Received: 9 December 2023 | Revised: 9 September 2024 | Accepted: 10 October 2024
DOI: 10.1111/mcn.13757

ORIGINAL ARTICLE

Maternal & Child Nutrition WILEY

Dietary diversity and nutrient adequacy among women in Bosomtwe District, Ghana

Charles Apprey[1] | Hammond Yaw Addae[1,2] | Grace Boateng[1] | Linda Esi Aduku[3] | Reginald Adjetey Annan[1]

[1]Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

[2]Nursing & Midwifery Training College, Kpembe, Ghana

[3]Grant and Research, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Correspondence
Hammond Yaw Addae, Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.
Email: Hamondd@yahoo.com

Abstract

The sustainable development goals seek to end all forms of malnutrition of women of reproductive age (WRA) by 2030. As such, recent data on nutrient adequacy are needed to aid in tracking progress. However, data on specific dietary nutrient intakes includes only iron, folate, vitamin A, and vitamin B_{12} in Ghana. Therefore, women's dietary diversity score (W-DDS) is often used as a proxy measure of nutrient adequacy. It is hypothesised that there is no association between W-DDS and Nutrient Adequacy among WRA in peri-urban Ghana. Hence, this research evaluated the associations between W-DDS and nutrient adequacy ratio (NAR) and assessed the determinants of mean nutrient adequacy ratio (MAR) in the Bosomtwe District of Ghana. A community-based cross-sectional study was conducted, and data collected on anthropometry, food insecurity, socio-demographic characteristics and dietary intake using the 24-hour recall from 407 WRA. In all, 21 nutrients were assessed. The mean age, W-DDS, and MAR were 29.0 ± 6.7 years, 5.3 ± 1.9, and 0.65 ± 0.19 respectively. The NAR were generally high for the macronutrients as compared to micronutrients and the nutrients with low NAR included vitamin C (0.27 ± 0.19), vitamin A (0.15 ± 0.23), vitamin B_{12} (0.54 ± 0.32), calcium (0.28 ± 0.20), zinc (0.52 ± 0.23) and iron (0.57 ± 0.28) - signifying the WRA may be consuming monotonous carbohydrate-based diet. The hierarchical multivariable linear regression found a significant association between W-DDS and MAR after controlling for confounders ($\beta = 0.404$, $p < 0.001$). The determinants of MAR were ethnicity ($\beta = 0.110$, $p = 0.006$) and body mass index ($\beta = 0.189$, $p < 0.001$). This study supports the use of W-DDS as a proxy indicator of nutrient adequacy. Strategies meant to address nutrient inadequacies should be adaptable to different ethnic groups and overweight-reducing strategies should be incorporated into broader nutrition initiatives.

KEYWORDS
body mass index, dietary diversity, dietary intake, Ghana, micronutrients, nutrients adequacy, women

1 | INTRODUCTION

In tandem with the sustainable development goals (SDGs), maternal nutrition remains important in safeguarding the health and well-being of future generations (World Health Organisation, 2015). Malnutrition remains an intractable public health challenge globally (Dukhi, 2020). Yet, unlike the more conspicuous macronutrient deficiencies, micronutrients are often obscured and only become apparent when very little can be done to remedy their ramifications. Such obscurity has stagnated progress in attaining nutrition SDG targets in most developing countries, including Ghana (Otekunrin et al., 2020; United Nations: Department of Economic and Social Affairs, 2022). Specifically, the SDGs target 2.2 seeks to end all forms of malnutrition and address the nutritional needs of adolescent girls and women by 2030 (World Health Organisation, 2015). As such, recent and accurate data are needed on nutrient adequacy to track progress if this target is to be achieved in Ghana. However, national data on the state of nutrient adequacy meant to provide dietary estimates include only iron, folate, vitamin A and vitamin B_{12} (Ghana Micronutrient Survey, 2017). This makes it challenging to estimate the prevalence of the other "lesser-known" yet equally important micronutrients. According to the Ghana Demographic Health Survey 2023, the prevalence of anaemia due to iron deficiency among women of reproductive age (WRA) (15–49 years) is still around 41% (Ghana Statistical Service, 2023). An estimated 82% of women in their reproductive age rely on iron and folic acid supplementation during pregnancy (Ghana Statistical Service, 2023). This high prevalence accentuates the need for periodic evaluation of nutrient adequacy of a lot more nutrients. Tracking a lot more nutrients may help reveal hidden nutrient deficiencies that might be affecting the population's health. This may enhance early detection and possible prevention of the occurrence of micronutrient deficiencies among women–as women are more vulnerable to these deficiencies (Liv Elin & Arimond, 2013). For WRA who have higher needs (per body weight) for some "lesser-known" nutrients, such as vitamin B_6 and selenium (Castillo-Duran, 2004), tracking and documenting these nutrient intake may provide a basis for well-targeted nutrition counselling and support. This is very relevant because the proportion of adequate intake of vitamin A, riboflavin, folate, thiamine, vitamin B_{12}, calcium and zinc had generally low estimates of 0.7%, 19%, 39.4%, 45.2%, 32%, 0.7% and 13.1% respectively, in a study among younger women in Ghana (Wiafe et al., 2023). Furthermore, when the determinants of nutrient adequacy are identified, it would help tackle the immediate causes of malnutrition, address disparities in nutrition outcomes and ensure efficient allocation of resources so nutrition interventions will target where their impact would likely be greatest.

Before WRA become pregnant, they need adequate stores of both macro and micronutrients in preparation for the physiological demands of foetal development and lactation (Williamson, 2006). Usually, the lack of diversified dietary intake due to low knowledge, low economic status, and malabsorption as a result of malaria and worm infestations, constrain the adequate consumption and utilisation of micronutrients (Ali et al., 2020; Shrestha et al., 2021). And hence makes women in developing countries susceptible to developing micronutrient deficiencies. In these settings with low dietary diversity (Islam, Nayan, et al., 2023), newborns are at an increased risk of low cognition, impaired linear growth, and some long-term negative outcomes such as low productivity among others. Populations that consume a diverse diet, on the other hand, are expected to have improved nutritional profiles and are more likely to have reduced maternal and child morbidity/mortality rates (Black et al., 2013; Huang et al., 2018).

Key messages

- This study estimates specific intakes of three macronutrients and 18 micronutrients among women of reproductive age (WRA) in a peri-urban locality, in Ghana.
- Nutrient adequacy ratio (NAR) values are lower for the micronutrients than macronutrients suggesting respondents may be consuming monotonous diets.
- NAR and mean adequacy ratio (MAR) were strongly correlated with dietary diversity, signifying the dietary diversity tool can be used as a proxy measure of nutrient adequacy among WRA.
- Strategies meant at addressing nutrient adequacies should be adaptable to different ethnic groups and women with increasing BMI as they were found to have lower MAR.

The sparse literature on nutrient adequacy in Ghana has led to the occasional use of dietary diversity scores as proxy measures of nutrient adequacy. Meanwhile, the very few studies on dietary diversity and nutrient adequacy in Ghana have centred on children under 5 years (Bandoh & Kenu, 2017; Nti, 2011), and pregnant women (Saaka, 2020) with a limited number of studies on non-pregnant WRA (Christian et al., 2022; Gernand et al., 2017). Although pregnant women are a subset of WRA, their physiology and nutrient requirements are not similar and hence incomparable. This necessitates research like this present study that centres on only nonpregnant WRA.

