Ghana Micronutrient Survey 2017

Ghana Micronutrient Survey 2017 (GMS 2017)

FINAL REPORT

Recommended Citation: University of Ghana, GroundWork, University of Wisconsin-Madison, KEMRI-WellcomeTrust, UNICEF. Ghana Micronutrient Survey 2017. Accra, Ghana; 2017

Survey collaborators

UNIVERSITY OF GHANA

Celebrating W 125 years
College of Agricultural & Life Sciences
UNIVERSITY OF WISCONSIN-MADISON

GroundWork
BUILDING GROUNDS FOR NUTRITION & HEALTH

KEMRI | Wellcome Trust

Funding agencies

unicef
for every child

Canada

Technical partners

GHANA HEALTH SERVICE
G H S
Your Health Our Concern

USDA ars
United States Department of Agriculture
Agricultural Research Service

Table of Contents

List of Figures

List of Tables

INVESTIGATORS AND INSTITUTIONAL AFFILIATIONS

Principal Investigators	Organization
Seth Adu-Afarwuah	Department of Nutrition and Food Science, University of Ghana-Legon
Fabian Rohner	GroundWork
Survey Coordinator	
Helena Bentil	Department of Nutrition and Food Science, University of Ghana-Legon
Investigators	
Matilda Steiner-Asiedu	Department of Nutrition and Food Science, University of Ghana-Legon
James P Wirth	GroundWork
Nicolai Petry	GroundWork
Bradley A Woodruff	GroundWork
Rita Wegmüller	GroundWork
Sherry Tanumihardjo	Department of Nutritional Sciences, University of Wisconsin-Madison
Laboratory Collaborators	
Thomas N Williams	KEMRI–Wellcome Trust Research Programme
Lindsay H Allen	USDA, Agricultural Research Service, Western Human Nutrition Research Center
Setti Shahab-Ferdows	USDA, Agricultural Research Service, Western Human Nutrition Research Center

Survey collaborators:
University of Ghana-Legon
GroundWork
University of Wisconsin-Madison
KEMRI-Wellcome Trust Research Programme

Funding agencies:
United Nations Children's Fund (UNICEF)
Global Affairs Canada

Technical partners:
Ghana Health Service (GHS)
United States Department of Agriculture–Agricultural Research Service

Acknowledgements

We are grateful to the many individuals and institutions whose support and commitment made this survey a reality:

- Parents and children who participated in the survey, for their cooperation and patience;
- UNICEF-Ghana and the Government of Canada for funding the survey; and Ms. Lilian Selenje, Dr. Victor Ngongalah and Mr. Abraham Mahama (UNICEF) for guidance and support during the survey proposal development and implementation;
- Ghana Health Service (GHS), especially Dr. Anthony Nsiah-Asare (Director General), Dr. Patrick Aboagye (Director, Family Health), and Ms. Esi Amoaful (Deputy Director, Nutrition), for support and overall guidance;
- Ghana Statistical Service (GSS), especially Ms. LucyTwumwaah Afriyie and Mr. Isaac Nyarko, for assisting with the selection of the enumeration areas and providing the cluster maps;
- Prof. Daniel Asiedu (Provost of the College of Basic and Applied Science) and Prof. Emmanuel Ohene Afoakwa (Head of the Department of Nutrition and Food Science), for their prompt responses in matters of administration concerning the survey within the University of Ghana;
- The Biomedical Technologists at the laboratories of the following hospitals and institutions for providing assistance with the cold storage of our blood samples: Mr. William Ofori Appawa at the Biochemistry Department of KNUST; Mr. Frank Asante at the Sunyani Regional Hospital; Mr Moses Banyeh at theTamale Central Hospital; Mr. Henry Quarshie and Mrs. Josephine Akorful at the Essikado Government Hospital; Mr. Samuel Asiamah and Mr. James Allotey at the Suhum Government Hospital; Saltpond Government Hospital; Half Asini Government Hospital;
- All the team members including Supervisors: Mr. Humphrey Thompson; Mr. William Ekow Spio-Donkor; Mr. Joe Nyefene Dare and Mrs. Elizabeth Boahen; Team Leaders: Ms. Juliet Vickar; Mr. Obed Harrison; Mr. Emmanuel Kwabena Fumador; Ms. Elizabeth Duah; Mr. Felix Kweku Kyereh; Mr. Isaac Boadu; Mr. Yvon Galaa; Mr. Naapong Kuuberme Edward; Mr. Richard Apini and Mr. Prosper Chapu; Interviewers: Mr. Daniel Armo-Annor; Mr. Kofi Amissah Appiah; Ms. Evelyn Danso; Mr. Amatus Annienu Baghri; Mr. Wisdom Kodzo; Mr. Nyamedor Evans Courage; Ms. Olivia Anokye; Mr. Eric Annor; Mr. Silas Appiah; Mr. Atta Boakye Jnr.; Ms. Salomey Boakye; Mr. Ebenezer Alangura; Mr. Alidu Ismael Atote; Mr. John Adateesi Aganah; Ms. Abu-Naa Zahari Aminbo; Mr. Mohammed Awal; Mr. Alhassan Ridwan; Mr. Ibrahim Abdul-Rahman; Mr. Gyekuu-Der Nichodemus; Mr. Zuberu Osman and Mr. Hudu Alhassan; Anthropometrists: Mr. Mensah Oppong Daniel; Mr. Sydney Phixon-Owoo; Mr. Ignatius Great Sakada; Ms. Patience Anku; Mr. Frederick Gyimah Yeboah; Ms. Barbara Boye; Mr. Michael Wiafe Akenteng; Ms. Koblaji Florence Akua; Mr. James Boyele Dakurah; Mr. Ishawu Iddrisu and Mr. Sulemani Bapula Herrick; Phlebotomists: Mr. Frank Boadi; Mr. Dennis Papa Acquah; Ms. Seyram Yaa Attivor; Ms. Joyce Antwi; Mr. Lawrence Ohuapo-Agyemang; Mr. Samuel Boafo Budu; Ms. Grace Nkansah; Mr. Samuel KofiTchum; Mr. Nestor Kukpieng; Mr. Solomon Okyere Koi; Mr. Adams Batiadan Abdul-Hanif and Mr. Obed Sarfo; Data: Mr. Ebenezer Adjetey and Mr. Richard Kofi Azumah; Drivers: Mr. Kofi Nanevi and Mr. Kwame Anom.

Abbreviations

AGP	α-1-acid glycoprotein
BMI	Body mass index
CRP	C-reactive protein
DHS	Demographic and Health Survey
EA	Enumeration area
ELISA	Enzyme linked immunosorbent assay
ERC	Ethical Review Committee, Ghana Health Service
GHS	Ghana Health Service
GMS 2017	Ghana Micronutrient Survey 2017
GSS	Ghana Statistical Service
HAZ	Height-for-age z-score
MICS	Multiple Indicator Cluster Survey
MoH	Ministry of Health
MRDR	Modified relative dose-response test
MUAC	Mid-upper arm circumference
NPW	Non-pregnant women (15-49 years)
ppm	Parts per million
PSC	Preschool-age children (6-59 months)
PW	Pregnant women
RBP	Retinol-binding protein
RDT	Rapid diagnostic test
TfR	Transferrin receptor
UNICEF	United Nations Children's Fund
WAZ	Weight-for-age z-score
WHO	World Health Organization
WHZ	Weight-for-height z-score

Foreword

In Ghana, micronutrient malnutrition continues to affect many children under five years of age and women. Although some reductions in micronutrient deficiencies have been achieved over the last decade, the prevalence of anaemia and deficiencies of vitamin A and iodine are still high and of public health concern. Notable causes of anaemia and micronutrient deficiencies include inadequate intakes of foods rich in the micronutrients, infections such as repeated bouts of malaria and diarrhoeal diseases, worm infestations and genetically-inherited conditions such as sickle-cell and -thalassemia diseases.

Over the past decades, several programmes have been implemented by the Ghana Health Service and other government agencies, with technical and funding support from partners, to help address micronutrient malnutrition in Ghana. These include routine vitamin A supplementation for children 6-59 months of age, iron and folic acid (IFA) supplementation for pregnant women attending antenatal clinics, IFA supplementation for adolescent girls aged 10-19 years in selected regions, routine deworming for school-age children, food fortification with vitamin A and iron, and salt iodization among others.

The Ghana Demographic and Health Survey provides some data on micronutrient malnutrition, however a comprehensive national data on the micronutrient situation in Ghana, especially for the vulnerable groups; such as children under five years of age and women of reproductive age have largely been unavailable. Recognizing the need for an updated, representative and reliable national data on the nutritional status of children under five years and women of reproductive age, the National Micronutrients Task team led by the Ghana Health Service held several consultative meetings with development partners, which ultimately led to the conduct of the Ghana National Micronutrient Survey in 2017. This survey was conducted by a consortium led by the University of Ghana and GroundWork, with technical and funding support from UNICEF and the Government of Canada.

The findings show there has been some modest reduction in anaemia prevalence in both women of reproductive age and children. This is indeed heartwarming and a possible indication of the success of on-going health interventions to prevent and control anaemia. We however hasten to indicate concern over the wide regional disparity that exists and also remain disturbed about the findings that indicate high rates of stunting levels and the wide variation in between regionsThis trend needs our special attention. The generation of program data including findings on the National Food Fortification Program is also of interest and will be a guide for policy makers to use in strengthening implementation.

We are grateful to all who supported the Ghana Micronutrient Survey 2017 in diverse ways and look forward to working with partners to drive policy and interventions aimed at improving the nutritional and micronutrient status of the Ghanaian populace.

Dr. Patrick Kuma Aboagye
The Director Family Health
Ghana Health Service

Executive Summary

Introduction

The African continent, in particular the sub-Saharan region, continues to be highly affected by malnutrition, which inhibits progress in human and economic development. In Ghana, despite two decades of sustained economic growth and reductions in some forms of malnutrition, progress on minimizing malnutrition, including micronutrient deficiencies, has been slow. Scarce data indicate that approximately 50% and 66% of non-pregnant and pregnant women and pre-school age children, respectively, suffer from anemia. Roughly 30% of pre-school children also suffer from iron and vitamin A deficiency. While 19% of children have been found to be stunted and 11% underweight in the 2014 Demographic and Health Survey (DHS), over 40% of women were found to be overweight or obese indicating the double burden of malnutrition is present in the Ghanaian population.

Currently, food fortification standards for iron, zinc, B-vitamins and vitamin A in wheat flour and vitamin A in vegetable oil exist in Ghana. Analyses conducted in 2011, however, showed that while 95% of oil samples in Ghana were adequately fortified (≥10 mg/kg for vitamin A), only 13% of wheat flour samples were adequately fortified (≥58.5 mg/kg for iron; [1]. Such low iron fortification levels in wheat flour and stability issues of retinyl palmitate added to vegetable oil, coupled with diets low in iron and provitamin A carotenoids, may be the reason for the high prevalence of anemia and vitamin A deficiencies in Ghana.

Objectives

The objective of this survey was to obtain updated and reliable information on the nutrition and micronutrient status of children 6-59 months of age, non-pregnant women 15-49 years of age, and pregnant women in Ghana, to formulate evidence-based recommendations improving the nutritional status of vulnerable groups.

Key nutrition indicators assessed included prevalence of anemia and malaria parasitemia in pre-school children, non-pregnant women, and pregnant women; deficiencies of iron and vitamin A in pre-school children and non-pregnant women; deficiencies of folate and vitamin B12 in non-pregnant women; prevalence of hemoglobinopathies in pre-school children and non-pregnant women; childhood wasting and stunting; child and adult overweight and obesity; and undernutrition in pregnant women.

Other variables that may potentially influence or cause various types of micronutrient deficiencies, such as socio-economic status, household food security, individual food consumption patterns, infant feeding and breastfeeding practices, intake of micronutrient supplements and information on the consumption of fortified vegetable oil and wheat flour were also assessed. At the cluster level, up to 6 flour samples were selected from bakeries and retail points to assess the coverage of adequately fortified (i.e., ≥58.5 ppm iron) wheat flour. For households, the coverage of adequately (i.e., ≥10 ppm vitamin A) fortified vegetable oil by quantitative measurement of vitamin A content was the primary indicator assessed.

Design

The GMS 2017 is a cross-sectional stratified survey based on a probability sample to produce estimates that have acceptable precision for priority indicators of nutritional status in children 6-59 months of age and non-pregnant women using three different strata across Ghana (Coastal belt, Middle belt, Northern belt) to represent areas with different agricultural and climatic conditions. Administrative regions included in each stratum are as follows: Coastal Belt (Greater Accra, Central, Volta, Western), Middle Belt (Brong-Ahafo, Ashanti, Eastern), and Northern Belt (Northern, Upper East, Upper West).

A two-stage sampling procedure was conducted to randomly select households. As a first stage, census enumeration areas (EAs) or clusters within each stratum were randomly selected with probability proportional to population size. For the second stage of sampling, a random selection of households in each EA or cluster was completed by using simple random sampling. The GMS 2017 survey was nationwide in scope, and collected data at the cluster level and from four target groups: 1) households, 2) children aged 6-59 months, 3) non-pregnant women of child-bearing age (15-49 years of age), and 4) pregnant women.

Results

In this executive summary, only national estimates are presented, but Table 1 refers readers to the corresponding table in the report containing more detailed results.

Table 1. Summary results of the Ghana Micronutrient Survey 2017

Target group	Indicator[a]	Result	Table[b]
Clusters			
	Flour iron ≥ 58.5 ppm	1.5 %	Table 15
Households			
	Oil vitamin A ≥ 10 ppm	55.6 %	Table 13
Children 6-59 months			
	Anemia	35.6 %	Table 27
	Mild anemia	17.8 %	Table A14-9
	Moderate anemia	17.0 %	Table A14-9
	Severe anemia	0.7 %	Table A14-9
	Iron deficiency	21.5 %	Table 27
	Iron deficiency anemia	12.2 %	Table 27
	Vitamin A deficiency (RBP)	20.8 %	Table 30
	Positive malaria RDT	20.3 %	Table 19
	Hemoglobinopathies, sickle cell disorder	13.1 %	Table 25
	Hemoglobinopathies, α-thalassemia	30.7 %	Table 25
	Stunting (i.e. HAZ < -2)	21.4 %	Table 22
	Wasting (i.e. WHZ (< -2)	7.0 %	Table 23
Non-pregnant women (15-49 years)			
	Anemia	21.7 %	Table 39
	Mild anemia	14.3 %	Table A15-1
	Moderate anemia	7.0 %	Table A15-1
	Severe anemia	0.4 %	Table A15-1
	Iron deficiency	13.7 %	Table 39
	Iron deficiency anemia	8.9 %	Table 39
	Vitamin A deficiency (RBP)	1.5 %	Table 41
	Folate deficiency	53.8 %	Table 42
	B12 deficiency	6.9 %	Table 43
	Positive malaria RDT	8.4 %	Table 38
	Hemoglobinopathies, sickle cell disorder	13.5 %	Table 37
	Hemoglobinopathies, α-thalassemia	34.6 %	Table 37
	Overweight (BMI>25)	24.7 %	Table 35
	Obesity (BMI>30)	14.3 %	Table 35
Pregnant women			
	Anemia	45.1 %	Table 48
	Malaria	9.5 %	Table 47
	Underweight (MUAC)	3.6 %	Table 46

[a] See text of method section for case definitions;
[b] Refer to the table indicated for more detailed analysis of the outcome, including group-specific results by age, region, wealth quintiles and other analyses.

Discussion

At the household level, most households had access to safe drinking water, but only 1 out of 10 households have adequate sanitary facilities. As such, access to adequate sanitation facilities should be increased, since access to safe drinking water alone is insufficient to reduce diarrhea in children.

Among household that had refined vegetable oil available, 56% were adequately fortified with vitamin A (i.e., having ≥ 10 µg RE/mL oil). This means that at the time of the survey, only 4 out of 10 households consumed adequately fortified oil nationally. That said, there are marked differences in proportions of adequately fortified oil by region and by agro-ecological zones, driven by the fact that the different oil brands reach different market segments and have varying vitamin A concentrations. For wheat flour, the GMS found that less than 2% of flour samples were adequately fortified, which is slightly lower that previous assessments. While wheat flour fortification is mandatory in Ghana [2], wheat flour milling companies have been reluctant to comply with national standards citing organoleptic changes following fortification.

Among preschool-aged children, infant and young child feeding practices are mostly adequate with regard to early initiation and continued breastfeeding, but clearly need improving with regard to minimum acceptable diet, both with regard to dietary diversity and food frequency. Also, vitamin A supplementation and deworming in the six months preceding the survey is quite low with only about one-third of the children receiving either of those interventions.

Child stunting affects close to 20% of the children under 5 years of age, a prevalence that is slightly lower but comparable to the 2014 DHS. Also similar to the DHS, the prevalence of overweight among pre-school children was quite low, affecting less than 1% of children. For stunting, the stunting prevalence was higher in rural children, and stunting prevalence decreased with increasing household wealth. A quarter of children 6-59 months of age reportedly had diarrhea during the two weeks preceding the interview, and a third or more reportedly had fever or cough during the same period. This high occurrence of illness is reflected by the high prevalence of elevated markers inflammation (AGP, CRP, or both) among the children.

Vitamin A deficiency affects about 20% of children in Ghana, with a higher prevalence in Ghana's northern belt (31%), and lower among children residing in wealthier households (9%). Despite the relatively high vitamin A deficiency prevalence in Ghanaian children based on retinol-binding protein, results from the modified relative dose response test are indicative of recent improvements of the vitamin A situation. Nonetheless, efforts to reduce vitamin A deficiency should be strengthened.

Anemia was markedly higher in the Northern belt (53.2%) compared to the Middle (28.2%) and Southern (32.3%) belts. A similar disparity was observed with ID and IDA as the prevalence in the Northern belt was substantially higher than in the other strata. To illustrate, IDA was nearly 30% in the Northern belt, but less than 8% in the Middle and Southern Belts. About 35% of anemic children had concurrent iron deficiency, which is slightly higher than the 28% estimate in a recent meta-analysis for countries in sub-Saharan Africa and indicates that iron deficiency continues to play an important role

in the etiology of anemia in Ghanaian children. The current analysis clearly suggests that there are multiple factors contributing to anemia in addition to ID. The GMS also illustrates that improving iron status may not always result in improved anemia prevalence. For example, children receiving deworming tablets had a significantly lower prevalence of ID and IDA, but no difference in the anemia prevalence was found. While children that consumed iron-fortified foods the day prior to the survey had very low levels of anemia (<2%), this finding may be a proxy for household wealth. About 10% and 30% of children in the fourth and wealthiest wealth quintile consumed iron-fortified foods, whereas these foods were consumed by 5% or less children in other wealth quintiles. As such, interventions focusing solely on reducing iron deficiency, although important, will not eradicate anemia.

Among non-pregnant women, about 50% consumed 5 or more food groups the day preceding the survey interview. Vitamin or mineral supplement intake when not pregnant was relatively rare, although a fifth of women stated having taken iron tablets in the previous six months. Almost seven out of ten women reported having consumed iron supplements during their last pregnancy; this coverage estimate is slightly higher compared to the 2014 DHS, where the corresponding coverage was 59%.

Nearly 40% of the Ghanaian women were overweight (25%) or obese (14%). Furthermore, prevalence of overweight/obesity is almost double in urban areas compared to rural areas, and is strongly positively associated with socio-economic status. While overweight and obesity increases with age, age likely serves as a proxy for parity. The overweight and obesity prevalence significantly increases from 12.2% in women with no births, to 28.6% in those with one birth, to 51.5% in those with two or more births. The well-documented link between overweight/obesity and type 2 diabetes, blood pressure, cardiovascular diseases and all-cause mortality highlights the importance of tackling the problem. Over and above, there is growing evidence of an intergenerational effect in that children born to overweight/obese mothers are more likely to be stunted or to also become overweight later in life.

One in five women was anemic, and about 14% and 9% had ID and IDA, respectively. Among anemic women, 40% had concurrent ID. ID is more prevalent in urban areas; there are differences by stratum for anemia and IDA, and a marginal difference for ID, with the Middle belt having higher prevalences. Sickle cell trait (HbAS) is also associated with slightly higher anemia prevalence, but it has to be noted that the numbers are small. ID and elevated inflammatory markers are highly and positively associated with anemia. Interestingly, many known risk factors for anemia were not significantly associated in the GMS 2017, such as current or recent malaria parasitemia, folate deficiency, recent iron supplement intake, folic acid supplement intake or multivitamin intake.

Vitamin A deficiency was hardly present in Ghanaian women, both when assessed using RBP and MRDR. We can conclude that the vitamin A status in Ghana appears to have improved over time and is likely due to diligent public health interventions. It is worth noting that in the Northern Belt, considerably more women are affected by VAD although the prevalence remains relatively low with 5%. Folate deficiency affects a bit over half of the women and although no prevalence thresholds for determining the

public health severity exist, can be considered highly prevalent. In contrast, vitamin B12 deficiency affects only 7% of women.

For pregnant women, because their number is limited, the GMS 2017 could only provide sub-group analyses for residence and stratum. Dietary diversity is comparable to non-pregnant women, yet supplement consumption is considerably higher.

Recommendations

Various programs and research projects are required to address the deficiency documented in the GMS. To address vitamin A deficiency in children, multiple approaches are needed. Ghana's vitamin A supplementation program should be strengthened as a measure to reduce the risk of mortality due to measles, diarrhea, and other illnesses. In addition, the vegetable oil fortification program should be strengthened to increase the coverage of adequately fortified vegetable oil, which would likely increase quantity of retinol consumed by children on a daily basis. In areas where vegetable oil is not widely consumed (e.g. Upper East and Upper West regions), policy makers should pursue social behavior change programs that increase the consumption of vitamin A-rich foods (i.e. foods other than fortified vegetable oil) and biofortification programs, if feasible in these areas.

To reduce anemia in children and women, programs should prioritize activities in regions in the Northern belt, as the anemia prevalence here is markedly higher than in the Middle and Southern strata. Interventions should include the promotion of age-appropriate infant and young child feeding practices, including the promotion of foods (fortified or unfortified) rich in iron and vitamin A. The GMS also recommends that malaria prevention programs be strengthened and targeted to rural and low-income households. Programs that reduce the prevalence of malaria in children will both help to reduce mortality and morbidity associated with malaria directly, and will also help to reduce anemia in children.

