RESEARCH ARTICLE

Association between late-pregnancy household food insecurity and birth weight: Evidence from Propensity Score Matching

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Abstract

Background

Food insecurity, a situation characterized by the absence or limited access to sufficient quality and quantity of food to meet dietary needs, exposes mothers to adverse pregnancy outcomes such as birth defects and low birth weight. Nevertheless, despite the massive burden of food insecurity among pregnant and lactating women residing in resource-limited and war-affected settings like Tigray, Northern Ethiopia, there is a scarcity of evidence on the effect of food insecurity on pregnancy outcomes, more specifically, birthweight. Therefore, the aim of this study was to assess the association between late-pregnancy household food insecurity and birthweight using propensity score matching.

Method

A facility-based cross-sectional study was conducted at Ayder Comprehensive Specialized Hospital in Mekelle, Tigray Region, Northern Ethiopia, from December 2024 to March 2025. The study included 286 mother–newborn pairs recruited using systematic random sampling. Data were collected by trained midwives using a structured questionnaire and checklist. Food security status was assessed using the Household Food Insecurity Access Scale. Data were analyzed in STATA version 19. Propensity score matching (PSM) was used to assess the effect of household food insecurity on birth weight. Results of PSM are reported using the Average Treatment Effect (ATE) and the Average Treatment Effect on the Treated (ATET). In addition, crude comparisons of mean differences were made using either the Independent-Samples T-Test or One-Way ANOVA. Statistical significance was declared at $p < 0.05$. In addition, subgroup, sensitivity, and robust multiple linear regression analyses methods are used to assess effect robustness and detect a dose-response relationship.

Competing interests: The authors have declared that no competing interests exist.

Abbreviations: ACSH, Ayder Comprehensive Specialized Hospital; ANC, Antenatal Care; APH, Antepartum Hemorrhage; ATE, Average Treatment Effect; ATET, Average Treatment Effect on the Treated; CI, Confidence Interval; DM, Diabetes Mellitus; ETB, Ethiopian Birr; FAO, Food and Agriculture Organization of the United Nations; GDM, Gestational Diabetes Mellitus; HFIAS, Household Food Insecurity Access Scale; HIV, Human Immunodeficiency Virus; IRERC, Institutional Research Ethics Review Committee; LBW, Low Birth Weight; M, Mean; MU, Mekelle University; MUAC, Mid-Upper Arm Circumference; ODK, Open Data Kit; PIH, Pregnancy Induced Hypertension; PROM, Premature Rupture of Membranes; PSM, Propensity Score Matching; SD, Standard Deviation; SDG, Sustainable Development Goals; TB, Tuberculosis.

Result

The mean age of the mothers was 28.7 years (SD = 3.9). Of the total participants, 177 (61.9%) were food-secure, while the remaining 109 (38.1%) were food-insecure. Among the food-insecure group, 49 (17.1%) experienced mild food insecurity, 40 (14.0%) moderate food insecurity, and 20 (7.0%) severe food insecurity. The magnitude of low birthweight (LBW) among food-insecure mothers was 48.6%, compared to 11.3% among food-secure mothers. Overall, the prevalence of LBW was 25.5%. On average, the birthweight of newborns born to food-insecure mothers was 204 grams lower (ATE = –204.0, 95% CI: –289.3 to –118.7, $p < 0.001$) than that of newborns born to food-secure mothers. Furthermore, the birthweight of newborns born to food-insecure mothers was 218 grams lower compared to the birthweight they would have had if their mothers had been food secure (ATET = –218.3, 95% CI: –411.2 to –25.3, $p = 0.027$).

Conclusions

Late-pregnancy maternal food insecurity was significantly associated with decreased neonatal birthweight and an increase in the magnitude of LBW. Hence, addressing maternal food access could substantially decrease the burden of LBW and its related complications. During antenatal care, emphasis should be placed on assessing a pregnant woman's nutritional and food security statuses, and on integrating social and behavioral nutrition interventions to promote food security. In addition, a focus should be given to nutrition education before and during pregnancy. Policymakers should also ensure food security and improve nutritional conditions by empowering women.

Introduction

The Sustainable Development Goal (SDG), adopted in 2015 by the United Nations General Assembly, set a global agenda to end hunger and ensure food security by 2030 [1]. The Food and Agriculture Organization (FAO) defines food security as physical, social, and economic access to adequate, safe, and nutritious food all the time by all people for a healthy life [2]. Conversely, food insecurity is defined as a state in which there is no or limited access to sufficient quality and quantity of food to meet dietary needs [3,4].

In 2018, the global prevalence of food insecurity was estimated to be 26.4%. In contrast, the prevalence of food insecurity in Africa was more than 50%, much higher than in the rest of the world. Furthermore, the highest level of food insecurity was recorded in East Africa (63% of the population) [5]. The three main reasons for food insecurity in East Africa are armed conflict, adverse climate, and poverty [6].

According to studies conducted in Iran, around one-third (33 to 35%) of pregnant women are affected by food insecurity [7,8]. In Pakistan, the magnitude of household

food insecurity among pregnant women can reach up to 60% [9]. A systematic review study also stated that food insecurity among pregnant women can range from 5.2 to 87% [10]. According to a community-based cross-sectional study conducted in Arba-Minch town, Ethiopia, 30% of postpartum women experience household food insecurity. A recent study conducted in the Tigray regional state of Ethiopia during 2023 also unveiled that 88% of pregnant and lactating women were food insecure following the intense armed conflict in the region that began on November 4, 2020 [11].

