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Article

Individual, Household, and Community-Level Determinants of Undernutrition among Pregnant Women in the Northern Zone of the Sidama Region, Ethiopia: A Multi-Level Modified Poisson Regression Analysis

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Abstract: Introduction: In Ethiopia, maternal undernutrition is a major public health concern. However, comprehensive evidence is lacking in the southern part of Ethiopia, specifically the household and community-level related determinants of undernutrition. Besides, the evidence about the prevalence and determinants of undernutrition is not yet documented in the current study setting. Thus, this study aimed to determine the prevalence of undernutrition and identify its determinants among pregnant women in Hawela Lida district of the Sidama region, Ethiopia. **Methods:** A community-based cross-sectional study was conducted on a sample of 515 pregnant women from June 1–25, 2024. A multi-stage sampling method was utilized to select eligible pregnant women. We collected data using the Open Data Kit smart phone device and exported it to Stata version 17 for further processing and analysis. A multi-level mixed-effects modified Poisson regression analysis with robust variance was used to account for between and with cluster effects. **Result:** The prevalence of undernutrition among pregnant women was 41.7% (95% CI: 37.3–45.6). The prevalence of undernutrition was associated with planned pregnancy (adjusted prevalence ratio [APR]: 0.80; 95% CI: 0.66–0.98), household food insecurity (APR: 1.64; 95% CI: 1.26–2.13), inadequate dietary diversity (APR: 1.79; 95% CI: 1.43–2.25), and women's poor knowledge of nutrition (APR: 1.68; 95% CI: 1.32–2.12) at individual levels. The identified determinants of undernutrition at the community level were low community literacy rates (APR: 4.62; 95% CI: 1.13–18.79) and low community wealth status (APR: 1.91; 95% CI: 1.10–3.31). **Conclusion:** Two in five pregnant women had an undernutrition problem in the study setting. Individual and community-level determinants contributed to the high prevalence of undernutrition. Thus, any prevention and control approaches to undernutrition should consider inter-sectorial collaboration to account for determinants at various levels. Besides, any program must emphasize the delivery of nutrition education about dietary diversity, particularly targeting pregnant mothers who have poor knowledge of nutrition and unplanned pregnancy at the individual level. Moreover, creating a small business reform for the community with low wealth status using agricultural extension workers must be considered.

Keywords: undernutrition; prevalence; determinants; pregnant women; modified poisson regression; multi-level analysis; Sidama region; Ethiopia

Introduction

Undernutrition is defined as a lack of the required calories and an overall insufficient intake of food and nutrients to meet a person's needs and maintain good health [1]. Furthermore, undernutrition was caused by a combination of elevated nutritional demands and insufficient food consumption during pregnancy due to normal physiological change [2]. Undernutrition during pregnancy has significantly contributed to negative birth outcomes, maternal morbidity, and mortality [3].

Globally, the prevalence of undernutrition remains a serious public health concern, with around 462 million pregnant women developing undernutrition in 2017 [4]. The burden of maternal undernutrition is disproportionately high in Southeast Asia and Africa, as per reports from different studies [5-7]. For instance, a systematic review and meta-analysis reported that the pooled prevalence of undernutrition among pregnant women was 23.5% in Africa [5]. Besides, small-pocket studies reported a very high and variable prevalence of undernutrition among pregnant women in Africa, such as in Kenya (39.7%) [8], Ghana (28.8%) [9], and Ethiopia (47.9%) [10]. The Ethiopian Demographic and Health Survey (EDHS) report showed that maternal undernutrition decreased from 30% to 22% between 2000 and 2016. However, the rate of decline was slow, and urban and rural disparities in the prevalence of undernutrition persisted for decades [11]. Similarly, our comprehensive review of the literature showed a huge disparity in the prevalence of undernutrition among pregnant women in different regions of Ethiopia, with the smallest in the Gonder hospital (14.4%) [12] and the highest in the Haramaya district of eastern Ethiopia [10].

High prevalence of undernutrition in pregnant women's has serious consequences such as morbidity, mortality, poor pregnancy and birth outcomes such as intrauterine fetal growth retardation (IUGR) and death, stillbirth, low birth weight, premature and neonatal mortality [13-15]. Also, research findings suggest that being vulnerable to undernutrition during pregnancy is associated with stunted growth and development in childhood, reduced intellectual and learning capacity, small stature in adulthood, lower academic attainment, and lower economic production [16,17]. Moreover, it has intergenerational effects, and malnutrition can be passed down from mother to child. If they are girls, they are more likely to become undernourished mothers, and the vicious cycle repeats [18,19].