The prevalence of overweight and obesity has increased in Ghana in the past decade, and it programs, particularly for women in urban areas, are needed to prevent the prevalence of overweight and obesity from rising further. Due to the association between increased parity and increased overweight and obesity prevalence, it is recommended that antenatal and postnatal care provided by doctors and nurses be expanded to include behavior change messages and counseling for mothers

The GMS documented a very high prevalence of folate deficiency in women. To address this deficiency, it is recommended that Ghana's health system promote and expand the distribution of folic acid supplements. In addition, the implementation of Ghana's wheat flour fortification program should be improved. The GMS results suggest that wheat flour fortification is poorly implemented in Ghana, and challenges have been cited in previous reports about Ghana's fortification program. To improve the performance of Ghana's wheat flour fortification program, it is recommended that monitoring and compliance activities be strengthened.

1. Introduction

1.1. Nutritional situation of young children and women in Ghana

The African continent, in particular the sub-Saharan region, is highly affected by malnutrition, including micronutrient deficiencies [3], underweight, and restricted growth, which inhibit progress in human and economic development. Women of reproductive age, particularly during pregnancy and lactation, exhibit increased nutrient needs and are therefore vulnerable population groups. Additionally, because of the critical link between maternal and child nutrition, public health efforts have turned to ensuring adequate child nutrition during the first 1,000 days: from conception to a child's second birthday.

In Ghana, despite two decades of sustained economic growth and reductions in some forms of malnutrition, progress on minimizing micronutrient deficiencies has been slow. While scarce, data on the micronutrient status of women of reproductive age indicate that nearly 50% of non-pregnant women and 50% of pregnant women suffer from anemia, and the same percentage of non-pregnant women suffer from iodine deficiency. More data are available in pre-school age children, indicating that 66% are anemic, and roughly 30% suffer from iron and vitamin A deficiency. While 19% of children have been found to be stunted and 11% underweight in the 2014 Demographic and Health Survey (DHS), over 40% of women were found to be overweight/obese indicating the double burden of malnutrition is present in the Ghanaian population as shown before [4]. This is further confirmed when comparing anthropometric data over the past 20 years using DHS data from 1993 and 2014 showing a clear decrease in stunting in children 6-59 months of age from 33% to 19% and a slight increase in overweight from <1% to 3% [5,6]. The trend in non-pregnant women is an alarming increase in overweight/obesity (BMI<25) over the past 10 years from 25% in 2003 to 40% in 2014 with a parallel decrease in thinness (BMI<18.5) from 9% to 6% [5,7].

1.2. Fortification programs to combat micronutrient deficiencies in Ghana

Food fortification in Ghana began in 1996 with a legislation that enforced the iodization of salt. About 10 years later a decision was made to fortify wheat flour and vegetable oil. At present, Ghana has food fortification standards for iodine in salt; iron, zinc, B-vitamins and vitamin A in wheat flour; and vitamin A in vegetable oil. Wheat flour and vegetable oil sample analyses in 2011 have shown that 95% of oil samples were adequately fortified (≥10 mg/kg) while only 13% of wheat flour samples were adequately fortified (≥ 58.5 mg/kg for iron) [1]. Such low fortification levels in wheat flour and stability issues of the retinyl palmitate added to vegetable oil may be the reason for the remaining high prevalence of anemia and vitamin A deficiencies in Ghana.

1.3. Rationale for the survey

While some data on the nutritional and micronutrient status of women and children are available, there is no comprehensive assessment of nutritional status measuring both micro- and macro-nutrient indicators in Ghana. Although the prevalence of anemia

and under- and over-nutrition has been collected as part of DHS and Multiple Indicator Cluster Surveys (MICS), these surveys do not include assessment of micronutrient status. Although they often measure hemoglobin concentration, inference from anemia prevalence to iron deficiency (ID) prevalence is challenging, as shown in micronutrient surveys in the region [8,9].

The Ghana National Micronutrient Survey 2017 (GMS) is expected to increase the understanding of the severity of micronutrient deficiencies and provide a baseline against which to measure the future progress of various national nutrition programs. In addition, it gives an indication on coverage and fortification levels of fortified wheat flour and vegetable oil. Due to a recent national iodine deficiency survey, no indicator of iodine was included in the current survey.

1.4. Primary objectives and indicators

The overall objective of this survey was to obtain updated and reliable information on the current micronutrient status of children 6-59 months of age and women 15-49 years of age in Ghana. This information would be useful for developing evidence-based policies to improve the nutritional status of these target groups.

The GMS 2017 was nationwide in scope, and collected data at the cluster level and from four target groups: 1) households, 2) children aged 6-59 months, 3) non-pregnant women of child-bearing age (15-49 years of age), and 4) pregnant women. The specific aims for the various target groups are:

1. To measure the prevalence and severity of anemia in children 6-59 months of age, non-pregnant women of child-bearing age, and pregnant women based on blood hemoglobin concentrations.
2. To assess the prevalence and severity of iron deficiency in children 6-59 months of age and non-pregnant women of child-bearing age by measuring serum ferritin concentration (adjusted for the presence of inflammation) and by measuring serum transferrin receptor (TfR) and to calculate what proportion of anemia is associated with iron deficiency. Indicators of iron deficiency were adjusted for the presence of inflammation as indicated by elevated levels of C-reactive protein (CRP) and/or alpha-1-acid glycoprotein (AGP).
3. To assess the vitamin A status of children 6-59 months of age and non-pregnant women of child-bearing age by measuring retinol-binding protein (RBP) in serum and by measuring the modified relative dose response (MRDR) in a sub-sample. Note, the subsample of children for MRDR was 18-59 months old.
4. To estimate the current prevalence of deficiencies of folate and vitamin B12 in non-pregnant women.
5. To estimate the prevalence of the inherited blood disorders alpha-thalassemia and sickle cell disease and trait among children 6-59 months of age and non-pregnant women.
6. To assess the prevalence of malaria in children 6-59 months of age and non-pregnant women of child-bearing age by using a rapid antigen test for the presence of *Plasmodium falciparum* parasites and other *Plasmodium* species.
7. To assess the household coverage of adequately fortified oil (vitamin A).
8. To assess the coverage of adequately fortified wheat flour at the cluster level (iron).

1.5. Secondary objectives and indicators

The GMS also investigated other variables that may influence various types of malnutrition or play a causative role. This questionnaire based data included household socio-economic status, individual food consumption patterns, infant feeding and breastfeeding practices, intake of micronutrient supplements (e.g. iron-folate supplementation in women of reproductive age), and deworming of pre-school children.

In addition, the GMS collected anthropometric data (length/height, weight) on children 6-59 months of age and non-pregnant women 15-49 years of age to assess the association between micronutrient status and anthropometric measures.

As high levels of iron in drinking water have been associated with high iron stores in women in other countries [10,11], drinking water samples from randomly selected households were collected to: a) document the concentration of iron in Ghana's drinking water, and b) to investigate the association between individual iron status and drinking water iron concentration for the subsample of selected households.

2. Methodology

2.1. Survey design and sampling procedure

The GMS was a cross-sectional stratified survey. To account for Ghana's administrative, agro-ecological and population-density zoning, three different strata were established: 1) Southern Belt, predominantly coastal savannah and rainforest and comprised of the Greater Accra, Central, Volta, and Western Regions; 2) Middle Belt, predominantly deciduous forest and comprised of the Brong-Ahafo, Ashanti, and Eastern Regions; and 3) Northern Belt, predominantly Guinea/Sudan Savannah and comprised of the Northern, Upper West, Upper East Regions. This stratification was previously used in Ghana's 2015 National Iodine Deficiency Survey [12].

A total of 90 Enumeration Areas (EAs) or clusters were selected for the survey sample by using a 2-stage sampling procedure. Separate sampling frames were created for each of the three strata, such that 30 EAs or clusters were selected from within each stratum. Prior to selecting the clusters, 20 *sub-strata* were created by separating each of Ghana's 10 regions into urban and rural areas.

For the first stage of sampling, the number of clusters to be selected from each sub-stratum was determined by using a probability proportional to size (PPS) approach, whereby the proportion of households in the sub-stratum in relation to the whole stratum was used to determine the number of clusters to select. Implicit stratification with proportional allocation was achieved at each of the lower administrative unit levels by sorting the cluster frame before the sample selection according to a certain geographical order. The selected clusters and a map of their locations are shown in APPENDIX 1.

The second stage of sampling consisted of random selection with equal probability of a specific number of households in each selected EA or cluster using a random number table. The number of households selected to obtain the required number of women and children depended on the region because household size is quite different in different regions: 29 households in the Southern and Middle strata, 20 households in the Upper West and Upper East regions of the Northern stratum, and 15 households in the Northern region of the Northern stratum. This was done by using a complete and up-to-date list of all households in that cluster which was obtained by the survey team carrying out a census of all households in the cluster. In each selected household, all members of target groups were recruited for the survey, and households without any members of a target group were also included.

2.2. Sample size determination

An a *priori* sample size for the entire survey and each stratum was based on the estimated prevalence, the desired precision around the resulting estimate of prevalence, and the expected design effect for priority indicators of nutritional status in children 6-59 months of age and non-pregnant women (see APPENDIX 2). Calculations assumed an expected household response rate of 92%. Individual response rates for interview questions and anthropometric measurements were assumed to be 95%, while response

rates for venipuncture were assumed to be lower (90% for women; 85% for children). All calculations used Fisher's formula for estimating the minimum sample size for estimating prevalence:

$$n = \frac{Z^2_{\alpha/2} P(1-P)}{d^2} \times DEFF \times \frac{100}{CombinedRR}$$

Where:
$Z\alpha/2$ = Z-value corresponding to the 95% confidence level
P = Assumed prevalence
d = Desired precision expressed as the half confidence interval in decimal form
DEFF = Design effect
RR = Overall response rate (household response x individual response) expressed as a decimal

In total, 2,250 households were selected to ensure sufficient sample size of households, children, and women. While children 6-59 months of age and pregnant women were recruited from all selected households, non-pregnant women of reproductive age were only selected from every other household to limit the number of women selected.

2.3. Allocation of clusters by stratum

Average household size, and thus the average number of eligible women and children per household, differs substantially in the different regions of Ghana (see APPENDIX 3) [13]. Therefore the number of households, which needed to be selected to find and recruit the minimum number of women and children, was different among strata and regions. The average household size in the regions included in the Southern and Middle strata was assumed to range from 3.8 in the Greater Accra region to 4.6 in the Brong-Ahafo region. Because this is a relatively narrow range demonstrating relatively small differences, calculation for all regions in the South and Central strata assumed the average value of 4.1 household members.

In contrast, the average household sizes of the regions included in the Northern stratum were assumed to be markedly different. Households in both Upper East and Upper West regions contained an estimated 6.0 members, whereas the Northern region contained an estimated 7.7 members.

In order to obtain roughly equal numbers of children and women in all three strata, a different number of households were selected in clusters in the Southern and Middle strata, as well as the Northern stratum regions of Upper East and Upper West, and the Northern stratum's Northern Region (see APPENDIX 4). Each stratum had 30 clusters; therefore, dividing the 1,709 households to be selected in the Southern and Middle strata by the 60 clusters in these two strata resulted in a selection of 29 households in each cluster. The Upper East and Upper West regions of the North stratum had about 41% of the population of the North stratum and, therefore, had 12 clusters. In each of these clusters, 20 households were selected. In the North Region, 15 households were selected in each of the 18 clusters in that region. In total, 2,217 households were required to be selected for the survey.

Specifically, for children, the selection of 2,217 households was expected to result in the recruitment of about 1,100 survey subjects for the entire survey sample, with about 1,000 of them expected to have their biological specimens collected. This number of children is lower than that required for some indicators, but higher than the number required for others. On the other hand, the selection of 2,217 households was expected to result in the recruitment of more than 2,000 non-pregnant women, which is substantially greater than the number needed for most indicators for which sample size is calculated in this target group. Therefore, non-pregnant women were recruited for survey participation in a random sample of ½ of selected households. Because of the expense of testing and the lower sample size required, folate and vitamin B12 were assessed in a random selection of ½ of these women only. This would result in the collection of interview data, anthropometric measurements, and blood specimens for hemoglobin, vitamin A, iron markers and blood disorders from about 900 women. About 430 women would have data on folate and vitamin B12 concentrations.

With this sample size and sampling scheme, the precision obtained for most indicators in most target groups was equal to or only slightly less than the desired precision. The glaring exception to this was pregnant women because it is usually difficult to recruit a large number of pregnant women in household-based surveys. Even in the highest fertility populations, pregnant women are still relatively rare in the general population. As a result, usable precision can be obtained for the prevalence of anemia among pregnant women only on a national level. The estimates for pregnant women in each stratum were expected to have low precision and will therefore not be calculated.

2.4. Study population

Table 2 below lists the inclusion criteria for enrollment into the survey for each of the target groups. Note that for pregnant women, only one nationally representative estimate is generated for the prevalence of anemia, malaria, and underweight. For all groups, an individual was excluded if, for pre-school children, the parent or guardian refused; for girls 15-17 years, the girl herself or a parent refused; and for an adult woman 18 years of age and older, the individual herself did not give consent.

2.5. Ethical considerations

Ethical approval for the survey was obtained from the Ethical Review Committee (ERC) of the Ghana Health Service (GHS); the approval letter is presented in APPENDIX 5. The survey protocol was registered with the Open Science Framework study registry (https://osf.io/j7bp9/).

For household interviews, oral consent was sought from the household head or in his/her absence, from another adult household member. The selected women and child caregivers were asked to provide written informed consent (see APPENDIX 6 for information sheet and consent form) for themselves and their participating children. If any consenting survey participants were unable to read and write, the consent form was read out loud to them and a thumbprint or fingerprint was taken as evidence of consent in lieu of a signature. Alternatively, the respondent could assign a witness to sign on their behalf. The respondents were also told that they are free to withdraw from participation in the survey at any time, even after written consent had been given.

Table 2. Inclusion criteria by targeted population group

Target population	Inclusion criteria
Households	• Household head or spouse or other adult household member gives oral consent for survey data collection • Members currently residing in selected EA
Children 6-59 months	• Age 6-59 months at the time of survey data collection • Considered a household member by adults living in the household • Mother or caretaker provided written consent for questionnaire, anthropometric measurements, and collection of biologic specimens
Non-pregnant women	• Age 15-49 years at the time of survey data collection • Currently non-pregnant by self-report • Gives written consent for survey questionnaire, anthropometric measurements, and collection of biologic specimens • Considered a household member by other adults living in the household
Pregnant women	• Currently pregnant by self-report • Gives written consent for survey questionnaire, anthropometric measurements, and collection of biologic specimens • Considered a household member by other adults living in the household

2.6. Field work and data collection

2.6.1. Instrument pre-testing, training of survey teams and field testing

Prior to data collection, team members were thoroughly trained, and all survey instruments were pre-tested during the training. We thoroughly checked the questionnaires regarding the flow and the appropriateness of different response options.

The training consisted of classroom instruction and practice and of field testing of all survey procedures. Particular attention was given to the procedures to list all households in an EA and randomly select households.

Survey staff also received extensive classroom training of each questionnaire, whereby interviewers and team leaders discussed each question, practiced reading the questions, and role-played interviews in local languages. In addition, instruction was provided on how to record, save, and upload data on the tablet computers (Galaxy, Samsung™) used in the GMS 2017 survey.

As part of classroom training, anthropometrists and phlebotomists were trained on anthropometric and blood collection techniques. A standardization exercise was

conducted for the survey anthropometrists, whereby an anthropometrist, assisted by the phlebotomist measured and recorded the length/height of 10 children, and their results were checked for precision as well as for accuracy when compared with those of the "gold standard". Regarding phlebotomy, blood collection procedures were practiced, including training on labeling of samples, processing of samples, labeling of aliquots, pipetting procedures, and maintenance of the cold chain when transporting blood specimens.

Following classroom training, two days of field testing was undertaken in two EAs in the vicinity of Accra, which were not included in the survey sample. The teams conducted the community sensitization, household listing and selection, interviewing and anthropometry/phlebotomy, and practiced transportation of specimens to a blood processing point and processing of blood samples. Wheat flour, oil and water samples were also collected.

To ensure that all survey staff ultimately hired could implement the survey procedures, 20% more survey workers than required were enlisted for the training. To assess their understanding of field procedures, a short exam containing questions about various survey procedures was given to all survey staff. The results of this exam, the results of the anthropometry standardization exercise, and observations from the survey trainers were used to: a) identify the best-performing team members and appoint a team leader for each team, and b) identify survey workers that could not adequately understand and implement the survey procedures. These individuals were released and were not included for the field work.

2.6.2. Community mobilization and sensitization

At the start of the fieldwork, the survey team was provided an authorization letter (see APPENDIX 7) from the Ghana Health Service. Before entering any cluster, teams presented this letter to the Regional and District Directors of Health Services to notify them that the GMS would be conducted in their area. Shortly before the team's arrival in a given EA, the team leader visited the EA to inform and pre-sensitize local authorities on the upcoming survey activities. Upon arrival of a team in an EA, the team met with the relevant authorities to inform them again about the work and also seek their support.

2.6.3. Household listing and random selection of households

Because Ghana's last national census took place in 2010, the lists of households in the selected EAs as used by the 2010 Census were no longer current. As such, an up-to-date list of households in each EA was created by the field workers immediately before the survey data collection.

Using EA maps provided by the Ghana Statistical Service, team members identified the boundaries of each EA with the assistance of a local guide. Once familiar with the EA boundaries, team members visited each household in the EA and listed each household on a separate line in the Household Listing Form.

Once completed, the team leader selected the required number of households at random using random number tables. After selection, the different households

were assigned to the interviewers and interviews with the head of households were scheduled.

2.6.4. Field work (interviews)

Data collection in 89 out of 90 EAs was conducted between 27th April and 30 May 2017, with most clusters completed before the start of Ramadan on 27th May 2017. Data collection in the final EA, located in the Southern stratum was conducted 7- 9 June 2017, since this EA was re-drawn to replace a selected EA that was located inside the boundaries of a military base (Burma Camp), and was thus inaccessible to survey workers.

Each of the 10 teams were comprised of one team leader, at least two interviewers, one phlebotomist, one anthropometrist and one driver. The composition of each team is provided in APPENDIX 8. While three teams were assigned to each of the Southern and Middle Belts, four teams were assigned to the North stratum. Four, rather than three teams were assigned to the North stratum to account for the geographic distribution for the EAs and to ensure that all EAs would be surveyed prior to the start of Ramadan. Each team was responsible for data collection in 7-12 EAs.

All reasonable attempts were made to recruit selected households. At least two repeat visits were made before dismissing a household as non-responding. No substitution of non-responding households was done as this had been taken into account during the sample size calculation.

For data collection at the household level, tablet computers were used for direct data entry. In addition to the questionnaires, a series of supporting instruments (loaded on the tablets, such as pictures of common micronutrient supplements, wall materials etc.) were used to facilitate field work and ensure high quality of the field work. Skip patterns were built into the questionnaires as uploaded in the tablets, which speeded up the interviewing process as well as minimized inappropriate entries. Interviewers administered the household questionnaire first, followed by the child and women questionnaires if the household had eligible children and/or women (as prompted by the tablet). During the household interview, a household roster was completed, and for individuals whose age was not known or could not be obtained from official documentation (e.g. Child Health Form), interviewers used two local event calendars for children <5 years old and individuals 5 to 60+ years old. Household and individual questionnaires were administered in English or were translated directly into the local language (e.g. Twi, Ga, Fante, Ewe, Dagaare, Waale, Frafra, Dagbani) depending on the interviewee's preference. Links to all questionnaires (in English) are provided in APPENDIX 9.

For selected women and children, interviewers prepared and labeled a biological form and directed those participants (or their mothers) to a central location in the EA where the anthropometrist and phlebotomist were stationed. The first two children and the first two women in each EA were recruited for the MRDR test, which followed a slightly different procedure and labeling. After the interviews, a sample of currently available refined vegetable oil was collected from each household. Drinking water samples from five randomly selected households in each cluster were also collected.

2.6.5. Field work (Anthropometry and phlebotomy)

First, anthropometric measurements from selected children and women were taken using standard methods [14]. For children who could not stand by themselves, the mother or caregiver was first measured alone, then together with the child, so that the child's weight was obtained by subtraction. Children's height or length was measured by using a standard wooden height board (UNICEF, #S0114540). The feet of children were examined for edema, and edema was only considered present if it was bilateral. For non-pregnant women, weight was measured using the same scale as used for children. Height was measured using the same standard wooden height board as used for the children. For pregnant women, only their mid-upper arm circumference (MUAC) was measured by using a recently developed MUAC tape (Médecins sans Frontières, UK).

For the individuals selected for the MRDR test, the procedure was completed as follows: A standardized dose (child: 5.3 µmol; woman: 8.8 µmol) of 3,4-didehydroretinyl acetate was administered when they arrived at the phlebotomy site. The dose was followed by 1 mL of unfortified vegetable oil and a high-fat snack (Nutella on crackers). If the infant was still being breastfed, the mother was encouraged to let the child suckle. Participants were then instructed to return to the site 4 to 6 hours after administration of the dose for anthropometry and phlebotomy.

Capillary blood was collected in all children except those recruited for the MRDR component. For the finger pick (children >11 mo of age) or heel-prick (children 6-11 mo of age), the site was cleaned with an alcohol pad and wiped dry with a sterile gauze pad. Following the lancet puncture (Becton Dickinson, Franklin Lakes, NJ, USA), the first two drops were wiped away with sterile gauze, and the third and fourth drops of blood were collected to measure hemoglobin concentration and malaria status. Thereafter, approximately 300-400 µl of blood was collected into a silica-coated Microtainer™ .

For children enrolled in the MRDR component as well as non-pregnant women, blood was collected via venipuncture into tubes containing clotting activator. Using a DIFF-Safe device (Becton Dickinson, Franklin Lakes, NJ, USA), a small amount of blood was extracted from the tubes onto a weighing boat to assess hemoglobin concentration and malaria status. Remaining whole blood was placed in a cool box containing cold packs to ensure they are stored cold but not frozen at ~4°C and in the dark until further processing later the same day. For pregnant women, blood was collected from a fingerstick for hemoglobin measurement and malaria RDT only.

Participants found to have severe acute malnutrition, severe anemia or malaria parasitemia were referred for treatment at the nearest health hospital or clinic. Blood was not collected in a fasting state as this was unnecessary, since no biomarkers sensitive to fasting state were measured.