Due to the disproportionate poor economic status of women, particularly in low-income countries like Ethiopia, women are at risk for food insecurity and its consequences. Indeed, evidence indicates that the likelihood of food insecurity is 75% higher among female-headed households than male-headed households [12]. Moreover, hardships like a husband/partner losing a job, depression, not having practical support, and intimate partner violence also put a pregnant woman at risk for food insecurity [13]. Consequently, food-insecure women are at risk for mental health problems, unsafe sex, gestational diabetes mellitus, adverse pregnancy outcomes (like birth defects, low birthweight, and perinatal mortality), a negative effect on human milk composition, and decreased breastfeeding [10,14–18]. Additionally, household food insecurity is linked with increased risk of illness, anemia, and stunting in children [4,7].

Nevertheless, despite the massive burden of food insecurity among pregnant and lactating women residing in resource-limited and war-affected settings like Tigray, Northern Ethiopia, there is a scarcity of evidence about the effect of food insecurity on pregnancy outcomes, more specifically, birthweight. Therefore, the aim of this study was to assess the association between late-pregnancy household food insecurity and birthweight using propensity score matching. Propensity score matching helps control for selection bias in observational studies and is ideal in situations where providing an intervention is not feasible or ethical [19].

Methods and materials

Study setting

A facility-based cross-sectional study was conducted in Ayder Comprehensive Specialized Hospital (ACSH). This hospital is one of the two referral hospitals found in the Tigray Regional State of Ethiopia. The hospital is located in Mekelle, the capital city of the region. The hospital has more than 500 beds, and the hospital provides services related to obstetrics and gynecology [20].

Study period

Data were collected from 28/12/2024 to 08/03/2025.

Population

This study was conducted among mothers who gave birth at ACSH during the specified period. The sampling unit was a mother and her baby.

Eligibility criteria

A mother/newborn pair during the immediate postpartum period was included. Mothers with twin pregnancies and severe fetal congenital malformations were excluded from the study [21]. In addition, critically ill mothers who were uncooperative and unsuitable for anthropometric assessment were excluded from the study.

Sample size and sampling procedure

Sample size is calculated using the single population proportion formula, assuming a 5% margin of error (d), a critical Z value for a 95% confidence level ($z\alpha/2$), which is 1.96, and a magnitude of low birthweight of 15%, which was taken

from a previous study conducted in the region [22]. The formula for a single proportion and the calculation are presented below:

$$n = \frac{(z_{\alpha/2})^2 p(1-p)}{d^2} = \frac{(1.96)^2 0.15(1-0.15)}{0.05^2} = 196$$

After adding a 10% non-response rate, the minimum sample size required for this study was 216. However, 286 mothers who gave a livebirth during the study period were recruited using systematic random sampling. Mother-newborn pairs were recruited at each third delivery until the required sample size was achieved.

Data collection procedure

Data were collected using a structured questionnaire and checklist. The structured questionnaire was used to collect primary data through face-to-face interviews with a mother. The interview was conducted by trained midwives holding master's degrees. The checklist was used to capture data from medical records and direct anthropometric measurements. The birth weight of every child was measured using a balanced weight scale immediately after birth. During each measurement, the weighing scales were checked and calibrated to the zero level to maintain measurement validity.

On a daily basis, the collected data were reviewed and checked for completeness. Additionally, the Open Data Kit (ODK) collect android application was used to minimize typos, avoid inconsistencies and invalid responses, and facilitate the provision of timely feedback.

Study variables

The outcome variable was birth weight; the first weight of a newborn measured in grams immediately after birth. Household food security was the main exposure (treatment) variable. The covariates or explanatory variables included sociodemographic and economic characteristics, obstetric and clinical characteristics, and anthropometric measurements.

Household food insecurity access scale

The Household Food Insecurity Access Scale (HFIAS) was used to measure the degree of food insecurity (access) in a household in the past four weeks (30 days) [23,24]. The HFIAS scale has 9 items, and each item's score ranges from 0 to 3 (i.e., 0 = None, 1 = Rarely, 2 = Sometimes, and 3 = Often). Then, based on the score of each item, the household of each mother was categorized into four levels (1 = Food Secure, 2 = Mildly Food Insecure Access, 3 = Moderately Food Insecure Access, 4 = Severely Food Insecure Access) as follows:

- *Food secure* = if [(item 1 = 0 or item 1 = 1) and item 2 = 0 and item 3 = 0 and item 4 = 0 and item 5 = 0 and item 6 = 0 and item 7 = 0 and item 8 = 0 and item 9 = 0]
- *Mildly food insecure access* = if [(item 1 = 2 or item 1 = 3 or item 2 = 1 or item 2 = 2 or item 2 = 3 or item 3 = 1 or item 4 = 1) and item 5 = 0 and item 6 = 0 and item 7 = 0 and item 8 = 0 and item 9 = 0]
- *Moderately food insecure access* = if [(item 3 = 2 or item 3 = 3 or item 4 = 2 or item 4 = 3 or item 5 = 1 or item 5 = 2 or item 6 = 1 or item 6 = 2) and item 7 = 0 and item 8 = 0 and item 9 = 0]
- *Severely food insecure access* = if [item 5 = 3 or item 6 = 3 or item 7 = 1 or item 7 = 2 or item 7 = 3 or item 8 = 1 or item 8 = 2 or item 8 = 3 or item 9 = 1 or item 9 = 2 or item 9 = 3]

In the present study, the HFIAS tool exhibited excellent internal consistency (Cronbach's alpha = 0.910). The STATA command used to categorize households based on their score for each HFIAS item is attached as S2 File.

Because data collection occurred during the immediate postpartum period, this measure primarily reflects food insecurity experienced in the late third trimester. It does not capture food insecurity throughout pregnancy, so our results should be interpreted as associations with late-pregnancy food insecurity rather than overall exposure across gestation.

Data analysis procedure

Data analysis was carried out using STATA 19 [25]. Frequency and percent were used to describe discrete variables. A sensible combination of measures of central tendency and measures of dispersion was used to describe a continuous variable. Mean birthweight comparisons were made using independent samples t-tests or one-way ANOVA, depending on the number of categories of each variable. For dichotomous variables and polytomous variables (≥3 categories), the Independent Samples t-test and One-way ANOVA were used, respectively. Equality of variances was assessed using Levene's test. The association between food security status and low birth weight was evaluated using the Chi-square test.

