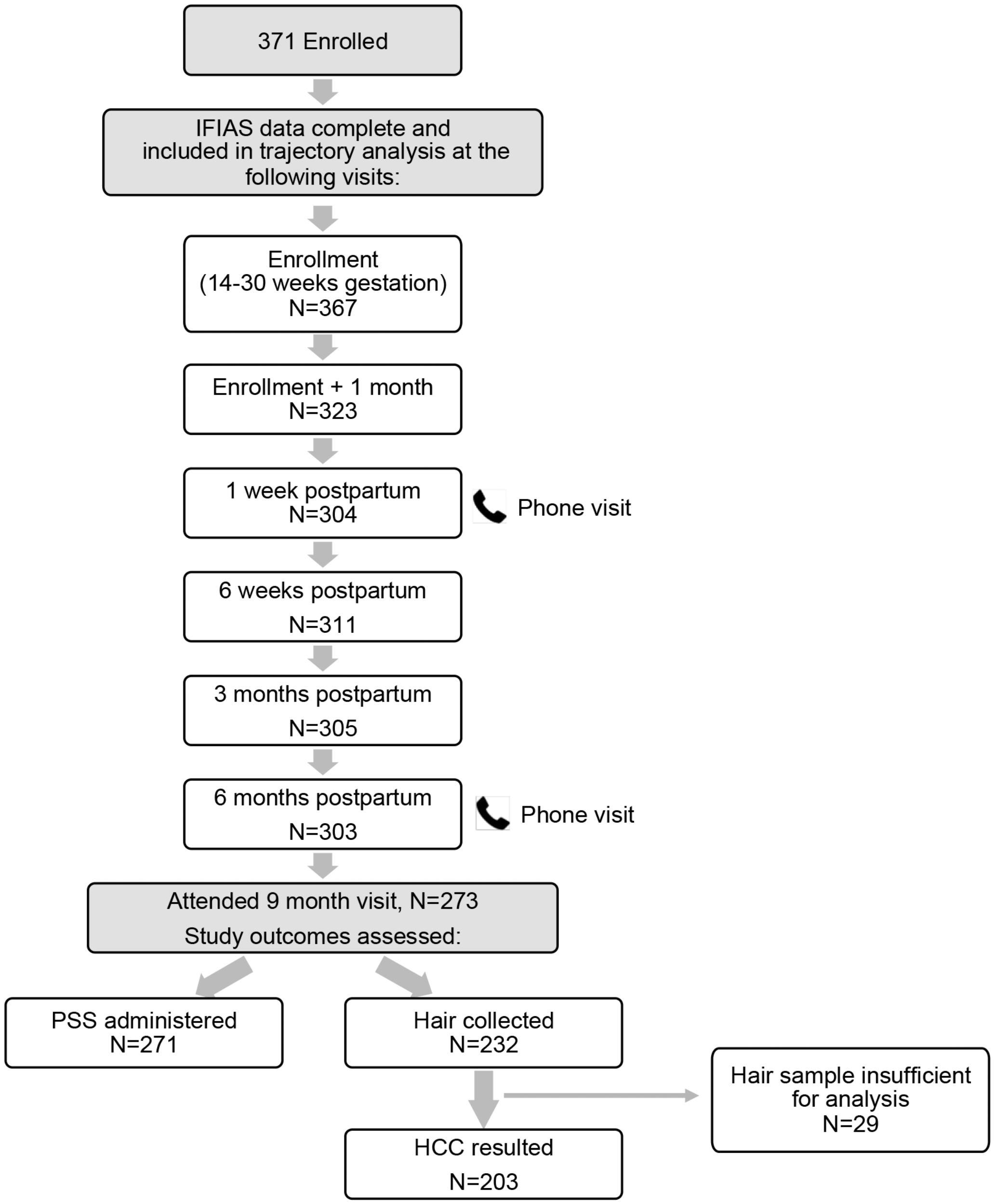

Figure 1.

Flow chart of participant follow-up and measured study outcomes.