To compensate for participants' time and the oil sample donated, households were given two long-bars of soap as a token of appreciation. At the end of each day, the team leader reviewed and collated the biological forms and consent forms, and reviewed data collected in ODK. Interviewers were notified of any errors and/ or omissions, whereupon they were instructed to make the necessary corrections, when possible.

Because wheat flour is rarely available directly at the level of household, samples were selected from up to 3 bakeries and up to 3 shops in each cluster. If there were more than 3 of the various sales points, the team leader selected the required number randomly. Further, if there was no bakery in the cluster, information on where each of the sampled sales point purchases for the bread was gathered, and the mentioned bakeries were visited if logistically possible, even if they were outside the cluster. A maximum of 6 flour samples were collected for each cluster.

2.6.6. Cold chain and processing of blood samples

Following collection, all blood samples were placed on cold packs (approximately 4°C) until processing. Phlebotomists recorded the temperature inside of the ice chests containing the cold packs every two hours.

The phlebotomists processed blood samples each evening. Blood was centrifuged at 3,000 rpm for 10 minutes. Serum and red blood cells (RBCs) were subsequently aliquoted into appropriately-labeled micro tubes.The micro tubes were kept in portable freezers (Dometic CFX-35W) at -20°C purchased for the survey, or transported in a portable freezer to a stationary freezer in a Government hospital (where possible) for the duration of the field data collection.Thereafter, all blood samples were transported to a central freezer (-20°C) at the University of Ghana, before being shipped on dry ice to international laboratories for analyses: the University of Wisconsin-Madison, USA (MRDR analysis); VitMin Laboratory in Germany (iron status indicators, RBP and inflammation markers); USDA - Agricultural Research Services laboratory, University of California, Davis, USA (folate and vitamin B12), and the KEMRI-Wellcome Trust Institute in Kenya (hemoglobinopathies). All shipments arrived frozen.

2.6.7. Supervision of fieldwork

Supervision was provided consistently. During the first week of field work, intense supervision was conducted to prevent potential flaws in operation. In addition to team leaders, a roaming supervisor was assigned to each stratum, who ensured that the correct survey procedures were followed. Furthermore, targeted visits to teams were conducted by the Principal Investigator and Survey Coordinator.

2.7. Definitions of indicators and specimen analysis

2.7.1. Anthropometric indicators

Pre-school children

In children, undernutrition (including wasting, stunting, and underweight) and overnutrition was defined using WHO Child Growth Standards [15]. Children with z-scores below -2.0 for weight-for-height and height-for-age were defined as wasted or stunted, respectively. Moderate wasting and stunting were defined as a z-score less than -2.0 but greater than or equal to -3.0, and severe wasting and stunting were denoted by z-scores less than -3.0. Children with bilateral pitting edema in the feet and/or lower legs were automatically considered as having severe wasting, regardless of their weight-for-height z-score. Overnutrition was defined as a weight-for-height z-score greater than +2.0. Overweight was defined as a weight-for-height z-score of greater than +2.0 but less than or equal to +3.0 and obesity as a weight-for-height z-score greater than +3.0.

Non-pregnant women

Chronic energy deficiency and overnutrition in non-pregnant women were assessed by using BMI. We used the following most commonly used cut-off points for BMI to define levels of malnutrition in non-pregnant women (19): <16.0 severe undernutrition, 16.0-16.9 moderate undernutrition, 17.0-18.4 at risk of undernutrition, 18.5-24.9 normal, 25.0-29.9 overweight and >30 obese.

Pregnant women

Because body weight in pregnancy is increased by the products of conception and extra body fluid, BMI is not a valid indicator of nutritional status. MUAC was used instead to measure the nutritional status of pregnant women. A MUAC of less than 23 cm was used to define a pregnant woman as undernourished [16].

2.7.2. Blood specimens

Malaria measurement

The qualitative assessment of malaria infection was done by using the SD BIOLINE Malaria Ag P.f/Pan rapid diagnostic test kit (Standard Diagnostics Inc, Gyeonggi-do, Republic of Korea), which detects *P. falciparum* and other *Plasmodium* species (*P. vivax, P. malariae or P. ovale).*

Anemia

Blood hemoglobin concentration was measured by using a HemoCue™ portable hemoglobinometer (Hb301, HemoCue, Ängelholm, Sweden). Quality control of the Hemocue devices was done daily using low, medium and high concentration liquid control blood commercially available from the device supplier. Control blood was kept in cold boxes (2-8°C) for the duration of the field work to prevent degradation.

Iron (serum ferritin and TfR), acute phase proteins (CRP, AGP), and vitamin A (RBP)

Serum ferritin and TfR were used to assess iron status of all young children and non-pregnant women. Ferritin concentration has been recommended by the World Health Organization (WHO) as the marker of first choice for iron deficiency in population based surveys [17]. Because serum ferritin levels can be elevated in the presence of infection or other causes of inflammation, the acute phase proteins AGP and CRP were used to detect the presence of inflammation in survey subjects. For children and women, ferritin values were adjusted for inflammation using the correction algorithm developed by Thurnham [18], and these adjusted ferritin values were used to calculated the prevalence of iron deficiency. Because TfR is thought to be less affected by inflammation, WHO recommends using it to measure the prevalence of iron deficiency in populations with high levels of inflammation.

RBP was used to assess vitamin A status of young children and non-pregnant women. RBP instead of serum retinol was used because it requires smaller quantities of serum, and is much cheaper to measure than retinol using HPLC. RBP concentration is highly correlated with serum retinol [27], which is the biomarker for vitamin A status recommended by WHO. Regardless, because RBP is not a WHO-recommended biomarker for assessment of vitamin A status, a sample of approx. 150 specimens from children and 150 specimens from non-pregnant women were analyzed for serum retinol concentration at the Tanumihardjo laboratory, University of Wisconsin-Madison

(see APPENDIX 10). As inflammation can depress RBP levels, the correction algorithm developed by Thurnham was used to adjust the RBP concentrations in children [19], and these adjusted RBP values were used to calculate the prevalence of vitamin A deficiency in children and women.

The Thurnham approach was compared with the approach developed by the *Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia* (BRINDA) Project (brinda-nutrition.org)[20,21]. Of note, the BRINDA project does not recommend any adjustments to RBP concentrations in women, and as such, no adjustments were made to RBP in non-pregnant women. A comparison of distributions and deficiency prevalences resulting from adjusting ferritin and RBP using both the Thurnham and BRINDA methods are presented for children and for women in the "additional tables and figures" appendices.

In addition to inflammation adjustments made to ferritin and RBP, acute phase proteins were used to categorize the various inflammation stages of individuals. Concentrations of CRP >5 mg/L and AGP >1 g/L denote acute and chronic inflammation, respectively. Using the approach developed by Thurnham [18,19], each individual was assigned to one of the following four inflammation categories: incubation (elevated CRP only), early convalescence (elevated CRP and AGP), and late convalescence (elevated AGP only), and no inflammation.

Serum ferritin, TfR, CRP, AGP, and RBP were analyzed using an enzyme linked immunosorbent assay (ELISA) technique [22]. The VitMin Laboratory in Germany, where these analyses were conducted, participates regularly in inter-laboratory quality assurance programs, such as the VITAL-EQA from the CDC.

Serum 3,4-didehydroretinol and retinol

The MRDR test was conducted in sub-samples of 149 children 18-59 months of age and 159 non-pregnant women. The MRDR test is a qualitative measure of liver stores of vitamin A. Serum samples were analyzed by using HPLC and a standardized method for 3,4-didehydroretinol and retinol [23]. β-apo-C23-carotenol was used as an internal standard to determine extraction efficiency. HPLC-purified retinol and 3,4-didehydroretinol were used to construct the external standard curves. In most population groups, a ratio of 3,4-didehydroretinol to retinol > 0.060 corresponds to depleted liver vitamin A reserves. The mean ratio was calculated as well as the prevalence of women or children above this cutoff.

Serum folate and vitamin B12

Serum folate and vitamin B12 concentrations (in half of the samples of non-pregnant women) were measured by using the Cobas e411 analyzer (Roche Diagnostics, Indianapolis, IN, USA).

Hemoglobinopathies

Testing for hemoglobinopathies (for all children 6-59 months of age and non-pregnant women) was conducted by using polymerase chain reaction (PCR) to genotype HbA and HbS alleles [58-60]. Hemoglobinopathies that were measured included sickle cell disease and trait (HbSS and HbS) and α-thalassemia.

2.7.3. Analysis of food and water samples

Iron in wheat flour and vitamin A (as retinyl palmitate) in vegetable oil were analyzed using the iCheck Iron and the iCheck Chroma 3 (BioAnalyt, Potsdam, Germany; [24,25]). Analyses were done at the University of Ghana by trained laboratory technicians. A fortified wheat flour as well as a fortified vegetable oil served as control samples and their analysis was repeated after each 10th sample for quality control.

Drinking water iron content was analyzed semi-quantitatively by using a commercially available test (HACH Iron test-kit, Model IR-18B; Loveland, CO, USA) measuring ferrous iron at the end of each day after the water sample was collected by interviewers in the field.

Following Ghana's food fortification standards [1], iron concentrations in wheat flour ≥58.5 ppm and retinol concentrations >10 ppm in vegetable oil were used to classify both food vehicles as "adequately fortified".

2.8. Data management and analysis

2.8.1. Data entry

Direct electronic data entry was done by using Open Data Kit (ODK[1]) during the household, child, and women interviews. For the parts of the individual questionnaires (biological form) that were completed by the anthropmetrist/phlebotomist using a paper form, the interviewers entered the data into ODK on the same or the following day on the additional data entry forms (biological form for children and women) pre-programmed in ODK.

2.8.2. Data monitoring

Interview data uploaded from the tablets to the cloud were monitored continuously and in case of systematic errors made by several teams, all team leaders were immediately informed about the problem, so the problem was not repeated; sporadic errors were directly reported to the respective team leaders. For errors that the teams could address, they were requested doing so immediately, while still in a given EA.

2.8.3. Data analysis

Data analysis was done by using Stata/IC version 14.2. All analyses on questionnaire data and biomarkers were conducted using a weighted analysis to account for the unequal probability of selection in the three strata. Further details on the calculation of the survey weights are given in APPENDIX 11. For analyses related to food samples, survey weights were only applied to vegetable oil indicators, such as proportion of vegetable oil samples that are adequately fortified. No weights were applied to analysis of iron content in water samples collected from households due to lack of variability in the iron concentration values. In addition, no weights were applied to wheat flour samples because these were collected using a convenience sample approach from markets within each cluster (see Section 2.7.3).

1 https://opendatakit.org/

For continuous variables, means with standard deviations and medians with interquartile ranges were calculated. For categorical variables, proportions were calculated to derive the prevalence of various outcomes. The statistical precision of all prevalence estimates was assessed by using 95% confidence limits which were calculated accounting for the complex sampling used in this survey, including the cluster and stratified sampling. All measures of precision, including confidence limits and chi square p values for differences, were calculated accounting for the complex cluster and stratified sampling used by the GMS 2017. The design effect for key outcome indicators are presented in APPENDIX 12.

Descriptive statistics were calculated for all children together and all women together (i.e., across all strata), for each stratum separately, and by sex (for children). Results are also presented by specific age sub-groups for non-pregnant women (15-19 years, 20-29 years, 30-39 years, and 40-49 years) and children (6-11 months, 12-23 months, 24-35 months, 36-47 months, and 48-59 months of age). For pregnant women, only national estimates for all ages were generated.

To geographically represent the coverage of adequately fortified wheat flour and vegetable oil, weighted prevalence estimates for each region were merged and displayed in geographic analysis software (Quantum GIS 2.6; http://qgis.osgeo.org).

2.8.4. Case definitions of deficiency

The cut-off values for each biomarker indicator used to determine nutritional status for each participant are presented in Table 3. For hemoglobin concentration multiple cut-offs were used to classify the severity of anemia. For other indicators, a single cut-off is used to identify deficiency or abnormality. For vitamin B12, WHO guidelines recommend a deficiency cut-off of <150 pmol/L, and this cut-off was used for national-level and all sub-group analyses [26]. As researchers have defined B12 concentrations from 150-220 pmol/L as "marginal" [27], we used a cut-off of 220 pmol/L to define both B12 marginal status and deficiency (see Section 4).

Table 3. Clinical cut-off points and classifications for biomarker indicators

Indicator	Cut-offs defining deficiency or abnormality		
Hemoglobin [28]	Severe	Moderate	Mild
Children 6-59 months of age	<70 g/L	70-99 g/L	100-109 g/L
and pregnant women			
Non-pregnant women	<80 g/L	80-109 g/L	110-119 g/L
Ferritin † [17]			
Children 6-59 months of age (PSC)		< 12 µg/L	
Non-pregnant women (NPW)		< 15 µg/L	
Transferrin receptor (TfR)			
PSC and NPW		>8.3 mg/L‡	
1-acid-glycoprotein (AGP) [18,19]			
PSC and NPW		>1 g/L	
C-reactive protein (CRP) [18,19]			
PSC and NPW		>5 mg/L	
Retinol-binding protein (RBP) †, §			
PSC and NPW		<0.7 µmol/L§	
Folate [26]			
NPW		<10 nmol/L	
Vitamin B12 [26]			
NPW		<150 pmol/L	
Serum 3,4-didehydroretinol/ retinol			
Children 18-59 months of age and		>0.060 (mol/mol)	
NPW		>0.060 (mol/mol)	

* The cut-off defining normal hemoglobin concentrations is typically adjusted for the number of cigarettes smoked per day following WHO guidelines (26). However, no women participating in the GMS 2017 smoked, and thus no adjustment was required.

† Ferritin and RBP values were adjusted for inflammation using appropriate algorithms [20,21].

‡ There is no generally agreed upon threshold for serum TfR, but the most commonly used commercial assay (Ramco) suggests the above threshold.

§ There is no general consensus on the cut-off point for RBP to be used to define vitamin A deficiency. Because of the 1:1 molar ratio of retinol and RBP in blood, many investigators use 0.70 µmol/L (the same cut-off used for serum retinol) although other cut-offs have been proposed [29].

2.8.5. Calculation of wealth index and socio-economic status

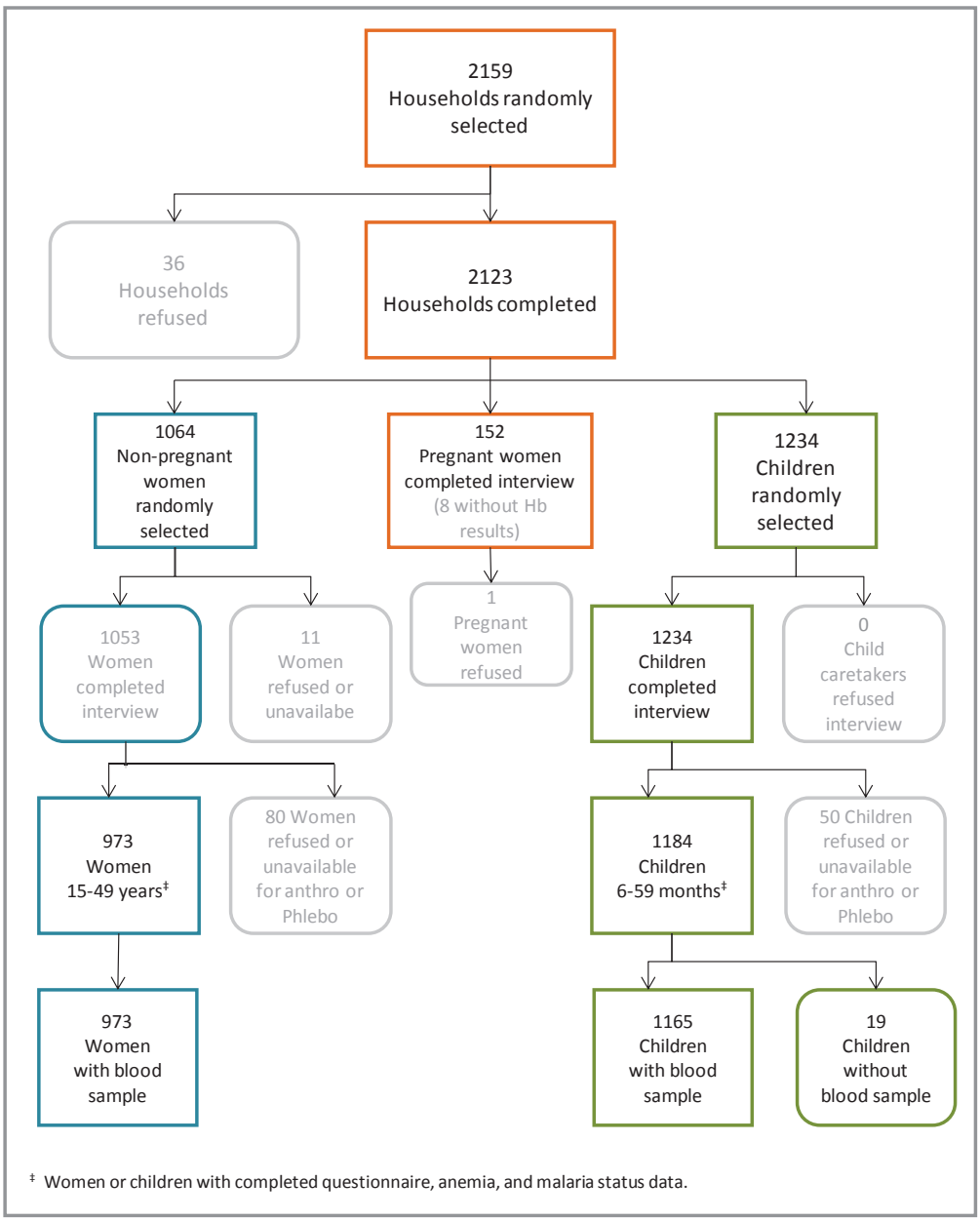
Using data on each household's dwelling, water and sanitation conditions and facilities, and ownership of durable goods, a wealth index was calculated by using the World Bank method [30]. Calculation of wealth index quintiles categorizes the continuous wealth index and permits the cross-tabulation and the subsequent presentation of key indicators by wealth quintile.

3. Results

3.1. Response rates for households, children, and women

Figure 1 below provides an overview of the number of respondents at the different survey stages, and illustrates that few households, women and children refused to participate in the survey. Only 1.6% of households refused to participate in the survey. Among women residing in the participating households, 1,064 non-pregnant women were identified, and only 1.0% of these women refused or were unavailable to participate. In these same households, 153 pregnant women were present, and only 1 of these pregnant women refused to participate. Among children, no caretakers refused to participate in the interview, but about 4% refused or were unavailable to participate in the anthropometry and phlebotomy component of the survey.

Figure 1. Flow diagram for participation of households, women and children, Ghana, 2017



‡ Women or children with completed questionnaire, anemia, and malaria status data.

3.2. Household characteristics

3.2.1. Demographic characteristics

Of the households selected, about 52% were located in rural areas, a similar proportion that was found in the 2010 Census [13]. The highest proportion of households was located in the Eastern Region, and the smallest proportion in the Upper West Region. The characteristics of participating households in the GMS 2017 are summarized in Table 4 below.

Table 4. Distribution of various demographic variables for participating households, Ghana 2017

	Survey Sample			Ghana Population [c]
Characteristic	n	% a	(95% CI)[b]	%
Residence				
Urban	982	52.1	(39.9; 64.0)	50.9
Rural	1141	47.9	(36.0; 60.1)	49.1
Stratum				
Southern Belt	788	41.1	(35.7; 46.8)	43.4
Middle Belt	840	43.0	(37.7; 48.5)	39.5
Northern Belt	495	15.8	(12.2; 20.3)	17.1
Region				
Western	192	7.7	(3.0; 18.2)	9.6
Central	174	8.2	(3.6; 17.6)	8.9
Greater Accra	279	17.0	(9.9; 27.7)	16.3
Volta	143	8.3	(3.6; 17.7)	8.6
Eastern	219	9.4	(4.4; 18.8)	10.7
Ashanti	420	24.3	(16.0; 35.1)	19.4
Brong Ahafo	201	9.3	(4.5; 18.5)	9.4
Northern	262	6.8	(4.6; 9.9)	10.1
Upper East	138	6.6	(2.9; 14.3)	4.2
Upper West	95	2.4	(1.0; 5.5)	2.8
TOTAL RESPONDING HOUSEHOLDS	2123	100	--	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Ghana Census Report 2010

On average, households had about four members, with nearly 85% of household containing 1-6 members (see Table 5). More than half of the households contained 1 woman 15-49 years old, and approximately 90% of households contained 0-1 children 6-59 months.

Table 5. Distribution of household composition of participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Average household size			
Mean	2123	4.2	(4.0; 4.4)
Median (IQR)	2123	4	(2; 6)
Number of household members			
1	307	16.3	(13.9; 19.0)
2	304	14.9	(13.3; 16.7)
3	309	14.9	(13.4; 16.6)
4	339	16.4	(14.5; 18.4)
5	272	11.8	(10.2; 13.6)
6	222	10.4	(8.9; 12.0)
7	122	4.9	(4.0; 6.1)
8	94	3.9	(3.1; 4.9)
9	52	2.2	(1.6; 2.9)
10+	102	4.3	(3.0; 6.0)
Number of women 15-49 years of age in households			
0	547	27.2	(24.8; 29.8)
1	1120	51.9	(49.3; 54.6)
2	324	15.2	(13.3; 17.5)
3	87	3.7	(2.8; 4.8)
4	29	1.2	(0.8; 1.7)
5 +	16	0.8	(0.2; 1.4)
Number of children 6-59 months in households			
0	1246	60.7	(57.5; 63.9)
1	605	27.8	(25.3; 30.5)
2	204	9.0	(7.5; 10.6)
3	44	1.7	(1.2; 2.5)
4	16	0.5	(0.3; 0.9)
5 +	8	0.3	(0.1; 0.5)

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
[a] Percentages weighted for unequal probability of selection.
[b] CI=confidence interval, calculated taking into account the complex sampling design.

About three-quarters of the household heads reported having attended school or pre-school. Of these, the majority stopped school in junior secondary (46.7%); less than 12% of household heads attended tertiary school, college, or university (see Table 6).