Despite the Women's Dietary Diversity Score (W-DDS) (FAO, & FHI 360, 2016) being a validated tool used for assessing the quality of dietary intake specifically in low-and-middle-income countries (LMICs), its association with nutrient adequacy ratio (NAR) among peri-urban women in Ghana remains unexplored. Additionally, there may be other socio-demographic and nutritional factors that could affect mean nutrient adequacy ratio (MAR). Hence, this research evaluated the proportion of WRA meeting specific nutrient requirements, it explored the associations between W-DDS and NAR and assessed the determinants of MAR among WRA in the Bosomtwe District of Ghana. It is envisaged that this research will fill this knowledge gap by shedding light on the dietary intakes and inadequacies among WRA in 11 communities in the Bosomtwe district of Ghana. This would serve as a basis on which future maternal nutrition intervention studies would rely.

2 | METHODS

2.1 | Study location and population

This cross-sectional community-based study was conducted in the Bosomtwe District of the Ashanti Region of Ghana and spanned from August 2020 to February 2021. Residents of 11 out of 66 communities in the district were included and these are Abono, Abuontem, Adwafo, Aputuogya, Esereso, Feyiase, Homobenase, Jachie, Sewua, Tetrefu, and Oyoko communities. The population of interest was WRA that is, nonpregnant women aged 15 to 49 years.

2.2 | Inclusion and exclusion criteria

This study was conducted among WRA and as such included only women aged 15–49 years (World Health Organiation, 2006). Additionally, only women who were permanent residents of the Bosomtwe district were included. If any woman was participating in a nutrition intervention, pregnant or lactating, or had a chronic illness such as HIV or cancer, they were excluded from this study - as these could significantly alter their dietary intake. Women who were unable to provide consent or requested to withdraw after consent was given, were also excluded.

2.3 | Sampling and sample size

This group of women were part of a training programme by the World Food Programme in the district and a representative sample was recruited to be part of this study. A multi-stage probability sampling procedure was used to select eligible women for this study. The sampling frame used was an updated frame from the Ghana Statistical Service 2010 housing and population census for the district (Ghana Statistical Service, 2013). First, 11 communities were selected from the 66 communities in the district using the lottery method. The noninclusion of all communities in the study was due to their homogeneous socio-demographic, economic and dietary characteristics (Bosomtwe District Assembly, 2018). For the second phase, the number of women to be recruited in each community was determined. Here, the minimum sample size was distributed among the 11 communities on a proportion-to-population size basis. Listing of households and updating of maps was conducted to compile a register of all eligible women in the communities similar to the Ghana demographic health survey (Ghana Statistical Service, 2023). Respondents were then selected by systematic random sampling from the compiled household registers. The sample interval was estimated by dividing the projected WRA population in the community by its corresponding sample size. During this selection process, a random number from 1 to the sample interval (say 10) was chosen using the lottery method. Subsequently, every 10th woman from that number on the compiled household list was contacted to be interviewed until the estimated sample size for that community was met; the next person on the register replaced any woman who did not meet the inclusion criteria, declined participation or requested a withdrawal. The sample size was determined based on the Cochrane (Cochran, 1977) formula as below;

$$n = \frac{Z^2 * p(1-p)}{E^2},$$

where p is the prevalence of dietary diversity among WRA in Ghana set at a maximum assumption of 50%, Z is 1.96, the standard normal deviation for a confidence level of 95% and E is the margin of error = 5% or 0.05. Hence the minimum sample size for this study was 385. Under these conditions, the 50% assumption is the assumption of maximum probability where the exact variability of the variable of interest cannot readily be ascertained (Eng, 2003).

2.4 | Data collection

Twenty WRA from a non-included community were first selected for questionnaire pre-testing to minimise error and further enhance data collector familiarity. The trained data collectors administered questionnaires to women face-to-face in the selected communities at home. Consent was explained to all eligible women in their preferred language and only when consent was given that questionnaires were administered. For respondents below 18 years, consent was sought from their parent(s) or guardian(s). The 24-hour recall method was used to obtain information about women's nutrient intake. Participants were asked to recall all foods, including drinks that they ate in the past 24 hour, at night and day and also outside and at home. Additionally, they were asked to provide approximate handy measures of meals and drinks that were eaten. Such measurements were based on the University of Ghana handy measurement and the Nutrient Analysis template (Ghana University of Ghana, 2010). The 'Nutrient analysis template' is a pre-designed Microsoft Excel-based software by the University of Ghana for the purposes of evaluating specific nutrients contained in foods consumed in Ghana using portion sizes. However, estimating portion sizes is challenging and a major source of error in dietary assessment (Subar et al., 2015; Walton, 2015). Therefore, the University of Ghana used locally-known handy measures such as 'milk container', 'margarine container' or 'coke bottle' as aids in standardising portion sizes of foods and converting their respective quantities into standard units (e.g., grams or millilitres). The quantities of food are then linked to a comprehensive food composition database that includes an extensive list of foods eaten in Ghana, so the nutrient content per portion can be estimated. For each recalled food item, the template multiplies the amount consumed by the nutrient content per gram or mL to estimate the specific quantities consumed. The nutrient intake from all the food items in the past 24 h were summed up to get the total nutrient intake for all the nutrients per participant. As such, once a participant reports to have eaten some food and the food is entered into the template together with its handy measures, the template produces the quantities of all nutrients consumed by the participant. This is the method used to estimate the specific quantities of macro and micronutrient content of the foods eaten by all participants. The calculated nutrients include carbohydrates, protein, fats, calcium, iron, zinc, vitamin C, vitamin A, magnesium, phosphorous, copper, manganese, selenium, thiamine, riboflavin, niacin, pantothenic acid, vitamin B_6, folate, vitamin B_{12} and vitamin E.

2.5 | Independent variable

2.5.1 | Assessment of W-DDS

Dietary diversity was determined based on the low-to-middle-income country validated minimum dietary diversity for women guidelines (FAO & FHI 360, 2016). Food consumed over the past 24 h was assessed based on the 10-food group categorisation; (1) grains, white roots and tubers, and plantains, (2) beans, peas and lentils, (3) nuts and seeds (4) milk and milk products (5) meat, poultry and fish, (6) eggs, (7) dark green leafy vegetables (8) other vitamin A rich fruits and vegetables, (9) other vegetables and (10) other fruits. The women were asked if they ate from these 10 groups within the past 24 h. There was no minimum amount for a food item to be included. Women were assigned zero if they did not consume any food group, or one if they did consume at least one of the listed foods. Summing up the 10 groups gave us a dietary diversity score scale ranging from 0 to 10. Per the stipulations of the FAO & FHI guidelines (FAO & FHI 360, 2016), women who consumed five or more food groups were deemed to have adequate dietary diversity.