Several determinants contribute to the high prevalence of undernutrition among pregnant women and can be categorized as distal (socio-demographic, economic, ecological, political, private, and public sector action), underlying (household food security with palatable and safe drinking water, appropriate dietary practice, food hygiene and safety, and nutrition education), and immediate (adequate dietary intake, good care, and infection) [20]. Studies also showed place of residence, literacy level, maternal age and age at first marriage, maternal health service use, meal skipping, meal frequency, maternal nutritional knowledge and attitude, mass media use, and socio-cultural food taboos contributed to the high prevalence of undernutrition in Ethiopia [16,21-26].

The World Health Organization (WHO) developed two broad strategies to combat undernutrition globally: nutrition-sensitive and nutrition-specific. Nutrition-specific methods address undernutrition's underlying causes, including insufficient dietary intake of hematological nutrients like iron or vitamin A, supplementation, and the availability of fortified foods. Dietary diversity is a technique meant to promote the availability, accessibility, and utilization of regionally available and acceptable foods that have high micronutrient content and bioavailability year-round [27]. The Ethiopian government has developed various efforts to combat undernutrition among pregnant women, such as promoting nutritional diversification and iron and folic acid supplements, malaria prevention and treatment, the use of bed nets, and deworming pills [28]. Furthermore, the government has made significant efforts to reduce maternal undernutrition by establishing and implementing a nutrition and food strategy, program, and policy. Furthermore, the government created the "Seqota Declaration" to ensure year-round 100% access to sufficient food throughout the country by 2030 [29]. Moreover, health extension programs, notably those concentrating on community-wide nutrition education, are regarded as the most important measures that can help to ensure appropriate nutrition throughout the first 1000 days [28].

Despite all governmental commitments, initiatives, programs, policies, and efforts, the prevalence of undernutrition among pregnant women was significant across the country, especially in rural areas [11,16,21-26]. Besides, there were significant regional and urban/rural variations in the prevalence of undernutrition at the national level [11], this implies that more research is needed regarding the prevalence of undernutrition in local settings. Previous research on the prevalence of undernutrition among pregnant women in Ethiopia, however, concentrated exclusively on individual-level factors, with little attention paid to household, community, and context-specific determinants. Furthermore, no evidence regarding the prevalence and determinants of undernutrition has been identified in the current study setting. Therefore, this study aimed to describe the prevalence and identify determinants of undernutrition among pregnant women in the Hawela Lida district of Sidama region, Ethiopia.

Methods

Study Area

This study was conducted in the Hawela Lida district of the Sidama region of Ethiopia. Hawela Lida district is one of the 36 districts in the Sidama region and is located 289 km away from Addis Ababa, the capital city of the country. It has 11 rural and 2 urban *kebeles* (the lowest administrative unit in Ethiopia). Based on the Sidama Regional State Health Bureau 2023 Report, the district has an overall population of 129,949 with an estimated total of 23,928 households. Of these, 24.30% were women of reproductive age (WRA) [30,31]. Agriculture is the major source of income-producing activity in *kebeles*. The main crops grown in the district are *enset*, maize, coffee, khat, barely, haricot beans, corns, sweet potatoes, and local varieties of cabbage. The district administration has a total of 425 health professionals of different disciplines, 20 health posts, and 4 health centers owned by the government; additionally, there are 5 private medium and two non-governmental (NGO) clinics, and 6 private drug stores. The health post is managed by health extension workers (HEWs) and provides services such as health education, nutritional screening and education, and treatment for children, pregnant women, etc. [32]. The potential health service coverage of the district by health facilities was 90% [33].

Study Design and Period

A community-based cross-sectional survey was conducted from June 1–25, 2024, among a sample of 515 randomly selected pregnant women.

Study Population

The source population was all pregnant women who were less than 3 months of gestational age and resided in the district.

Study Population

The study population was all randomly selected pregnant women who were less than 3 months of gestational age and had resided in the district for at least 6 months.

Inclusion and Exclusion Criteria

All randomly selected pregnant women who have less than 3 months of gestational age and have resided in the district for at least 6 months were included in this study. Pregnant women who had a severe illness during the data collection period were excluded from this study due to their inability to communicate. Further, pregnant women who have temporarily resided in the district were excluded.

Sample Size Calculation

The sample size was computed using OpenEpi version 3 for all papers. Finally, a sample size of 528 was obtained based on calculations and used for this study.

