Determinants of anemia among pregnant women in northern Ghana

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Abbreviations

ANC	Antenatal Care
aOR	Adjusted Odds Ratio
CI	Confidence Interval
DHS	Demographic and Health Survey
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GHS	Ghana Health Service
GHS	Ghana Cedis
GHSERC	Ghana Health Service Ethics Review Committee
Hb	Hemoglobin
HC	Health Centre
HF	Health Facility
HIV	Human Immuno-Deficiency Virus
IPT	Intermittent Preventive Treatment
ITN	Insecticide Treated Mosquito Net
MDD-W	Minimum Dietary Diversity for Women
OR	Odds Ratio
PCA	Principal Component Analysis
RCH	Reproductive and Child Health
TB	Tuberculosis
USD	United State Dollars

ABSTRACT

Anemia is a global public health issue affecting half of all pregnant women in developing countries. In 2014, 42% of Ghanaian pregnant women aged 15-49 years were anemic (<11.0g/dl) but information on the determinants of anemia, particularly dietary diversity during the critical third trimester of pregnancy is limited. We assessed the association between determinants and anemia among pregnant women in northern Ghana.

We employed a cross-sectional design involving 624 pregnant women (≥20 weeks of gestation) attending four antenatal care (ANC) health facilities ~25 kilometres north of Tamale, Ghana between July and August 2017. Hemoglobin concentration (measured using Hemocue HB 301) was classified as severe, moderate, or mild. Other data included socio-demographic characteristics, malaria prevention, deworming, and iron/folate tablet use. The FAO Minimum Dietary Diversity (MDD-W) metric was used to categorize women into "inadequate" (MDD-W <5 food groups) and "adequate" (MDD-W ≥5). Logistic regression models were used to determine the association between moderate/severe anemia (Hb<9.0g/dl) and mild anemia (9.0-10.9g/dl), or with 'no anemia' (≥11.0g/dl) using STATA 14 software.

Of 624 women sampled, hemoglobin data were available for 601. The mean age was 27.81±0.25 years, gestational age was 31.93±0.13 weeks, ANC attendance was 3.89±0.07; Hb concentration was 9.73g/dl±0.07, and MDD-W index for ten food groups was 5.33±0.04. Anemia (Hb<11.0g/dl) was observed in 74.8% of women (moderate/severe anemia=33.4% and mild anemia=41.4%). Using adjusted logistic regression, women who received deworming medication had lesser odds of being moderate/severe anemic (aOR=0.51, P=0.021). While women who were engaged in other occupation (herdsmen) and no previous parity had higher odds of being moderate/severe anemic (aOR=2.90, P=0.042) and (aOR=2.13, P=0.004) respectively. Moderate/severe anemia was not statistically associated with MDD-W, nor with socioeconomic status/wealth index. Conclusion, anemia in

pregnancy was nearly twice that of Ghana as a whole. Deworming medication was found to be protective intervention for anemia during pregnancy.

Key words: Anemia, malaria, Diet Diversity, Pregnancy, Ghana

INTRODUCTION

Anemia is characterized by low blood hemoglobin (Hb) concentration and constitutes an important public health problem globally. Anemia has both short- and long-term consequences such as preterm, low birth weight, morbidity and mortality [1,2,3,4]. In 2016, World Health Organization (WHO) estimated that anemia affected 38.2% of pregnant women globally, with the highest prevalence in South-East Asia (48.7%) and Africa (46.3%) [5,6]. Anemia affects about 1.62 billion people, 56 million of whom are pregnant women [5]. An estimated 800,000 pregnant women globally have severe anemia (Hb<7.0g/dl). In Ghana, a national Demographic and Health Survey in 2014 determined that 42% of pregnant women were anemic compared to 70% in rural parts of the country [7].

Anemia often results from decreased red blood cell production or increased destruction/loss [3]. Causes include environmental, behavioral, and social factors [8] that limit adequate nutrient intake and absorption, or exposure to infectious diseases. In addition, anemia risk is related to household-level factors such as access to water and sanitation, availability of health services, access to diverse food sources, use of insecticide treated nets (ITNs) and knowledge about anemia prevention. Other household- or community-level factors include socioeconomic status, culture, wealth status and education attainment [5,9,8].

In developing countries, pregnant women often start gestation with depleted or low body iron stores, making them especially vulnerable to iron deficiency anemia [6,10,11,12]. Hb concentration declines during pregnancy, partly because of expanded plasma volume compared to red cell mass [10,13]. This is

49 influenced partly by the iron status of the pregnant woman,[12] representing a major public health
50 problem in sub-Saharan Africa [9,10]. Another contributor to anemia is parasitic infections/infestation
51 such as malaria, hookworm and schistosomiasis, especially in areas of Ghana where these infections
52 are endemic [5]. In addition, chronic infections such as tuberculosis (TB) and human immune-deficiency
53 virus (HIV) increase risk of anemia [5]. This condition may lead to premature delivery, intrauterine
54 growth retardation, and increased risk of malnutrition, morbidity and mortality for the mother, growing
55 fetus and newborn [10,11,14].

56 Poor maternal diet during preconception and pregnancy is a major contributor to adverse
57 pregnancy outcome such as preterm, low birth weight, still birth and mortality. Diets of pregnant
58 women in developing countries are often limited to a few plant-based foods, with little consumption of
59 micronutrient-dense animal-source foods, or diverse fruits and vegetables [13,15]. Poor dietary intake and
60 low iron bioavailability are key determinants of low iron reserves and anemia [16], particularly with little
61 dietary diversity among poor populations [17], who consume mainly carbohydrates with little or no
62 animal products, fruits and vegetables [10,18]. Little is known about diet and anemia among pregnant
63 women in Ghana. Our study focused on northern Ghanaian women at high-risk of anemia in their third
64 trimester of pregnancy [7]. We aimed to assess the association between determinants, particularly dietary
65 diversity and moderate/severe anemia, with the hypothesis that, greater dietary diversity would be
66 associated with lower anemia risk.

67

68 # Materials and methods

69 ## Study Area/Design

70 Ghana is a West African nation of 29 million people who are mostly concentrated in the
71 southern and coastal regions. Economically, Ghana ranks in the top third of African nations
72 (GDP/capita = US$ 4,600), with considerable geographic variation in wealth. Our study was conducted

in Northern Region, a poorer, predominantly agricultural area, made up of 28 Districts and Municipalities. Four government antenatal care (ANC) health facilities in Savelugu Municipality, located ~ 25 kilometres north of Tamale, served as the source of the study women. We employed a cross-sectional design involving pregnant women (≥20 weeks of gestation) seeking ANC, using our own questionnaire and ANC medical record data to identify risk factors of anemia. The study was undertaken during July-August 2017 (rainy season), using a questionnaire that had been pre-tested at a nearby health center.