Table 6. Educational level of household head for participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Head of household ever attended school or preschool			
Yes	1482	74.9	(70.8; 78.6)
No	635	24.8	(21.2; 28.9)
Highest level of school attended by household head			
Kindergarten	2	0.1	(0.0; 0.6)
Primary	235	14.9	(12.5; 17.7)
JSS – Junior Secondary School	673	46.7	(43.2; 50.2)
SSS – Senior Secondary School	313	20.4	(17.2; 24.1)
Vocational, commercial, nursing, technical, or teaching	65	4.5	(3.5; 5.9)
Tertiary, college, or university	176	12.0	(9.7; 14.6)
Don´t know	18	1.3	(0.8; 2.1)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
[a] Percentages weighted for unequal probability of selection.
[b] CI=confidence interval, calculated taking into account the complex sampling design.

Almost 80% of the household heads self-identified as Christian and 14% as Muslim. 5% of the household heads identified themselves as following traditional religions, the same proportion as reported to have no religion. The majority of household heads (52.6%) reported that Akan was their first language (see Table 7).

Table 7. Distribution of religion and language for participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Religion of household head			
Christian			
Catholic	245	11.1	(8.8; 14.0)
Anglican	15	1.0	(0.5; 1.9)
Methodist	143	7.1	(5.4; 9.4)
Presbyterian	136	7.0	(5.3; 9.3)
Pentecostal/Charismatic	632	31.8	(28.7; 35.1)
Other	345	17.7	(14.9; 20.9)
Muslim	363	13.8	(10.7; 17.7)
Traditional	130	5.0	(3.0; 8.0)
No religion	113	5.4	(4.1; 7.0)
First language of household head			
Akan	989	52.6	(45.1; 60.0)
Ga/Dangme	91	4.5	(2.7; 7.2)
Ewe	279	14.6	(9.7; 21.5)
Guan	10	0.2	(0.1; 0.5)
Mole-Dagbani	124	3.7	(2.4; 5.8)
Grusi	27	1.9	(0.6; 6.0)
Gurma	15	0.5	(0.3; 1.0)
Mande	4	0.2	(0.1; 0.7)
Other[c]	582	21.7	(17.4; 26.6)
Don´t know	2	0.1	(0.0; 0.4)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
[a] Percentages weighted for unequal probability of selection.
[b] CI=confidence interval, calculated taking into account the complex sampling design.
[C] Other languages include lesser known Ghanaian languages and language from neighboring countries

3.2.2. Agricultural activities and livestock ownership

About half of the households owned some land, with a median size of 1.4 hectare. Approximately 35% of the included households owned some livestock. Of those households, more than 80% owned poultry, almost half owned goats and one quarter owned sheep. Pigs, cows and oxen were less commonly owned. Ownership of animals apart from poultry, goats, pigs, cows and oxen was uncommon (see Table 8).

Table 8. Proportion of livestock and agriculture variables for participating households, Ghana 2017

Characteristic	n	%[a]	(95% CI)[b]
Member of household owns any agricultural land			
Yes	1183	51.6	(44.7; 58.5)
No	933	48.0	(41.2; 54.9)
If own land, median amount (in hectares)	1127	1.4	(1.0; 1.8)
Household owns any livestock			
Yes	848	34.6	(29.3; 40.4)
No	1273	65.3	(59.5; 70.6)
Household owns livestock, specific [c]			
Oxen (Bullocks)	48	6.1	(3.2; 11.3)
Cows for milk	54	6.1	(3.8; 9.7)
Cattle for beef	33	2.5	(1.4; 4.4)
Goats	433	48.3	(41.5; 55.1)
Sheep	235	26.9	(22.0; 32.6)
Rabbits	15	2.3	(1.4; 3.6)
Pigs	94	9.6	(5.8; 15.4)
Grasscutter (cane-rat)	5	0.7	(0.3; 1.8)
Poultry (chicken, ducks, etc.)	720	83.7	(80.3; 86.5)
Donkeys	3	0.2	(0.1; 0.7)
Cats or dogs	25	0.9	(0.5; 1.6)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
[a] Percentages weighted for unequal probability of selection.
[b] CI=confidence interval, calculated taking into account the complex sampling design.
[c] Question only asked to households responding "Yes" to livestock ownership

3.2.3. Cooking fuel

Cooking was done in virtually all households, most of them using natural fuels, of which 40% was wood and 31% charcoal (see Table 9). About a quarter of household used liquefied petroleum gas for cooking.

Table 9. Distribution of cooking fuel variables for participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Type of fuel used for cooking			
Electricity	18	0.9	(0.4; 1.7)
Liquefied petroleum gas (LPG)	428	23.0	(18.0; 29.0)
Natural gas	2	0.1	(0.0; 0.3)
Kerosene	2	0.1	(0.0; 0.4)
Charcoal	601	31.4	(26.9; 36.4)
Wood	997	39.7	(31.9; 48.1)
Straw, shrubs, or grass	34	2.6	(0.6; 10.0)
Agricultural crop residue	1	0.0	(0.0; 0.2)
Animal dung	1	0.0	(0.0; 0.2)
No food cooked in household	36	2.0	(1.3; 3.0)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
[a] Percentages weighted for unequal probability of selection.
[b] CI=confidence interval, calculated taking into account the complex sampling design.

3.2.4. Water and sanitation

As shown in Table 10, nine out of ten households had an improved source of water for drinking. Only about 3% of households reported treating their water to make it safe to drink; however, the majority of these households already consume water from an improved source. As a result, the proportion of households actually drinking "safe" water (either from an improved source or adequately treated at home) is very high at approximately 91%. On the other hand, only 13% of households have improved sanitation facilities, consisting of either a flush or pour flush toilet or pit latrine with slab not shared with another.

Table 10. Distribution of water and sanitation variables for participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Main source of water for drinking [c]			
Improved source	1842	90.7	(85.1; 94.3)
Unimproved source	281	9.3	(5.7; 14.9)
Treat water to make safe to drink			
Yes	82	3.2	(2.5; 4.2)
No	2040	96.7	(95.6; 97.5)
Drink safe water [d]			
Yes	1849	90.9	(85.3; 94.4)
No	274	9.1	(5.6; 14.7)
Household sanitation [e]			
Adequate	256	13.1	(10.1; 16.8)
Inadequate	1867	86.9	(83.2; 89.9)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b CI=confidence interval, calculated taking into account the complex sampling design.

c Improved source = water from piped system, tube well or borehole, protected well, protected spring, rainwater collection, bottled water or sachet water. Unimproved source = water from unprotected well, unprotected spring, tanker truck or cart, surface water or other.

d Composite variable of main source of drinking water and treating water to make safe for drinking

e Composite variable of toilet type and if toilet facilities are shared with non-household members; Adequate Sanitation = flush or pour flush toilet or pit latrine with slab not shared with another household. Inadequate sanitation= open pit, bucket latrine, hanging toilet/latrine, no facility, bush, field.

Less than 20% of households had a fixed sink or basin for handwashing and in the majority of the household handwashing was done outside the house or compound. 63.7% of the surveyed households washed hands anywhere around the dwelling. Two-thirds of the households had water available at the handwashing place, which is less than the proportion of households with some kind of soap placed at the handwashing site (about 85%).

Table 11. Distribution of handwashing variables for participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Location of handwashing site			
Sink or fixed basin (observed)	303	15.9	(12.4; 20.3)
Hands washed anywhere around dwelling (observed)	1357	63.7	(57.9; 69.0)
Tippy tap (observed)	92	3.2	(1.7; 6.2)
Not in dwelling / plot / yard (not observed)	299	13.8	(10.2; 18.3)
Permission to see handwashing area not given	11	0.7	(0.3; 1.5)
Other	61	2.7	(1.2; 6.2)
Water is available at observed handwashing place [c]			
Yes	1115	63.7	(56.7; 70.1)
No	637	36.3	(29.9; 43.3)
Soap seen at handwashing site [c]			
Bar soap	986	56.6	(50.1; 62.9)
Detergent	210	12.5	(10.0; 15.4)
Liquid soap	271	16.8	(13.1; 21.2)
Ash / mud / sand	43	1.7	(0.9; 3.0)
Any soap in household for handwashing	1620	93.5	(91.4; 95.1)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
[a] Percentages weighted for unequal probability of selection.
[b] CI=confidence interval, calculated taking into account the complex sampling design.
[c] Data available only if handwashing place observed

3.2.5. Oil consumption and vitamin A content

Approximately 70% of the households purchased vegetable oil either daily, weekly, or monthly. Of note, nearly 26% of households reported that they did not use vegetable oil (see Table 12). The proportion of households not consuming vegetable oil was highest in the Northern belt (48%), with 26%, 57%, and 83% of households not consuming vegetable oil in the Northern, Upper East, and Upper West regions, respectively (data not shown).

Among the households consuming vegetable oil (n=1432), the majority (n=1237) provided a sample. Three-quarters of those households reported using the brand Frytol (see Table 12). Quantitative analyses of 1218 oil samples showed that 55.6% were adequately fortified with vitamin A concentrations ≥ 10 ppm. There are significant differences between the three strata (<0.05) as well as between the ten regions (p<0.05). Only 35.7% of the oil collected in the Northern Belt was adequately fortified, whereas in the Southern and Middle Belt 51.9% and 63.5% of the oil was sufficiently fortified. Lowest coverage with adequately fortified oil was found in the Western Region (29.5%), Upper East (33.2%) and Northern region (35.3); and highest in Volta Region (73.1%), Central (69.4%) and Ashanti (65.9%). Significant differences have also

been detected in the vitamin A concentration of the analyzed vegetable oil brands. The brands Vikings and Ok Oil had the highest proportion of adequately fortified oil with 76.8% and 69.7%, respectively. On the other hand other oil brands such as Unoli had a very low proportion of samples ≥ 10 ppm vitamin A (9.4%; see Table 13).

Table 12. Presence of refined vegetable oil, brand and purchase pattern for participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Frequency of vegetable oil purchase by household			
Daily	171	7.9	(6.1; 10.2)
Weekly	609	28.5	(24.8; 32.5)
Monthly	652	33.9	(29.5; 38.5)
I don't use it	604	25.7	(21.4; 30.7)
Don't know / not sure	87	3.9	(2.6; 5.9)
Vegetable oil is purchased by household			
Yes	1432	70.3	(65.1; 75.0)
No	604	25.7	(21.4; 30.7)
Don't know / not sure	87	3.9	(2.6; 5.9)
Household agrees to provide vegetable oil sample [c]			
Yes	1246	81.9	(75.3; 87.0)
No	264	18.1	(13.0; 24.7)
Household provides vegetable oil sample			
Yes	1237	99.6	(98.9; 99.8)
No	9	0.4	(0.2; 1.1)
Brand of vegetable oil (observed) [d]			
Frytol	933	73.8	(68.1; 78.7)
Obaapa	11	1.0	(0.5; 1.8)
Sunny oil	36	2.7	(1.5; 4.6)
Gino oil	10	0.9	(0.5; 1.9)
Vikings	6	0.5	(0.2; 1.3)
Ok Oil	14	1.2	(0.6; 2.4)
Unoli	23	2.4	(1.4; 4.0)
Other	109	10.2	(7.2; 14.3)
Unknown	95	7.3	(5.6; 9.5)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

[a] Percentages weighted for unequal probability of selection.

[b] CI=confidence interval, calculated taking into account the complex sampling design.

[c] Data not collected from households that reported that they did not consume vegetable oil.

[d] Vegetable oil brand only collected for households that provided a vegetable oil sample.

Table 13. Proportion of vegetable oil specimens with a vitamin A concentration ≥ 10 ppm in participating households and per brand, Ghana 2017

Characteristic	n	Proportion adequately fortified (%) [a]	(95% CI)[b]	P value [c]	Mean vitamin A concentration (ppm)	(95% CI)[b]	P value [c]
Residence							
Urban	625	52.3	(42.3; 52.3)	0.33	10.5	(9.1; 12.0)	0.87
Rural	593	59.6	(48.6; 69.7)		10.7	(9.4; 12.0)	
Stratum							
Southern Belt	434	51.9	(40.2; 63.4)	<0.05	11.2	(9.6; 12.9)	<0.01
Middle Belt	555	63.5	(51.8; 73.8)		10.9	(9.5; 12.4)	
Northern Belt	229	35.7	(22.3; 51.7)		7.4	(5.5; 9.4)	
Region							
Western	105	29.5	(16.4; 47.1)	<0.05	8.2	(6.5; 10.0)	<0.01
Central	51	69.4	(49.0; 84.3)		10.6	(8.8; 12.4)	
Greater Accra	159	44.3	(28.6; 61.2)		11.7	(9.0; 14.3)	
Volta	119	73.1	(70.6; 75.4)		12.7	(10.4; 15.1)	
Eastern	114	56.2	(30.0; 79.4)		10.0	(5.5; 14.4)	
Ashanti	302	65.9	(50.5; 78.5)		11.0	(9.3; 12.6)	
Brong Ahafo	139	63.2	(41.5; 80.7)		11.7	(8.5; 14.9)	
Northern	156	35.3	(19.0; 55.8)		7.7	(4.8; 10.6)	
Upper East	58	33.2	(12.7; 63.0)		6.5	(4.1; 8.8)	
Upper West	15	58.7	(43.8; 72.2)		11.2	(10.5; 11.8)	
Wealth Quintile							
Lowest	237	49.1	(36.5; 61.8)	0.22	8.9	(7.4; 10.5)	0.33
Second	236	57.8	(43.0; 71.4)		10.8	(8.9; 12.9)	
Middle	222	60.1	(50.1; 69.2)		11.1	(9.4; 12.9)	
Fourth	246	61.3	(51.3; 70.5)		10.8	(9.5; 12.1)	
Highest	277	48.6	(37.4; 59.8)		10.8	(8.7; 12.9)	
Vegetable oil brand							
Frytol	889	63.3	(54.9; 71.0)	<0.0001	11.3	(10.0; 12.5)	0.13
Obaapa	11	24.7	(7.5; 57.0)		6.5	(2.4; 10.7)	
Sunny oil	36	39.8	(24.3; 57.6)		9.6	(5.5; 13.7)	
Gino oil	9	57.5	(21.2; 87.2)		10.3	(6.8; 13.8)	
Vikings	5	76.8	(32.3; 95.8)		11.8	(9.9; 13.8)	
Ok Oil	14	69.7	(38.7; 89.3)		10.2	(4.7; 9.5)	
Unoli	23	9.4	(2.2; 31.9)		11.6	(7.7; 10.6)	
Other	104	21.4	(12.8; 33.5)		7.1	(4.7; 9.5)	
Unknown	93	52.2	(37.3; 66.8)		9.1	(7.7; 10.6)	
ALL HOUSEHOLDS	1218	55.6	(37.0; 52.0)		10.6	(9.6; 11.6)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Figure 2 visually presents the geographic coverage of adequately fortified vegetable oil

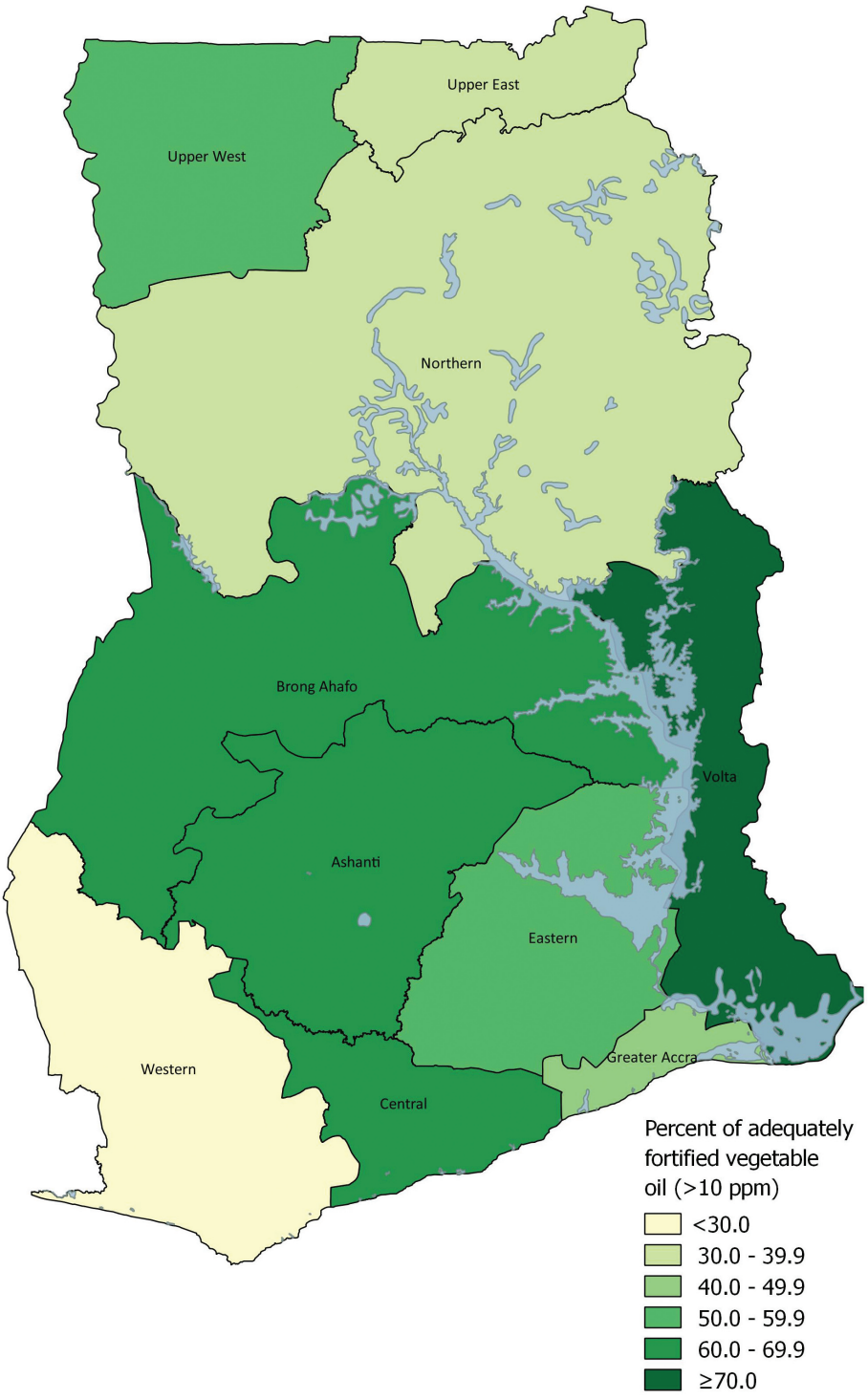
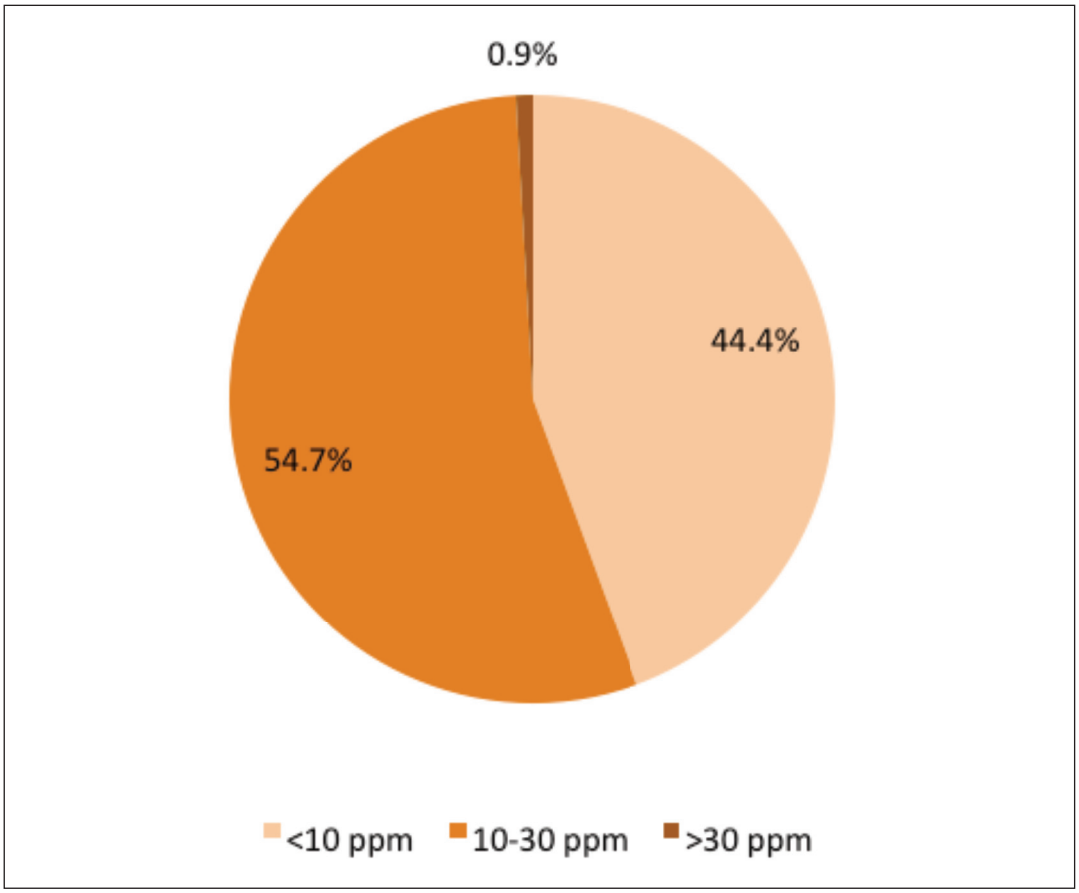


Figure 2. Coverage map of adequately fortified (≥10 ppm vitamin A) vegetable oil, Ghana 2017

Almost 45% of oil specimens were fortified at a concentration of less than 10 ppm (see Figure 3) and it is striking to find that almost one third of the oils were presumably not fortified at all. Only a relatively small proportion of oil samples are in the grey zone of some but inadequate fortification, indicating either technical challenges at the refineries or stability problems of the retinyl palmitate content.

Figure 3. Weighted distribution of household vegetable oil vitamin A concentrations, Ghana 2017



3.2.6. Wheat flour consumption and iron content

As shown in Table 14 nearly 70% of households reported that bread was the most commonly consumed wheat flour product. Approximately 12% noted that donuts, biscuits or pastries were the wheat flour products most often consumed, and nearly 20% reported not consuming wheat flour. Among households where wheat flour was consumed as bread, factory-made white bread was the most common type of bread consumed.