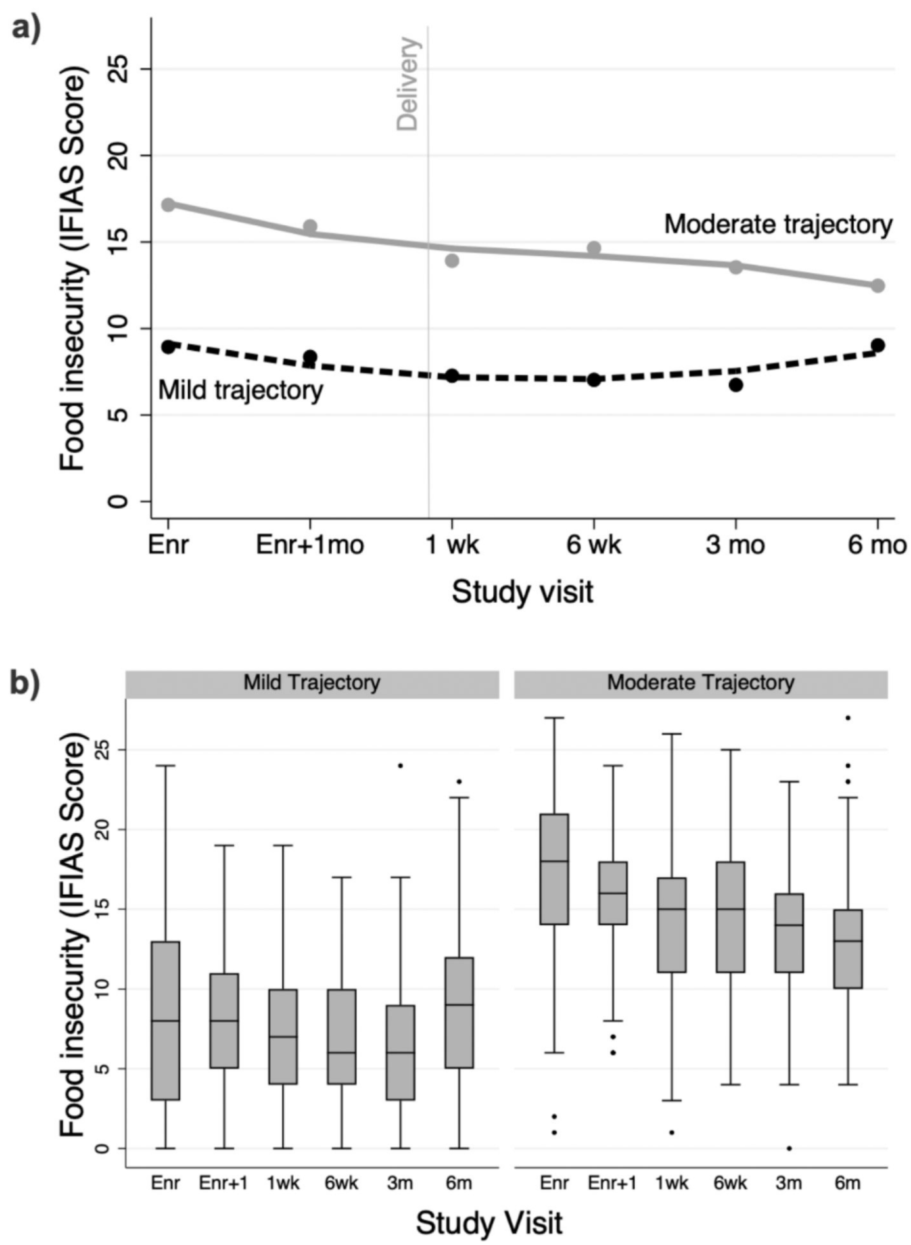

Figure 2.

Food insecurity trajectory groups. a) Lines represent model-estimated mean IFIAS (Individually-focused Food Insecurity Access Scale) scores over time. Points represent observed mean IFIAS scores, by trajectory group at each visit. b) Observed distribution of IFIAS scores by visit and trajectory group. Boxes represent interquartile ranges (IQR), lines extend to adjacent values (Quartile 1-IQR*1.5; Quartile 3+IQR*1.5), dots represent extreme values.