Study population and protection of human subjects

Data were collected from pregnant women attending health facilities in the North, South, East and West quadrants of the Municipality. One health facility (HF) was randomly selected in the South (Janjori Kukuo Health Centre) to pre-test the tools/questionnaire. Then, a HF was randomly selected from each of the remaining three quadrants: Moglaa Health Centre (West), Savelugu Reproductive and Child Health (East) and Pong Tamale Health Centre (North). The fourth HF sampled was Savelugu Hospital, a major referral and health-seeking hospital centrally located in the Municipality that serves many ANC-seeking women. During the ANC days of the four HFs, pregnant women were recruited following informed consent. Women attending the ANC were informed of the study in the native language, Dagbani, by a member of the study team. Women were eligible to participate if they were at the HF to receive ANC, pregnant with a gestational age of at least 20 weeks, 18 or more years of age, and had not been diagnosed with sickle cell anemia. The maternal records of interested pregnant women were examined for compliance to these inclusion criteria. For eligible women, a sticker with a unique identification number was placed on their maternal record book and they were invited to stay for an interview. The women were then seen one-on-one with a trained interviewer who explained the details of the study, including risks and benefits. Women who agreed to

participate gave their consent via thumb print, and were then provided with a signed copy of their consent form in English, as the native language is not commonly written, and many people are illiterate.

The study protocol was approved before its implementation by the Ghana Health Service Ethical Review Committee (GHSERC/12/05/17) and the University of Michigan Institutional Review Board for Health Sciences and Behavioral Sciences (HUM00128583). Additionally, official approval letters were obtained from the Regional Director and District Director of Ghana Health Service in Northern Region and Savelugu Municipality, respectively, as well as heads of the four HFs.

Data sources and derived variables:

Data were gathered from oral interviews using a pretested questionnaire, and from the ANC record of each woman. The outcome of interest was the pregnant woman's anemia status. ANC is mostly free to pregnant women in Ghana, and provides various interventions and preventative care to combat anemia and infections [7]. Public health service procedures ensure all pregnant women have their hemoglobin tested to monitor anemia during each ANC visit, and receive iron supplementation, intermittent preventive treatment of malaria during pregnancy (IPTp), deworming medication, insecticide treated bed nets (ITN), and education about diet and malaria prevention [7]. While these services are, in theory, widely available to all pregnant women, there are many factors influencing whether a woman actually receives this care. Even though the ANC services are free, the transportation to the clinic is not. Some women have to walk for many miles to reach the nearest ANC center. Rural health centers are often poorly staffed and poorly supplied with materials and medications needed for the services. Additionally, attending ANC may mean the loss of a day's income, which may not be possible for lower-income women. Despite these challenges, a recent study reported that 97% of pregnant Ghanaian women attended at least one ANC visit in 2014, and 87% had attended four or more visits [7]. In the Northern Region where our study occurred, ANC attendance is likely to be lower due to

lower income and fewer health centers. Even with high ANC attendance, anemia remains a major problem for adult women in many regions of Ghana, particularly in areas like our study sites where poverty levels are high, and access to health centers is hindered [7].

The interviews were conducted by trained local research assistants with health education backgrounds (e.g. Bachelor of Science degree in Nursing or Community Nutrition). Each hired research assistant was fluent in the Dagbani and English languages, as well as other local native Ghanaian languages. The interviews were conducted in a private room or area of the HF to protect women's privacy. Individual women were asked questions concerning their demographic situation, as well as characteristics of their housing, water, toilets, and household assets. In addition, they were asked about the ANC services they had received, and were administered a 24-hour dietary recall survey, collecting information on all food items and beverages consumed in the previous day. Interviewers asked individual women to recall all foods they had consumed in the previous 24-hour, and after responding were probed to ensure that no meal or snack was left out (breakfast, snack before lunch, lunch, snack after lunch, dinner and snack before going to bed). The foods were then categorized into ten (10) food groups [19]. Information on Hb concentration, and gestation, were extracted from the maternal health records that are kept for each pregnant woman.

Hb concentration determination differed between the HFs. The Savelugu hospital used a spectrophotometer operated by trained laboratory scientist/technicians. The three health centers used a Hemocue HB 301 operated by HF workers. A blood sample for Hb concentration was taken on the day of the interview in most cases, but for very few participants this occurred one week after the interview.

Our study used results from tests that are routinely conducted at ANC visits, as recommended by the Government of Ghana. All tests were performed by HF staff. Occasionally, tests were not performed on the day of interview due to shortages of supplies. However, tests for these women were completed in the following weeks if they returned to the same HF. Overall, 27 women did not return

for testing. After completing the interview and data extraction, participants were given GHS10.00 (US$ 2.27) to compensate them for transportation back to their homes.

Statistical analysis:

Data were cleaned and analyzed using STATA 14 software. Frequency tables were generated to describe the distribution of anemia status and all hypothesized explanatory variables. Logistic regression was performed to determine the unadjusted associations between anemia status and each independent explanatory variable. Adjusted logistic regression analyses were performed to evaluate relationships among independent factors and anemia status. As with the Demographic and Health Survey's (DHS) classification scheme, we defined anemia as severe (Hb<7.0g/dl), moderate (Hb =7.0-8.9g/dl), or mild (Hb=9.0-10.9g/dl), with no anemia being Hb≥11.0g/dl. This cut-off was selected in accordance with the Demographic and Health Survey for Ghana and previous studies of anemia in pregnant women [3,7,10]. For our study, severe and moderate anemia were combined (moderate/severe) as Hb <9.0g/dl, and analyzed in comparison with mild/no anemia. Anemia prevalence was analyzed for the entire study population, as well as for each HF, using logistic regression tests to evaluate risk factor associations.