To evaluate the association between household food insecurity and birthweight, a propensity score matching (PSM) analysis was conducted using a logistic treatment model, a caliper of 0.1 to obtain close matches between food-insecure mothers (treatment group) and food-secure mothers (control group), a nearest-neighbor match of 1, and a 95% confidence level. Standard errors were estimated using the robust Abadie-Imbens method. The matching procedure generated a balanced, weighted sample with equal numbers of treated and control observations, corresponding to an effective 1:1 matching ratio.

Propensity score matching was chosen to reduce selection bias and approximate a randomized comparison, as it allows balancing of observed covariates between food-secure and food-insecure mothers. Covariates were selected based on prior literature and biological plausibility for influencing both household food insecurity and birthweight. Therefore, we included covariates that could affect both the treatment assignment and the outcome [26]. The covariates included were gestational age (categorized as preterm (<37 weeks) and term (37 to 41 weeks)), maternal age category (Categorized as 20–24 years, 25–29 years, 30–34 years, and ≥35 years), household income (categorized as <5,000 ETB, 5,000–9,999 ETB, and ≥10,000ETB), presence of obstetric complication (categorized as "Yes" or "No"), presence of chronic medical illness (categorized as "Yes" or "No"), parity (dichotomized as primiparous or multiparous), abortion history (categorized as "Yes" or "No"), gestational weight gain (categorized as <10 kg or ≥10 kg), antenatal care contacts (categorized as <4 and ≥4), pregnancy plan (categorized as planned and unplanned), mid-upper arm circumference (MUAC) (categorized as MUAC<23cm and MUAC≥23cm). Observations that violated the overlap assumption were identified using the *osample* option and excluded from the analysis. Treatment effects were computed using the *teffects psmatch* command of STATA. The computed treatment effects are the Average Treatment Effect (ATE) and the Average Treatment Effect on the Treated (ATET).

The Average Treatment Effect (ATE) is the difference in the estimated average outcomes between the treatment and control groups and is expressed as follows:

$$ATE = E\left(Y_1 \middle| W = 1\right) - E(Y_0|W = 0)$$

Where

- $E\left(Y_1|W = 1\right)$ is the average observable outcome in the treatment group and
- $E\left(Y_0|W = 0\right)$ is the average observable outcome in the control group
- W is a binary variable, with 1 indicating receipt of treatment and 0 indicating no treatment.

Therefore, ATE measures the average treatment effect across the entire population.

The Average Treatment Effect on the Treated (ATET) measures the effect only within the treatment group and can be expressed as follows:

$$ATET = E\left(Y_1 - Y_0 \middle| W = 1\right)$$

Where

- $E\left(Y_1|W = 1\right)$is the average observable outcome in the treatment group and
- $E\left(Y_0|W = 1\right)$is the average estimated outcome in the treatment group they would have had without treatment. This is estimated using matched controls [19].

Balance diagnostics were carried out using the STATA commands *tebalance summarize, tebalance box*, and *tebalance density*. Adequate balance is characterized by standardized mean differences (SMDs) between treated and control groups that are close to zero and a variance ratio close to 1. The thresholds for assessing balance were SMD < 2.5 and a Variance ratio between 0.5 and 2.0 [27–29].

The STATA commands used to conduct Propensity Score Matching (PSM) and the dataset are attached as supplementary files (see S1 and S2 Files). Statistical significance is considered at a p-value below 0.05.

In addition, subgroup, sensitivity, and robust multiple linear regression analyses are used to assess the robustness of effects and detect a dose-response relationship. Model fit for the multiple regression model is evaluated using the F-test and R-squared. Multicollinearity is assessed using the Variance Inflation Factor (VIF), and a VIF below 5 is used to indicate the absence of multicollinearity.

Ethical consideration

Ethical clearance was obtained from the Institutional Research Ethics Review Committee of Mekelle University College of Health Sciences, with ethical clearance number MU-IRB 2419/2024. Permission to collect data was obtained from the Chief Clinical Director and the Department of Obstetrics and Gynecology. Data collected in this study were de-identified to maintain privacy and confidentiality. Verbal informed consent was obtained from the mothers and approved by the Institutional Research Ethics Review Committee of Mekelle University College of Health Sciences. Our study strictly adhered to the Declaration of Helsinki regarding studies involving humans and human data.

Result

Sociodemographic characteristics

A total of 286 mothers and their respective newborns were included in this study. The mean age of the mothers was 28.7 years (SD = 3.9). More than half (166, 58.0%) of the newborns were male. Term and preterm deliveries accounted for 215 (75.2%) and 71 (24.8%), respectively. The birth weight of newborns increased significantly with maternal age ($p < 0.001$). Regarding educational status, half (144, 50.3%) of the mothers had completed secondary school. The remaining attained either primary school (78, 27.3%) or college or above (64, 22.4%). Nearly all (269, 94.1%) of the mothers reside in urban areas. More than half (147, 51.4%) had an average monthly income of 5,000–9,999 ETB. Birthweight was significantly related to average monthly income ($p < 0.001$). On average, the birthweight of newborns from a mother with income below 5,000 ETB, 5,000–9,999 ETB, and ≥10,000 ETB was 2378.9 grams, 2958.8 grams, and 3252.5 grams, respectively. See Table 1.

Obstetric characteristics

Primiparous and multiparous mothers accounted for 85 (29.7%) and 201 (70.3%) of the participants, respectively. The mean birthweight was statistically significantly less in primiparous women by 268.3 grams ($p < 0.001$). Mothers who ever

Table 1. Sociodemographic characteristics of mothers and their newborns, and their relationship with birthweight (N = 286).