Table 14. Wheat flour product consumption and purchase pattern in participating households, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Type of wheat flour product consumed most often by household			
Bread	1416	68.1	(61.8; 73.8)
Pancakes	6	0.4	(0.1; 1.3)
Doughnuts	159	7.2	(5.2; 9.9)
Biscuits, pastries	101	5.1	(3.7; 7)
Other/Don't know	15	0.7	(0.3; 1.3)
Households does not eat wheat flour products	426	18.5	(13.7; 24.4)
Type of bread most often consumed by households [c]			
Factory white bread	1277	89.4	(84.9; 92.7)
Factory brown bread	108	8.9	(5.8; 13.4)
Other bread from bakery or factory	31	1.7	(0.8; 3.4)
TOTAL RESPONDING HOUSEHOLDS	2123	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
[a] Percentages weighted for unequal probability of selection.
[b] CI=confidence interval, calculated taking into account the complex sampling design.
[c] Question only asked to households that stated bread was the most commonly consumed wheat flour product.

Quantitative testing of iron in flour samples revealed that nearly all flour samples were below Ghana's national fortification standard (see Table 15). Only 5.7% of flour samples were adequately fortified, and approximately 61% of samples contained less than 20ppm of iron (see Figure 4). No difference was observed by residence, strata, or location of where the flour sample was collected.

Table 15. Proportion of wheat flour specimens with iron concentration ≥ 58.5 ppm [1] in participating clusters, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]	P value [c]
Residence				
Urban	115	9.6	(5.3; 16.6)	0.011
Rural	114	1.7	(0.4; 6.9)	
Stratum				
Southern Belt	92	4.3	(1.6; 11.2)	
Middle Belt	68	7.3	(3.0; 16.8)	0.718
Northern Belt	69	5.8	(2.1; 14.7)	
Origin of flour				
Bakery	199	6.5	(3.8; 10.9)	0.149
Retail shop	30	0.0	-	
TOTAL RESPONDING	229	5.7	(3.3; 9.6)	

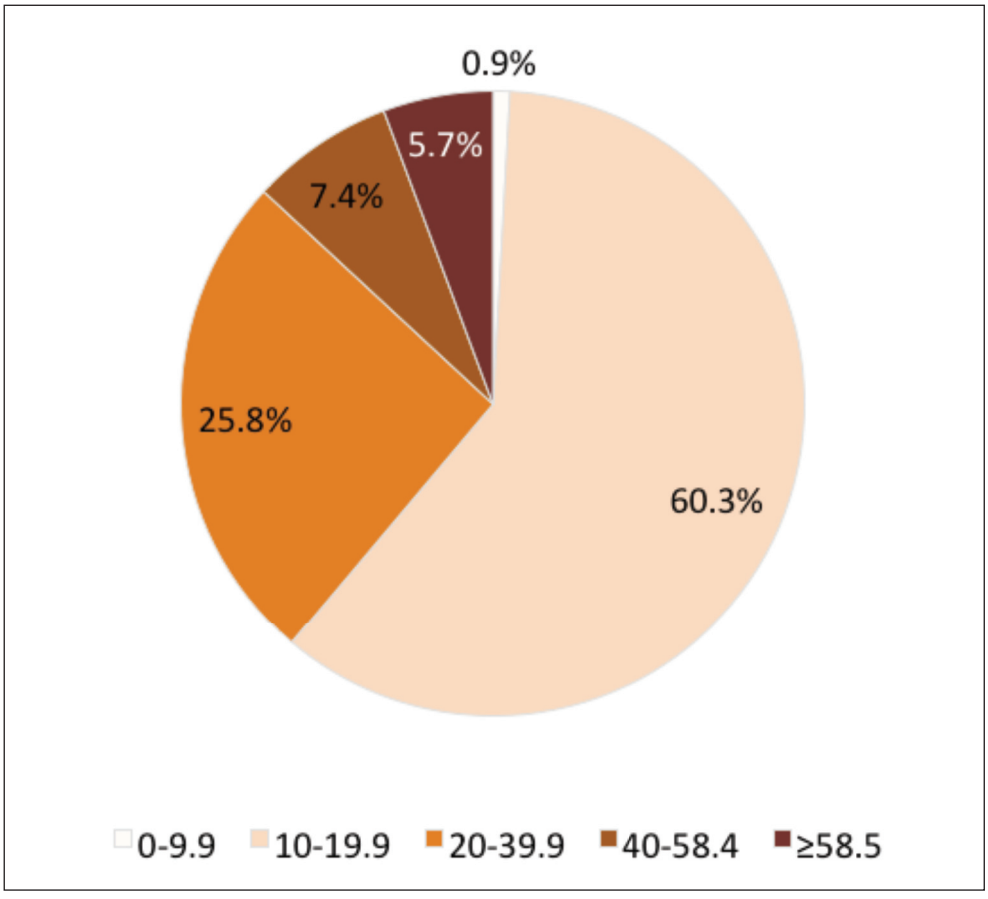
Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages are un-weighted.

b CI=confidence interval were calculated using the normal approximation, and were not calculated to account for complex sampling design

c Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Figure 4. Distribution of cluster wheat flour iron concentration, Ghana 2017



3.2.7. Iron in drinking water

Water samples were collected from 419 households, and 401 samples contained no iron (0 ppm). Of the 18 samples that had some ferrous iron, the concentrations were negligible. Because of the low number of samples with any measurable water iron content, no further sub-group analyses were conducted.

3.3. Preschool children

3.3.1. Characteristics

Table 16 describes the demographic characteristics of children participating in the GMS. The survey sample included slightly more boys than girls, a higher proportion (about 56%) lived in rural areas of Ghana. Of the surveyed children, 45% resided in the Middle Belt, and nearly one-quarter resided in the Ashanti region.

Table 16. Description of sampled pre-school age children (6 - 59 months), Ghana 2017

		Survey Sample	
Characteristic	n	% [a]	(95% CI) [b]
Age Group (in months)			
6-11	125	10.0	(8.2; 12.1)
12-23	292	24.1	(21.1; 27.4)
24-35	279	23.1	(20.8; 25.6)
36-47	270	21.8	(19.4; 24.5)
48-59	266	20.8	(18.8; 22.9)
Sex			
Male	615	50.3	(47.1; 53,6)
Female	617	49.7	(46.4; 52.9)
Residence			
Urban	465	43.7	(31.9; 56.3)
Rural	769	56.3	(43.7; 68.1)
Stratum			
Southern Belt	345	32.2	(26.1; 38.9)
Middle Belt	467	43.9	(37.3; 50.7)
Northern Belt	422	24.0	(18.9; 29.8)
Region			
Western	88	5.9	(2.4; 13.9)
Central	83	7.8	(3.0; 18.7)
Greater Accra	107	11.5	(6.2; 20.2)
Volta	67	7.0	(3.0; 15.4)
Eastern	117	9.2	(4.1; 19.1)
Ashanti	236	25.2	(16.1; 37.1)
Brong Ahafo	114	9.6	(4.5; 19.3)
Northern	285	13.7	(9.0; 20.3)
Upper East	82	7.7	(3.2; 17.1)
Upper West	55	2.6	(1.0; 6.3)
TOTAL RESPONDING	1232	100.0	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b CI=confidence interval, calculated taking into account the complex sampling design

3.3.2. Low birth weight

Mothers and caretakers reported that nearly 70% of participating children were weighed at birth. Of these, more than half had their birthweight recorded on health cards. Of the children without a recorded birthweight, mothers of only 26.2% could recall the child's birthweight (see Table A14-1). Among children with either recorded or recalled birthweights, about 15% weighed less than 2.5 kg, the threshold for low birthweight (see Table 15-2). A significantly higher proportion of female newborns had low birth weight compared to males ($p<0.05$). The prevalence of low birthweight in the survey sample did not significantly differ by urban vs. rural residence and wealth quintiles.

3.3.3. Recent illness and treatment

Almost one-quarter of children had diarrhea in the two weeks prior to the survey, and about 3% of children had diarrhea with blood (see Table 17). Fever and illness with a cough was very common; almost one-third of children had a caregiver-reported fever and more than one- quarter had illness with cough in the past two weeks. Only about 2% of children had lower respiratory infections. Almost half of the children had elevation of at least one marker of inflammation. Although a small number were in the incubation phase with only elevated CRP (2.8%), almost 18% of children were in the early convalescent phase with elevation of both CPR and AGP, and more than 25% were in the late convalescent phase with only elevated AGP.

For children with reported fever in the past 2 weeks, 20% were taken for health care and were reported to have been tested for malaria (see Table 18). More than 60% of these children were reported to be positive for malaria infection. Of the children tested for malaria as part of the survey, 15.9% had *P. falciparum* only, and 3.9% tested positive for *P. falciparum* and another *Plasmodium* species (e.g. *P. vivax, P. malariae or P. ovale*). Only 0.5% tested positive for *P. vivax* or *P. malariae* or *P. ovale* with no *P. falciparum* infection.

Table 19 presents the combined prevalence of all malaria species, and shows that approximately 20% were positive. Notably, malaria prevalence increased with age from 9.7% in 6-11 months old children to 29.2% in 48-59 months old children ($p<0.001$). There was significant difference in malaria infection prevalence by child's sex ($p<0.05$), residence ($p<0.001$) and the household´s living standard ($p<0.0001$). A higher proportion of male children and children living in rural areas were suffering from malaria infection and children living in households with higher living standards (fourth and highest wealth quintile) were less likely to be infected with malaria.

Malaria infection was more common ($p<0.01$) in children with heterozygous α-thalassemia (27.6%) compared to children with homozygous α-thalassemia (21.6%) or children without α-thalassemia (17.6%). Sickle cell disease or sickle cell trait were not predictors of malaria incidence.

Table 17. Proportion of preschool age children with caregiver-reported diarrhea, fever, cough and measured inflammation, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Diarrhea in the past 2 weeks			
Yes	294	22.9	(20.2; 25.8)
No	937	76.8	(73.9; 79.5)
Diarrhea with blood in the past 2 weeks			
Yes	36	2.8	(1.9; 4.2)
No	1194	96.9	(95.4; 97.9)
Fever the past 2 weeks			
Yes	409	32.1	(27.9; 36.6)
No	823	67.7	(63.2; 72.0)
Illness with a cough in the past 2 weeks			
Yes	319	25.8	(21.9; 30.2)
No	912	73.9	(69.6; 77.9)
Lower respiratory infection [c]			
Yes	28	1.8	(1.0; 3.2)
No	1206	98.2	(96.8; 99.0)
Inflammation [d]			
None	644	54.0	(47.8; 60.0)
Incubation (elevated CRP only)	39	2.8	(1.9; 4.0)
Early convalescence (elevated CRP and AGP)	199	17.7	(14.1; 22.0)
Late convalescence (elevated AGP only)	283	25.5	(22.1; 29.3)

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Lower respiratory infection defined as fever, cough, and difficulty breathing due to problem in chest
d CRP=C-reactive protein, AGP=alpha1-acid-glucoprotein

Table 18. Treatment of fever variables in children 6-59 months, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Malaria test given if child was ill with fever			
Yes	80	20.2	(15:7; 25.6)
No	318	76.8	(71.1; 81.7)
Malaria status if child was ill with fever and tested for malaria			
Positive	51	61.5	(49.4; 72.3)
Negative	18	26.2	(15.5; 40.9)
Don´t know	11	12.2	(6.7; 21.2)

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.

Table 19. Proportion testing positive on malaria rapid diagnostic test for *P. falciparum* and other *Plasmodium* species in children 6-59 months of age, by various characteristics, Ghana 2017

Characteristic	n	Malaria %[a, b]	(95% CI)[c]	P value [d]
Age Group (in months)				
6-11	116	9.7	(5.4; 17.1)	<0.005
12-23	259	15.9	(10.0; 24.2)	
24-35	242	19.7	(13.6; 27.6)	
36-47	252	22.3	(15.7; 30.7)	
48-59	242	29.2	(21.5; 38.4)	
Sex				
Male	553	23.5	(17.7; 30.6)	<0.05
Female	558	17.2	(11.8; 24.2)	
Residence				
Urban	400	8.0	(3.8; 16.1)	<0.001
Rural	716	29.3	(22.3; 37.4)	
Stratum				
Southern Belt	324	23.5	(14.0; 36.7)	0.14
Middle Belt	387	23.4	(15.7; 33.6)	
Northern Belt	402	11.2	(6.1; 19.6)	
Sickle cell				
Sickle cell disease (SS)	9	-	-	0.27
Sickle cell trait (AS)	124	19.9	(13.3; 28.6)	
Normal (AA)	941	20.5	(15.0; 27.4)	
α-thalassemia				
Homozygous	33	21.6	(8.9; 43.8)	<0.01
Heterozygous	300	27.6	(20.2; 36.4)	
Normal	692	17.6	(12.9; 23.6)	
Wealth Quintile				
Lowest	408	24.9	(17.4; 34.1)	<0.0001
Second	239	36.1	(26.5; 46.9)	
Middle	202	21.9	(15.2; 30.4)	
Fourth	144	3.2	(0.8; 11.5)	
Highest	120	2.0	(0.5; 7.8)	
TOTAL RESPONDING	1113	20.3	(15.2; 26.6)	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b Malaria %= % of children identified as malaria positive using rapid diagnostic tests for plasmodium falciparum and other plasmodium species

c CI=confidence interval, calculated taking into account the complex sampling design.

d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

3.3.4. Infant and young child feeding indicators

Table 20 presents several of the standard infant and young child feeding indicators recommended by WHO and UNICEF [31]. For children 6-23 months, more than three-quarters of mothers reported initiating breastfeeding in the first hour after the child's birth and less than 10% initiated breastfeeding more than 12 hours after birth. Continued breastfeeding was nearly universal among children 12-15 months of age. Similar to this, almost all children 6-8 months old had received complementary foods the day before the survey. For children 6-23 months of age, almost half of the children had a sufficiently diverse diet, but only one-third ate with sufficient frequency. Within this age group, few children had a minimally acceptable diet, an indicator combining diversity and frequency. See Table A14- 3 - Table A14 - 9 in APPENDIX 14 for subgroup analyses of these feeding indicators by age group, sex, urban vs rural residence, region and household wealth.

Table 20. Proportion of children with various infant and young child feeding indicators in children 6 - 23 months of age, Ghana 2017

Characteristic	n	%[a]	(95% CI)[b]
Early initiation of breastfeeding [c]			
Initiated breastfeeding in first hour after birth	275	78.6	(7.4; 16.5)
Initiated breastfeeding in 1-12 hours after birth	45	11.2	(4.3; 12.0)
Initiated breastfeeding in >12 hours after birth	25	7.2	(1.5; 6.1)
Continued breastfeeding at 1 year [d]			
Breastfed the day before the interview	97	93.1	(81.9; 97.6)
Introduction of solid, semi-solid or soft foods [e]			
Eating complementary food the day before the interview	56	94.7	(83.8; 98.4)
Minimum dietary diversity [f]			
Adequate dietary diversity the day before the interview	410	42.3	(36.0; 48.9)
Minimum meal frequency [f]			
Adequate meal frequency the day before the interview	411	38.3	(33.5; 43.2)
Minimum acceptable diet [f]			
Acceptable diet the day before the interview	410	14.3	(10.8; 18.6)

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b CI=confidence interval, calculated taking into account the complex sampling design.

c Results presented for children 6-23 months of age

d Results presented for children 12-15 months of age

e Results presented for children 6-8 months of age

f Results presented for children 6-23 months of age

3.3.5. Consumption of vitamins and supplements

Relatively few children had consumed Ready-to-use Therapeutic Foods (RUTF) (1.1%), micronutrient powders (1.5%), iron fortified cookies or foods (8.1%), or infant formula with iron (2.9%) the day prior to the survey (see Table 21). In the six months prior to the survey, more than 20% of children were given iron tablets or syrup as well as multivitamins. In the six months prior to the survey, less than 30% of children 6-59 months of age had received a vitamin A capsule, and 37% of children 24-59 months of age received deworming medication (e.g. Albendazole) during this 6-month time period. In Ghana, deworming is recommended for children 24 months of age or older. Of note, 25.1% (95% CI: 19.0; 32.3) of children 12-23 months of age received deworming medication (data not shown).

Table 21. Proportion of children 6-59 months of age consuming RUTF, vitamins and mineral supplements, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Consumed Ready-to-use Therapeutic Food (RUTF)			
Yes	13	1.1	(0.6; 1.9)
No	1216	98.5	(97.4; 99.1)
Consumed micronutrient powders			
Yes	18	1.5	(0.9; 2.5)
No	1212	98.2	(96.9; 98.9)
Consumed iron-fortified cookies or foods			
Yes	87	8.1	(5.8; 11.2)
No	1143	91.4	(88.2; 93.8)
Consumed infant formula with added iron			
Yes	34	2.9	(2.0; 4.1)
No	1194	96.6	(95.3; 97.5)
Given iron tablets or syrup in past six months			
Yes	265	22.5	(19.2; 26.2)
No	935	74.4	(70.8; 77.8)
Given multi-vitamins in past six months			
Yes	231	20.7	(17.6; 24.1)
No	951	75.3	(71.7; 78.6)
Given a vitamin A capsule in past six months [c]			
Yes	349	28.5	(24.9; 32.4)
No	738	59.0	(55.2; 62.6)
Not sure it was vitamin A / Don't know	147	12.6	(10.3; 15.2)
Given deworming medication in past six months [d]			
Yes	258	37.3	(32.7; 42.2)
No	546	61.2	(56.4; 65.8)
Don't know	11	1.5	(0.7; 2.9)

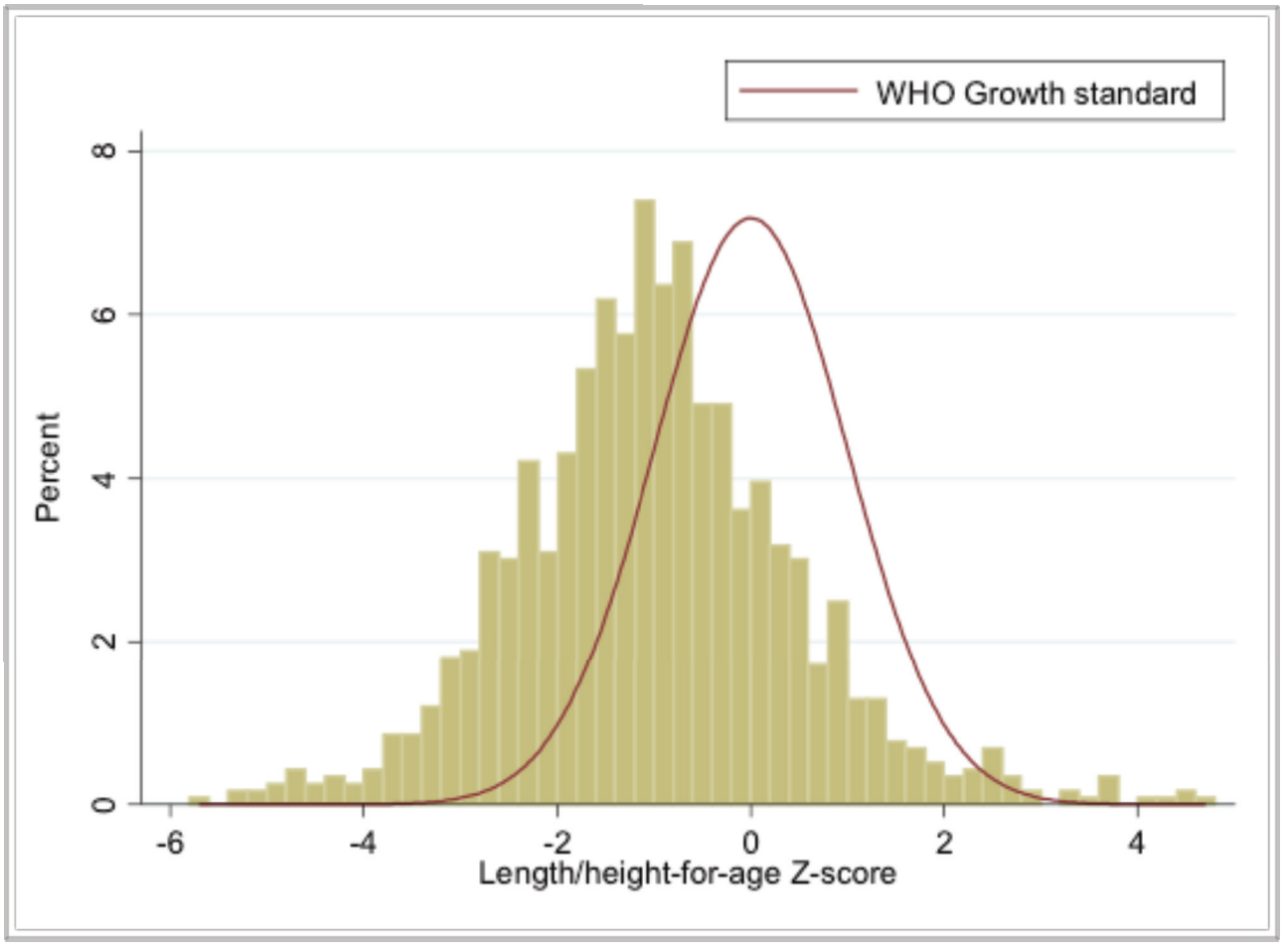
Note: The n's are un-weighted denominators for each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Includes only children 6-59 months of age.
d Includes only children 24-59 months of age.

3.3.6. Stunting

Overall, stunting is common in Ghana with 7.2% and 14.2% of children 6-59 months of age being severely or moderately stunted, totaling to a stunting prevalence of 21.4% (Table 22). The prevalence of stunting is significantly higher ($p<0.0001$) in rural areas (27.1%), compared to urban areas (13.5%). Significant differences have also been found for household living standards, with stunting being less common in children living in the wealthiest households ($p<0.001$). The results did not show any statistically significant differences for children's sex, strata, region, and for adequate vs. inadequate household sanitation. Child stunting was not significantly associated with fever status ($p=0.835$) nor positive malaria RDT results ($p= 0.509$), but recent diarrhea was moderately associated with stunting ($p=0.082$) with 25.0% of children with recent diarrhea stunted compared to 20.3% for those without diarrhea (data not shown).