Dietary diversity was calculated using the reported number of different food groups consumed by each woman in the previous 24 hours. Food was reclassified into ten distinct food groups: (1) grains, roots and tubers, (2) Pulses-beans, peas and lentils, (3) Nuts and seeds, (4) Dairy, (5) Meat, poultry and fish, (6) Eggs, (7) Dark green leafy vegetables, (8) Vitamin A-rich fruits and vegetables, (9) Other vegetables and (10) Other fruits. These mutually exclusive food groups are those that comprise the FAO Minimum Dietary Diversity for Women (MDD-W) indicator [19]. The FAO MDD-W metric was used to categorize participants into "inadequate" (MDD-W <5 food groups) and "adequate" (MDD-W ≥5). A wealth index was calculated using Principal Component Analysis (PCA) of household assets,

169 housing conditions, water facilities and toilet facilities. Other risk factors that were analyzed included
170 maternal education, religion, ethnicity, and occupation as well as socio-demographic characteristics,
171 ANC attendance, parity, ITN ownership and ITN utilization. The relation between each individual risk
172 factor and moderate/severe anemia was determined using bivariate logistic regression to obtain the
173 odds ratios (ORs), confidence intervals (CIs) and probability values (p-value) for the whole sample.
174 Separate adjusted logistic regression models were constructed for the whole sample using ten (10)
175 selected risk factors with a significance test level of alpha = 0.05. Odds ratios were used to interpret
176 the associations of risk factors with moderate/severe or mild anemia/no anemia.
177

178 # RESULTS

179 ## Study population characteristics:

180 In total, 624 pregnant women at ≥20 weeks of gestation were enrolled, but analysis was limited
181 to 601 participants (96.3%) for whom Hb measurements were available (**Table 1**). The mean age was
182 27.81 (±0.25) years, with gestation age =31.93 (±0.13), ANC= 3.89 (±0.07), Hb =9.73 (±0.07) and
183 MDD-W = 5.33 (±0.04). More than half (58%) of the participants who received ANC services at the
184 Savelugu Hospital and 53% were between 20 and 29 years old. Nearly all women (96%) were from the
185 Dagomba ethnic group. Three-quarters (75%) had no formal education, and nearly all (97%) belonged
186 to the Islamic religion, with 98% being married (monogamous or polygamous marriages). About 69%
187 of the participants were either farmers (39%) or petty traders (30%), while very few (2%) were salaried
188 workers. Most women (91%) were between 28 and 36 weeks of gestation when interviewed, while
189 very few (2%) were between 20 and 27 weeks of gestation. Approximately 92% of the participants had
190 access to improved water sources and about one-quarter (24%) reported using improved toilet facilities.
191 About 85% of the participants achieved the MDD-W indicator, that is, consumed five or more
192 food groups in the previous 24 hours. In addition, 91% of the participants reported household

ownership of at least one ITN, with 83% having slept under an ITN on the night preceding the interview. About three-quarters (76%) of the participants had previously delivered live babies. While 52% had attended ≥4 ANC visits and 84% received at least one IPTp treatment, only 14% received any deworming medication. In addition, 99% of the participants reported they had received iron and folic acid tablets during ANC visits.

Prevalence of moderate/severe anemia and risk factors

Three-quarters (75%) of the pregnant women in the study were anemic with 41% experiencing mild anemia and 33% experiencing moderate/severe anemia. Forty-one percent of participants who were <20 years of age had moderate/severe anemia. Anemia prevalence declined with increasing age. Moderate/severe anemia was least prevalent among salaried workers (29%) and petty traders (30%), but highest among unemployed (41%) and others, such as herdsmen (63%).

Nearly half (49%) of the participants without household ownership of ITNs were moderate/severe anemic compared to 32% among those with ITNs. Those who did not sleep under ITN on the previous night preceding the survey were more likely to experience moderate/severe anemia (44%) compared to those who slept under an ITN (31%). In addition, 41% of the participants who did not receive Intermittent Preventive Treatment (IPT) had moderate/severe anemia compared to 32% in those who did receive IPT.

Women with no previous delivery had the greater risk of moderate/severe anemia (48%) compared to women with at least one previous deliveries. More than a third of pregnant women who did not receive deworming medication had moderate/severe anemia compared to about one-fifth among those who did take deworming drugs. Similarly, about 33% of the participants who received iron tablets or folic acid tablets did not have moderate/severe anemia (**Table 1**).

Participants who consumed pulses (41%), dairy (35%), meat, poultry and fish (34%), eggs (36%), dark green leafy vegetables (34%), and other vegetables (34%) had greater risk of moderate/severe anemia than those who did not. However, participants who consumed nuts/seeds (33%), vitamin A-rich fruits and vegetables (20%) and other fruits (30%) were less likely to have moderate/severe anemia compared to those who did not consume.

Table 1: Socio-demographic factors and dietary diversity by anemia status among pregnant women in northern Ghana (n=601)

Variables	Total Sample (N=601)	Moderate/severe anemia (<9.0g/dl)	Mild anemia (9.0-10.9g/dl)	No anemia (≥11.0g/dl)
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Name of Health Facility				
Savelugu hospital	349(58.1)	157(45.0)	108(31.0)	84(24.0)
Moglaa HC	93(15.5)	14(15.0)	54(58.1)	25(26.9)
Pong Tamale HC	77(12.8)	18(23.4)	44(57.1)	15(19.5)
Savelugu RCH	82(13.6)	12(14.6)	43(52.4)	27(33.0)
Age (in years)				
<20	34(5.7)	14 (41.2)	15(44.1)	5(14.7)
20-29	319(53.1)	112(35.1)	125(39.2)	82(25.7)
30-39	226(37.6)	73(32.3)	95(42.0)	58(25.7)
≥40	22(3.6)	2(9.1)	14(63.6)	6 (27.3)
Ethnicity				
Dagomba	576(96.2)	195(33.8)	236 (41.0)	145(25.2)
Fulani	8(1.3)	2(25.0)	5(62.5)	1(12.5)
Others (Akan, Ewe etc.)	15(2.5)	3(20.0)	7(46.7)	5(33.3)
Education status				
None	450(74.9)	139(30.9)	204(45.3)	107(23.8)
Primary	46(7.7)	19(41.3)	16(34.8)	11(23.9)
JSS/Middle School	53(8.8)	22(41.5)	15(28.3)	16(30.2)
Senior Secondary	38(6.3)	17(44.7)	11(29.0)	10(26.3)
Tertiary	14(2.3)	4(28.6)	3(21.4)	7(50.0)
Religious denomination				
Islam	582(97.3)	196(33.7)	238(40.9)	148(25.4)
Christianity	13(2.2)	4(30.8)	7(53.8)	2(15.4)
Traditionalist	3(0.50)	0(0.0)	2(66.7)	1(33.3)
Marital status				
Single	12(2.0)	5(41.7)	7(58.3)	0(0.0)
Married-monogamous	329(54.7)	103(31.3)	139(42.3)	87(26.4)
Married-polygamous	260(43.3)	93(35.8)	103(39.6)	64(24.6)
Occupation status				
Farmer	233(38.8)	73(31.3)	108(46.4)	52(22.3)
Petty trader	181(30.1)	54(29.9)	73(40.3)	54(29.8)
Salaried worker	14(2.3)	4(28.6)	4(28.6)	6(42.8)
Artisan/laborer	79(13.1)	27(34.2)	34(43.0)	18(22.8)