Sampling Technique

A multi-stage sampling method was utilized to select the representative pregnant women until the determined sample size was reached. The first stage was the selection of Hawela Lida district from the Sidama region using a purposive sampling method. We selected the district purposefully to facilitate supervision and coordination of our interventional study because, immediately following this baseline survey, our project was designed and implemented. This district is near Hawassa City, which is the capital city of the Sidama region, and provides good geographic access. Second stage was selection of representative *kebeles* from the Hawela Lida district utilizing a lottery sampling technique. Based on the section procedure, 10 *kebeles*, namely Hawela 01, Murancho, Hayisa Wita, Hayisa Baraha, Chafe 01, Galuko Hireye, Gara Galo, Dulacha Tewerako, Hawela Lida rural, and Ramada were randomly selected from the district. The third stage was a selection of households with pregnant women. The household with pregnant women was identified by conducting a house-to-house census, and a sampling frame was prepared. Finally, study respondents were drawn using a systematic sampling technique. Pregnant women which were not available after three consecutive visits were considered as non-respondent for this study. One mother was included by using a lottery sampling procedure when two or more pregnant mothers occur in the chosen households.

Study Variables

The outcome variable was the prevalence of undernutrition. In this study, the mid-upper arm circumference (MUAC) measurements of pregnant mothers who fell below a cutoff point of 23 cm were classified as undernourished, while those who measured 23 cm or more were classified as normal. A flexible, non-stretchable tape was used to measure the mothers' MUAC by placing them in the Frankfurt plane and observing them sideways to measure the left side arm to the nearest 0.1 cm. The mothers' arms were hanging lightly at the side, with their palms facing inward.

The independent variables were classified into individual and community-level covariates. The individual-level covariates were socio-economic and demographic covariates like women age, occupation of the women and their husbands, education of the women and their husbands, wealth index, mass media use and family size; reproductive characteristics such as women age at first marriage and childbirth, gravidity and parity status, history of stillbirth and neonatal death, and pregnancy planning status; knowledge and attitude toward nutrition; household food security and dietary diversity. The community-level covariates are place of residence, distance from the nearest health facilities, community-level road access, community-level literacy rate, community-level women's autonomy, and community-level poverty.

Measurement of Variables

Dietary diversity scores were calculated using Food and Agriculture Organization (FAO) guidelines [34]. After computation, the score was divided into two groups, namely adequate and inadequate. Nine food groups were created from all of the pregnant women's reported foods and drinks consumed the day before the survey: cereals and starchy staples; oils and fats; dark green leafy vegetables and vitamin A-rich fruits and vegetables; legumes; nuts and seeds; other fruits and vegetables; meat and fish; organ meat; milk and products; and eggs. Pregnant women who have eaten the food in each subgroup (at least once) received a score of 1, and otherwise, 0 was assigned.

The household food insecurity questionnaires are based on food and nutritional technical assistance (FANTA) version 3 and have been modified for the local context; they contain 27 questions [35]. The first 9 questions were answered "yes" or "no," and the results were divided into four groups: food secured, mildly, moderately, and severely food insecure. The details of variable measurement are provided in Supplementary File 1 (S1 File).

Data Collection Tools and Techniques

The study tool was a structured and pretested interviewer-administrated questionnaire developed from similar previous studies [36-38]. The questionnaire was initially prepared in English (see S2 File). This tool was translated to the Sidaamu Afoo language (the local language spoken by the local residents) and reconverted back to English to assure similarity between two versions. The translation was conducted by a language expert in both English and Sidaamu Afoo. The translated study tool was reviewed by the principle investigator (PI) and another person who is also an expert in both languages. At that moment, the inconsistency was corrected between the two languages version as per the identified problems. The data collection procedure was managed by 20 data collectors and 4 supervisors. The PI monitored and controlled the overall process of data collection and made appropriate corrections for any issues.

Data Quality Assurance

The training regarding the study tool was provided for the data collectors, field assistant and field supervisors by the PI for 2 days. During the training, attention was given to the importance of the research, the data collection procedure, objectives, sampling procedures, blood sample collection procedures, and ethical considerations. The data collection was conducted using a properly designed, standardized, pretested, structured, face-to-face interviewer-administered questionnaire. After the pre-test, essential adjustments were carried out prior the main data collection process on the tool. The data collection process was carefully supervised. A completeness, consistency and accuracy of data were checked on daily basis during data collection. The data were cleaned, coded, and exported to Stata 17 for further processing and analysis. To minimize the risk of reporting bias, data collectors, field assistants and supervisors were blinded for the exposure and outcome variables. In addition, to minimize the risk of bias, maximum efforts were made by careful selection of subjects that represent the source population, maximizing response, and providing training for the data collectors, field assistants and supervisors.