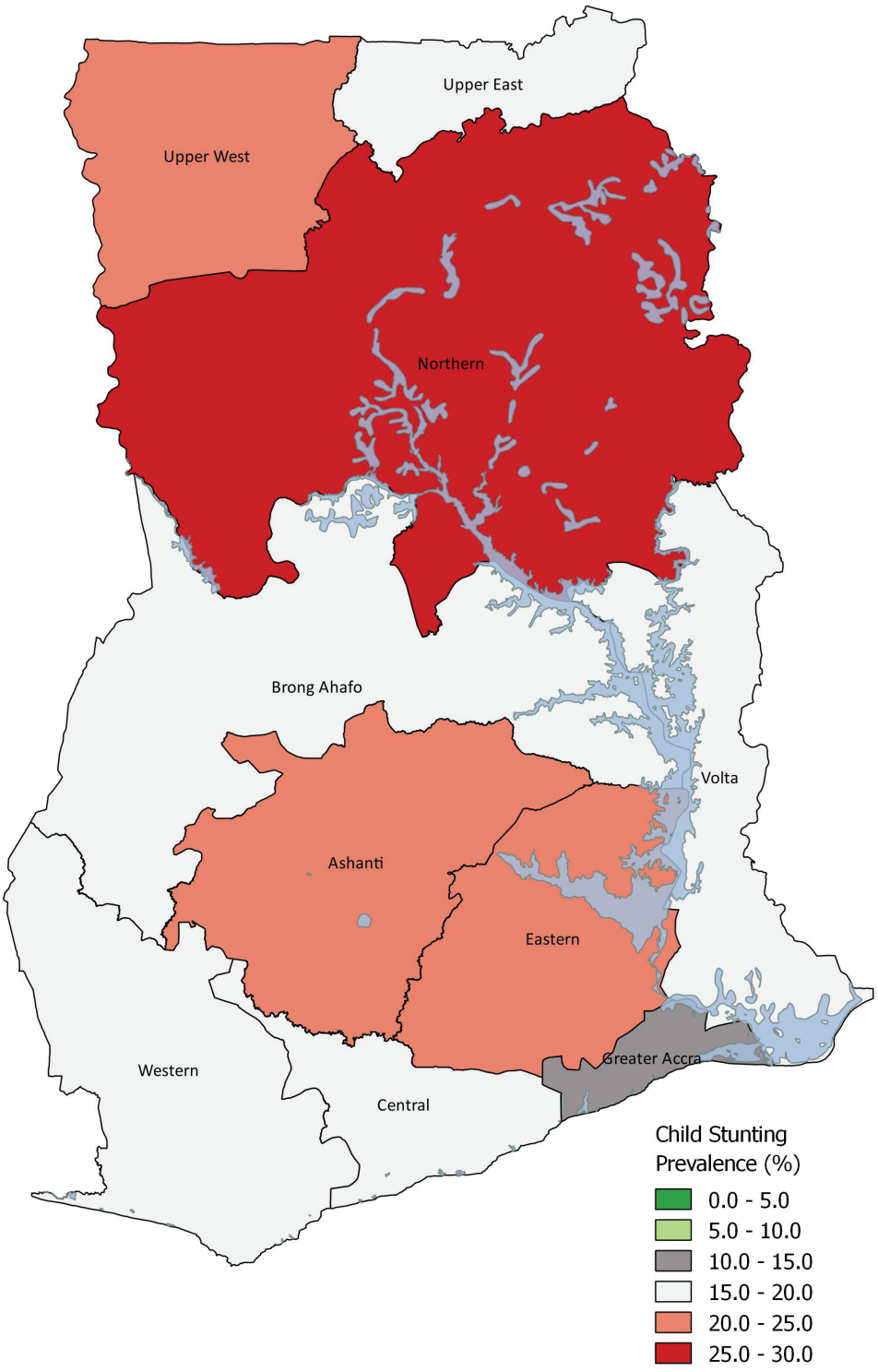
Figure 5 shows the distribution of the height-for-age z-score in the surveyed population of children 6-59 months of age. It clearly demonstrates that the distribution is shifted towards the left of the standard growth curve.

Figure 5. Histogram of height-for-age z-scores of the GMS 2017 compared to the WHO growth curve, preschool-age children, Ghana 2017



As shown Figure 6, most regions in Ghana have a stunting prevalence below 20%, with the lowest prevalence observed in Greater Accra. According to WHO classifications [32], a stunting prevalence less than 20% denotes a low public health problem. Stunting prevalence exceeds 20% in four regions, with the highest prevalence observed in the Northern region.

Figure 6. Prevalence of stunting by region, preschool-age children, Ghana 2017



3.3.7. Wasting

The overall prevalence of wasting among children 6-59 months of age in Ghana was relatively high (7.1%), therefore Ghana can be classified as moderately/borderline food insecure (wasting >3% but <10% (<-2WHZ)). Most of the wasted children suffered from moderate acute malnutrition (5.2%) and only 1.9% had severe acute malnutrition (Table 23). The survey found significant differences in wasting for the different age groups ($p<0.01$), with highest prevalence in the youngest children (6-11 months of age). The survey did not show any significant differences in wasting prevalence by sex, urban vs. rural, strata, regions, household living standards and adequate vs. inadequate household sanitation.

Figure 7 shows the distribution of the height-for-age z-score in the surveyed population of children 6-59 months of age. It clearly demonstrates that the distribution is shifted towards the left of the standard growth curve. Consequently, the prevalence of overweight (WHZ>2 SD) in children was below 1%. Due to such a low prevalence of overweight, no further sub-group analyses were conducted.

Bilateral edema was found in only 10 children, or 0.8% (95% CI: 0.4; 1.6). Due to the small number of children with edema, sub-group analysis by age group, sex, strata, and wealth quintile was not conducted.

3.3.8. Underweight

Overall undernutrition was common in Ghana with more than 15% prevalence (Table 24 and Figure 8). Severe undernutrition (4.3%) was less prevalent than moderate undernutrition (10.9%) and significant differences were detected between wealth quintiles ($p<0.05$), as well as between male and female children ($p<0.05$). No differences were found by age group, urban vs. rural residency, stratum, region, and adequate vs. inadequate household sanitation

Figure 7. Histogram of weight-for-height z-scores of the GMS 2017 compared to the WHO growth curve, preschool-age children, Ghana 2017

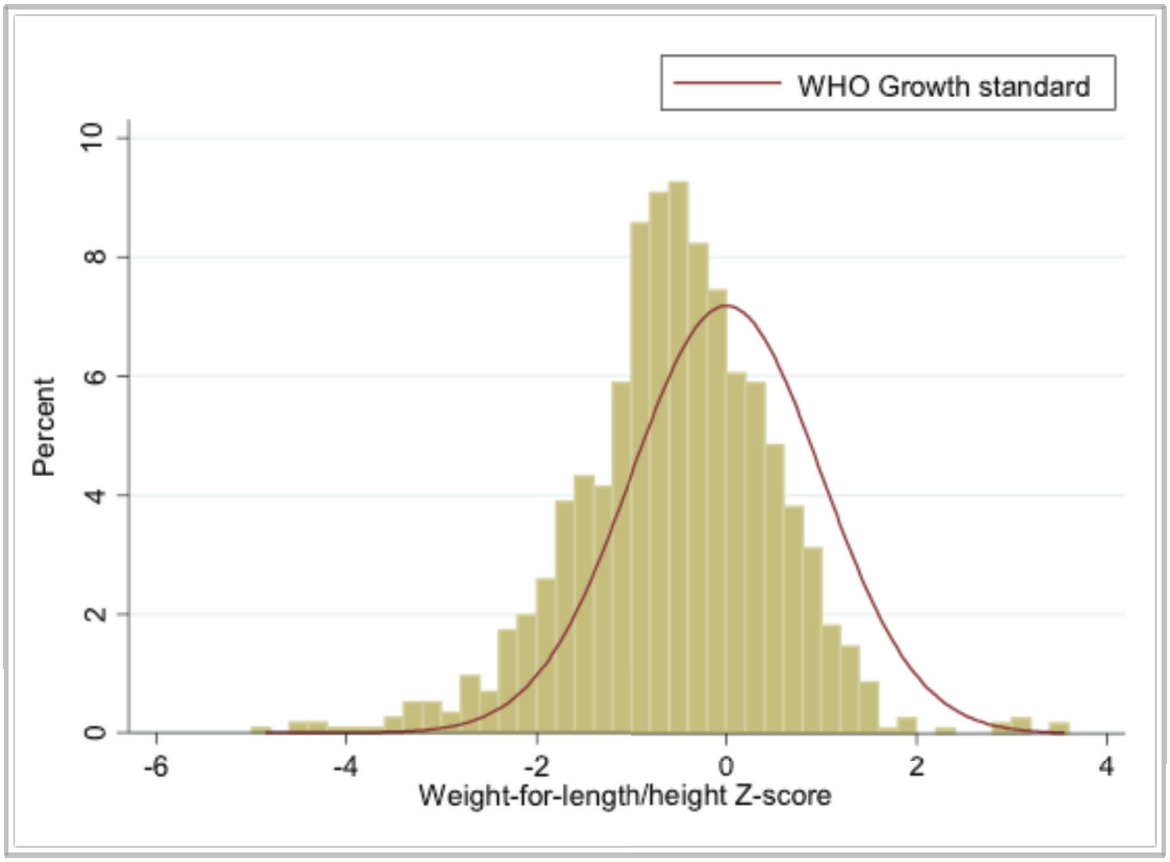


Figure 8. Histogram of weight-for-age z-scores of the GMS 2017 compared to the WHO growth curve, preschool-age children, Ghana 2017

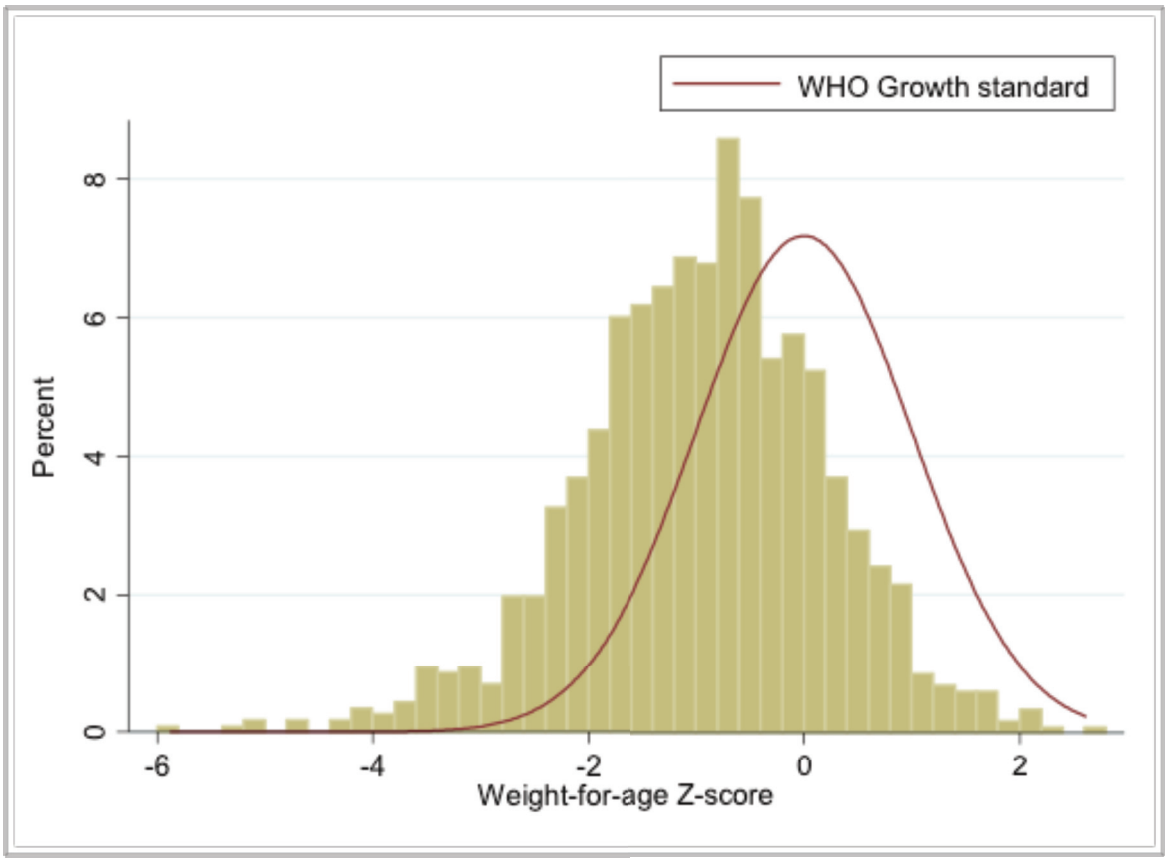


Table 22. Percentage of children (6-59 months) with stunting, Ghana 2017

Characteristic	n	Stunting % Severe[a,b]	(95% CI)	% Moderate[a,c]	(95% CI)	% Any[a,d]	(95% CI)	Chi-Square p-value[e]
Age Group (in months)								6-11
120	1.3	(0.3; 5.2)	10.4	(5.7; 18.3)	11.7	(6.8; 19.5)	0.23	
12-23	276	8.7	(4.6; 15.7)	13.0	(9.2; 18.2)	21.7	(15.5; 29.7)	24-35
254	7.3	(4.5; 11.7)	17.1	(11.4; 24.9)	24.5	(17.5; 33.1)		
36-47	262	7.1	(4.4; 11.2)	15.5	(11.0; 21.3)	22.5	(17.2; 29.0)	
48-59	249	8.5	(5.0; 14.3)	12.7	(8.7; 18.2)	21.3	(15.9; 27.9)	
Sex								
Male	578	7.5	(5.6; 10.0)	15.1	(12.2; 18.4)	22.6	(19.1; 26.5)	0.33
Female	581	7.0	(4.6; 10.5)	13.2	(10.3; 16.8)	20.2	(15.8; 25.5)	
Residence								
Urban	427	3.8	(2.0; 7.3)	9.7	(6.6; 14.0)	13.5	(9.4; 19.0)	<0.001
Rural	732	9.7	(7.3; 12.9)	17.4	(15.1; 20.0)	27.1	(23.2; 31.4)	
Stratum								
Southern Belt	310	5.9	(3.9; 8.9)	10.7	(7.2; 15.5)	16.6	(11.9; 22.6)	0.14
Middle Belt	448	7.8	(4.7; 12.5)	14.8	(11.5; 18.7)	22.5	(17.0; 29.2)	
Northern Belt	401	7.9	(4.9; 12.5)	17.4	(13.6; 22.0)	25.3	(19.8; 31.6)	
Region								
Western	79	9.3	(5.2; 16.0)	9.7	(3.0; 27.4)	19.0	(10.6; 31.7)	0.40
Central	73	4.6	(1.4; 14.1)	12.3	(4.0; 31.8)	16.8	(5.5; 41.3)	
Greater Accra	95	2.5	(0.7; 8.5)	10.5	(6.5; 16.5)	13.1	(7.4; 22.0)	
Volta	63	9.8	(8.2; 11.6)	10.1	(6.2; 15.8)	19.8	(15.7; 24.6)	
Eastern	113	8.5	(3.6; 18.7)	15.0	(11.7; 19.1)	23.5	(17.3; 31.1)	
Ashanti	229	8.9	(4.9; 15.8)	15.2	(10.8; 20.9)	24.1	(16.2; 34.3)	
Brong Ahafo	106	3.8	(1.2; 11.2)	13.2	(6.6; 24.9)	17.0	(9.2; 29.4)	
Northern	267	8.8	(4.9; 15.3)	20.5	(15.1; 27.2)	29.3	(22.0; 37.8)	
Upper East	82	6.9	(2.4; 18.6)	12.7	(8.5; 18.4)	19.6	(11.0; 32.5)	
Upper West	52	6.2	(2.4; 15.1)	15.6	(12.0; 20.2)	21.8	(13.9; 32.5)	
Wealth Quintile								
Lowest	415	7.8	(5.3; 11.2)	17.5	(14.8; 20.7)	25.3	(21.2; 29.8)	<0.001
Second	244	11.4	(6.7; 18.9)	15.4	(12.2; 19.3)	26.8	(20.4; 34.4)	
Middle	209	7.8	(4.4; 13.3)	14.2	(9.5; 20.5)	21.9	(15.4; 30.3)	
Fourth	157	3.3	(1.3; 7.9)	15.0	(10.2; 21.5)	18.3	(13.2; 24.9)	
Highest	134	3.2	(1.4; 7.5)	4.4	(1.8; 10.4)	7.6	(3.9; 14.3)	
Household sanitation [f]								
Inadequate	1030	7.9	(5.9; 10.5)	14.2	(12.0; 16.8)	22.1	(18.5; 26.1)	0.23
Adequate	133	3.0	(1.3; 6.6)	13.8	(8.3; 21.8)	16.7	(10.4; 25.8)	
TOTAL RESPONDING	1159	7.2	(5.4; 9.7)	14.2	(12.0; 16.6)	21.4	(18.0; 25.2)	--

Note: The n's are un-weighted denominators for each subgroup; subgroups that do not sum to the total have missing data.
a Percentages weighted for non-response and survey design.
b Severe stunting represents children who are below -3 standard deviations (SD; z-scores) from the WHO Child Growth Standards population median
c Moderate stunting includes children who are equal to or above -3 standard deviations (SD) and below-2 SD from the WHO Child Growth Standards population median
d Any stunting includes both severely and moderately stunted children
e Chi-square p-value <0.05 indicates that the variation in the values of the subgroup are significantly different from all other subgroups. Chi-square results are based on any stunting.
f Composite variable of toilet type and if toilet facilities are shared with non-household members; Adequate Sanitation = flush or pour flush toilet or pit latrine with slab not shared with another household. Inadequate sanitation= open pit, bucket latrine, hanging toilet/latrine, no facility, bush, field

Table 23. Percentage of children (6-59 months) with wasting, Ghana 2017

Characteristic	n	Wasting						
		% Severe [a,b]	(95% CI)	% Moderate [a,c]	(95% CI)	% Any [a,d]	(95% CI)	Chi-Square p-value [e]
Age Group (in months)								
6-11	119	1.8	(0.4; 7.7)	10.7	(6.1; 18.2)	12.6	(7.5; 20.3)	<0.01
12-23	274	3.9	(2.0; 7.2)	7.2	(4.1; 12.5)	11.1	(7.2; 16.7)	
24-35	250	0.6	(0.1; 3.1)	2.4	(1.1; 5.3)	3.1	(1.5; 6.3)	
36-47	263	1.7	(0.7; 4.2)	3.9	(1.9; 7.8)	5.6	(3.1; 9.9)	
48-59	248	1.2	(0.4; 3.8)	3.9	(1.9; 8.1)	5.1	(2.5; 10.1)	
Sex								
Male	577	1.6	(0.8; 3.2)	6.5	(4.3; 9.6)	8.1	(5.7; 11.5)	0.2120
Female	579	2.2	(1.2; 4.0)	3.9	(2.3; 6.6)	5.8	(3.6; 9.2)	
Residence								
Urban	424	2.4	(1.4; 4.1)	5.5	(3.2; 9.1)	7.9	(5.1; 12.0)	0.55
Rural	732	1.5	(0.8; 2.8)	5.0	(3.1; 3.6)	6.5	(4.2; 10.0)	
Stratum								
Southern Belt	310	1.4	(0.6; 3.2)	3.6	(1.8; 7.0)	4.9	(2.7; 8.9)	0.1
Middle Belt	443	2.3	(1.3; 4.0)	1.8	(2.4; 7.3)	6.5	(4.0; 10.4)	
Northern Belt	403	1.8	(0.8; 4.2)	7.0	(5.2; 15.5)	10.9	(6.5; 17.5)	
Region								
Western	76	0.6	(0.1; 4.9)	1.2	(0.3; 5.8)	1.9	(0.4; 9.2)	0.36
Central	66	3.2	(0.9; 11.1)	3.5	(0.8; 15.0)	6.8	(1.7; 23.5)	
Greater Accra	90	1.4	(0.3; 5.7)	3.9	(1.8; 8.3)	5.3	(3.2; 8.8)	
Volta	60	0.0	-	4.9	(1.0; 20.3)	4.9	(1.0; 20.3)	
Eastern	104	4.0	(2.1; 7.6)	4.9	(2.6; 9.1)	8.9	(5.2; 14.8)	
Ashanti	215	1.3	(0.4; 3.7)	3.6	(1.2; 9.8)	4.8	(1.9; 11.9)	
Brong Ahafo	95	3.4	(1.7; 6.8)	5.2	(3.0; 9.0)	8.7	(5.9; 12.5)	
Northern	240	2.3	(0.9; 5.9)	9.5	(4.8; 17.7)	11.8	(7.2; 18.7)	
Upper East	70	1.5	(0.2; 8.8)	10.3	(3.5; 26.8)	11.8	(3.8; 31.1)	
Upper West	52	0.0		3.1	(0.4; 19.6)	3.1	(0.4; 19.6)	
Wealth Quintile								
Lowest	416	1.8	(0.8; 3.9)	6.2	(3.3; 11.4)	8.0	(4.5; 3.9)	0.74
Second	244	1.5	(0.5; 4.3)	6.1	(3.3; 10.9)	7.6	(4.5; 12.5)	
Middle	209	3.2	(1.5; 6.5)	4.7	(2.2; 9.7)	7.9	(4.2; 14.2)	
Fourth	152	1.7	(0.6; 4.9)	2.8	0.8; 9.7)	4.5	(1.9; 10.3)	
Highest	135	0.6	(0.1; 4.3)	5.4	(2.7; 10.5)	6.0	(3.2; 11.1)	
Household sanitation [f]								
Inadequate	1022	1.9	(1.2; 2.9)	5.2	(3.6; 7.4)	7.1	(5.2; 9.6)	0.085
Adequate	134	2.0	(0.6; 6.3)	4.4	(1.5; 12.0)	6.4	(2.4; 16.0)	
TOTAL RESPONDING	1156	1.9	(1.3; 2.9)	5.1	(3.5; 7.3)	7.0	(5.1; 9.5)	--

Note: The n's are un-weighted denominators for each subgroup; subgroups that do not sum to the total have missing data.
a Percentages weighted for non-response and survey design.
b Severe wasting represents children who are below -3 standard deviations (SD; z-scores) from the WHO Child Growth Standards population median
c Moderate wasting includes children who are equal to or above -3 standard deviations (SD) and below-2 SD from the WHO Child Growth Standards population median
d Any wasting includes both severely and moderately stunted children
e Chi-square p-value <0.05 indicates that the variation in the values of the subgroup are significantly different from all other subgroups. Chi-square results are based on any stunting.
f Composite variable of toilet type and if toilet facilities are shared with non-household members; Adequate Sanitation = flush or pour flush toilet or pit latrine with slab not shared with another household. Inadequate sanitation= open pit, bucket latrine, hanging toilet/latrine, no facility, bush, field