No occupation	75(12.5)	31(41.3)	27(36.0)	17(22.7)
Others	19(3.2)	12(63.2)	3(15.8)	4(21.0)
Wealth index				
Poorest	118(19.6)	34(28.8)	53(44.9)	31(26.3)
Poor	119(19.8)	41(37.5)	50(42.0)	28(23.5)
Medium	120(20.0)	45(37.5)	51(42.5)	24(20.0)
Wealthy	122(20.3)	38(31.1)	45(36.9)	39(32.0)
Wealthiest	122(20.3)	43(35.2)	50(41.0)	29(23.8)
Gestational age (in weeks)				
20-27	11(1.8)	4(36.4)	4(36.4)	3(27.2)
28-36	547(91.0)	182(33.2)	229(41.9)	136(24.9)
≥37	43(7.2)	15(34.9)	16(37.2)	12(27.9)
Drinking water source				
Non-improved	48(8.0)	12(25.0)	25(52.1)	11(22.9)
Improved	553(92.0)	189(34.2)	224(40.5)	140(25.3)
Toilet facility				
Non-improved	457(76.0)	155(33.9)	185(40.5)	117(25.6)
Improved	144(24.0)	46(31.94)	64(44.44)	34(23.61)
Grains/roots/tubers/plantain				
No	1(0.2)			
Yes	600(99.8)			
Pulses				
No	452(75.3)	139(30.8)	194(42.9)	119(26.3)
Yes	148(24.7)	61(41.2)	55(37.2)	32(21.6)
Nuts/seeds				
No	133(22.2)	48(36.1)	53(39.8)	32(24.1)
Yes	467(77.8)	153(32.8)	195(41.7)	119(25.5)
Dairy				
No	477(79.4)	158(33.1)	197(41.3)	122(25.6)
Yes	124(20.6)	43(34.7)	52(41.9)	29(23.4)
Meat/poultry/fish(amaani)				
No	7(1.2)	2(28.6)	3(42.8)	2(28.6)
Yes	594(98.8)	199(33.5)	246(41.4)	149(25.1)
Eggs				
No	555(92.5)	185(33.3)	233(42.0)	137(24.7)
Yes	45(7.5)	16(35.6)	16(35.6)	13(28.8)
Dark green leafy vegetables				
No	40(6.7)	10(25.0)	22(55.0)	8(20.0)
Yes	561(93.3)	191(34.0)	227(40.5)	143(25.5)
Vitamin A-rich fruits & vegetables				
No	555(92.3)	192(34.6)	223(40.2)	140(25.2)
Yes	46(7.7)	9(19.6)	26(56.5)	11(23.9)
Other vegetables				
No	11(1.8)	3(27.3)	6(54.5)	2(18.2)
Yes	590(98.2)	198(33.6)	243(41.2)	149(25.2)
Other fruits				
No	570(95.0)	191(33.5)	234(41.1)	145(25.4)
Yes	30(5.0)	9(30.0)	15(50.0)	6(20.0)
Minimum dietary diversity score				

<5	91(15.1)	27(29.7)	40(43.9)	24(26.4)
≥5	510(84.9)	174(34.1)	209(41.0)	127(24.9)
Household livestock				
No	116(19.3)	36(31.0)	45(38.8)	35(30.2)
Yes	485(80.7)	165 (34.0)	204(42.1)	116(23.9)
Household ITN				
No	55(9.2)	27(49.1)	17(30.9)	11(20.0)
Yes	546(90.8)	174(31.9)	232(42.5)	140(25.6)
Slept under ITN previous night				
No	104(17.3)	46(44.2)	35(33.7)	23(22.1)
Yes	497(82.7)	155(31.2)	214(43.1)	128(25.7)
No. of previous deliveries				
0	142(23.6)	68(47.9)	48(33.8)	26(18.3)
1	122(20.3)	40(32.8)	54(44.3)	28(22.9)
2-3	214(35.6)	59(27.6)	91(42.5)	64(29.9)
≥4	123(20.5)	34(27.7)	56(45.5)	33(26.8)
Total ANC visits				
< 4	286(47.6)	97(33.9)	123(43.0)	66(23.1)
4-7	286(47.6)	96(33.6)	111(38.8)	79(27.6)
≥8	29(4.8)	8(27.6)	15(51.7)	6(20.7)
IPT received				
No	99(16.5)	41(41.4)	38(38.4)	20(20.2)
Yes	502(83.5)	160(31.9)	211(42.0)	131(26.1)
Deworming medication				
No	515(85.7)	183(35.5)	198(38.5)	134(26.0)
Yes	86(14.3)	18(20.9)	51(59.3)	17(19.8)
Received iron tablets				
No	3(0.5)	1(33.3)	1(33.3)	1(33.3)
Yes	598(99.5)	200(33.4)	248(41.5)	150(25.1)
Received folic acid				
No	3(0.5)	1(33.3)	1(33.3)	1(33.3)
Yes	598(99.5)	200(33.4)	248(41.5)	150(25.1)
Prevalence of anemia				
Severe-moderate (<9.0g/dl)	201(33.5)			
Mild (9.0-10.9g/dl)	249(41.4)			
No anemia	151(25.1)			
Prevalence of anemia types				
Severe (<7.0g/dl)	25(4.2)			
Moderate (7.0-8.9g/dl)	175(29.2)			
Mild (9.0-10.9g/dl)	249(41.5)			
No anemia (≥11.0g/dl)	151(25.1)			
Means	**Mean (CI)**	**Standard Error**		
Age (in years)	27.81(27.33, 28.29)	0.246		
Gestational age (in weeks)	31.93(31.68, 32.18)	0.128		
Number of ANC visits	3.89(3.76, 4.03)	0.070		
Hemoglobin level	9.73(9.59, 9.88)	0.074		
Minimum Dietary diversity	5.33(5.25, 5.42)	0.042		

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Analysis of risk factors and any anemia or moderate/severe anemia