Ethics Statement

The ethical approval of this study was obtained from the institutional review board (IRB) at the College of Medicine and Health Sciences of Hawassa University. A support letter was obtained from Hawassa University School of Public Health, Sidama region, Hawela Lida district, and *kebeles* leaders. Written consent was secured from pregnant women before data collection and after provision of information about this study. All data collection methods were carried out with confidentiality. Specific personal identifiers were not collected, and only researchers had access to data that could recognize individual respondents during or after data collection. Besides, pregnant women with severe undernutrition detected during the survey were referred to a nearby health facility for further investigation and treatment.

Data Analysis Techniques

Before the main analysis, quantitative variables were handled by recoding, calculations, and categorizations. Descriptive analyses were done to get descriptive measures for the important variables of interest, like frequency, percentage, mean, and standard deviation (SD). The Principal Component Analysis (PCA) was carried out for the computation of the wealth index for this study [39] and details of variable preparation and analysis procedures were provided in Table S2 of the S1 file.

We calculated intra-class correlation coefficient (ICC) using a multi-level logistic regression intercept only model [40,41]. The calculated ICC value was greater than 5% which is one indicator to consider the multi-level analysis regression analysis for this study. Both bi-variable and multivariable analyses using multi-level mixed effects modified Poisson regression models with robust standard error were carried out to examine the effects of clusters and known confounders. Those variables with p-values < 0.25 on the bi-variable analysis and practical significance backed from relevant

literature were built-in in a multivariable regression model to find out determinants independently associated with undernutrition, adjusting for other variables in the model [42].

We have developed multi-level models to account for the effects of clustering and the hierarchical nature of our data. Thus, four models were assessed for this study. Model 1 was an empty model or intercept-only model; Model 2 contained only individual-level determinants; model 3 contained only community-level determinants; and the final model (Model 4) contained both individual and community-level determinants. The ICC value and the median prevalence ratio (MPR) were used to assess the random model information [43]. The MPR is a predictor of the unexplained *kebeles*-level heterogeneity, while the ICC value was utilized to characterize the percentage of variability in the prevalence of undernutrition that is attributable to the clustering variable (*kebele*). The MPR was computed using the formula, $MPR = e^{0.95 \cdot \sqrt{(\text{estimated variance of clusters})}}$ and is defined as the mean of the prevalence ratio between the areas at the highest and lowest risk of undernutrition prevalence when two areas are randomly selected [44,45].

Effect modification and multicollinearity was examined for this study. The variance inflation factor (VIF) < 5 was used to declare that the effect of multicollinearity was minimal enough to affect the findings of this study [46]. The details of the effect modification results were provided in the S1 file.

The strength and presence of a statistically significant relationship between undernutrition and the independent variables were assessed using APRs with a 95% CI and 5% level of significance. A statistically significant relationship between the undernutrition and the independent variables was confirmed when the 95% CI of the APRs did not contain 1 or a P-value less than 0.05.

Results

Study Participants' Socio-Demographic Characteristics

We successfully interviewed 515 pregnant women from 528, for a response rate of 97.53% for this study. The mean age (\pm SD) of study participants was 25.89 (\pm 4.53) years. Almost all 486 (94.4%) study participants were of Sidama ethnicity. The majority, 438 (85.2%) of study participants, were Protestant Christian followers. Nearly all, 511 (99.2%) and 468 (90.9%) of pregnant women were married and housewives, respectively (Table 1).

Table 1. Socio-demographic characteristics of pregnant women in the Hawela district of Sidama region, Ethiopia, 2024.

| Variables | Categories | Frequency (%) |
|------------------|------------|---------------|
| Ethnicity | Sidama | 486 (94.4) |
| | Amhara | 18 (3.4) |
| | Wolayita | 6 (1.2) |
| | Gurage | 5 (1.0) |
| Religions | Protestant | 438 (85.2) |
| | Orthodox | 34 (6.6) |

| | | |
|------------------------------------|-----------------------------|------------|
| | Catholic | 25 (4.9) |
| | Muslim | 14 (2.5) |
| | Others | 4 (0.8) |
| Education status | Illiterate | 65 (12.6) |
| | Can read and write only | 105 (20.4) |
| | Primary education | 271 (52.6) |
| | Secondary education | 53 (10.3) |
| | College diploma | 17 (3.3) |
| | University degree and above | 4 (0.8) |
| Occupation status | Housewife | 468 (90.9) |
| | Merchant | 30 (5.8) |
| | Government employee | 17 (3.3) |
| Education status of husband | Illiterate | 18 (3.5) |
| | Can read and write only | 58 (13.3) |
| | Primary education | 282 (55.2) |
| | Secondary education | 105 (20.5) |
| | College diploma | 23 (4.5) |
| | University degree and above | 15 (2.9) |
| Education status of husband | Governmental employee | 16 (3.1) |
| | Merchant | 151 (29.5) |
| | Farmer | 311 (60.9) |

| | | |
|-------------------------------|-------------------------------|------------|
| | Daily laborer | 25 (4.9) |
| | Private organization employee | 3 (0.6) |
| | Others | 5 (1.0) |
| Marital status | Married | 511 (99.2) |
| | Divorced | 4 (0.8) |
| Family size | Small | 376 (73.0) |
| | Large | 139 (27.0) |
| Mass media utilization | Yes | 205 (39.8) |
| | No | 310 (60.2) |
| Wealth status | Lowest | 103 (20.0) |
| | Second lowest | 106 (20.6) |
| | Middle | 100 (19.4) |
| | Fourth | 99 (19.2) |
| | Highest | 107 (20.8) |