Table 24. Percentage of children (6-59 months) underweight, Ghana 2017

Characteristic	n	Underweight % Severe [a,b]	(95% CI)	% Moderate [a,c]	(95% CI)	% Any [a,d]	(95% CI)	Chi-Square P-value [e]
Age Group (in months)								
6-11	120	4.3	(1.6; 11.0)	13.0	(7.3; 22.0)	17.3	(10.8; 26.4)	0.42
12-23	275	5.3	(3.0; 9.2)	15.1	(10.9; 20.5)	20.4	(15.1; 26.9)	
24-35	255	3.5	(1.5; 7.8)	10.6	(6.9; 16.0)	14.1	(9.7; 20.0)	
36-47	264	5.2	(3.0; 8.9)	8.4	(5.5; 12.6)	13.6	(9.6; 19.1)	
48-59	249	3.3	(1.3; 7.9)	10.7	(7.0; 15.9)	14.0	(9.3; 20.5)	
Sex								
Male	580	4.3	(2.9; 6.3)	13.3	(10.4; 16.9)	17.6	(14.2; 21.5)	<0.05
Female	584	4.3	(2.8; 6.5)	8.4	(6.0; 11.7)	12.7	(9.6; 16.6)	
Residence								
Urban	428	3.4	(1.9; 6.2)	9.1	(6.2; 3.2)	12.6	(8.7; 17.8)	0.14
Rural	736	4.9	(3.6; 6.7)	12.2	(9.7; 15.2)	17.1	(13.9; 20.9)	
Stratum								
Southern Belt	318	3.5	(1.9; 6.3)	9.3	(5.9; 14.3)	12.8	(8.8; 18.2)	0.05
Middle Belt	443	3.5	(2.1; 5.8)	10.0	(7.3; 13.6)	13.5	(9.8; 18.3)	
Northern Belt	403	6.6	(4.4; 9.9)	14.4	(0.5; 19.5)	21.1	(15.9; 27.3)	
Region								
Western	84	7.8	(5.1; 11.9)	4.9	(1.5; 14.5)	12.77	(9.8; 16.3)	0.41
Central	74	3.4	(0.7; 14.8)	6.4	(1.9; 18.9)	9.7	(2.6; 30.2)	
Greater Accra	97	0.8	(0.1; 5.7)	12.2	(7.3; 19.8)	13.0	(8.3; 19.8)	
Volta	63	4.2	(1.6; 10.7)	11.6	(5.4; 23.2)	15.8	(7.5; 30.3)	
Eastern	112	5.3	(2.0; 13.1)	8.1	(5.6; 11.6)	13.4	(7.5; 22.9)	
Ashanti	227	2.9	(1.4; 5.9)	10.8	(6.7; 16.9)	13.7	(8.4; 21.5)	
Brong Ahafo	104	3.3	(1.7; 6.3)	9.8	(6.2; 15.1)	13.1	(8.8; 19.1)	
Northern	269	8.2	(5.1; 13.0)	14.3	(8.6; 22.9)	22.5	(14.9; 32.6)	
Upper East	82	6.1	(3.4; 10.8)	14.4	(9.6; 21.1)	20.5	(13.9; 29.1)	
Upper West	52	0		15.0	(10.1; 21.8)	15.0	(10.1; 21.8)	
Wealth Quintile								
Lowest	420	5.6	(3.7; 8.3)	13.0	(9.8; 17.1)	18.6	(14.2; 24.0)	<0.05
Second	243	5.9	(3.7; 9.2)	15.1	(11.1; 20.4)	21.0	(15.3; 28.1)	
Middle	211	5.1	(2.7; 9.5)	8.8	(4.6; 16.1)	13.9	(8.2; 22.5)	
Fourth	154	1.0	(0.3; 3.8)	10.2	(6.0; 17.0)	11.2	(6.8; 17.9)	
Highest	136	1.5	(0.4; 6.1)	4.6	(2.0; 10.3)	6.1	(3.1; 11.8)	
Household sanitation f								
Inadequate	1030	4.4	(3.3; 5.9)	12.1	(10.0; 14.6)	16.5	(13.9; 19.5)	0.16
Adequate	135	3.9	(1.3; 11.0)	7.3	(3.6; 14.3)	11.2	(6.1; 19.6)	
TOTAL RESPONDING	1164	4.3	(3.2; 5.7)	10.9	(8.9; 13.3)	15.1	(12.6; 18.2)	--

Note: The n's are un-weighted denominators for each subgroup; subgroups that do not sum to the total have missing data.
a Percentages weighted for non-response and survey design.
b Severe underweight represents children who are below -3 standard deviations (SD; z-scores) from the WHO Child Growth Standards population median
c Moderate underweight includes children who are equal to or above -3 standard deviations (SD) and below-2 SD from the WHO Child Growth Standards population median
d Any underweight includes both severely and moderately stunted children
e Chi-square p-value <0.05 indicates that the variation in the values of the subgroup are significantly different from all other subgroups. Chi-square results are based on any stunting.
f Composite variable of toilet type and if toilet facilities are shared with non-household members; Adequate Sanitation = flush or pour flush toilet or pit latrine with slab not shared with another household. Inadequate sanitation= open pit, bucket latrine, hanging toilet/latrine, no facility, bush, field

3.3.9. Hemoglobinopathies

As shown in Table 25 the prevalence of sickle cell disease in children 6-59 months of age is very low (1.3%). The proportion of children carrying only one abnormal allele of the hemoglobin beta gene is 12.6%. Similar to this, the prevalence of homozygote α-thalassemia is very low (3.3%), whereas almost one third of the children had heterozygous α-thalassemia.

Table 25. Prevalence of hemoglobinopathies in children 6-59 months, Ghana 2017

Characteristic	n	% a	(95% CI)b
Sickle cell disorder (N=1138)			
Normal	995	86.1	(82.7; 88.9)
SS (disease)	10	1.3	(0.7; 2.3)
AS (trait)	133	12.6	(10.0; 15.8)
α-thalassemia (N=1081)			
Normal	731	69.3	(65.8; 72.5)
Homozygous	35	3.3	(2.3; 4.7)
Heterozygous	315	27.4	(24.4; 30.7)

For sub-group analysis, children with sickle cell disease (n=10) were excluded from the analysis. These children were also excluded as sickle cell disease results in severe anemia, whereas sickle cell trait – while resulting in mild anemia – offers protection against malaria. Children with and homozygote α-thalassemia, they were merged with those having sickle cell trait or heterozygote α-thalassemia, respectively, for sub group analyses (Table 26). The survey found significant differences in the prevalence of sickle cell disorders by urban vs. rural residence ($p< 0.005$), strata ($p< 0.05$), regions ($p< 0.05$) and household living standards ($p< 0.05$), but not by age and sex (data not shown). Highest prevalence were found in urban areas, the Middle Belt and in Eastern Region and Greater Accra. Sub group analyses for α-thalassemia only showed significant differences between regions (<0.05), with highest prevalence in Eastern Region, Volta Region, Northern Region and Greater Accra.

Table 26. Sickle cell trait, α-thalassemia (heterozygote and homozygote) in children 6-59 months of age, Ghana 2017

	Sickle cell trait [a]				α-thalassemia [b]			
Characteristic	n	% [c]	(95% CI)[d]	P value [e]	n	% [c]	(95% CI)[d]	P value [e]
Age Group (in months)								
6-11	120	12.8	(7.8; 20.2)	0.2736	110	26.2	(18.1; 36.4)	0.24
12-23	267	16.1	(11.8; 21.6)		257	37.6	(30.5; 45.4)	
24-35	250	10.0	(6.6; 14.8)		236	30.0	(23.7; 37.2)	
36-47	250	11.8	(8.0; 16.9)		245	29.6	(23.9; 36.0)	
48-59	241	13.0	(8.8; 18.8)		231	27.2	(21.1; 34.3)	
Residence								
Urban	408	17.5	(13.1; 22.8)	0.0048	396	29.8	(25.1; 35.0)	0.63
Rural	720	9.4	(6.7; 12.9)		685	31.4	(27.1; 36.1)	
Stratum								
Southern Belt	308	12.5	(8.8; 17.4)	0.0381	285	35.0	(29.6; 41.0)	0.19
Middle Belt	432	15.9	(10.8; 22.6)		416	27.6	(22.8; 33.0)	
Northern Belt	388	7.5	(5.1; 10.8)		380	31.1	(24.3; 38.9)	
Region								
Western	79	13.7	(9.5; 19.3)	0.0326	77	33.3	(26.6; 40.9)	<0.05
Central	72	11.4	(5.4; 22.6)		68	32.5	(26.2; 39.5)	
Greater Accra	95	18.0	(12.3; 25.5)		91	36.6	(24.7; 50.5)	
Volta	62	4.0	(1.3; 11.6)		49	37.0	(27.3; 47.8)	
Eastern	113	21.7	(12.7; 34.7)		105	37.8	(29.9; 46.5)	
Ashanti	213	14.2	(7.8; 24.5)		209	26.1	(19.5; 34.1)	
Brong Ahafo	106	14.1	(8.7; 22.2)		102	21.4	(17.7; 25.6)	
Northern	260	7.2	(4.3; 11.9)		254	37.5	(31.6; 43.8)	
Upper East	78	6.4	(2.9; 13.3)		76	20.1	(10.0; 36.2)	
Upper West	50	12.2	(5.9; 23.6)		50	30.7	(20.5; 43.3)	
Wealth Quintile								
Lowest	406	10.0	(6.9; 14.4)	0.0693	391	33.8	(26.9; 41.5)	0.71
Second	241	11.7	(6.4; 20.5)		228	26.0	(19.9; 33.3)	
Middle	209	13.6	(9.2; 19.6)		198	32.0	(24.8; 40.2)	
Fourth	149	9.7	(6.3; 14.8)		139	31.1	(22.3; 41.6)	
Highest	123	22.2	(13.3; 34.6)		125	29.1	(19.1; 41.6)	
TOTAL	1128	12.8	(10.1; 16.0)		1081	30.7	(27.5; 34.2)	

Note: The n's are un-weighted denominators for each subgroup; subgroups that do not sum to the total have missing data.
a Includes all children with sickle cell trait only.
b Includes all children with homozygous and heterozygous α-thalassemia.
c Percentages weighted for non-response and survey design.
d CI=confidence interval, adjusted for cluster sampling design.
e Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly

3.3.10. Anemia, iron deficiency, and iron deficiency anemia

More than 35% of children were anemic (see Table 27). Only about 0.7% of anemia in children has been classified as severe, whereas 17.0% and 17.8% have been classified as moderate and mild, respectively (see APPENDIX 14). According to WHO, a prevalence of anemia between 20-39.9% is considered a severe public health problem [28]. Anemia prevalence significantly differed by child's age ($p<0.0001$), sex ($p<0.05$), residence ($p<0.001$), stratum ($p<0.0001$) and wealth quintile ($p<0.0001$). Anemia prevalence was highest in children between 12-23 months (46.1%) progressively decreasing to 23.4% in children 48-59 months of age. Furthermore, anemia was significantly higher in male children (38.4%) compared to female children (32.8%), children living in rural areas (42.1%) compared to urban areas (26.8%) and children residing in the Northern Belt (53.2%) compared to the Middle Belt (28.2%) and the Southern Belt (32.3%). Lower prevalence of anemia has been detected in children living in households of the highest wealth quintile (13.8%). In addition, the study showed that thalassemia ($p<0.05$), but not sickle cell disease or sickle cell trait were predictors of anemia.

The prevalence of ID (21.5%) and iron deficiency anemia (IDA) (12.2%) in children 6-59 months of age was found to be relatively high (see Table 27). Similar to anemia, the highest prevalence of ID (34.4%) and IDA (22.1%) was found in children 12-23 months of age, and then progressively decreased with increasing age. The prevalence of ID and IDA was slightly higher in boys than girls ($p<0.05$), and markedly higher among children residing in the Northern Belt compared to the Middle Belt and the Southern Belt ($p<0.0001$). Household wealth was significantly associated with both ID and IDA, but a clear trend of decreasing prevalence was only observed with IDA. Neither residence nor hemoglobinopathies were predictors of ID and IDA. The prevalence of ID calculated using TfR is presented in APPENDIX 14.

As shown in Table 28, the prevalence of anemia was only about 2% in children consuming iron-fortified foods the day before the survey, however consuming these foods was not associated with lower ID and IDA prevalences. The survey found no significant differences in anemia, ID, and IDA for children consuming iron or multivitamin supplements in the 6 month prior to the survey. Children receiving deworming medication had a significantly lower prevalence of ID ($p<0.01$) and IDA ($p<0.05$) compared to those receiving no medication. Only 13 children consumed RUTF the day before the survey and thus, no sub-group analysis was conducted.

Figure 9 illustrates the considerable overlap between anemia and ID in children 6-59 months of age. Among anemic children (n=445), approximately 35% had concurrent ID (data not shown).

Figure 9. Venn diagram showing overlap between anemia and iron deficiency in children 6-59 months of age, Ghana 2017

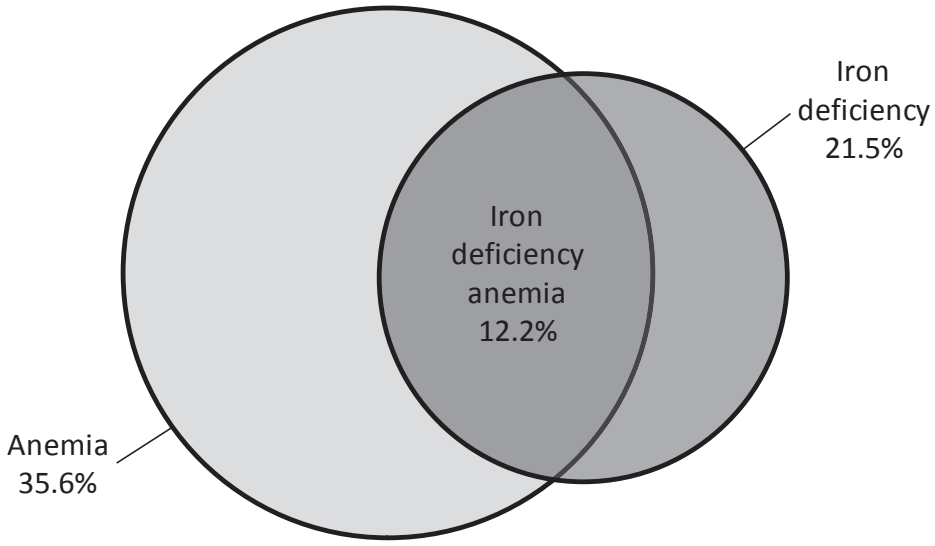


Figure 10 shows the distribution of haemoglobin concentrations measured in Ghanaian children aged 6-59 months. The peak of the histogram is slightly on the right of the anemia cut-off of 110 g/L, but the distribution is skewed to the left.

Figure 10. Histogram of hemoglobin concentration (g/L), preschool children, Ghana 2017

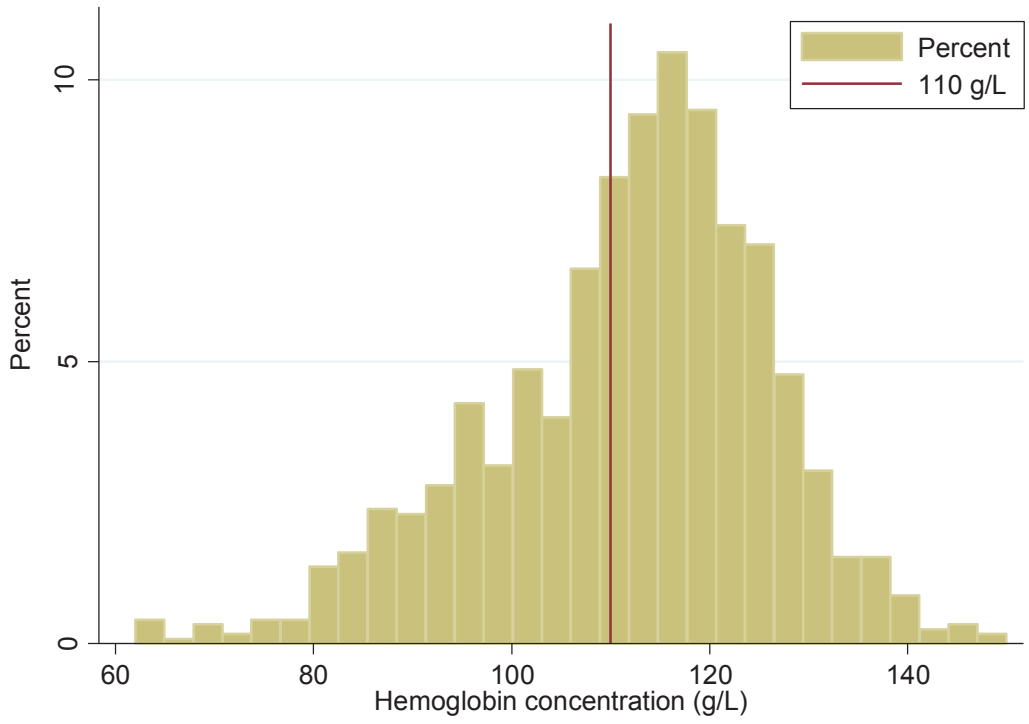


Table 27. Anemia, iron deficiency, and iron deficiency anemia in pre-school age children 6-59 months of age, Ghana 2017

Characteristic	Anemia				Iron deficiency				Iron deficiency anemia			
	n	% [a, b]	(95% CI)[c]	P value [d]	n	% [a, e]	(95% CI)[c]	P value [d]	n	% [a, f]	(95% CI)[c]	P value [d]
Age Group (in months)												
6-11	120	44.6	(35.7; 53.8)	<0.0001	122	29.3	(21.2; 39.0)	<0.0001	122	15.2	(9.9; 22.6)	<0.0001
12-23	276	46.1	(39.1; 53.3)		276	34.4	(28.6; 40.7)		275	22.1	(17.2; 27.8)	
24-35	256	36.7	(30.3; 43.7)		255	22.5	(17.6; 28.3)		255	12.6	(9.4; 16.7)	
36-47	265	30.2	(22.9; 38.6)		263	13.6	(8.6; 20.8)		264	6.5	(3.9; 10.8)	
48-59	253	23.4	(18.1; 29.6)		249	10.2	(6.3; 16.1)		250	5.0	(2.7; 9.0)	
Sex												
Male	581	38.4	(33.5; 43.5)	<0.05	578	24.3	(20.6; 28.3)	0.0135	579	14.2	(11.4; 17.5)	0.0285
Female	589	32.8	(28.4; 37.6)		585	18.9	(15.2; 23.2)		585	10.3	(7.8; 13.4)	
Residence												
Urban	432	26.8	(21.1; 33.4)	<0.001	426	21.2	(16.8; 26.5)	0.8870	429	10.0	(7.0; 14.0)	0.1684
Rural	740	42.1	(37.3; 47.0)		739	21.8	(17.1; 27.3)		737	13.9	(10.6; 18.0)	
Stratum												
Southern Belt	323	32.3	(25.2; 40.2)	<0.0001	319	12.6	(9.8; 16.1)	<0.0001	320	5.2	(3.4; 8.0)	<0.0001
Middle Belt	447	28.2	(22.1; 35.3)		444	17.8	(13.9; 22.6)		444	7.9	(5.8; 10.7)	
Northern Belt	402	53.2	(46.6; 59.8)		402	39.6	(32.1; 47.6)		402	29.0	(23.1; 35.6)	
Sickle cell status												
Normal	990	35.6	(31.7; 39.8)	0.58	990	23.3	(19.9; 27.2)	0.0371	987	13.1	(10.8; 15.8)	0.1227
Sickle cell trait	132	31.3	(23.0; 41.1)		133	12.4	(7.7; 19.3)		132	8.0	(4.4; 14.3)	
Sickle cell disease	10	44.8	(17.0; 76.3)		10	11.8	(1.6; 53.4)		10	0.0	--	
α-thalassemia												
Normal	727	32.1	(28.2; 36.3)	<0.05	726	20.9	(17.1; 25.1)	0.9176	725	11.5	(9.2; 14.3)	0.9792
α-thalassemia heterozygote	315	42.1	(34.8; 49.7)		315	20.1	(15.1; 26.3)		315	11.9	(8.1; 17.2)	
α-thalassemia homozygote	35	38.0	(23.8; 54.6)		34	23.1	(11.2; 41.8)		34	11.8	(4.2; 29.1)	
Wealth Quintile												
Lowest	420	47.0	(40.3; 53.8)	<0.0001	418	28.8	(23.0; 35.3)	0.0200	419	20.0	(15.4; 25.6)	<0.001
Second	247	36.4	(28.5; 45.2)		248	21.3	(14.5; 30.1)		247	10.3	(6.4; 16.0)	
Middle	213	38.8	(32.4; 45.6)		210	16.3	(11.5; 22.6)		209	10.4	(6.8; 15.7)	
Fourth	154	28.3	(20.7; 37.3)		154	20.5	(15.4; 26.6)		154	10.1	(5.9; 16.6)	
Highest	138	13.8	(9.0; 20.6)		135	18.0	(13.1; 24.2)		137	5.2	(2.8; 9.6)	
TOTAL RESPONDING	1172	35.6	(31.7; 39.6)		1165	21.5	(18.4; 25.0)		1166	12.2	(10.1; 14.7)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b Anemia defined as hemoglobin < 110 g/L.
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups
e ID= Iron deficiency defined as serum ferritin < 12 µg/l, values are adjusted for inflammation according to BRINDA
f IDA= Iron deficiency anemia, defined as low Hb (< 110 g/L) with low serum ferritin (< 12.0 µg/L).