When all three levels of anemia were combined (<11.0g/dl) and compared with no anemia using bivariate (unadjusted) logistic regression (**Table 2**), anemia risk was significantly lower with tertiary education (**OR=0.31**, 95%CI:0.11, 0.91), and higher with medium wealth (**OR=1.88**, 95%CI:1.04, 3.38) and greater parity (**OR=1.90,** 95%CI:1.14, 3.19). However, when comparison involved women classified as moderate/severe anemic (<9.0g/dl) versus combined mild/no anemia, nine (9) explanatory variables were significantly associated. Women seeking ANC services at Savelugu Hospital were more likely to have moderate/severe anemia than those at the other three HFs, including Moglaa HC (**OR=0.22**, 95%CI:0.12, 0.40), Pong Tamale HC (**OR=0.37**, 95%CI:0.21, 0.66) and Savelugu RCH (**OR=0.21**, 95%CI:0.11, 0.40). Moderate/severe anemia was less frequent among women who were older (**OR=0.18,** 95%CI:0.04, 0.81). Participants who consumed vitamin A-rich fruits and vegetables were less likely to have moderate/severe anemia than those who did not consume (**OR=0.46,** 95%CI:0.22, 0.97). Similarly, women who received deworming medication were at lower risk to have moderate/severe anemia than those who did not receive (**OR=0.48**, 95%CI:0.28, 0.83). Interestingly, moderate/severe anemia was more likely among women who were engaged in other occupations (e.g. herdsmen) (**OR=3.76**, 95%CI:1.42, 9.94), or who consumed pulses (**OR=1.58,** 95%CI:1.06, 2.32).

The relationship between malaria and anemia was linked with both household ownership of an ITN and reported sleeping under an ITN. Women who did not own ITN were more than twice as likely to be moderate/severe anemic (**OR=2.06,** 95%CI:1.18, 3.60), while women who reported not sleeping under an ITN the previous night had almost twice the risk of being moderate/severe anemic (**OR=1.75**, 95%CI:1.14, 2.69). Those women who had not previously delivered were more than twice as likely to be moderate/severe anemic compared to women with one or more births (OR=**2.41**, 95%CI:1.55, 3.77). None of the remaining hypothesized risk factors, such as socioeconomic status, minimum dietary

250 diversity, gestational age, and number of ANC visits, were significantly associated with
251 moderate/severe anemia.

252 **Table 2: Bivariate odd ratios for anemia status among pregnant women in Northern Ghana (n=601)**
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		Anemia (<11.0g/dl)	No anemia (≥11.0g/dl)	Anemia (<11.0g/dl) versus no anemia (≥11.0g/dl)		Moderate/ severe anemia (<9.0g/dl)	Mild/no anemia (≥9.0g/dl)	Moderate severe anemia (<9.0g/dl) versus mild/no anemia (≥9.0g/dl)	
	Frequency	%	%	unadjusted OR(CI)	P-value	%	%	unadjusted OR(CI)	P-value
Health Facility									
Savelugu hospital	349	75.9	24.1	Ref		45.0	55.0	Ref	
Moglaa HC	93	73.1	26.9	0.86(0.51, 1.45)	0.576	15.1	84.9	0.22(0.12, 0.40)	**<0.001**
Pong Tamale HC	77	80.5	19.5	1.31(0.71, 2.42)	0.389	23.4	76.6	0.37(0.21, 0.66)	**0.001**
Savelugu RCH	82	67.1	32.9	0.65(0.38, 1.09)	0.100	14.6	85.4	0.21(0.11, 0.40)	**<0.001**
Age (in years)									
<20	34	85.3	14.7	2.01(0.75, 5.36)	0164	41.2	58.8	1.29 (0.63, 2.66)	0.484
20-29	319	74.3	25.7	Ref		35.1	64.9	Ref	
30-39	226	74.3	25.7	1.00(0.68, 1.48)	0.991	32.3	67.7	0.88(0.61, 1.27)	0.495
≥40	22	72.7	27.3	0.92(0.35, 2.44)	0.871	9.1	90.9	0.18(0.04, 0.81)	**0.025**
Ethnicity									
Dagomba	576	74.8	25.2	Ref		33.8	66.2	Ref	
Fulani	8	87.5	12.5	2.35(0.28, 19.30)	0.425	25.0	75.0	0.65(0.13, 3.26)	0.602
Others (e.g. Akan, Ewe etc.)	15	66.7	33.3	0.67(0.23, 2.00)	0.476	20.0	80.0	0.49(0.14, 1.75)	0.271
Education status									
None	450	76.2	23.8	Ref		30.9	69.1	Ref	
Primary	46	76.1	23.9	0.99(0.49, 2.02)	0.984	41.3	58.7	1.57(0.85, 2.93)	0.151
JSS/Middle School	53	69.8	30.2	0.72(0.39, 1.35)	0.306	41.5	58.5	1.59(0.89, 2.84)	0.119
Senior Secondary	38	73.7	26.3	0.87(0.41, 1.86)	0.725	44.7	55.3	1.81(0.93, 3.54)	0.082
Tertiary	14	50.0	50.0	0.31(0.11, 0.91)	**0.033**	28.6	71.4	0.89(0.28, 2.90)	0.853
Occupation status									
Farmer	233	77.7	22.3	Ref		31.3	68.7	Ref	
Petty trader	181	70.2	29.8	0.68 (0.43, 1.05)	0.083	29.8	70.2	0.93(0.61, 1.42)	0.743
Salaried worker	14	57.1	42.9	0.38(0.13, 1.15)	0.088	28.6	71.4	0.88(0.27, 2.89)	0.829
Artisan/laborer	79	77.2	22.8	0.97(0.53, 1.79)	0.931	34.2	65.8	1.14(0.66, 1.96)	0.640
No occupation	75	77.3	22.7	0.98(0.53, 1.83)	0.950	41.3	58.7	1.54(0.90, 2.64)	0.112
Others	19	78.9	21.1	1.08(0.34, 3.39)	0.899	63.2	36.8	3.76(1.42, 9.94)	**0.008**
Wealth index									
Poorest	118	73.7	26.3	1.32(0.75, 2.31)	0.332	28.8	71.2	0.89(0.51, 1.56)	0.693