Reproductive Health Features of Study Participants

The mean age at first marriage (\pm SD) of study participants was 21.01 ± 3.10 years. 81 (15.7%) women have a previous history of abortion, and 93 (18.1%) had an infection during their current pregnancy. Similarly, 49 (9.5%) and 28 (5.4%) women have histories of previous stillbirths and neonatal deaths, respectively (Table 2).

Table 2. Reproductive characteristics of pregnant women in the Hawela district of Sidama region, Ethiopia, 2024.

| Variables | Frequency (%) |
|---|----------------------|
| | N (%) |
| Women's age during first marriage | 21.01 ± 3.10 |
| Women's age during first pregnancy | 22.37 ± 3.17 |
| Previous history of abortions | |
| No | 434 (84.3) |
| Yes | 81 (15.7) |
| Infection during the current pregnancy | |
| No | 422 (81.9) |
| Yes | 93 (18.1) |
| Previous history of stillbirth | |
| No | 466 (90.5) |
| Yes | 49 (9.5) |
| Previous history of neonatal death | |
| No | 487 (94.6) |
| Yes | 28 (5.4) |
| Last pregnancy planned | |
| No | 83 (16.1) |
| Yes | 432 (83.9) |

Prevalence of Under-Nutrition

The overall prevalence of under-nutrition among pregnant women was 41.7% (95% CI: 37.3-45.6) (Figure 1).

Determinants of Under-Nutrition

Pregnant women who had an unplanned pregnancy had a 20% higher likelihood of under-nutrition than their counterparts (APR = 0.80; 95% CI: 0.66-0.98). Pregnant women's inadequate dietary diversity increased the likelihood of under-nutrition prevalence (APR = 1.79; 95% CI: 1.43-2.25) by 79% compared to women who have adequate dietary diversity. Pregnant women in the food-insecure household had 64% more under-nutrition prevalence as compared to the food-secure household (APR = 1.64; 95% CI: 1.26-2.13). Women who have poor knowledge of nutrition had a higher prevalence of under-nutrition than their counterparts (APR = 1.68; 95% CI: 1.32-2.12). While the low community-level literacy rate increased the likelihood of under-nutrition prevalence (APR = 4.62; 95% CI: 1.13-18.79) as compared to the high community-level literacy rate, the likelihood of under-nutrition prevalence was 91% higher for pregnant women who lived in low wealth status communities (APR = 1.91; 95% CI: 1.10-3.13) as compared to women who lived in high wealth status communities (Table 3).

Table 3. Determinants of under-nutrition among pregnant women in the Hawela Lida district of Sidama region, Ethiopia, 2024.

| Variables | Nutritional status | | CPR (99% CI) | APR (99% CI) |
|--------------------------------------|--------------------|------------|-------------------|-------------------|
| | Under-nutrition | Normal | | |
| Individual level determinants | | | | |
| Women's education | | | | |
| Have formal education | 139 (40.3) | 206 (59.7) | Ref | Ref |
| No formal education | 76 (44.7) | 94 (55.3) | 0.96 (0.87, 1.06) | 0.92 (0.83, 1.23) |
| Family size | | | | |
| Small | 156 (38.4) | 250 (61.4) | Ref | Ref |
| Large | 59 (54.1) | 50 (45.9) | 1.10 (0.91, 1.34) | 1.11 (0.82, 1.51) |
| Mass media utilization | | | | |
| Yes | 74 (36.1) | 131 (63.9) | Ref | Ref |
| No | 141 (45.5) | 169 (54.5) | 1.05 (0.97, 1.15) | 1.11 (0.99, 1.23) |