2.6 | Dependent variable

2.6.1 | Assessment of nutrient adequacy

To evaluate the nutrient adequacy of diets consumed by women, the dietary nutrient intake of each nutrient was compared with the WHO gender and age-specific recommended daily allowance values (WHO/FAO, 2004). The NAR was calculated as suggested by the International Dietary Data Expansion Project (INNDEX Project, 2018). Such that NAR for each nutrient is derived when actual nutrient intake is divided by the WHO-recommended RDAs.

$$NAR = \frac{Actual\ nutrient\ intake\ by\ woman}{Woman's\ RDA\ for\ that\ nutrient}.$$

Similar to previous studies (Islam, Jubayer, et al., 2023; Saaka, 2020), the MAR of WRA was calculated by adding the truncated NAR values and dividing by the number of nutrients in the study. The truncation of NAR at one was necessary to prevent masking the deficiency of a nutrient with a low NAR value (closer to 0) by another nutrient with an NAR value above one (INNDEX Project, 2018). The intention is to have MAR values where the least and highest value for nutrient adequacy were reported on a scale of zero to one. With zero signifying no nutrient adequacy was met and one meaning all nutrient adequacies were met.

$$\text{MAR} = \frac{\sum NAR\ (truncated\ to\ zero\ or\ 1)}{number\ of\ nutrients}.$$

The value of NAR for a specific nutrient ranging from 0 to 0.66 was considered as inadequate nutrient intake while from 0.67 to 1 was considered adequate intake (Gupta, 2017; Saaka, 2020). Meanwhile, the MAR was the overall indicator of nutrient adequacy for each woman.

2.7 | Covariates

2.7.1 | Socio-demographic characteristics

The socio-demographic information of the women included age, educational level, occupation, marital status, religion, parity and ethnicity. Ethnicity was categorised as Ashanti, Fante, Mole-Dagbani, or others.

2.7.2 | Body mass index

The SECA weight electronic weighing scale and the adult Microtoise were used to measure weight and height to the nearest 0.1 kg and 0.1 cm respectively. Anthropometric measurements were conducted according to the established procedures (Center for Disease Control, 2007). Duplicate measurements of weight and height were averaged to reduce random instrumental error. The Body Mass Index (BMI) was used to define the overweight/obesity status of women. BMI was obtained by dividing the weight (kg) by the height (m) squared. Women with BMI $<25\ kg/m^2$ were classified as not overweight and those with BMI $\geq 25\ kg/m^2$ were classified as overweight or obese.

2.7.3 | Household food insecurity

The Food Insecurity Experience Scale (FIES) (Ballard et al., 2013) was used to evaluate the food insecurity of households of respondents. The indicator is made up of 8 yes or no questions spanning mild food insecurity in question 1 to severe food insecurity in question 8. Answering yes to any of the questions received a score of one and a score of zero for no. Summing up the score gave a scale ranging from 0 to 8. Similar to a previous study (Azupogo et al., 2023), the FIES was classified as a dichotomous variable with 0–2 indicating food security and ≥3 indicating food insecurity.

2.7.4 | Household poverty

The Lived Poverty Index (LPI) (Dulani et al., 2013) was used to assess household poverty levels. It is a five-level tool comprising of access to 'enough food to eat', 'enough water for home use', 'medicines and medical treatment', 'fuel to cook food' and 'enough cash income'. Respondents provided responses ranging from 0 to 4 for each item on the tool. The average of these scores was computed to attain a composite poverty score for each respondent.

2.7.5 | Food prices

This variable was measured by asking respondents 'How are food prices today (date data was being collected) compared with when food was in abundance?' This variable elicited a dichotomous response that is, low or high.

2.8 | Statistical analysis

The Statistical Package for Social Scientists (SPSS Version 22) was used for statistical analysis of data. Some questionnaires had missing values that were 'Missing Completely at Random' and were excluded from the analysis to reduce bias and ensure the validity of the data set (Mack et al., 2008). For background characteristics, variables were presented using frequencies, percentages, means and standard deviation. The relationships between dietary diversity and NAR of all nutrients were assessed using the Pearson's *r* correlation coefficient. Dichotomised nutrient adequacy of each nutrient and minimum dietary diversity were analysed using Chi-square analysis. The covariates were identified from the literature and those with significant level below 0.25 in our data (Hosmer & Lemeshow, 2004) were added to the multivariable analysis. Ashanti group was made the reference category in the multivariable analysis. The multivariable analysis involved using multiple linear regression to evaluate the determinants of MAR. Three hierarchical models were evaluated, controlling for demographic, health and household variables. The main exposure variable (W-DDS) was included as the only independent variable in model 1. The second model included demographic variables such as education and ethnicity. Model 3 adjusted for women's health and household factors such as BMI, fever, cough, LPI and food prices. Before conducting these regression analyses, several assumptions were tested to ensure the reliability of the model. These assumptions include normality of residuals, homoscedasticity, independence, linearity and absence of multicollinearity. The normality of variables was assessed using Kolmogorov–Smirnov and Shapiro–Wilk test as well as visual inspection of Q-Q plots of the residuals. The absence of heteroscedasticity was confirmed by the Breusch-Pagan test. The Durbin-Watson test was used to measure autocorrelation and to ascertain the independence of the residuals. Linearity was assessed by visually inspecting the scatter plots of predictors (continuous variables) and the MAR. Multicollinearity between the independent variables was assessed using the variance inflation factor (VIF) and tolerance. A VIF greater than two signified the presence of multicollinearity. Throughout this study, $p < 0.05$ at 95% confidence level were deemed statistically significant.

2.9 | Ethics statement

The committee on Human Research, Publications, and Ethics of the Kwame Nkrumah University of Science and Technology, School of Medical Science and Komfo Anokye Teaching Hospital in Kumasi, Ghana, evaluated and approved the study protocol (Reference: CHRPR/AP/231/20). To notify women who took part in the study, a participant information booklet was distributed to them. Participants were also given a thorough explanation of the study in their preferred native language. Women who were participating in the study provided signatures or thumbprints to signify consent. Code numbers were assigned to the participants from whom data was collected. This report did not include any names or personally identifiable indicators, and no publications resulting from the study will do so.

3 | RESULTS

3.1 | Background characteristics

The data of 417 WRA were entered in SPSS and after excluding incomplete questionnaires, the results of 407 WRA were analysed, and their background characteristics are presented in Table 1. The mean age (years) of WRA was 29.0 ± 6.7. About three-fifths (58.4%) of WRA had at least a Junior High School education and 5.4% had no education. Nearly 6 in 10 (58.5%) women did not experience any form of poverty with a mean LPI of 0.45 ± 0.71. Majority (78.1%) were Ashantis, about 9 in 10 (86.7%) belonged to the Christian religion and 63.4% were married. With respect to nutrition, 70% of the women were overweight or obese, 35.9% were food insecure and 32.7% did not meet the minimum dietary diversity score. The respective proportion of food consumption had grains, roots and tubers, and plantains group being the highest (98.4%) and milk and milk products group being the least (20.9%) consumed food group (Supporting Information S1: Figure S1).