Poor	119	76.5	23.5	1.53(0.86, 2.70)	0.145	34.5	65.5	1.16(0.68, 1.99)	0.585
Medium	120	80.0	20.0	1.88(1.04, 3.38)	**0.035**	37.5	62.5	1.33(0.78, 2.26)	0.298
Wealthy	122	68.0	32.0	Ref		31.2	68.8	Ref	
Wealthiest	122	76.2	23.8	1.51(0.86, 2.65)	0.154	35.3	64.7	1.20(0.71, 2.05)	0.497
Gestational age (in weeks)									
20-27	11	72.7	27.3	0.88(0.23,3.37)	0.855	36.4	63.6	1.15(0.33, 3.97)	0.830
28-36	547	75.1	24.9	Ref		33.3	66.7	Ref	
≥37	43	72.1	27.9	0.85(0.43, 1.71)	0.658	34.9	65.1	1.07(0.56, 2.06)	0.829
Drinking water source									
Non-improved	48	77.1	22.9	1.14(0.57, 2.30)	0.713	25.0	75.0	0.64(0.33, 1.26)	0.199
Improved	553	74.7	25.3	Ref		34.2	65.8	Ref	
Toilet facility									
Non-improved	457	74.4	25.6	Ref		33.9	66.1	Ref	
Improved	144	76.4	23.6	1.11(0.72, 1.73)	0.631	31.9	68.1	0.91(0.61, 1.36)	0.662
Pulses									
No	452	73.7	26.3	Ref		30.7	69.3	Ref	
Yes	148	78.4	21.6	1.30 (0.83, 2.02)	0.253	41.2	58.8	1.58(1.06, 2.32)	**0.020**
Nuts/seeds									
No	133	75.9	24.1	1.08(0.69, 1.69)	0.739	36.1	63.9	1.16(0.77, 1.73)	0.473
Yes	467	74.5	25.5	Ref		32.8	67.2	Ref	
Dairy									
No	477	74.4	25.6	Ref		33.1	66.9	Ref	
Yes	124	76.6	23.4	1.13 (0.71, 1.79)	0.617	34.7	65.3	1.07(0.71, 1.62)	0.744
Meat/poultry/fish(amaani)									
No	7	71.4	28.6	0.84(0.16, 4.36)	0.833	28.6	71.4	0.79(0.15, 4.13)	0.784
Yes	594	74.9	25.1	Ref		33.5	66.5	Ref	
Eggs									
No	555	75.3	24.7	Ref		33.3	66.7	Ref	
Yes	45	71.1	28.9	0.81(0.41, 1.58)	0.532	35.6	64.4	1.10(0.58, 2.08)	0.761
Dark green leafy vegetables									
No	40	80.0	20.0	1.37(0.62, 3.04)	0.441	25.0	75.0	0.65(0.31, 1.35)	0.245
Yes	561	74.5	25.5	Ref		34.1	65.9	Ref	
Vitamin A-rich fruits & vegetables									
No	555	74.8	25.3	Ref		34.6	65.4	Ref	

Yes	46	76.1	23.9	1.07(0.53, 2.17)	0.844	19.6	80.4	0.46(0.22, 0.97)	**0.042**
Other vegetables									
No	11	81.8	18.2	1.52(0.32, 7.12)	0.595	27.3	72.7	0.74(0.19, 2.83)	0.663
Yes	590	74.7	25.3	Ref		33.6	66.4	Ref	
Other fruits									
No	570	74.6	25.4	Ref		33.5	66.5	Ref	
Yes	30	80.0	20.0	1.36(0.54, 3.40)	0.505	30.0	70.0	0.85(0.38, 1.89)	0.691
Dietary diversity									
<5	91	73.6	26.4	0.93(0.56, 1.54)	0.766	29.7	70.3	0.81(0.50, 1.32)	0.408
≥5	510	75.1	24.9	Ref		34.1	65.9	Ref	
Household livestock									
No	116	69.8	30.2	0.73(0.46, 1.14)	0.164	31.0	69.0	0.87(0.56, 1.35)	0.540
Yes	485	76.1	23.9	Ref		34.0	66.0	Ref	
Household ITN									
No	55	80.0	20.0	1.38(0.69, 2.74)	0.360	49.1	50.9	2.06(1.18, 3.60)	**0.011**
Yes	546	74.4	25.6	Ref		31.9	68.1	Ref	
Slept under ITN previous night									
No	104	77.9	22.1	1.22(0.74, 2.02)	0.437	44.2	55.8	1.75(1.14, 2.69)	**0.011**
Yes	497	74.3	25.7	Ref		31.2	68.8	Ref	
No. of previous deliveries									
0	142	81.7	18.3	1.90(1.14, 3.19)	**0.015**	47.9	52.1	2.41(1.55, 3.77)	**<0.001**
1	122	77.1	22.9	1.43(0.86, 2.39)	0.170	32.8	67.2	1.28(0.79, 2.08)	0.314
2-3	214	70.1	29.9	Ref		27.6	72.4	Ref	
≥4	123	73.2	26.8	1.16(0.71, 1.91)	0.548	27.64	72.36	1.00(0.61, 1.65)	0.989
Total ANC visits									
< 4	286	76.9	23.1	Ref		33.9	66.1	Ref	
4-7	286	72.4	27.6	0.79(0.54, 1.15)	0.212	33.6	66.4	0.98(0.70, 1.39)	0.930
≥8	29	79.3	20.7	1.15(0.45, 2.94)	0.771	27.6	72.4	0.74(0.32, 1.74)	0.492
IPT received									
No	99	79.8	20.2	1.39(0.82, 2.37)	0.218	41.4	58.6	1.51(0.97,2.35)	0.067
Yes	502	73.9	26.1	Ref		31.9	68.1	Ref	
Deworming medication									
No	515	74.0	26.0	Ref		35.5	64.5	Ref	
Yes	86	80.2	19.8	1.43(0.81, 2.51)	0.218	20.9	79.1	0.48(0.28, 0.83)	**0.009**

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In adjusted logistic regression models that included statistically significant risk factors from bivariate analysis (**Table 3**), tertiary education **(aOR=0.20,** 95%CI:0.04, 0.96) and no previous delivery (**aOR=2.13,** 95%CI:1.18, 3.85) were the only two factors that were significantly associated with anemia (<11.0g/dl) (**Table 3**). The current study found that maternal dietary diversity (<5 MDD-W) was not statistically associated with anemia (aOR=0.80, 95%CI:0.67, 1.38) or moderate/severe anemia (aOR=0.74, 95%CI:0.44, 1.24). However, in using moderate/severe anemia (<9.0g/dl) as the cut-off point for anemia, three explanatory factors were significantly associated. That is, participants whose occupation status was categorized as "other" (e.g. herdsmen) were three times more likely to have moderate/severe anemia (**aOR=2.90,** 95%CI: 1.04, 8.09). Women who had no previous delivery continued to be more likely to have moderate/severe anemia (**aOR=2.13,** 95%CI: 1.28, 3.54). Finally, participants who received deworming medication remained at lower risk of moderate/severe anemia (**aOR=0.51,** 95%CI:0.29, 0.90) than those who did not take these medications.