| | | | | |
|---|------------|------------|-------------------|--------------------|
| Wealth quintile | | | | |
| Lowest | 56 (54.4) | 47 (45.6) | Ref | Ref |
| Second | 39 (36.8) | 67 (63.2) | 1.13 (0.87, 1.48) | 1.17 (0.91, 1.50) |
| Middle | 36 (36.0) | 64 (64.0) | 1.06 (0.83, 1.35) | 0.83 (0.59, 1.15) |
| Fourth | 44 (44.4) | 55 (56.6) | 1.24 (1.04, 1.49) | 0.82 (0.58, 1.17) |
| Highest | 40 (37.4) | 67 (62.6) | 1.19 (0.95, 1.48) | 0.78 (0.53, 1.13) |
| Infection during current pregnancy | | | | |
| No | 169 (40.0) | 253 (60.0) | Ref | |
| Yes | 46 (49.5) | 47 (50.5) | 1.17 (0.81, 1.69) | 1.01 (0.76, 1.33) |
| Last pregnancy planned | | | | |
| No | 42 (50.6) | 41 (49.4) | Ref | Ref |
| Yes | 173 (40.0) | 259 (60.0) | 0.54 (0.36, 0.81) | 0.80 (0.66, 0.98)* |
| Decision making power of women | | | | |
| Autonomous | 105 (33.2) | 211 (66.8) | Ref | Ref |
| Non-autonomous | 110 (55.3) | 89 (44.7) | 2.66 (1.21, 5.83) | 1.51 (0.50, 4.50) |
| Received model family training | | | | |
| No | 72 (47.7) | 79 (52.3) | Ref | Ref |
| Yes | 143 (39.3) | 221 (60.7) | 0.62 (0.38, 1.01) | 0.76 (0.57, 1.03) |

| | | | | |
|---|------------|------------|-------------------|---------------------|
| Food security status | | | | |
| Secured households | 92 (28.7) | 228 (71.3) | Ref | Ref |
| Insecure households | 123 (63.1) | 72 (36.9) | 1.93 (1.22, 3.06) | 1.64 (1.26, 2.13)** |
| Dietary diversity status | | | | |
| Adequate | 64 (26.1) | 181 (73.9) | Ref | Ref |
| Inadequate | 151 (55.9) | 119 (44.1) | 1.94 (1.33, 2.82) | 1.79 (1.43, 2.25)** |
| Women's knowledge about nutrition | | | | |
| Good | 80 (28.2) | 204 (71.8) | Ref | Ref |
| Poor | 135 (58.4) | 96 (41.6) | 2.22 (1.50, 3.29) | 1.68 (1.32, 2.12)** |
| Women's attitude towards nutrition | | | | |
| Positive | 125 (38.2) | 202 (61.8) | Ref | Ref |
| Negative | 90 (47.9) | 98 (52.1) | 1.18 (0.73, 1.87) | 1.13 (0.90, 1.41) |
| Community-level determinants | | | | |
| Place of residence | | | | |
| Urban | 18 (19.8) | 73 (80.2) | Ref | Ref |
| Rural | 197 (46.5) | 227 (53.5) | 1.21 (0.82, 1.76) | 1.49 (0.76, 2.95) |
| Community-level wealth status | | | | |
| High | 85 (27.9) | 220 (72.1) | Ref | Ref |

| | | | | |
|------------------------------------|------------|------------|--------------------|---------------------|
| Low | 130 (61.9) | 80 (38.1) | 2.27 (1.13, 4.56) | 1.91 (1.10, 3.31)* |
| Community-level distance | | | | |
| Not big problem | 126 (38.7) | 200 (61.3) | Ref | Ref |
| Big problem | 89 (47.1) | 100 (52.9) | 1.30 (0.90, 1.89) | 0.74 (0.49, 1.11) |
| Community-level literacy | | | | |
| High | 19 (13.4) | 123 (86.6) | Ref | Ref |
| Low | 196 (52.5) | 177 (47.5) | 7.10 (1.64, 30.58) | 4.62 (1.13, 18.79)* |
| Community-level road access | | | | |
| Accessible | 122 (37.9) | 200 (62.1) | Ref | Ref |
| Inaccessible | 93 (48.2) | 100 (51.8) | 1.32 (0.96, 1.82) | 1.27 (0.48, 3.39) |

APR: adjusted prevalence ratio; *: significant association ($p < 0.05$); **: highly significant association ($p < 0.01$); CI: confidence interval; CPR: crude prevalence ratio; Ref: reference group. .

Random Effect Model and Model Fitness Information on Under-Nutrition Prevalence

Our assessment showed that the multi-level modified Poisson regression model fit more accurately than the standard Poisson regression model ($p < 0.001$). According to the ICC value, being involved in *kebeles* accounted for 30.15% of the variation in the prevalence of under-nutrition among pregnant women. When two people were randomly chosen from different residential areas, the MPR value showed that the residual heterogeneity between the areas was associated with 1.82 times the individual probabilities of a prevalence of under-nutrition. The final model showed that the variation in under-nutrition prevalence across residential areas remained statistically significant even after correcting for all possible contributing factors.