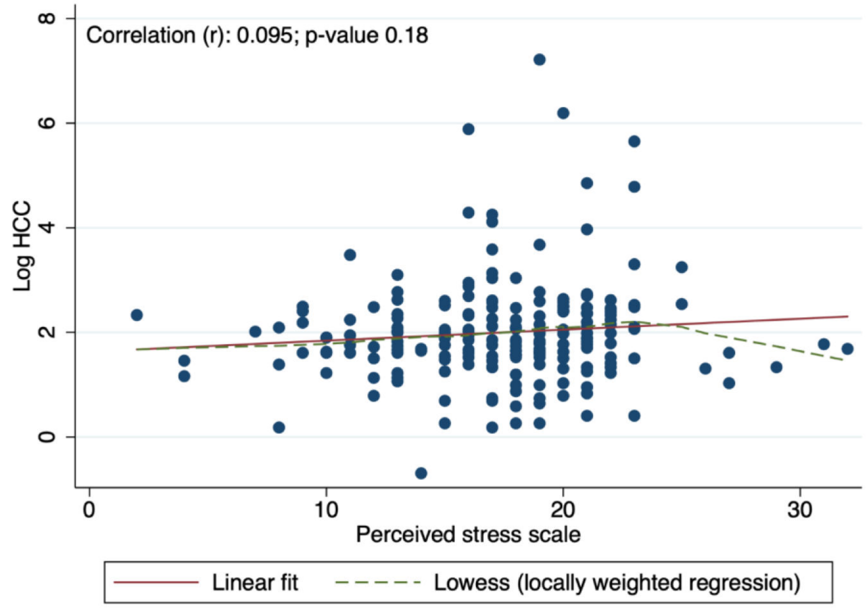

Figure 3.
Scatter plot of log-transformed hair cortisol concentrations (HCC, ng/pg) and the Perceived Stress Scale (PSS) at 9 months postpartum

Table 1.

Maternal characteristics at enrollment, by food insecurity trajectory group.

	median (IQR) or n (%)			
	Total Population	Mild FI Trajectory	Moderate FI Trajectory	
Baseline characteristic	**N=371**	**N=148**	**N=223**	**p-value***
Age, years	24 (21, 28)	24 (20, 27)	25 (21, 29)	0.04
Marital status				0.87
Married/living as married	333 (91)	132 (91)	201 (91)	
Other	34 (9)	13 (9)	21 (9)	
Highest level of education				0.002
None	7 (2)	2 (2)	5 (3)	
Some primary	91 (31)	31 (26)	60 (34)	
Complete primary	82 (28)	27 (23)	55 (31)	
Some secondary	47 (16)	16 (14)	31 (17)	
Complete secondary or more	69 (23)	42 (36)	27 (15)	
number missing education	*75*	*30*	*45*	
HIV status				0.24
Positive	69 (47)	118 (53)	187 (50)	
Negative	79 (53)	105 (47)	184 (50)	
Household asset index (range −2.1, 6.5)	−0.52 (−1.1, 0.7)	−0.24 (−1.1, 1.4)	−0.52 (−1.1, 0.2)	0.02
Household composition				
Size (number of members)	4 (3, 6)	5 (3, 6)	4 (3, 6)	0.30
Dependency ratio (range 0, 0.86)	0.5 (0.33, 0.60)	0.5 (0.33, 0.60)	0.5 (0.33, 0.60)	0.85
number missing household composition	*114*	*69*	*45*	
Gestational age at enrollment, weeks	24 (20, 26)	24 (20, 26)	24 (20, 26)	0.66
Gravidity	3 (2, 4)	3 (2, 4)	3 (2, 4)	0.11
Perceived Stress Scale (PSS, range 0–40) [27]	20 (17, 23)	19 (16, 22)	20 (18, 23)	0.002
Depression (CES-D, range 0–60) [42]	18 (12, 23)	15 (10, 22)	19 (14, 24)	0.0001
Quality of Life (SF-8, range 0–40) [43]	27 (24, 32)	31 (26, 34)	26 (23, 30)	0.0001
Social Support Index (range 0–30) [40]	26 (20, 32)	29 (23, 33)	25 (20, 30)	0.0001

* We tested for baseline differences between trajectory groups with the Wilcoxon rank-sum test for continuous variables and the chi-squared test for categorical variables.

Table 2.

Distribution of Perceived Stress Scale (PSS) scores and hair cortisol concentrations (HCC) pg/mg at 9 months postpartum, by food insecurity (FI) trajectory and by HIV status.