3.2 | Recommended daily allowance and nutrient adequacy ratio of women

In all, the mean intakes and NAR of the 21 nutrients were compared to their respective RDA and the results are presented in Table 2. The mean carbohydrate consumption was 270.2 ± 136.0 g, twice as much as its RDA of 130 g. About nine in ten women met the adequate NAR for carbohydrate. The mean intakes of protein, fats and oil, calcium, iron, vitamin C, vitamin A, vitamin B_{12} and folate were 54.3 ± 30.0 g, 49.3 ± 28.9 g, 285.4 ± 205.6 mg, 11.9 ± 6.4 mg, 12.5 ± 11.0 mg, 84.8 ± 167.1 µg, 1.6 ± 1.4 µg and 337.0 ± 150.5 µg respectively. About 67% (2 out of 3) of the macronutrients had mean intakes higher than their RDAs and 72% (13 out of 18) of the micronutrients had mean intakes lower than their respective RDAs. The nutrients with the lowest proportion of population meeting the nutrient adequacy ratio are vitamin C (5.4%), calcium (6.4%), zinc (27.7%), iron (38.5%), vitamin A (6.9%), pantothenic acid (5.7%), vitamin B_{12}

TABLE 1 Background characteristics of women of reproductive age ($n = 407$).

Variable	Frequency (%)/Mean ± SD
Age in years	
Under 25	104 (25.3)
25–34	214 (52.1)
35+	93 (22.6)
Mean age (years)	29.0 ± 6.7
Education	
No education	22 (5.4)
Primary	52 (12.7)
Junior High School	240 (58.4)
At least Senior High School	97 (23.6)
Occupation	
Agricultural activities	77 (18.7)
Artisan	85 (20.7)
Professional	26 (6.3)
Trader	191 (46.5)
Others[†]	32 (7.8)
Lived poverty index	
No poverty	238 (58.5)
Experienced some poverty	169 (41.5)
Mean lived poverty index score	0.45 ± 0.71
Ethnicity	
Ashanti	318 (78.1)
Fante	26 (6.4)
Mole-Dagbani	33 (8.1)
Others[‡]	30 (7.4)
Religion	
African Traditional Religion	37 (9.1)
Christian	353 (86.7)
Muslem	17 (4.2)
Marital status	
Married	258 (63.4)
Not married	149 (36.6)
Food Insecurity	
Food secured (0–2)	261 (64.1)
Food insecure (3–8)	146 (35.9)
Mean food insecurity score	1.9 ± 2.3
Body Mass Index (BMI)	
Not Overweight (BMI <25 kg/m^2)	122 (30.0)
Overweight/Obese (BMI ≥25 kg/m^2)	285 (70.0)
Mean BMI	27.6 ± 4.8

TABLE 1 (Continued)

Variable	Frequency (%)/Mean ± SD
Women Dietary Diversity Score (W-DDS)	
Inadequate (<5 groups)	133 (32.7)
Adequate (≥5 groups)	274 (67.3)
Mean W-DDS	5.3 ± 1.9
Food prices	
Low	162 (39.8)
High	245 (60.2)
Household size	4.01 ± 2.11
Alcohol	
No	65 (16.0)
Yes	342 (84.0)
Fever	
No	32 (7.9)
Yes	375 (92.1)
Cough	
No	66 (16.2)
Yes	341 (83.8)
Health Insurance	
No	33 (8.1)
Yes	374 (91.9)
Parity	1.42 ± 1.47

[†]Others = Pastor, Volunteer and Miners.

[‡]Others = Akyem, Akuapem, Ewe, Kwahu, Bono, Nzema and Wangara.

(18.4%) and vitamin E (47.6%). The MAR of all women was calculated to be 0.65 ± 0.19.

3.3 | Women dietary diversity score and nutrient adequacy ratio among WRA

The NAR of all the nutrients were significantly positively correlated with dietary diversity score except for carbohydrates and folate. The minerals and B vitamins had approximately similar correlation coefficients–they mostly round up to 0.4. The MAR was also positively significantly correlated ($r = 0.44$, $p < 0.001$) with dietary diversity (Table 3).

3.4 | The association between dietary diversity and nutrient adequacy ratio

All micronutrients had significant associations with dietary diversity except pantothenic acid, folate and vitamin C. Contrastingly,

TABLE 2 Proportion of WRA meeting the recommended daily allowance and nutrient adequacy ratio.

Nutrient	Mean intake ± SD	RDA†	Mean ± SD NAR	Number (%) of WRA meeting RDA	Number (%) of WRA meeting NAR
Carbohydrate (g)	270.2 ± 136.0	130	0.94 ± 0.18	330 (81.1)	372 (91.4)
Protein (g)	54.3 ± 30.0	46	0.81 ± 0.29	244 (60.0)	304 (74.7)
Fats (g)	49.3 ± 28.9	50	0.77 ± 0.30	177 (43.5)	274 (67.3)
Calcium (mg)	285.4 ± 205.6	1000	0.28 ± 0.20	2 (0.5)	26 (6.4)
Iron (mg)	11.9 ± 6.4	20	0.57 ± 0.28	41 (10.1)	157 (38.5)
Zinc (mg)	2.6 ± 1.4	4.9	0.52 ± 0.23	19 (4.7)	113 (27.7)
Vitamin C (mg)	12.5 ± 11.0	45	0.27 ± 0.19	9 (2.2)	22 (5.4)
Vitamin A (µg)	84.8 ± 167.1	500	0.15 ± 0.23	12 (2.9)	28 (6.9)
Magnesium (mg)	294.9 ± 141.4	220	0.88 ± 0.24	290 (71.3)	343 (84.2)
Phosphorous (mg)	914.7 ± 454.1	700	0.87 ± 0.25	279 (68.6)	338 (83.0)
Copper (mg)	3.5 ± 1.7	0.9	0.97 ± 0.11	377 (92.6)	392 (96.3)
Manganese (mg)	156.3 ± 95.6	310	0.49 ± 0.29	27 (6.6)	123 (30.2)
Selenium (µg)	21.0 ± 9.6	26	0.74 ± 0.24	79 (19.4)	298 (73.2)
Thiamine (mg)	0.87 ± 0.60	1.1	0.67 ± 0.31	117 (28.7)	222 (54.5)
Riboflavin (mg)	1.5 ± 0.91	1.1	0.84 ± 0.27	267 (65.6)	315 (77.3)
Niacin (mg)	9.7 ± 4.6	14	0.66 ± 0.28	68 (16.7)	220 (54.0)
Pantothenic (mg)	1.8 ± 0.99	5	0.36 ± 0.19	6 (1.5)	23 (5.7)
Vitamin B6 (mg)	2.8 ± 1.8	1.3	0.88 ± 0.24	286 (70.3)	350 (85.9)
Folate (µg)	337.0 ± 150.5	400	0.77 ± 0.23	81 (19.9)	303 (74.4)
Vitamin B_{12} (µg)	1.6 ± 1.4	2.4	0.54 ± 0.32	75 (18.4)	151 (37.1)
Vitamin E (mg)	5.3 ± 2.4	7.5	0.67 ± 0.23	69 (17.0)	194 (47.6)
Mean adequacy ratio of nutrients	0.65 ± 0.19				

Abbreviations: NAR, nutrient adequacy ratio; RDA, recommended daily allowance; WRA, women of reproductive age.
†(WHO/FAO, 2004).

carbohydrates ($\chi2 = 1.8$, $p = 0.179$) and Fats and oil ($\chi2 = 0.33$, $p = 0.567$) did not have significant associations. Results of categorical NAR and W-DDS are shown in Table 4.