268 **Table 3: Multivariate analysis of anemia status among pregnant women in Northern Ghana (n=601)**
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		Anemia (<11.0g/dl)	No anemia (≥11.0g/dl)	Anemia (<11.0g/dl) versus no anemia (≥11.0g/dl)		Moderate/severe anemia (<9.0g/dl)	Mild/no anemia (≥9.0g/dl)	Moderate/severe anemia (<9.0g/dl) versus mild/no anemia (≥9.0g/dl)	
	Frequency	%	%	Adjusted OR(CI)	P-value	%	%	Adjusted OR(CI)	P-value
Education status									
None	450	76.2	23.8	Ref		30.9	69.1	Ref	
Primary	46	76.1	23.9	0.96(0.45, 2.03)	0.908	41.3	58.7	1.48(0.76, 2.88)	0.253
JSS/Middle School	53	69.8	30.2	0.59(0.30, 1.18)	0.135	41.5	58.5	1.31(0.69, 2.49)	0.407
Senior Secondary	38	73.7	26.3	0.64(0.27, 1.52)	0.312	44.7	55.3	1.19(0.54,2.62)	0.657
Tertiary	14	50.00	50.00	**0.20**(0.04, 0.96)	**0.044**	28.6	71.4	0.75(0.15, 3.71)	0.723
Occupation status									
Farmer	233	77.7	22.3	Ref		31.3	68.7	Ref	
Petty trader	181	70.2	29.8	0.72(0.45, 1.17)	0.185	29.8	70.2	0.95(0.60, 1.51)	0.840
Salaried worker	14	57.1	42.9	0.85(0.16, 4.46)	0.852	28.6	71.4	0.95(0.19, 4.72)	0.948
Artisan/laborer	79	77.2	22.8	0.95(0.48, 1.89)	0.874	34.2	65.8	0.83(0.45, 1.53)	0.549
No occupation	75	77.3	22.7	0.93(0.47, 1.86)	0.844	41.3	58.7	1.32(0.72, 2.41)	0.367
Others	19	78.9	21.1	1.17(0.35, 3.87)	0.797	63.2	36.8	**2.90**(1.04, 8.09)	**0.042**
Wealth index									
Poorest	118	73.7	26.3	1.14(0.62, 2.08)	0.676	28.8	71.2	0.96(0.52, 1.75)	0.893
Poor	119	76.5	23.5	1.40(0.77, 2.54)	0.277	34.5	65.5	1.33(0.74, 2.38)	0.337
Medium	120	80.0	20.0	1.80(0.98, 3.31)	0.059	37.5	62.5	1.46(0.83,2.57)	0.191
Wealthy	122	68.0	32.0	Ref		31.2	68.8	Ref	
Wealthiest	122	76.2	23.8	1.65(0.90, 3.01)	0.102	35.3	64.7	1.20(0.68, 2.12)	0.533
Gestational age (in weeks)									
20-27	11	72.7	27.3	1.17(0.28, 4.89)	0.830	36.4	63.6	1.23(0.34, 4.54)	0.752
28-36	547	75.1	24.9	Ref		33.3	66.7	Ref	
≥37	43	72.1	27.9	0.63(0.28, 1.41)	0.261	34.9	65.1	1.25(0.58, 2.68)	0.572
Dietary diversity									
<5	91	73.6	26.4	0.80(0.47, 1.38)	0.427	29.7	70.3	0.74(0.44, 1.24)	0.249
≥5	510	75.1	24.9	Ref		34.1	65.9	Ref	
Slept under ITN previous night									
No	104	77.9	22.1	1.15(0.67, 1.96)	0.621	44.2	55.8	1.48(0.93, 2.35)	0.101
Yes	497	74.3	25.7	Ref		31.2	68.8	Ref	

No. of previous deliveries									
0	142	81.7	18.3	**2.13**(1.18, 3.85)	**0.012**	47.9	52.1	**2.13**(1.28, 3.54)	**0.004**
1	122	77.1	22.9	1.57(0.89, 2.75)	0.116	32.8	67.2	1.21(0.72, 2.03)	0.477
2-3	214	70.1	29.9	Ref		27.6	72.4	Ref	
≥4	123	73.2	26.8	1.10(0.65, 1.84)	0.728	27.6	72.4	0.97(0.58, 1.64)	0.916
Total ANC visits									
< 4	286	76.9	23.1	Ref		33.9	66.1	Ref	
4-7	286	72.4	27.6	0.91(0.61, 1.38)	0.663	33.6	66.4	1.12(0.76, 1.64)	0.564
≥8	29	79.3	20.7	1.91(0.64, 5.74)	0.248	27.6	72.4	0.88(0.32,2.37)	0.795
IPT received									
No	99	79.8	20.2	1.26(0.72, 2.19)	0.424	41.4	58.6	1.54(0.95, 2.48)	0.080
Yes	502	73.9	26.1	Ref		31.9	68.1	Ref	
Deworming medication									
No	515	74.0	26.0	Ref		35.5	64.5	Ref	
Yes	86	80.2	19.8	1.53(0.85, 2.76)	0.158	20.9	79.1	**0.51**(0.29, 0.90)	**0.021**

DISCUSSION

We sought to assess the independent contributions of dietary diversity and other predictors to anemia status during pregnancy. Three-quarters of women were anemic (<11.0g/dl), including one-third of whom had moderate/severe anemia. This prevalence of anemia in our study area is considered by WHO to be a severe public health problem [3], and is higher than that for Ghana as a whole, and for the Africa region. Indeed, this anemia prevalence is considerably higher than the 44.6% reported in the 2014 Ghana Demographic and Health Survey (GDHS) report. Other studies of pregnant women indicated anemia prevalences of 70.0% in northern Ghana, 62.6% in Southern Ghana and 51.9%-to-59.6% in Africa [3,7,20,21,22]. Not surprisingly, anemia prevalence among pregnant women varies by geographical area, culture, seasonality and countries [23] such as 75% in the current study, compared with 18% and 57% in Ethiopia [24,25]. The high prevalence that we observed might be due to increased physiological demands for nutrients during the second and third trimesters of pregnancy [26]. It could also be attributed to increased demand for iron by the growing fetus, particularly during the last trimester of pregnancy [27]. In addition to these possible explanations, the specific causes underlying the high anemia prevalence in the study setting might be attributed to the geographical area and cultural preferences, as was seen in northern Ghana with prevalences of 47% mild, 20% moderate, and 3% severe [10].