Variable	N (%)	Birthweight in grams, M (SD)	Test[a]
N	286	2958.0 (571.5)	
Sex of the newborn			0.260
Male	166 (58.0%)	2990.4 (566.7)	
Female	120 (42.0%)	2913.1 (577.6)	
Gestational age at delivery			<0.001
Preterm (<37 weeks)	71 (24.8%)	2172.4 (304.2)	
Term (37 to 41 weeks)	215 (75.2%)	3217.4 (363.9)	
Age group (M = 28.7, SD = 3.9)			<0.001
20–24	36 (12.6%)	2823.6 (569.5)	
25–29	148 (51.7%)	2835.3 (545.3)	
30–34	74 (25.9%)	3132.5 (529.4)	
35+	28 (9.8%)	3317.9 (571.6)	
Religion			0.082
Christian	261 (91.3%)	2939.8 (569.9)	
Muslim	25 (8.7%)	3148.0 (565.6)	
Maternal educational status			0.101
Primary	78 (27.3%)	2910.6 (654.1)	
Secondary	144 (50.3%)	2923.9 (540.1)	
College or above	64 (22.4%)	3092.2 (518.6)	
Residence			0.224
Rural	17 (5.9%)	2794.1 (565.1)	
Urban	269 (94.1%)	2968.3 (571.4)	
Marital status			0.669
Non-married	8 (2.8%)	2872.5 (462.7)	
Married	278 (97.2%)	2960.4 (574.9)	
Employment status			0.692
Unemployed	133 (46.5%)	2943.6 (578.0)	
Employed	153 (53.5%)	2970.5 (567.5)	
Income (M = 8,645.8, SD = 3,899.8)			<0.001
<5,000 ETB	47 (16.4%)	2378.9 (452.3)	
5,000 to 9,999 ETB	147 (51.4%)	2958.8 (520.3)	
≥10,000 ETB	92 (32.2%)	3252.5 (473.6)	

[a]Mean birthweight comparisons were made using independent samples t-tests or one-way ANOVA, depending on the number of categories of each variable.

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had an abortion were 58 (20.3%). Only three mothers had no antenatal care (ANC) contact. Mothers who had ANC contacts of four or more were 260 (90.9%). The birthweight of newborns born to a mother who had ANC contacts of four or more was significantly higher by 558.8 grams ($p < 0.001$). Obstetric complications were reported in 71 (24.8%) mothers. Therefore, from four mothers, one mother had an obstetric complication. The most frequently encountered obstetric complication was premature rupture of membranes (PROM), which was found in 34/71 (47.9%), followed by pregnancy-induced hypertension, 25/71 (35.2%). See Table 2.

Clinical and anthropometric characteristics

Mothers who had chronic medical illnesses were 25 (8.7%), and the most common chronic medical illness was diabetes, which was found in ten mothers. Mothers who reported physical trauma or assault during pregnancy were 23 (8.0%).

Table 2. Obstetric characteristics of mothers and their newborns, and their relationship with birthweight (N = 286).

Variable	N (%)	Birthweight in grams, M (SD)	Test[a]
Gravidity category			0.778
Primigravida	16 (5.6%)	2918.8 (664.5)	
Multigravida	270 (94.4%)	2960.3 (566.9)	
Parity category			<0.001
Primiparous	85 (29.7%)	2769.4 (558.3)	
Multiparous	201 (70.3%)	3037.7 (559.5)	
Have you ever had abortion			0.498
No	228 (79.7%)	2946.4 (565.6)	
Yes	58 (20.3%)	3003.4 (597.1)	
ANC contact			0.705
No	3 (1.0%)	2833.3 (838.6)	
Yes	283 (99.0%)	2959.3 (570.1)	
ANC 4+			<0.001
<4	26 (9.1%)	2450.0 (607.6)	
4+	260 (90.9%)	3008.8 (543.4)	
Obstetric complication			0.290
No	215 (75.2%)	2937.4 (548.9)	
Yes	71 (24.8%)	3020.2 (635.4)	
Type of obstetric complication (N = 71)			
APH	9 (12.7%)	3133.3 (634.4)	0.571
PROM	34 (47.9%)	2933.0 (640.4)	0.273
PIH	25 (35.2%)	2916.0 (677.4)	0.312
GDM	10 (14.1%)	3460.0 (374.8)	0.017
Pregnancy plan			0.088
Unplanned	56 (19.6%)	2841.0 (522.9)	
Planned	230 (80.4%)	2986.4 (580.3)	
Bad obstetric history			0.019
Yes	139 (48.6%)	2876.4 (585.1)	
No	147 (51.4%)	3035.1 (549.3)	
Type of bad obstetric history			
Stillbirth	21 (7.3%)	3138.1 (577.5)	0.134
Low birth weight	55 (19.2%)	2711.2 (620.3)	<0.001
Preterm delivery	65 (22.7%)	2859.2 (567.7)	0.113
Congenital malformation	11 (3.8%)	3054.5 (459.1)	0.569

[a]Mean birthweight comparisons were made using independent samples t-tests or one-way ANOVA, depending on the number of categories of each variable.

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Mean weight gain during pregnancy was 9.2 kilograms, and more than half (151, 52.8%) of mothers gained less than 10 kilograms. On average, the birthweight of newborns born to mothers who had a weight gain below 10 kilograms was significantly less by 547.5 grams compared to those born to mothers who had a weight gain of 10 kilograms or more ($p < 0.001$). Mothers who were undernourished (MUAC <23 cm) were 67 (23.4%), and the birthweight of newborns born to undernourished mothers was significantly less by 785.6 grams compared to well-nourished (MUAC ≥23 cm) mothers ($p < 0.001$). Mothers who were food insecure during pregnancy were 109 (38.1%). See Table 3.

Table 3. Clinical and anthropometric characteristics of mothers and their newborns, and their relationship with birthweight (N = 286).