3.5 | Determinants of nutrient adequacy among women of reproductive age

The final multivariable linear regression model is shown in Table 5. The analyses indicate that belonging to the Ashanti ethnic group is associated with 0.11 standard units higher MAR ($\beta = 0.107$, $p = 0.013$) relative to not being Ashanti. A unit increase in BMI is associated with 0.19 standard units higher MAR ($\beta = 0.186$, $p < 0.001$) among women. Similarly, women with adequate dietary diversity are associated with 0.40 standard unit higher MAR ($\beta = 0.404$, $p < 0.001$) as compared with women with inadequate dietary diversity.

4 | DISCUSSION

This study evaluated the proportion of WRA meeting the nutrient requirements of 21 nutrients. It evaluated the association between W-DDS and NAR and assessed the determinants of MAR among 407 women in 11 communities in the Bosomtwe district of Ghana. This study found that two-thirds of women met the W-DDS, and MAR was found to be a little higher than in some studies with similar demographics (Islam, Nayan, et al., 2023; Oldewage-Theron & Kruger, 2011). The NAR were generally high for the macronutrients as compared to the micronutrients. For instance, the nutrients with the lowest proportion of population meeting the nutrient adequacy ratio were vitamin C, calcium, zinc, iron, vitamin A, pantothenic acid, vitamin B_{12} and vitamin E. Additionally, majority of the micronutrients were significantly associated with dietary diversity, unlike the macronutrients. The determinants of MAR included dietary diversity score, ethnicity and BMI. These findings are similar to

TABLE 3 Correlations between women dietary diversity score, nutrient adequacy ratio, and mean adequacy ratio.

Nutrient/Mean Adequacy Ratio	Pearson's (*r*) correlation coefficient	*p* value
Carbohydrate	0.135	$p = 0.07$
Protein	0.357	$p < 0.001$
Fats	0.347	$p < 0.001$
Calcium	0.237	$p < 0.001$
Iron	0.364	$p < 0.001$
Zinc	0.332	$p < 0.001$
Vitamin C	0.231	$p < 0.001$
Vitamin A	0.120	$p < 0.001$
Magnesium	0.309	$p < 0.001$
Phosphorous	0.313	$p < 0.001$
Copper	0.347	$p < 0.001$
Manganese	0.295	$p < 0.001$
Selenium	0.310	$p < 0.001$
Thiamine	0.243	$p < 0.001$
Riboflavin	0.331	$p < 0.001$
Niacin	0.354	$p < 0.001$
Pantothenic	0.313	$p < 0.001$
Vitamin B_6	0.313	$p < 0.001$
Folate	0.111	$p = 0.06$
Vitamin B_{12}	0.232	$p < 0.001$
Vitamin E	0.222	$p < 0.001$
Mean adequacy ratio	0.442	$p < 0.001$

another study among reproductive-aged women in Bangladesh (Islam, Nayan, et al., 2023). Most women not meeting the RDAs for relevant micronutrients might indicate the consumption of less diversified diets. The consumption of less diversified diets containing low micronutrients could be due to seasonality resulting in occasional high costs of fruits and vegetables (Doku et al., 2013). Given the relevance of fruits and vegetables in reproduction and immune function (Gombart et al., 2021), it is important to implement interventions that would make fruits and vegetables readily available throughout the year. Aside from the extensively documented antioxidative properties of vitamin C (Bendich & Langseth, 1995; Chauhan et al., 2020; Julia et al., 2020), adequate intake of vitamin C is known to aid iron metabolism/absorption in haemoglobin formation (Lane & Richardson, 2014). However, dietary calcium intake is also associated with a reduced risk of pre-eclampsia among pregnant women (Hofmeyr et al., 2007). The low nutrient adequacy ratio of vitamin C, vitamin B_{12} and iron could partly explain the reported high prevalence of anaemia among similar women in other peri-urban communities in Ghana (Agbemafle et al., 2016). As inadequate micronutrient intake has been found to be a risk factor that predisposes women to a host of diseases due to several factors including a weakened immune system (Gombart et al., 2021). The low intake of these important vitamins and minerals brings to fore the relevance of promoting the consumption of fruits and vegetables as well as milk products among women. Such low micronutrient intake, specifically iron, vitamin B_{12} and folate intake could also predispose offspring to being born low birth weight or stillbirth (Smith et al., 2017; Villalpando, 2008). On the contrary, protein and some micronutrients such as magnesium, riboflavin, vitamin B_6 and phosphorous were found to have higher NAR as compared to women with similar characteristics elsewhere (Oldewage-Theron & Kruger, 2011). This may be because of the availability of a river nearby i.e. Lake Bosomtwe, where inhabitants fish for household consumption.

The very wide differences in nutrient adequacy between micronutrients and macronutrients may suggest the consumption of monotonous diets. This finding adds empirical evidence that the diets of women in some LMICs may be carbohydrate-based and lack adequate amounts of micronutrients as found by other studies (Trijsburg et al., 2019).

With regard to the relationship between NAR, MAR and dietary diversity, the correlation analysis revealed that dietary diversity was positively significantly associated with the NAR of all 21 nutrients except carbohydrate and folate. However, the Chi-square analysis found that majority of the micronutrients were significantly associated with dietary diversity, unlike the macronutrients. Such an outcome is corroborated by a systematic review involving 50 articles (Verger et al., 2021) and other studies (Gómez et al., 2020; Verger et al., 2021). This may be due to the W-DDS's sensitivity towards only micronutrients as intended by its developers (FAO, & FHI 360, 2016) and not a true lack of association with macronutrients. W-DDS also correlated positively and significantly with MAR. This may support the potential use of W-DDS as a proxy indicator of nutrient adequacy (Verger et al., 2021).

The determinant with the highest effect size was the dietary diversity score. This could imply that micronutrient deficiency which is typically characteristic of low MAR may require multiple micronutrient consumption approaches. This may include consuming a variety of diets to ensure adequate nutrient intake. In the Ghanaian dietary landscape, there are some nutrition projects that are targeted at reducing micronutrient deficiencies. However, these projects are usually carried out in an unharmonized approach (Aryeetey & Coomson, 2022). Such that despite the weekly supplementation of Folic acid and Iron among some adolescent girls and women in Ghana (Ghana Health Service, 2017), among other projects, the prevalence of anaemia is still very high. Therefore, a synergistic and comprehensive strategy that co-ordinates all these unharmonized projects may be needed to reduce anaemia and other micronutrient deficiencies. Other programmes such as wheat flour fortification with zinc, iron and the B vitamins including the fortification of vegetable oil with vitamin A, have been passed into law. Although such programmes hold promise in reducing micronutrient deficiencies, they

TABLE 4 The association between women minimum dietary diversity and nutrient adequacy.