In bivariate analysis, some socio-demographic factors (e.g. older age) were associated with lower odds of moderate/severe anemia among pregnant women, while others such as occupation (e.g. herdsmen) and parity (primigravidae) were associated with higher odds of moderate/severe anemia. Our finding that increased age and greater parity were associated with lower risk of moderate/severe anemia may be due to the experience acquired by women during previous pregnancies and with ANC services, for example in the use of ITN and IPT. A similar study conducted in northern Ghana also found that increased parity was associated with reduced anemia, – ranging from 75.0% anemia among primigravidae to 43.7% among multigravidae [20]. Also, another investigation in southern Ghana reported

295 mean Hb concentrations of 9.7g/dl for primigravidae, 10.1g/dl for secundigravidae and 10.5g/dl for
296 multigravidae [28]. However, other studies have found that higher parity (multigravidae) was associated
297 with greater risk of anemia [25,29,30,31]. This might be due to differences in birth spacing rather than total
298 parity. For example, pregnant women with short pregnancy intervals were more likely to develop anemia
299 during pregnancy than those with longer birth spacing [27].

300 Our results indicated that pregnant women who worked in other occupations (e.g. herdsmen)
301 were are at greater risk of moderate/severe anemia. Usually, these families live in the peripheral settings
302 of rural Ghana communities, and therefore have reduced access to health facilities. In addition, they are
303 often from minority ethnic groups, hence are more likely to delay ANC initiation until second or third
304 trimester of pregnancy. Thus, they fail to exploit all opportunities offered by the ANC [32]. Salaried
305 workers and traders had lower odds of moderate/severe anemia when compared to farmers. This may be
306 due to their increased access to food, greater dietary diversity and improved food security compared to
307 farmers, for example, whose livelihood depends on seasonal crops to meet their nutrient requirements.

308 Greater parity was associated with lower odds of moderate/severe anemia in multivariable
309 analyses (Table 3). Specifically, first-time pregnant women were more than twice as likely to be
310 moderate/severe anemic. This is consistent with previous studies where primigravidae had increased risk
311 of anemia compared to multigravidae [12]. Until uncertain rituals are performed by the family members of
312 the husband to publicly declare or announce the pregnancy, they are unwilling to start ANC visits for
313 fear of miscarriage or other complications.

314 Dietary diversity may be an indicator of food access and use, and of diet quality. We observed
315 that after controlling for potential confounding factors (maternal education, occupation, wealth index,
316 ITN ownership and utilization, parity, ANC attendance, IPT and deworming medication) in multivariate
317 logistic regression model, achieving the MDD-W indicator was not associated with moderate/severe
318 anemia. Previous research in Ghana found consumption of other fruits or and seeds/nuts was statistically

319 associated with anemia and MDD-W was not associated with anemia [10], but another study found that
320 high maternal MDD-W was associated with a decreased risk of anemia [20]. Diet is an important factor for
321 anemia. Some eating patterns or habits may predispose pregnant women to an increased risk of
322 developing anemia. Poor dietary diversity leads to inadequacies in minerals and vitamins. Though we
323 observed that 85% of the pregnant women consumed ≥5 food groups in the previous day, dietary
324 diversity was not associated with a higher Hb concentration. This lack of association between MDD-W
325 and moderate/severe anemia may be due to inappropriate kinds of foods (i.e. animal-source foods with
326 highly bioavailable iron) that would be linked to lower anemia risk or challenges of nutrients
327 bioavailability from the consumed diets. We also found that consumption of animal-source foods was
328 not associated with lower odds of anemia in the current study.

329 Overall, 91% of pregnant women reported of ITN ownership and 83% slept under the ITN the
330 night before the interview. The coverage and utilization of ITN higher than a previous study conducted
331 in southern Ghana where 75% of pregnant women reported ownership of ITN and only 49% slept under
332 it the night preceding enrolment [33]. Similarly, the coverage of at least one IPT dose (84%) in the current
333 study exceeds the national average (68%) [33]. Independent of malaria interventions (household ownership
334 of ITN and slept under ITN on previous night), ≥4 ANC visits and deworming medication were
335 associated with lower odds of moderate/severe anemia among pregnant women aged ≥20 weeks of
336 gestation. In our study, deworming medication was protective against moderate/severe anemia. This
337 varies from the a previous study which reported that iron supplementation and deworming treatment was
338 not significant associated with anemia [30]. We observed that pregnant women who received IPT (83%)
339 had lesser of risk to develop moderate/severe anemia. An explanatory factor such as IPT was not
340 associated with moderate/severe anemia. Our current finding is similar to a study conducted in Ghana
341 which found that IPT shown a weak association with anemia using bivariate analysis but no association
342 when adjusted for confounders in multivariate analysis [20]. In a previous study conducted in Ethiopia,

malaria infection during pregnancy had higher risk to develop anemia [27]. Our study found that ownership of ITN and utilization of ITN were associated with reduced odds of moderate/severe anemia. This is suggestive of effective intervention in the study area. Deworming medication was associated with moderate/severe anemia. Parasitic infections are known to be a major cause of anemia. Thus, treatment against intestinal parasites help to improve hemoglobin concentration [3].

Strengths and Limitations

In terms of strength, the study focused on an important category of pregnant women with implications on birth outcomes. The sample size was also large and representative of the population accessing ANC services at HFs. This is probably the first study to assess the predicators of moderate/severe anemia among pregnant women (≥20 gestational weeks) in northern Ghana.

This study had several limitations and the findings should be interpreted as such. The study design was cross-sectional and does not allow us to assess causality. In addition, participant recall bias was a limitation but the interviews were conducted using a structured questionnaire and the interviewers were trained nurses and health science educators to mitigate the effect of recall bias. The study sample was limited to pregnant women who received ANC services at HFs, thus, some pregnant women were excluded. This may not be reflective of the study setting. However, the majority of Ghanaian women now seek ANC services.

CONCLUSION

The prevalence of anemia among pregnant women was nearly twice as national estimate in Ghana, and varied by maternal age, parity and occupation. Minimum dietary diversity was not associated to moderate/severe anemia. Household ownership of ITN, use of ITN and deworming medication were

associated with moderate/severe anemia. There is the need to intensify education on ANC services, ITN utilization and deworming medication to prevent and reduce anemia prevalence among pregnant women.

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Data Availability Statement

The dataset used and/or analyzed during the study is available from the corresponding author upon request.

Author contributions

MNA and MW conceptualized and designed the protocol and received support from AJ and RA. MW and RA supervised the implementation of the study. MNA and MY conducted the study. MNA and MW drafted the manuscript. RA, AJ and MY edited the manuscript. All authors read and approved the final manuscript.

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