Variable	N (%)	Birthweight in grams, M (SD)	Test[a]
Chronic medical illness			0.207
No	261 (91.3%)	2944.7 (567.4)	
Yes	25 (8.7%)	3096.0 (608.4)	
Type of chronic medical illness (N = 25)			
Hypertension	3 (12.0%)	3081.8 (646.2)	0.760
DM	10 (40.0%)	3400.0 (359.0)	0.038
Anemia	6 (24.0%)	2841.7 (624.8)	0.248
Respiratory disease	2 (8.0%)	2900.0 (1272.8)	0.645
Other (Liver and heart diseases, TB, HIV)	4 (16.0%)	2737.5 (844.0)	0.205
Physical assault during pregnancy			0.889
No	263 (92.0%)	2956.6 (572.7)	
Yes	23 (8.0%)	2973.9 (570.5)	
Alcohol intake during pregnancy			0.019
No	177 (61.9%)	3019.9 (565.8)	
Yes	109 (38.1%)	2857.3 (569.1)	
Weight gain during pregnancy (M = 9.2, SD = 2.7)			<0.001
<10Kg	151 (52.8%)	2699.5 (581.2)	
≥10Kg	135 (47.2%)	3247.0 (396.5)	
MUAC category			<0.001
<23cm	67 (23.4%)	2356.4 (401.1)	
≥23cm	219 (76.6%)	3142.0 (482.8)	

[a]*Mean birthweight comparisons were made using independent samples t-tests or one-way ANOVA, depending on the number of categories of each variable.*

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Household Food Insecurity Access Scale (HFIAS)

Food-secure mothers were 177 (61.9%). The remaining 109 (38.1%) mothers were food insecure. Of all, mild, moderate, and severe forms of food insecurity were found in 49 (17.1%), 40 (14.0%), and 20 (7.0%) mothers, respectively. See Table 4.

The average birth weight of newborns decreased significantly as food insecurity increased ($p < 0.001$). The mean birthweight of newborns among food-secure mothers was 3153.1 grams, whereas among mildly, moderately, and severely food-insecure mothers it was 2927.9 grams, 2430.0 grams, and 2360.0 grams, respectively. See Fig 1.

Magnitude of low birthweight

The prevalence of low birthweight among food-insecure mothers was 53/109 (48.6%; 95% CI: 39.3%−58.0%), whereas among food-secure mothers, it was 20/177 (11.3%; 95% CI: 7.4%−16.9%). The overall prevalence of low birthweight was 73 (25.5%), with a 95% CI of 20.8% to 30.9%. The difference in the distribution of low birthweight was statistically significant (Chi-squared = 49.4, df = 1, $p < 0.001$). See Fig 2.

Propensity scores matching result

Covariance balance summary. Although the total sample size of this study was 286, 10 unmatched observations from the treatment group were excluded because they violated the overlap assumption; these were identified using

Table 4. Household Food Insecurity Access Scale categories among mothers (N = 286).

Variable	N (%)	Birthweight in grams, M (SD)	Test[a]
Household Food Insecurity Access Scale category			<0.001
Food secure	177 (61.9%)	3153.1 (497.3)	
Mildly food-insecure access	49 (17.1%)	2927.9 (514.2)	
Moderately food-insecure access	40 (14.0%)	2430.0 (448.5)	
Severely food-insecure access	20 (7.0%)	2360.4 (456.6)	
Household food security status			<0.001
Secure	177 (61.9%)	3153.1 (497.3)	
Insecure	109 (38.1%)	2641.1 (543.4)	

[a]Mean birthweight comparisons were made using independent samples t-tests or one-way ANOVA, depending on the number of categories of each variable.

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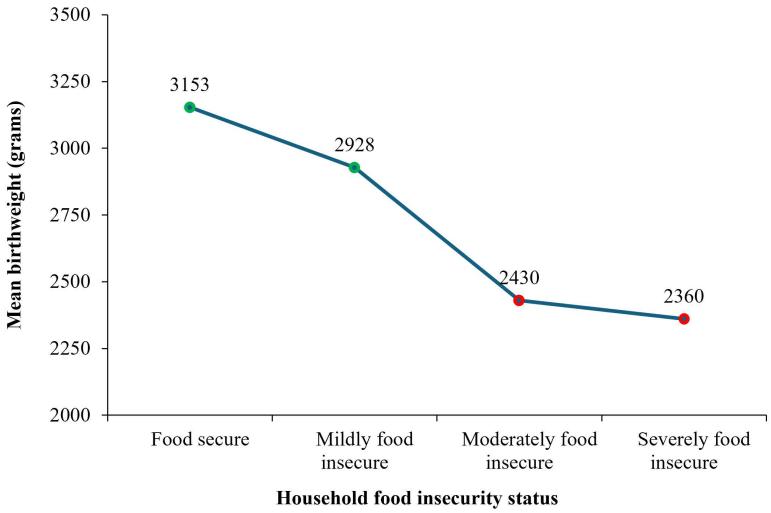


Fig 1. Mean Birthweight of Newborns by Household Food Insecurity Access Scale Category (N = 286).

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the `osample` option. A comparison of included and excluded treated observations revealed significant differences in gestational age, educational level, income, and MUAC. However, there were no statistically significant differences in the sex of the newborn, maternal age group, religion, ethnicity, marital status, employment status, gravidity, parity, abortion history, obstetric complications, chronic medical conditions, or weight gain during pregnancy. See S4 File for the comparison of excluded and included treated observations.

Therefore, the total number of observations before matching was 276 (food-insecure (treated) = 99 and food-secure (control) = 177). After propensity score matching, a balanced weighted matched sample (276 treated and 276 control) was generated. See Table 5.

After matching, there was a remarkable decrease in the standardized mean differences between the treated and control groups for most variables, and the variance ratio was close to 1, indicating that the matching achieved an adequate balance of covariates across most variables. See Table 6.