Nutrient adequacy ratio (NAR)	Total	Women dietary diversity score Inadequate (<5 groups)	Adequate (≥5 groups)	Chi-square, *p* value
Carbohydrate				$\chi^2 = 1.8$, $p = 0.179$
No	35	15	20	
Yes	372	118	254	
Protein				$\chi^2 = 4.1$, $p = 0.043$
No	103	42	61	
Yes	304	91	213	
Fats and oil				$\chi^2 = 0.33$, $p = 0.567$
No	133	46	87	
Yes	274	87	187	
Calcium				$\chi^2 = 2.3$, $p < 0.139$
No	381	128	253	
Yes	26	5	21	
Iron				$\chi^2 = 27.8$, $p < 0.001$
No	250	106	144	
Yes	157	27	130	
Zinc				$\chi^2 = 14.1$, $p < 0.001$
No	294	112	182	
Yes	113	21	92	
Vitamin C				$\chi^2 = 3.8$, $p = 0.05$
No	385	130	255	
Yes	22	3	19	
Vitamin A				$\chi^2 = 11.6$, $p < 0.001$
No	379	132	247	
Yes	28	1	27	
Magnesium				$\chi^2 = 48.9$, $p < 0.001$
No	64	45	19	
Yes	343	88	255	
Phosphorous				$\chi^2 = 55.5$, $p < 0.001$
No	69	49	20	
Yes	338	84	254	
Manganese				$\chi^2 = 5.5$, $p = 0.019$
No	284	103	181	
Yes	123	30	93	
Selenium				$\chi^2 = 31.1$, $p < 0.001$
No	109	59	50	
Yes	298	74	224	
Thiamine				$\chi^2 = 22.9$, $p < 0.001$
No	185	83	102	
Yes	222	50	172	

(Continues)

TABLE 4 (Continued)

Nutrient adequacy ratio (NAR)	Total	Women dietary diversity score Inadequate (<5 groups)	Adequate (≥5 groups)	Chi-square, *p* value
Riboflavin				$\chi^2 = 46.3$, p < 0.001
No	92	57	35	
Yes	315	76	239	
Niacin				$\chi^2 = 34.9$, p < 0.001
No	187	89	98	
Yes	220	44	176	
Pantothenic				$\chi^2 = 2.6$, $p = 0.108$
No	384	129	255	
Yes	23	4	19	
Vitamin B_6				$\chi^2 = 64.5$, p < 0.001
No	57	45	12	
Yes	350	88	262	
Folate				$\chi^2 = 1.5$, $p = 0.224$
No	104	39	65	
Yes	303	94	209	
Vitamin B_{12}				$\chi^2 = 12.8$, p < 0.001
No	256	100	156	
Yes	151	33	118	
Vitamin E				$\chi^2 = 22.5$, p < 0.001
No	213	92	121	
Yes	194	41	153	

Note: NAR from 0 to 0.66 = No (inadequate intake); NAR from 0.67 to 1 = Yes (adequate intake) (Gupta, 2017; Saaka, 2020).

TABLE 5 Determinants of nutrient adequacy among Women of reproductive age.

Model	Standardised coefficients Beta	*t*	Sig.	95.0% Confidence interval for B Lower bound	Upper bound	Collinearity statistics Tolerance	VIF
(Constant)		1.733	0.084	−0.015	0.232		
Dietary diversity score	0.404	9.338	<0.001	0.031	0.048	0.970	1.031
Education	0.047	1.086	0.278	−0.010	0.033	0.990	1.011
Ethnicity (Ashanti)	0.107	2.482	0.013	0.010	0.088	0.986	1.015
Parity	−0.076	−1.761	0.079	−0.021	0.001	0.986	1.015
Women BMI	0.186	4.246	<0.001	0.004	0.011	0.957	1.044
Cough	0.082	1.904	0.058	−0.002	0.094	0.992	1.008
Fever	0.056	1.285	0.200	−0.022	0.106	0.967	1.035
Lived poverty score	0.082	1.883	0.060	0.000	0.010	0.972	1.028
Food price	0.067	1.554	0.121	−0.007	0.059	0.977	1.024

Note: Model fit statistics: adjusted $R^2 = 0.258$; F-test = 16.68; $p < 0.001$.

Abbreviations: BMI, Body Mass Index; VIF, variance inflation factor.

are still saddled with organoleptic challenges and therefore not universally adopted in Ghana (Ghana Micronutrient Survey, 2017). Additionally, behaviour change communication strategies which aim to improve green leafy vegetables produce-and-consume initiatives, and storage of fruits and vegetables for out-of-season consumption may help improve nutrient inadequacies of WRA. Such an approach may help provide the needed micronutrients while helping overweight women lose weight. In this study, the majority Ashanti ethnic group is associated with an increased likelihood of having a higher MAR as compared to other ethnic groups. This finding highlights the relevance of being sensitive to the food choices and cultural habits of ethnic minorities in implementing nutrition interventions intended at enhancing dietary adequacy.

The adjusted R^2 statistic explains the proportion of the outcome variable that is accounted for by the independent variables. This R^2 value in this study was 25.8%, which implies there may be other residual factors that this study may not have accounted for. Causal inferences could not be established owing to the cross-sectional study design. Measures being subjects of recall bias cannot be ruled out completely, due to the type of dietary recall used. The 24-h recall may not be an accurate reflection of usual dietary intake. However, 24-h dietary recall remains a widely used and accepted method for dietary intake estimation in cross-sectional studies. These challenges notwithstanding, this study is one of the nutrient adequacy studies with the highest number of nutrients analysed; three macro and 18 micronutrients were assessed. The large sample size and robust statistical analysis are additional strengths of this study.

5 | CONCLUSION

The dietary intake of vitamin C, calcium, zinc, iron, vitamin A, pantothenic acid, vitamin B_{12} and vitamin E were below average of their recommended intake. The dietary diversity was significantly associated with the NAR of almost all micronutrients and total MAR. The determinants of MAR were dietary diversity, BMI and ethnicity of women of reproductive age. As such, strategies meant to address nutrient adequacies among WRA should be adaptable to different ethnic groups and overweight-related factors should be incorporated into broader nutrition initiatives.

AUTHOR CONTRIBUTIONS

Charles Apprey, Grace Boateng, and Reginald Adjetey Annan conceived this research, Charles Apprey, Hammond Yaw Addae, Grace Boateng, Linda Esi Aduku and Reginald Adjetey Annan designed and contributed to data acquisition, analysis and interpretation of data. Charles Apprey, Hammond Yaw Addae, Grace Boateng, and RAA drafted the manuscript and Charles Apprey, Hammond Yaw Addae, Grace Boateng, and Reginald Adjetey Annan critically revised the manuscript for intellectual content and coherence. All authors approved the final version of the manuscript to be published and take full responsibility for the content of the manuscript.