The prevalence of under-nutrition model fitness evaluation test revealed that the empty model (AIC = 750.10, BIC = 758.59, and log-likelihood = -373.05) was the least fit. However, the models' fitness improved significantly, especially the final model (AIC = 635.48, BIC = 673.68, and log-likelihood = -308.74). Consequently, when compared to the other models, the final model fits the data the best (Table 4).

Table 4. Multi-level Modified Poisson regression analysis result of random effect model and model selection information.

| Measure of variation | Model 0 (95% CI) | Model 1 (95% CI) | Model 2 (95% CI) | Model 3 (95% CI) |
|-----------------------|---------------------|-------------------|-------------------|-------------------|
| Variance of intercept | 0.40 (0.27, 0.59) | 0.42 (0.24, 0.72) | 0.11 (0.03, 0.48) | 0.07 (0.03, 1.67) |
| ICC percentage | 30.15 (14.30-52.75) | | | |

| | | | | |
|----------------------|-------------------|---------|---------|-------------------|
| MPR | 1.82 (1.63 -2.07) | | | 1.28 (1.17, 3.42) |
| Model fitness | | | | |
| Log-likelihood ratio | -373.05 | -325.65 | -335.63 | -308.74 |
| AIC | 750.10 | 669.30 | 683.28 | 635.48 |
| BIC | 758.59 | 707.50 | 708.74 | 673.68 |

MPR: Median prevalence ratio and ICC: Intra-class correlation coefficient; AIC: Akaike information criteria; BIC: Bayesian information criteria; CI: confidence interval.

Discussion

The prevalence of undernutrition among pregnant women was 41.7%. Unplanned pregnancy, inadequate dietary diversity, food-insecure status, poor knowledge of nutrition, a low community-level literacy rate, and low community wealth status were determinants of under-nutrition among pregnant women.

The prevalence of undernutrition among pregnant women was 41.7%. This finding is in agreement with studies conducted in Southern Ethiopia (41.2%) [26], Tigray region of Ethiopia (40.6%) [47], Konso district of Southern Ethiopia (43.1%) [48], Eastern Ethiopia (43.8%) [49], and Sidama region of Ethiopia (38.0%) [50]. However, this finding is higher than studies done in the Silte Zone (22%) [21], Gambella region (28%) [22], and Gondar of the Amhara region (14%) [51]. Similarly, lower prevalence reported studies conducted in Ghana (11%) [52], the Silte Zone of southern Ethiopia (21.8%) [21], systematic reviews from Africa (20%) [53], south Sudan (18.9%) [54], Bangladesh (20%) [55], and Kenya (19.3%) [56].

Our finding is lower than the study done in the Haramaya district of eastern Ethiopia (47.9%) [10]. The varying prevalence of undernutrition in different parts of Ethiopia and other nations could be attributed to differences in socio-demographic factors, degree of economic development, study area, level of health service coverage, and sample size. Our study was focused on rural pregnant women and community-based, whereas the other studies were focused on urban areas and institution-based. Evidence suggests that undernutrition is more prevalent among rural residents.

This research indicated that the pregnant women who have planned pregnancy decreased the prevalence of undernutrition. This result is consistent with research from low- and middle-income nations that shows unintended pregnancies can have an impact on health care, child nutrition, and maternal nutrition [57,58]. This is due to the fact that mothers who have planned pregnancies have programs in place to help them feed themselves and get ready to have a variety of food types in their homes. Besides, a pregnant woman who has planned a pregnancy might have better knowledge of nutrition, be more autonomous in her decision-making, and be well educated.

Pregnant women's inadequate dietary diversity was significantly related with undernutrition prevalence. Similar findings were described from the studies carried out in the Gambella region, the south Omo zone of Ethiopia, and Kenya [22,24,56]. This might be the case because women who practice food diversity may receive diverse nutrients from a variety of diets, potentially making them more nutrient-dense than mothers whose dietary diversity score is below average. Besides, this could be because women do not eat extra meals during pregnancy, and maternal dietary habits, socio-cultural beliefs and food taboos can all have an impact on nutrition during pregnancy. The prevention of malnutrition in all its manifestations, both before and during pregnancy, depends on good nutrition practices, vital nutrition services, and nutritious diets. Thus, it is essential for all prenatal care to provide pregnant women with dietary education and counseling, and this should be increased. Furthermore, the researchers argued that this could be stated as follows: eating a wide range of foods

is essential to getting all the nutrients needed to prevent undernutrition caused on by nutrient deficiency [59].