The box and density plots of the propensity scores also showed adequate covariance balance between the control and treated groups. See Fig 3.

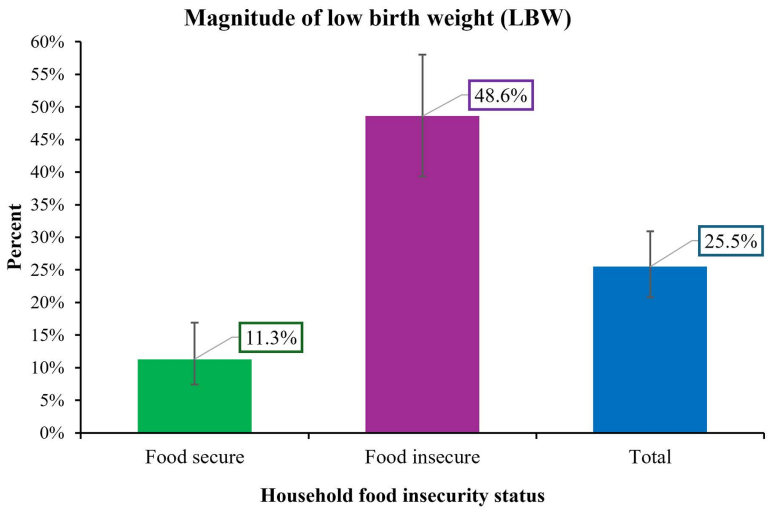


Fig 2. Magnitude of Low Birthweight Among Food Insecure and Food Secure Mothers (N = 286).

https://doi.org/10.1371/journal.pone.0363151.g002

Table 5. Number of Treated and Control Observations Before and After Propensity Score Matching.

Covariance balance summary	Raw	Matched
Number of observations	276	552
Treated observations	99	276
Control observations	177	276

https://doi.org/10.1371/journal.pone.0363151.t005

Table 6. Standardized Mean Differences and Variance Ratio Before and After Propensity Score Matching.

Variable	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Gestational age	−0.724	−0.303	2.432	1.547
Age category				
25-29	0.128	−0.116	0.992	1.019
30-34	−0.176	0.214	0.818	1.204
35+	−0.072	−0.181	0.817	0.501
Income				
5000-9999ETB	0.231	0.036	0.960	0.997
≥1000ETB	−1.082	0.008	0.229	1.006
Obstetric complication	0.049	−0.018	1.065	0.971
Chronic medical illness	0.056	−0.016	1.176	0.937
Bad obstetric history	−0.286	−0.087	1.011	0.986
Parity	−0.280	0.216	1.253	0.819
Abortion history	0.142	0.230	1.240	1.327
Weight gain during the current pregnancy	−0.682	−0.182	0.852	0.978
Four or more antenatal care contacts	−0.467	−0.192	5.846	2.466
Planned and wanted pregnancy	−0.371	−0.062	1.860	1.133
History of low birthweight	0.354	0.160	1.787	1.303
Mid-upper arm circumference (MUAC)	−0.931	−0.018	3.645	1.030

https://doi.org/10.1371/journal.pone.0363151.t006

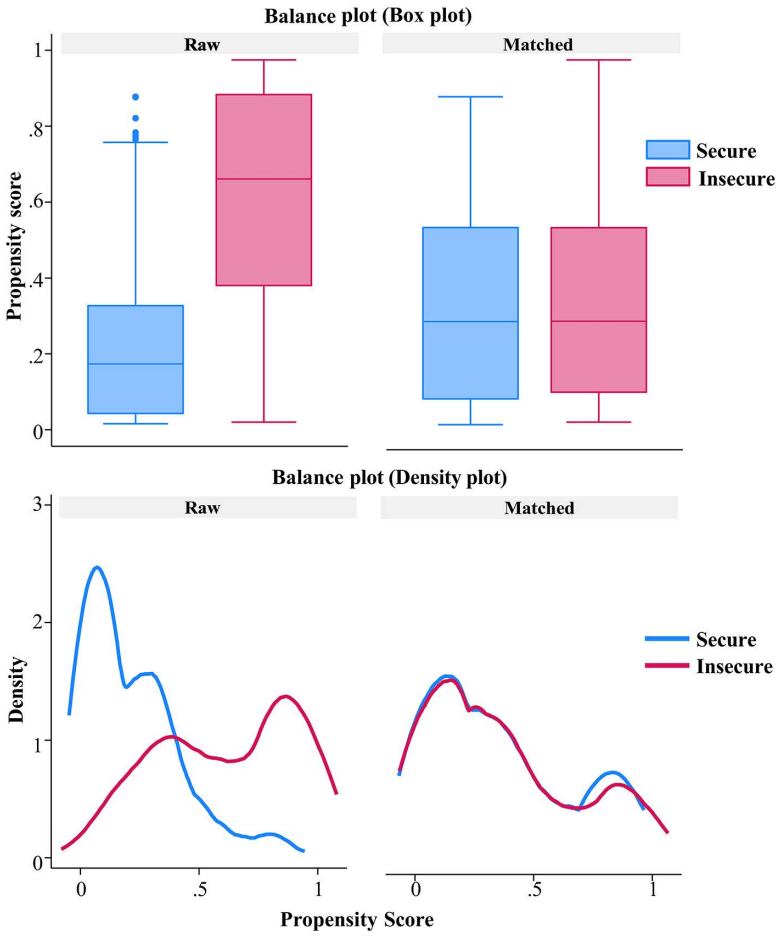


Fig 3. Box and Density Plots of The Propensity Scores Before and After Matching.

https://doi.org/10.1371/journal.pone.0363151.g003

Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATET). On average, newborns born to food-insecure mothers weighed 204 grams less (ATE = −204.0, 95% CI: −289.3 to −118.7, $p < 0.001$) than those born to food-secure mothers. This effect was statistically significant ($p < 0.001$). The birthweight of newborns born to food-insecure mothers was 218 grams lower than it would have been if their mothers had been food secure, and this effect was statistically significant (ATET = −218.3, 95% CI: −411.2 to −25.3, $p = 0.027$). See Table 7.