	Mild FI Trajectory		Moderate FI Trajectory	
	N	**median (IQR)**	**N**	**median (IQR)**
PSS				
Total sample	108	16 (13, 19)	163	19 (17, 21)
HIV +	44	16 (13.5, 20)	92	18 (16.5, 21)
HIV −	64	15 (13, 18)	71	19 (17, 21)
HCC (pg/mg)				
Total sample	85	5.8 (4, 8.6)	118	7.3 (4.6, 12)
HIV +	33	5.2 (4, 9)	65	7.2 (5, 12.1)
HIV −	52	6.5 (4.15, 8.15)	53	7.9 (4.6, 11.9)

Table 3.

Association between moderate food insecurity (FI) trajectory group (vs. mild FI) and 1) Perceived Stress Scale (PSS) scores; 2) hair cortisol concentrations (HCC) in pregnant and postpartum women.

Outcome: Perceived Stress Scale (PSS)	Unit change in PSS	95% CI	p-value
Primary analysis (multiple imputation of outcomes and covariates, N=371)			
Moderate FI trajectory (vs. mild)			(0.06) *
Among HIV-negative women	3.6	2.2, 5.0	<0.0001
Among HIV-positive women	1.6	0.0, 3.2	0.05
HIV positive (vs. negative, among food secure) **	1.0	−0.7, 2.7	0.25
Completed secondary education (vs. less)	−0.9	−2.3, 0.4	0.17
Maternal age, per year	0.1	0.0, 0.2	0.21
Household asset index (range −2.1 to 6.5)	0.0	−0.3, 0.4	0.85
Social support at baseline (range 0–30)	0.0	0.0, 0.1	0.41
Perceived stress at baseline (range 0–40)	0.1	−0.1, 0.2	0.29
Household size 4+ (vs 1–3)	−1.2	−2.7, 0.3	0.11
Dependency ratio, per 10% increase	0.0	−0.3, 0.3	0.97
Sensitivity analyses			
Multiple imputation of covariates, limited to observed outcomes, N=271			
Moderate FI trajectory (vs. mild)			(0.04) *
Among HIV-negative women	3.8	2.3, 5.3	<0.0001
Among HIV-positive women	1.6	0.1, 3.1	0.04
HIV positive (vs. negative, among food secure)	1.0	−0.7, 2.7	0.24
Complete case analysis, N=225			
Moderate FI trajectory (vs. mild)			(0.02) *
Among HIV-negative women	4.0	2.3, 5.6	<0.0001
Among HIV-positive women	1.3	−0.3, 3.0	0.11
HIV positive (vs. negative, among food secure)	1.2	−0.7, 3.0	0.22
Outcome: Hair cortisol concentrations (HCC)	% change in HCC	95% CI	p-value
Primary analysis (multiple imputation of outcomes and covariates, N=371)			
Moderate FI trajectory (vs. mild)	22	−7, 61	0.15
HIV positive (vs. negative) **	−13	−33, 12	0.27
Completed secondary education (vs. less)	−6	−31, 29	0.71
Maternal age, per year	1	−2, 4	0.36
Household asset index (range −2.1 to 6.5)	−1	−9, 8	0.81
Social support at baseline (range 0–30)	1	−1, 3	0.23
Perceived stress at baseline (range 0–40)	3	0, 6	0.05
Household size 4+ (vs 1–3)	43	1, 101	0.04
Dependency ratio, per 10% increase	1	−6, 9	0.75
Sensitivity analyses: estimates for moderate FI vs. mild			
Multiple imputation of outcomes and covariates			
HCC outliers excluded	25	0, 56	0.05

Outcome: Perceived Stress Scale (PSS)	Unit change in PSS	95% CI	p-value
HCC outliers Winsorized	23	−3, 55	0.08
Multiple imputation of covariates, limited to observed outcomes, N=203			
All HCC outcomes (including outliers)	26	−6, 69	0.12
HCC outliers excluded	33	5, 69	0.02
HCC outliers Winsorized	30	0, 69	0.05
Complete case analysis, N=169			
All HCC outcomes (including outliers)	22	−12, 68	0.24
HCC outliers excluded	28	−1, 65	0.06
HCC outliers Winsorized	26	−5, 67	0.12

*Interaction term p-values are in parentheses.

**Categories for known HIV positive vs. newly diagnosed did not improve model fit.