ACKNOWLEDGEMENTS

We are grateful to the women for their patience and time in responding to our questionnaires. The authors received no specific funding.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Hammond Yaw Addae https://orcid.org/0000-0002-0174-6862

REFERENCES

Agbemafle, I., Steiner-Asiedu, M., Saalia, F., Setorglo, J., Chen, J., & Philips, R. (2016). Anaemia prevalence and nutrient intake among women in peri-urban settlements in Accra, Ghana. *African Journal of Food Agriculture Nutrition and Development*, *16*(4), 11152–11167. https://doi.org/10.18697/ajfand.76.15550

Ali, S. A., Abbasi, Z., Shahid, B., Moin, G., Hambidge, K. M., Krebs, N. F., Westcott, J. E., McClure, E. M., Goldenberg, R. L., & Saleem, S. (2020). Prevalence and determinants of anemia among women of reproductive age in Thatta Pakistan: Findings from a cross-sectional study. *PLoS One*, *15*(9 September), 0239320. https://doi.org/10.1371/journal.pone.0239320

Aryeetey, R., & Coomson, J. (2022). A rapid review of key policies and programs linked with. *The African Journal of Food, Agriculture, Nutrition and Development*, *22*(2), 19727–19777. https://doi.org/10.18697/ajfand.107.21825

Azupogo, F., Saeed, N., Wemakor, A., Addae, H. Y., Boah, M., & Brouwer, I. D. (2023). Moderate-to-severe household food insecurity is associated with depression among adolescent girls in Northern Ghana: A cross-sectional analysis. *BMJ Nutrition, Prevention & Health*, *6*(1), 56–64. https://doi.org/10.1136/bmjnph-2022-000523

Ballard, T., Kepple, A., & Cafiero, C. (2013). The food insecurity experience scale: Developing a global standard for monitoring hunger worldwide. *Technical Paper*, 1(Issue October), 1. https://www.fao.org/fileadmin/templates/ess/voh/FIES_Technical_Paper_v1.1.pdf

Bandoh, D. A., & Kenu, E. (2017). Dietary diversity and nutritional adequacy of under-fives in a fishing community in the central region of Ghana. *BMC Nutrition*, *3*(1), 2. https://doi.org/10.1186/s40795-016-0120-4

Bendich, A., & Langseth, L. (1995). The health effects of vitamin C supplementation: A review. *Journal of the American College of Nutrition*, *14*(2), 124–136. https://doi.org/10.1080/07315724.1995.10718484

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., Ezzati, M., Grantham-Mcgregor, S., Katz, J., Martorell, R., & Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, *382*(9890), 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Bosomtwe District Assembly. (2018). *Bosomtwe District Profile* (Issue January). http://bosomtwe.gov.gh/sites/default/files/2020-04/District

Castillo-Duran, C. (2004). Micronutrient deficiencies during the weaning period and the first years of life. In J. M. Pettifor, & S. Zlotkin (Eds.), *Epidemiology of micronutrient deficiencies in developing and developed* *countries, specifically zinc, copper, selenium and iodine*. Nestlé Nutrition. https://doi.org/10.1159/000080438

Center for Disease Control. (2007). Anthropometry procedures manual. *National Health and Nutrition Examinatory Survey (NHANES)*, 102. https://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf%0Ahttp://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf

Chauhan, M., Garg, V., Zia, G., & Dutt, R. (2020). Potential role of phytochemicals of fruits and vegetables in human diet. *Cancer*, *7*(2).

Christian, A. K., Steiner-Asiedu, M., Bentil, H. J., Rohner, F., Wegmüller, R., Petry, N., Wirth, J. P., Donkor, W. E. S., Amoaful, E. F., & Adu-Afarwuah, S. (2022). Co-occurrence of overweight/obesity, anemia and micronutrient deficiencies among non-pregnant women of reproductive age in Ghana: Results from a Nationally Representative Survey. *Nutrients*, *14*(7), 1427. https://doi.org/10.3390/nu14071427

Cochran, W. G. (1977). Sampling Techniques third edition. *John Wiley & Sons*, 87–96. https://hwbdocuments.env.nm.gov/Los

Doku, D., Koivusilta, L., Raisamo, S., & Rimpelä, A. (2013). Socio-economic differences in adolescents' breakfast eating, fruit and vegetable consumption and physical activity in Ghana. *Public Health Nutrition*, *16*(5), 864–872. https://doi.org/10.1017/S136898001100276X

Dukhi, N. (2020). Global prevalence of malnutrition: Evidence from literature. *Malnutrition*, *1*, 1–16.

Dulani, B., Mattes, R., & Logan, C. (2013). After a decade of growth in Africa, little change in poverty at the grassroots. *Afrobarometer Policy Brief*, *2001*(1), 22. http://afrobarometer.org/files/documents/policy_brief/ab_r5_policybriefno1.pdf

Eng, J. (2003). Sample size estimation: How many individuals should be studied? *Radiology*, *227*(2), 309–313.

FAO, & FHI 360. (2016). *Minimum dietary diversity for women: A guide for measurement*. http://www.fao.org/3/a-i5486e.pdf

Gernand, A. D., Aguree, S., Pobee, R., & Murray-Kolb, L. E. (2017). Micronutrient deficiencies in Ghanaian women before pregnancy. *The FASEB Journal*, *31*(S1):786.20. https://doi.org/10.1096/fasebj.31.1_supplement.786.20

Ghana Health Service. (2017). *Iron & Folic Acid (IFA) Supplementation for Adolescent Girls and Women Participants. Manual for Health Workers*. file:///C:/Users/Harrison/AppData/Local/Mendeley Ltd./Mendeley Desktop/Downloaded/Ghana Health Service, Ghana Education Service - 2017 - Iron & Folic Acid (IFA) Supplementation for Adolescent Girls and Women Participan.pdf

Ghana Micronutrient Survey. (2017). University of Ghana, GroundWork, University of Wisconsin-Madison, KEMRI-WellcomeTrust, UNICEF. In *Ghana Micronutrient Survey* (Vol. *13*, Issue 1). https://www.unicef.org/ghana/media/1276/file/UN368291.pdf

Ghana Statistical Service. (2013). 2010 population & Housing Census National Analytical Report. *Ghana Statistical Service*, *1*, 1–91. https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2010_PHC_National_Analytical_Report.pdf

Ghana Statistical Service. (2023). Ghana Demographic and Health Survey 2022: Key Indicators Report. In *Ghana Demographic and Health Survey 2022: Key Indicators Report* (Vol. *1*, Issue 1). https://dhsprogram.com/pubs/pdf/PR149/PR149.pdf

Ghana University of Ghana. (2010). *The nutrient analysis template excel spreadsheet*.

Gombart, A. F., Adeline, P., & Maggini, S. (2021). A review of micronutrients and the immune system—working in harmony to reduce the risk of infection. *Nutrients*, *13*(11), 1–41. https://doi.org/10.3390/nu13114180

Gómez, G., Nogueira Previdelli, Á., Fisberg, R. M., Kovalskys, I., Fisberg, M., Herrera-Cuenca, M., Cortés Sanabria, L. Y., Yépez García, M. C., Rigotti, A., Liria-Domínguez, M. R., Guajardo, V., Quesada, D., Murillo, A. G., & Brenes, J. C. (2020). Dietary diversity and micronutrients adequacy in women of childbearing age: Results from elans study. *Nutrients*, *12*(7), 1994. https://doi.org/10.3390/nu12071994

Gupta, S. (2017). Dietary practices and nutritional profile of female nurses from Government Hospitals in Delhi, India. *Iranian Journal of Nursing and Midwifery Research*, *22*(5), 348–353. https://doi.org/10.4103/ijnmr.IJNMR_167_16

Hofmeyr, G., Duley, L., & Atallah, A. (2007). Dietary calcium supplementation for prevention of pre-eclampsia and related problems: A systematic review and commentary. *BJOG: An International Journal of Obstetrics & Gynaecology*, *114*(114), 933–943. https://doi.org/10.1111/j.1471-0528.2007.01389.x