Subgroup and sensitivity analysis. To evaluate the robustness of the PSM finding, subgroup and sensitivity analyses were conducted. The subgroup analysis found an ATE of −130.3 among term newborns, indicating that, among food-insecure mothers, term newborns weigh 130 grams less than those born to food-secure mothers, and the effect was statistically significant (ATE = −130.2, 95% CI: −214.3 to −46.4, $p = 0.002$). In addition, the decrease in the effect from −204 to −130 suggests that part of the association is mediated by shortened gestational duration.

Sensitivity analysis was conducted by removing key covariates one at a time. As shown in Table 8, the negative effect remained consistent across model specifications, though the effect size varied with the included covariates. Among term newborns, the ATE was −130.3 (95% CI: –214.3 to –46.4; $p = 0.002$). When gestational age was excluded, the effect increased to –225.3 (95% CI: –421.9 to –28.7; $p = 0.025$). Excluding parity slightly reduced the effect to –171.9 (95% CI: –287.0 to –56.7; $p = 0.003$), while removing gestational weight gain produced an estimate close to that of the original

Table 7. Average Treatment Effect (ATE) and Average Treatment Effect on the Treated, A Propensity Score Matching (N = 276).

Measure of effect	Coefficient [95% CI]	SE	Z	p-value
ATE (Food insecure vs food secure)	−204.0 [−289.3, −118.7]	43.5	−4.7	<0.001
ATET (Among food-insecure/treated)	−218.3 [−411.2, −25.3]	98.5	−2.2	0.027

https://doi.org/10.1371/journal.pone.0363151.t007

Table 8. Subgroup and Sensitivity Analyses for the Propensity Score Matched Model.

Subgroup/excluded covariate	ATE [95% CI]	P-value
PSM model among term newborns	−130.3 [−214.3, −46.4]	0.002
PSM model without gestational age	−225.3 [−421.9, −28.7]	0.025
PSM model without parity	−171.9 [−287.0, −56.7]	0.003
PSM model without gestational weight gain	−200.2 [−304.9, −95.5]	<0.001

https://doi.org/10.1371/journal.pone.0363151.t008

model (–200.2; 95% CI: –304.9 to –95.5; $p < 0.001$). Overall, these analyses showed that the negative treatment effect is stable and statistically significant, with gestational age and parity having the greatest impact on its magnitude.

A robust multiple linear regression model was also fitted to quantify the effects of key covariates and assess whether a dose-response relationship exists between household food insecurity and birthweight. After adjustment, the mean birthweight of term newborns was 847.1 g higher ($p < 0.001$) than that of preterm newborns. Compared with newborns born to primiparous mothers, those born to multiparous mothers had a mean birthweight 172.7 g higher (95% CI: 87.6–257.9, $p < 0.001$, $\beta = 0.1$).

There was a negative dose-response association between household food insecurity and infant birth weight, with moderately insecure households having newborns weighing 137.7 g less (95% CI: −251.9 to −23.4, $p = 0.018$, $\beta = -0.1$) and severely insecure households having newborns weighing 182.1 g less (95% CI: −324.0 to −40.3, $p = 0.012$, $\beta = -0.1$) than those in food-secure households. Mild insecurity was not statistically significant. The overall model was highly significant ($F(8, 277) = 110.5$, $p < 0.001$), with an R^2 of 0.686, indicating good explanatory power, and there were no multicollinearity issues (maximum VIF = 2.1, mean VIF = 1.4). See Table 9.

Discussion

The primary aim of this study was to assess the association between late-pregnancy household food insecurity and birthweight among pregnant women using propensity score matching. Standardized mean differences, variance ratios, and balance plots indicated adequate covariate balance after propensity score matching. The ATE was statistically significant, indicating that newborns born to food-insecure mothers weighed 204 grams less than those born to food-secure mothers. According to the ATET, newborns born to food-insecure mothers could have had birth weights 218 grams higher if their mothers had been food secure. Among term newborns, those born to food-insecure mothers had birth weights 130.3 grams lower than those born to food-secure mothers, and the effect was statistically significant.

In this study, nearly two-fifths of mothers were food insecure. The overall low birthweight (LBW) rate was 25.5%, with a large discrepancy between food-insecure and food-secure mothers. The LBW rates among food-insecure and food-secure mothers were 48.6% and 11.3%, respectively.

The overall magnitude of LBW was higher than the report from Northern Shoa, Ethiopia, where the magnitude of LBW was reported to be 17.7% [30]; the pooled prevalence of LBW in Ethiopia, which is 17.3% [31]; a previous study conducted in Tigray, Ethiopia, reporting 15% [22]; a study from Addis Ababa demonstrating 8.8% [32]; African studies conducted in Ghana and Nigeria showing LBW prevalence ranging from 8.3% to 16.9% [33–35]; the magnitude reported in Iran (8.7%) [36]; and in Brazil, where LBW magnitude ranged from 7.6% to 9.6% [37,38]. However, the finding is

Table 9. Predictors of Newborn Birthweight: A Robust Multiple Linear Regression Model.