This study indicated that household food-insecure status was positively related with undernutrition prevalence. Studies done in the Arbaminch district of southern Ethiopia [25], Gambella [22], Tigray region of northern Ethiopia [60], and Nepal [61] reported similar findings. This could be because a lack of food in the family typically leads to inadequate daily nutritional needs and low dietary intake, which causes undernutrition in pregnant women. Researchers also argued that one of the main underlying causes of undernutrition is household food insecurity, which arises when a household does not always have physical, social, or financial access to enough food that satisfies their nutritional needs for the healthy life. Women tend to eat less than men do; therefore, this could be related to the period of low food availability. Furthermore, the women employed coping mechanisms to limit their food intake and provide nourishment for their young children and newborns amid a food scarcity. In light of this, enhancing community food security for households is crucial to preventing and reducing acute undernutrition and its detrimental long-term impacts [62].

Pregnant women's poor knowledge of nutrition increased the prevalence of undernutrition. This finding is consistent with study results conducted in the Silte zone of southern Ethiopia [21] and Dessie town, northeastern Ethiopia [63]. This might be because inadequate nutritional knowledge about nutrition typically leads to inadequate dietary intake, which causes undernutrition. Also, women who have good knowledge of nutrition may be better able to recognize the advantages of eating a healthy and adequate diet during their pregnancy and be ready to follow a healthy and adequate diet practice.

This study documented that a low community-level literacy rate increased the prevalence of undernutrition. Educated communities have greater nutritional awareness and health-seeking behavior. Women with a high community-level literacy rate are more independent and financially independent, have more work possibilities, and are aware of the benefits of proper dietary diversity. Another factor could be that literate populations use more community-level mass media, which may boost the conversation regarding maternal health problems in the community. According to the WHO report, mothers who live in high-income communities may have more exposed to mass media, increasing their awareness and knowledge of nutrition and adequate dietary diversification practices [64]. This notion is further supported by findings from a studies conducted in low-income countries [65,66].

The prevalence of undernutrition increased for pregnant women who lived in low-income communities. The possible justification for this might be that community-level poverty will decrease the affordability of food. Researchers also discussed that when women have the money to buy these foods, they can access a wider variety of foods, and people's ability to make purchases influences the kinds of foods they eat [67-69]. The current study's findings of higher risks of undernutrition among disadvantaged women are in line with those of a prior study conducted on young Ethiopian pregnant women [70]. Women in underprivileged nations like Ethiopia are less likely to be employed and are therefore unable to provide for their families' daily necessities. Therefore, it stands to reason that funding for women's economic empowerment would improve pregnant women's nutritional status.

Conclusions

The prevalence of under-nutrition among pregnant women in the Hawela Lida district of southern Ethiopia is still a severe public health problem. This is an indication that much work remains to be done to improve the nutrition status of pregnant women in the study setting. The health system organization at various levels does not widely address pregnant mothers' nutritional knowledge to improve their nutritional status. Unplanned pregnancy, inadequate dietary diversity, food-insecure status, poor knowledge of nutrition, a low community-level literacy rate, and low community wealth status were significant determinants contributing to the high prevalence of under-nutrition among pregnant women. Thus, any programs related to maternal nutritional improvement strategies should address these determinants that continue to contribute to the high prevalence of under-nutrition. Likewise, particularly intervention approaches should be considered for pregnant women with poor

knowledge of nutrition, pregnant women who are in unplanned pregnancy, and pregnant mothers who have inadequate dietary diversity. Furthermore, food insecurity is very high in the study area, contributing to the high prevalence of under-nutrition among pregnant women. Thus, there is a thoughtful requirement to design and enhance the promotion of food security strategies based on Ethiopian national directives and WHO guidelines. Furthermore, there is a top requirement to educate communities with low literacy rates to circumvent the high prevalence of under-nutrition. Finally, creating small economic reforms for low-income communities with the help of rural agricultural extension workers should be considered.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. S2 file: Detail information of some methods and result section (DOCX); S1 file: English version study questionnaire (DOCX); S3 file: Stata data set.

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List of Abbreviations: AIC: Akaike information criteria; APR: Adjusted prevalence ratio; BIC: Bayesian information criteria; CI: confidence interval; CPR: Crude prevalence ratio; EDHS: Ethiopian Demographic and Health Survey; FANTA: Food and nutrition technical assistance; FAO: Food and agriculture organization; HCPS: HEW: Health extension worker; MPR: Median prevalence ratio; NGO: Non-governmental organization; PI: Principal Investigator; ICC: Intra-class correlation coefficient; IUGR: Intrauterine growth retardation; IRB: Institutional review board; SD: Standard deviation; WHO: World Health Organization; WRA: Women of reproductive age; VIF: Variance inflation factor.

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