Hosmer, D. W., & Lemeshow, S. (2004). Applied logistic regression *(3rd Editio)*. John Wiley & Sons. https://books.google.com.gh/books?id=Po0RLQ7USIMC

Huang, M., Sudfeld, C., Ismail, A., Vuai, S., Ntwenya, J., Mwanyika-Sando, M., & Fawzi, W. (2018). Maternal dietary diversity and growth of children under 24 months of age in Rural Dodoma, Tanzania. *Food and Nutrition Bulletin*, *39*(2), 219–230. https://doi.org/10.1177/0379572118761682

INNDEX Project. (2018). *Data4Diets: Building blocks for diet-related food security analysis*. https://doi.org/10.1016/B978-0-12-391884-0.00001-9

Islam, M. H., Nayan, M. M., Jubayer, A., & Amin, M. R. (2023). A review of the dietary diversity and micronutrient adequacy among the women of reproductive age in low- and middle-income countries. *Food Science & Nutrition*, *12*(3), 1367–1379. https://doi.org/10.1002/fsn3.3855

Islam, M. H., Jubayer, A., Nowar, A., Nayan, M. M., & Islam, S. (2023). Dietary diversity and micronutrients adequacy among the women of reproductive age at St. Martin's island in Bangladesh. *BMC Nutrition*, *9*(1), 52. https://doi.org/10.1186/s40795-023-00715-y

Julia, K.-B., Boguszewska, K., Adamus-Grabicka, A., & Karwowski, B. T. (2020). Two faces of vitamin C—antioxidative and pro-oxidative agent. *Nutrients*, *12*(5), 1501. https://doi.org/10.3390/nu12051501

Lane, D. J. R., & Richardson, D. R. (2014). The active role of vitamin C in mammalian iron metabolism: Much more than just enhanced iron absorption! *Free Radical Biology and Medicine*, *75*, 69–83. https://doi.org/10.1016/j.freeradbiomed.2014.07.007

Liv Elin, T., & Arimond, M. (2013). Diet quality: An evidence-based approach. *Diet Quality: An Evidence-Based Approach*, *1*, 1–325. https://doi.org/10.1007/978-1-4614-7339-8

Mack, C., Su, Z., & Westreich, D. (2018). Managing missing data in patient registries: Addendum to registries for evaluating patient outcomes: A user's guide, third edition. *Agency for Healthcare Research and Quality*, *17*(18), 1–17. https://doi.org/10.23970/AHRQREGISTRIESMISSDATA

Nti, C. A. (2011). Dietary diversity is associated with nutrient intakes and nutritional status of children in Ghana. *Asian Journal of Medical Sciences*, *2*, 105–109.

Oldewage-Theron, W., & Kruger, R. (2011). Dietary diversity and adequacy of women caregivers in a peri-urban informal settlement in South Africa. *Nutrition*, *27*(4), 420–427. https://doi.org/10.1016/j.nut.2010.05.013

Otekunrin, O. A., Otekunrin, O. A., Sawicka, B., & Ayinde, I. A. (2020). Response to claudio schuftan on "three decades of fighting against hunger in Africa: Progress, challenges and opportunities." *World Nutrition*, *11*(4), 112–113. https://doi.org/10.26596/wn.2020114112-113

Saaka, M. (2020). Dr. Adequacy of nutrient intakes among pregnant women in Northern Ghana. *World Nutrition*, *11*(1), 145–164. https://doi.org/10.26596/wn.2020111145-164

Shrestha, V., Paudel, R., Sunuwar, D. R., Lyman, A., Manohar, S., & Amatya, A. (2021). Factors associated with dietary diversity among pregnant women in the Western hill region of Nepal: a community based crosssectional study. *PLoS One*, *16*(4 April), 0247085. https://doi.org/10.1371/journal.pone.0247085

Smith, E. R., Shankar, A. H., Wu, L. S. F., Aboud, S., Adu-Afarwuah, S., Ali, H., Agustina, R., Arifeen, S., Ashorn, P., Bhutta, Z. A., Christian, P., Devakumar, D., Dewey, K. G., Friis, H., Gomo, E., Gupta, P., Kæstel, P., Kolsteren, P., Lanou, H., … Sudfeld, C. R. (2017). Modifiers of the effect of maternal multiple micronutrient supplementation on stillbirth, birth outcomes, and infant mortality: A meta-analysis of individual patient data from 17 randomised trials in low-income and middle-income countries. *The Lancet Global Health*, *5*(11), e1090–e1100. https://doi.org/10.1016/S2214-109X(17)30371-6

Subar, A. F., Freedman, L. S., Tooze, J. A., Kirkpatrick, S. I., Boushey, C., Neuhouser, M. L., Thompson, F. E., Potischman, N., Guenther, P. M., Tarasuk, V., Reedy, J., & Krebs-Smith, S. M. (2015). Addressing current criticism regarding the value of self-report dietary data. *The Journal of Nutrition*, *145*(12), 2639–2645.

Trijsburg, L., Talsma, E. F., De Vries, J. H. M., Kennedy, G., Kuijsten, A., & Brouwer, I. D. (2019). Diet quality indices for research in low- and middle-income countries: A systematic review. *Nutrition Reviews*, *77*(8), 515–540. https://doi.org/10.1093/nutrit/nuz017

United Nations: Department of Economic and Social Affairs. (2022). *The Sustainable Development Goals Report 2022*. https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf

Verger, E. O., Le Port, A., Borderon, A., Bourbon, G., Moursi, M., Savy, M., Mariotti, F., & Martin-Prevel, Y. (2021). Dietary diversity indicators and their associations with dietary adequacy and health outcomes: A systematic scoping review. *Advances in Nutrition*, *12*(5), 1659–1672. https://doi.org/10.1093/advances/nmab009

Villalpando, S. (2008). Discussion: Effects of folate and vitamin B12 deficiencies during pregnancy on fetal, infant, and child development. *Food and Nutrition Bulletin*, *29*(2 Suppl.), 101–111. https://doi.org/10.1177/15648265080292s115

Walton, J. (2015). Dietary assessment methodology for nutritional assessment: A practical approach. *Topics in clinical nutrition*, *30*(1), 33–46.

WHO/FAO. (2004). *Vitamin and mineral requirements in human nutrition*. World Health Organization.

Wiafe, M. A., Apprey, C., & Annan, R. A. (2023). Dietary diversity and nutritional status of adolescents in rural Ghana. *Nutrition and Metabolic Insights*, *16*, 25–27. https://doi.org/10.1177/11786388231158487

Williamson, C. S. (2006). Nutrition in pregnancy. *Nutrition Bulletin*, *31*(1), 28–59. https://doi.org/10.1111/j.1467-3010.2006.00541.x

World Health Organiation. (2006). Reproductive health indicators: guidelines for their generation, interpretation and analysis for global monitoring.

World Health Organization. (2015). *Health in 2015: from MDGs, millennium development goals to SDGs, sustainable development goals*.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Apprey, C., Boateng, G., Addae, H. Y., Aduku, L. E., & Annan, R. A. (2024). Dietary diversity and nutrient adequacy among women in Bosomtwe District, Ghana. *Maternal & Child Nutrition*, e13757. https://doi.org/10.1111/mcn.13757