		95% CI of coefficient				
Predictor	**Coefficient**	**LL**	**UL**	**P-value**	**Beta**	**VIF**
Gestational age						
Preterm	Ref.					
Term	847.1	714.6	979.6	<0.001	0.6	1.7
Parity						
Primiparous	Ref.					
Multiparous	172.7	87.6	257.9	<0.001	0.1	1.1
Gestational diabetes mellitus						
Yes	165.9	−62.9	394.7	0.155	0.1	1.1
No	Ref.					
Weight gain during pregnancy						
<10 kg	Ref.					
≥10 kg	92.1	−12.5	196.7	0.084	0.1	1.5
MUAC category						
<23 cm	Ref.					
≥23 cm	104.9	−4.5	214.4	0.060	0.1	2.1
Household food-insecurity status						
Food secure	Ref.					
Mildly insecure	−66.1	−165.2	33.1	0.191	−0.0	1.1
Moderately insecure	−137.7	−251.9	−23.4	0.018	−0.1	1.5
Severely insecure	−182.1	−324.0	−40.3	0.012	−0.1	1.4

F (8, 277) = 110.5, p < 0.001, R-squared = 0.686.

Maximum VIF = 2.1, Mean VIF = 1.4.

CI = Confidence Interval; LL = Lower Limit; UL = Upper Limit; Ref. = Reference.

https://doi.org/10.1371/journal.pone.0363151.t009

comparable to those from cross-sectional studies conducted in Dire Dawa and Debre Markos, Ethiopia, which reported LBW prevalences of 21% and 21.6%, respectively [39,40].

The magnitude of LBW in the present study is 10% higher than the level reported before the recent armed conflict in Tigray, which began on November 4, 2020 [22]. The rise in the magnitude of LBW may be attributed to the detrimental effects of the recent Tigray armed conflict that disrupted access to food, nutritional counselling, and maternal and child health services [41]. Exposure to armed conflict is said to reduce birth weight by 2.8% and increase the incidence of LBW by 3.2% [42]. Furthermore, other studies also conveyed that pregnant women's exposure to armed conflict increases the likelihood of very low birth weight (VLBW) by fourfold [43].

In the present study, the magnitude of LBW among newborns born to food-insecure mothers was significantly higher, by more than fourfold, compared to newborns born to food-secure mothers. The finding is in line with several studies. The finding is supported by an unmatched case-control study conducted in three public hospitals of North Shoa Zone, Ethiopia, during 2017. The study found that the odds of LBW were four times higher among mothers from food-insecure households as compared to food-secure mothers (AOR = 4.42; 95% CI: 1.02–22.25) [44]. Our finding is also consistent with another cross-sectional study conducted during 2021 in Northern Shoa Zone public hospitals, Ethiopia, which revealed that the odds of LBW were double among newborns born to food-insecure mothers compared to those born to food-secure mothers (AOR = 2.3; 95% CI: 1.1–4.8) [30]. Similarly, a case-control study conducted in West Ethiopia reported that the odds of LBW were threefold higher among newborns born to mothers living in food-insecure households

[45]. In support of the present study's findings, a study conducted in the Silte zone, Southern Ethiopia, also revealed that household food insecurity increases the odds of LBW by about 7-fold [46].

A systematic review and meta-analysis study also highlighted that maternal food insecurity increases the risk of low birth weight by threefold [47]. Another systematic review and meta-analysis also noted that the odds of LBW are doubled among mothers with low dietary diversity. Food insecurity limits maternal nutritional intake, dietary diversity, pre-pregnancy weight, and gestational weight gain, all of which are key factors in fetal and infant growth. In other words, maternal food insecurity exposes mothers to micronutrient deficiencies, including anemia and psychosocial stress, thereby limiting intrauterine growth and development of the fetus, decreasing birth weight, and increasing the incidence of LBW [44,48].

The magnitude of LBW among food-secure mothers (11.3%) indicates that, even in the absence of food insecurity, other determinants, including obstetric complications, maternal age, parity, adequacy of antenatal care (ANC), and gestational age, remain important contributors to LBW.

Despite the study's use of propensity score matching to reduce selection bias and improve causal inference, it is not without limitations. Residual confounding cannot be ruled out due to unmeasured variables such as genetic predispositions and environmental exposures, as well as covariates with larger standardized mean differences (SMDs). Including potential intermediate variables and excluding observations outside the region of common support may have led to over-adjustment and selection bias, which could have affected the estimated effects. The generalizability of this study to stable populations is limited because it was conducted in an armed-conflict-affected and resource-limited setting. Although household food security status was assessed for the four weeks immediately preceding delivery, the cross-sectional design limits the ability to establish temporal relationships between food insecurity and birthweight. In addition, there is a possibility of recall bias due to reliance on maternal recall, and of measurement error arising from self-reported household food insecurity status and other sociodemographic variables. Lastly, the mothers' economic status was measured by average monthly income, which may not accurately reflect their true economic status.

Conclusions

In conclusion, late-pregnancy maternal food insecurity is significantly associated with newborns having, on average, 204 grams less birthweight. The mean birthweight of newborns born to moderately or severely food-insecure mothers was below 2500 grams. The magnitude of LBW was higher compared to the national pooled estimate for Ethiopia and the pre-war level in the Tigray region. More importantly, the magnitude of LBW was fourfold higher among food-insecure mothers compared to food-secure mothers. The findings of this study are consistent with the available body of scientific evidence.

Hence, addressing maternal food access could substantially decrease the burden of LBW and its related complications. Therefore, routine screening for food insecurity during ANC visits should use tools such as the HFIAS, and prompt interventions should be provided to mothers experiencing food insecurity, including nutrition education and social and behavioral nutrition interventions. Policymakers should also ensure that pregnant and lactating women are food secure by empowering them through education and financial support, especially in conflict-affected and resource-limited settings.

Supporting information

S1 File. This Microsoft Excel file contains the dataset used for this study.
(XLSX)

S2 File. This file contains the STATA commands used to generate Household Food Insecurity Access Scale categories and perform Propensity Score Matching (PSM) analysis.
(DOCX)

S3 File. This Word document contains the questionnaire and checklist used to obtain data.
(DOCX)

S4 File. This Word document contains a comparison between excluded treated observations due to violation of the overlap assumption (i.e., observations outside the region of common support) and included observations during propensity score matching.
(DOCX)

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