Table 28. Anemia, iron deficiency and iron-deficiency anemia in pre-school age children 6-59 months of age, by RUTF and vitamin and mineral supplement indicators, Ghana 2017

Characteristic	n	Anemia % [a, b]	Anemia (95% CI)[c]	Anemia P value [d]	n	Iron deficiency % [a, e]	Iron deficiency (95% CI)[c]	Iron deficiency P value [d]	n	Iron deficiency anemia % [a, f]	Iron deficiency anemia (95% CI)[c]	Iron deficiency anemia P value [d]
Consumed iron-fortified foods yesterday												
No	1090	33.7	(29.8; 37.9)	0.05	1149	21.3	(18.1; 24.9)	0.886	1150	12.1	(10.0; 14.7)	0.385
Yes	78	1.6	(1.0; 2.6)		13	23.4	(5.7; 60.7)		13	6.9	(1.7; 24.7)	
Consumed iron tablets or syrup in past six months												
No	890	36.1	(32.0; 40.4)	0.35	1084	19.4	(16.3; 23.0)	0.264	885	12.9	(10.4; 16.0)	0.607
Yes	251	34.9	(28.0; 42.4)		77	2.1	(1.4; 3.3)		250	10.4	(6.4; 16.6)	
Not sure	24	21.8	(9.0; 43.9)		4	0.0	--		24	8.8	(2.1; 30.2)	
Consumed multivitamins in past six months												
No	906	35.5	(31.9; 39.3)	0.96	885	22.5	(18.7; 26.8)	0.486	900	12.0	(9.6; 14.9)	0.663
Yes	216	36.5	(27.6; 46.4)		249	18.5	(13.7; 24.4)		216	13.5	(9.7; 18.5)	
Not sure	40	34.7	(20.5; 52.3)		24	21.6	(8.8; 43.9)		40	9.0	(3.3; 22.4)	
Received deworming medication in past six months [f]												
No	730	36.5	(31.9; 41.3)	0.22	727	24.1	(19.3; 29.6)	<0.01	726	14.2	(11.0; 18.1)	0.023
Yes	304	30.3	(22.7; 39.2)		300	14.7	(10.8; 19.8)		302	7.7	(4.8; 12.2)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b Anemia defined as hemoglobin < 110 g/L.

c CI=confidence interval, calculated taking into account the complex sampling design.

d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

f Includes only children 12-59 months of age

The survey found that malaria was a strong predictor of anemia; a significantly higher proportion of children with malaria were suffering from anemia (54.7%; p<0.0001) compared to children without malaria (31.2%). In addition, anemia was associated with morbidity; specifically, children with diarrhea (p<0.05) or fever (p<0.0001) in the past 2 weeks prior to the survey were more likely to present with anemia than children without. Furthermore, the lowest prevalence of anemia was found in children without infection (26.2%) and the highest prevalence in children with elevated CRP and AGP (52.5; p<0.0001). Both, iron (p<0.0001) and vitamin A deficiency (p<0.005) were found to be determinants of anemia since about half of the children suffering from vitamin A and/or iron deficiency were also anemic.

Table 29. Anemia in pre-school age children 6-59 months of age, by infection-related characteristics and vitamin A and iron status, Ghana 2017

Characteristic	n	Anemia % [a, b]	(95% CI) [c]	P value [d]
Malaria status [e]				
Negative	879	31.2	(27.0; 35.6)	<0.0001
Positive	233	54.7	(47.4; 61.8)	
Child had any type of diarrhea in the past 2 weeks				
No	882	33.8	(29.7; 38.0)	<0.05
Yes	289	41.2	(34.4; 48.2)	
Child had a cough in the past 2 weeks				
No	864	35.4	(31.0; 40.2)	0.79
Yes	307	36.0	(29.4; 43.2)	
Child had fever in the past 2 weeks				
No	256	30.8	(26.9; 35.0)	<0.0001
Yes	189	45.2	(39.3; 51.2)	
Inflammation				
None	640	26.2	(22.2; 30.7)	<0.0001
Incubation (elevated CRP only)	39	47.5	(29.8; 65.8)	
Early convalescence (elevated CRP and AGP)	198	52.2	(45.4; 58.9)	
Late convalescence (elevated AGP only)	282	40.9	(34.7; 47.4)	
Vitamin A deficient [f]				
No (RBP≥0.7 µmol/L)	919	31.3	(27.9; 35.0)	<0.0001
Yes (RBP<0.7 µmol/L)	240	49.6	(42.1; 57.1)	
Iron deficient [f]				
No (ferrtin≥12 µg/L)	882	29.2	(25.5; 33.1)	<0.0001
Yes (ferritin<12 µg/L)	277	57.1	(50.4; 63.5)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b Anemia defined as hemoglobin < 110 g/L adjusted for altitude.

c CI=confidence interval, calculated taking into account the complex sampling design.

d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly

e Positive malaria status identified using rapid diagnostic tests during GMS data collection

f RBP and ferritin values adjusted for inflammation using Thurnham approach

3.3.11. Vitamin A deficiency

Nationally, about one-fifth of children had vitamin A deficiency using RBP as the indicator (see Table 30), denoting a severe public health problem according to WHO classifications [33]. Statistically significant differences were not found by child age, sex, residence, vitamin A supplementation in the past 6 months. In addition, there was no significant difference in vitamin A deficiency by vegetable oil fortification status, which was only measured in households that provided vegetable oil samples. Significant differences were observed by stratum and wealth quintile, with a higher deficiency prevalence in children in the Northern Belt, and lower prevalence among children living in household with the highest wealth quintile.

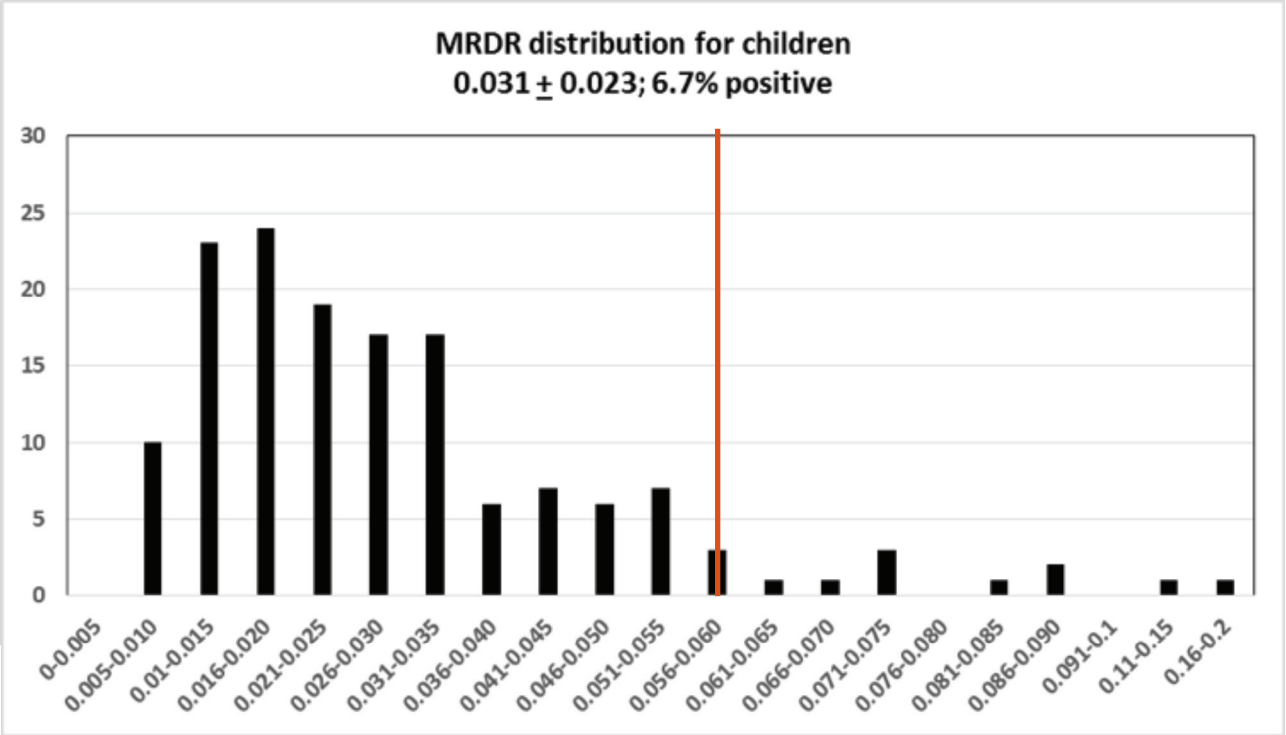
Table 30. Proportion of children 6-59 months of age with vitamin A deficiency, by various characteristics, Ghana 2017

Characteristic	n	Vitamin A deficiency %[a, b]	(95% CI)[c]	P value [d]
Age Group (in months)				
6-11	122	16.3	(9.0; 27.5)	0.360
12-23	276	19.7	(14.3; 26.4)	
24-35	255	18.3	(13.4; 24.5)	
36-47	263	25.1	(20.3; 30.7)	
48-59	249	22.5	(16.9; 29.3)	
Sex				
Male	578	22.0	(18.3; 26.2)	0.385
Female	585	19.6	(16.0; 23.9)	
Residence				
Urban	426	18.0	(13.4; 23.9)	0.149
Rural	739	22.9	(19.7; 26.4)	
Stratum				
Southern Belt	319	17.0	(12.4; 22.9)	<0.001
Middle Belt	444	18.1	(14.0; 23.1)	
Northern Belt	402	30.6	(26.0; 35.7)	
Wealth Quintile				
Lowest	418	25.1	(20.1; 30.8)	0.014
Second	248	21.4	(15.6; 28.7)	
Middle	210	22.9	(18.6; 27.9)	
Fourth	154	19.6	(13.2; 28.2)	
Highest	135	9.1	(4.7; 16.9)	
Vitamin A supplement received in past 6 months				
No	696	22.0	(18.8; 25.6)	0.108
Yes	331	16.5	(12.4; 21.5)	
Not sure/don't know	138	25.1	(17.0; 35.5)	
Household possessed adequately fortified vegetable oil				
No	348	20.7	(15.9; 26.6)	0.884
Yes	358	21.4	(15.9; 28.2)	
TOTAL RESPONDING	1165	20.8	(18.1; 23.9)	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b Vitamin A deficiency (VAD) defined as retinol binding protein (RBP) <0.70 µmol/L; RBP concentrations adjusted for inflammation using Thurnham approach.
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Using the MRDR test in a subsample of 149 children, 6.7 % of children had vitamin A deficiency (MRDR ≥ 0.060). The mean MRDR value in children was 0.031 indicating adequate liver stores.

Figure 11. The distribution of MRDR values from children in Ghana



3.4. All Women

3.4.1. Pregnancy and birth history

Table 31 below shows the distribution of pregnancy related variables among all women, both non-pregnant (randomly selected for the survey) and pregnant. At the time of the survey more than 10% of the women were pregnant and more than one-quarter were lactating. One-quarter of the surveyed women have never been pregnant and the number of women with 1-6 pregnancies was almost equally distributed.

Table 31. Distribution of pregnancy and birth variables in randomly selected non-pregnant women 15-49 years of age and pregnant women

Characteristic	n	% [a]	(95% CI)[b]
Currently Pregnant			
Yes	153	11.3	(9.4; 13.4)
No	1064	88.7	(86.6; 90.6)
Currently lactating [c]			
Yes	227	28.6	(24.7; 32.9)
No	506	71.4	(67.1; 75.3)
Number of pregnancies			
0	283	24.0	(21.1; 27.2)
1	169	15.4	(13.2; 17.9)
2	153	13.0	(11.4; 14.8)
3	160	14.0	(11.9; 16.4)
4	148	12.5	(10.5; 14.8)
5	125	9.6	(8.0; 11.5)
6+	152	11.5	(9.3; 14.0)
Number of births (live and still)			
0	20	3.3	(1.8; 6.1)
1	54	7.0	(5.1; 9.6)
2	154	22.0	(19.2; 25.1)
3	161	22.6	(19.5; 26.0)
4	144	19.0	(16.3; 22.1)
5	112	14.3	(12.2; 16.8)
6	107	11.7	(9.2; 14.7)
TOTAL RESPONDING	1217	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Question only ask if women had previously given birth to a child

3.4.2. Knowledge and practices related to fortified vegetable oil and wheat flour

Only just over one-fifth of the women included in the survey had heard of fortified vegetable oil, fewer women had heard of fortified wheat flour (9.0%). For both fortified oil and wheat flour, the majority of women mentioned "improves health status" as the benefit, followed for oil by "prevents blindness" and "prevents vitamin A deficiency" (both about 15%) and for flour by "gives blood" and "reduces anemia" (see Table 32).

Table 32. Extent of knowledge about and use of fortified foods in all women (non-pregnant 15-49 years of age and pregnant)

Characteristic	n	% [a]	(95% CI)[b]
Have heard of fortified vegetable oil			
No	891	72.4	(68.5; 76.0)
Yes	254	22.2	(18.7; 26.1)
Reported benefits of fortified vegetable oil [c]			
Prevents blindness	40	15.1	(9.6; 22.9)
Reduces mortality	9	3.4	(1.7; 6.8)
Prevents vitamin deficiency	35	15.1	(8.7; 24.8)
Improves health status	186	74.2	(65.9; 81.0)
Other	26	9.2	(5.3; 15.7)
Have heard of fortified wheat flour			
No	1037	84.4	(80.8; 87.5)
Yes	98	9.0	(6.8; 12.0)
Reported benefits of fortified wheat flour [c]			
Gives blood	16	13.3	(8.0; 21.3)
Reduces anemia	14	10.9	(5.9; 19.1)
Reduces mortality	8	8.0	(3.4; 17.8)
Improves health status	68	68.3	(53.9; 79.9)
Better school performance	5	4.2	(1.4; 11.8)
Better work output	12	10.8	(6.0; 18.6)
Other	3	1.4	(0.4; 4.8)
TOTAL RESPONDING	1143	100.0	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Benefits of fortified vegetable oil and wheat flour only asked of women who had heard of fortified vegetable oil or wheat flour previously. Respondents could report more than one benefit.

3.5. Non-pregnant women of reproductive age

3.5.1. Characteristics

Characteristics of non-pregnant women randomly selected for the survey are presented in Table 33. Non-pregnant women included in the survey sample were equally distributed between rural and urban areas. Almost one-fifth of the women never attended school, and more than one-quarter were illiterate. The majority of the women were either married (59.9%) or have never married/never lived with a man (30.7%). More than half of the women had no job outside the home; however, almost one-third had a skilled or professional job. Smoking was uncommon among non-pregnant women.

Table 33. Description of sampled non-pregnant women (15-49 years), Ghana 2017

Characteristic	Survey Sample n	% [a]	(95% CI)[b]
Age Group (in years)			
15-19	222	20.8	(18.2; 23.8)
20-24	175	17.1	(14.3; 20.2)
25-29	187	18.6	(15.8; 21.7)
30-34	181	16.7	(13.9; 19.9)
35-39	123	11.4	(9.4; 13.7)
40-44	110	10.8	(8.7; 13.3)
45-49	50	4.7	(3.5; 6.3)
Residence			
Urban	474	49.8	(37.3; 62.4)
Rural	590	50.2	(37.6; 62.7)
Stratum			
Southern Belt	331	36.1	(29.7; 43.2)
Middle Belt	429	45.3	(38.4; 52.3)
Northern Belt	304	18.6	(14.6; 23.3)
Woman's Education			
Never attended school	250	18.7	(15.6; 22.2)
Completed primary school or less	167	15.3	(12.6; 18.3)
Attend or completed JSS	427	43.8	(39.5; 48.3)
Attended SSS or higher	208	22.2	(18.6; 26.4)
Woman's Literacy			
Illiterate	210	25.7	(21.7; 30.2)
Partly or fully literate	591	74.3	(69.8; 78.3)
Marital Status			
Never married, never lived with man	318	30.7	(27.2; 34.4)
Currently married or living with man	648	59.9	(56.5; 63.2)
Divorced or separated	63	7.2	(5.8; 8.9)
Widowed	24	2.2	(1.5; 3.4)
Occupation			
No job	546	50.8	(46.8; 54.9)
Agriculture or unskilled labor	180	16.2	(12.7; 20.5)
Skilled labor or professional	327	32.9	(27.5; 38.8)
Cigarette Smoking			
Smokes cigarettes	-	-	
Does not smoke	1053	100.0	
TOTAL RESPONDING	1053	100.0	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b CI=confidence interval, calculated taking into account the complex sampling design.

3.5.2. Dietary diversity and consumption of vitamins and supplements

Most non-pregnant women had consumed foods from 4-5 food groups in the 24 hours prior to their survey interview (see Table 34). The mean number of food groups was 4.4 (4.4; 4.6). Almost one-quarter had taken iron supplementation and about 13% had taken folic acid tablets in the prior 6 months. Over 16% of women reported having taken multivitamins during this time period. More than two-thirds of women had taken iron or folic acid supplements for more than 3 months during their most recent pregnancy, and a much smaller proportion (26.9%) had received vitamin A supplementation after their most recent delivery.

Table 34. Dietary diversity and vitamin/supplement consumption in non-pregnant women 15-49 years, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Proportion with minimal dietary diversity	1053	47.2	(42.3; 52.1)
Mean number of food groups	1053	4.4	(4.3; 4.6)
Consumed iron tablets or syrup in past six months			
No	807	76.0	(72.9; 78.9)
Yes	226	22.0	(19.2; 24.9)
Consumed folic acid tablets in past six months			
No	912	85.6	(82.4; 88.2)
Yes	123	12.8	(10.1; 16.2)
Consumed multi-vitamin supplements in past six months			
No	866	81.2	(78.2; 83.9)
Yes	164	16.2	(13.8; 18.9)
Not sure	23	2.6	(1.5; 4.4)
Consumed iron or folic acid supplements during last pregnancy for 90 days or more [c]			
No	113	18.0	(14.4; 22.2)
Yes	430	68.2	(62.2; 73.6)
Not sure	73	13.9	(10.5; 18.1)
Consumed vitamin A capsule after last delivery [c]			
No	309	50.0	(43.4; 56.5)
Yes	160	26.9	(21.6; 33.0)
Not sure	139	23.1	(18.9; 27.9)
TOTAL RESPONDING	1053	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Calculated only for non-pregnant women that had previously given birth

3.5.3. Anthropometry

The prevalence of undernutrition and overnutrition/overweight, as measured by body mass index, is shown in Table 41 and Figure 12 below. Of the women weighted and measured, 8.0% were underweight, 53.0% normal weight. Nearly one-quarter of women were overweight, and nearly 15% were obese. Overall, undernutrition is somewhat present in Ghanaian women, but the majority of underweight women had BMIs between 17.0-18.4 and as such were only at risk for chronic energy deficiency.

On the other hand, overweight and obesity were very common in Ghanaian women and tended to increase with age, which is also reflected in the gradually increasing mean BMI by age group. In urban areas, almost twice the number of women was overweight and obese compared to rural areas. Also, there appears to be strong correlation of the prevalence of overweight and obesity with household wealth as both indicators progressively increase with household living standards; a three-fold for overweight from the poorest to the wealthiest households and 6-fold for obesity from the poorest to the wealthiest households. In addition, the prevalence of overweight (14.6%) and obesity (3.9%) was considerably lower in the Northern Belt than in the Southern Belt (overweight: 28.0%; obesity: 19.1%) and the Middle Belt (overweight: 26.3%; obesity: 14.9%).

Figure 12. Prevalence of underweight, normal weight, and overweight and obesity in non-pregnant women, Ghana 2017

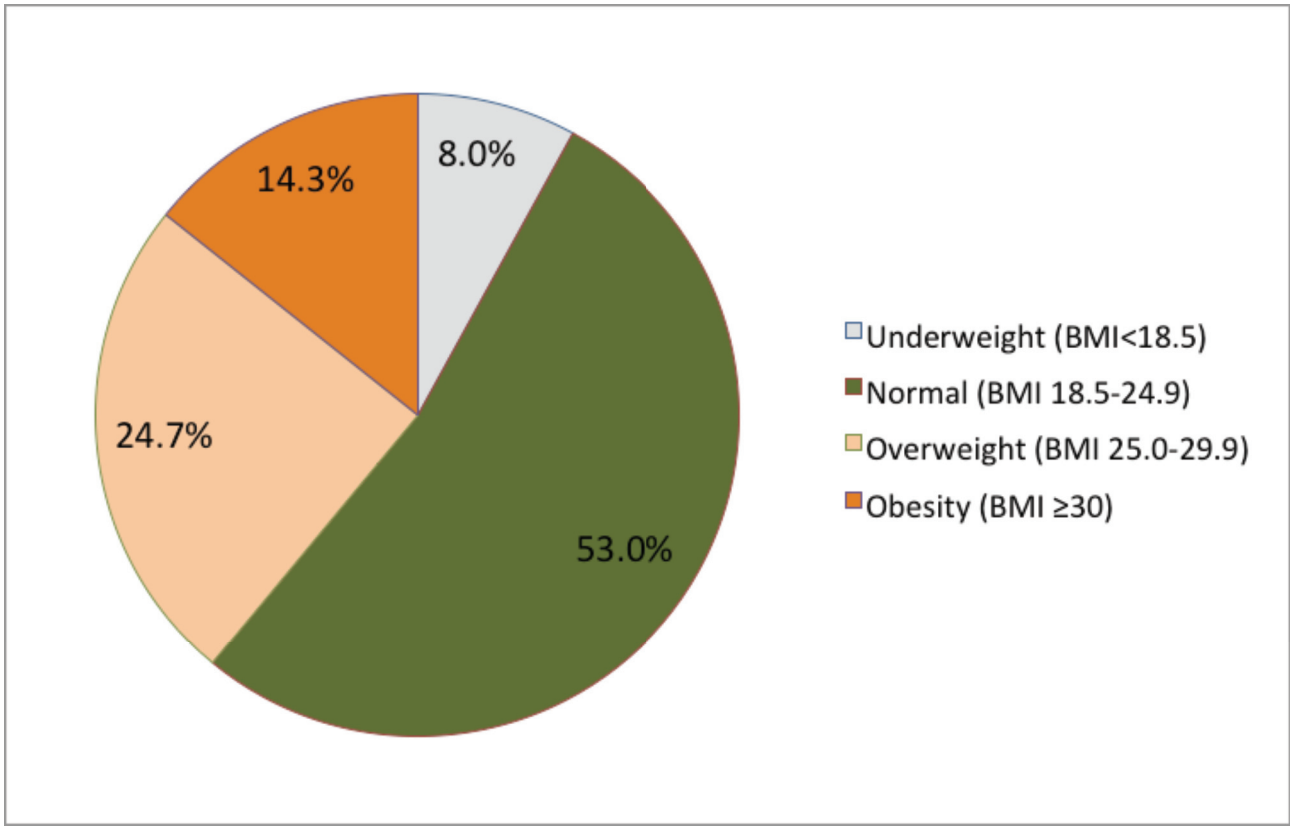


Figure 13. Prevalence of normal weight, overweight, and obesity in non-pregnant women by age group, Ghana

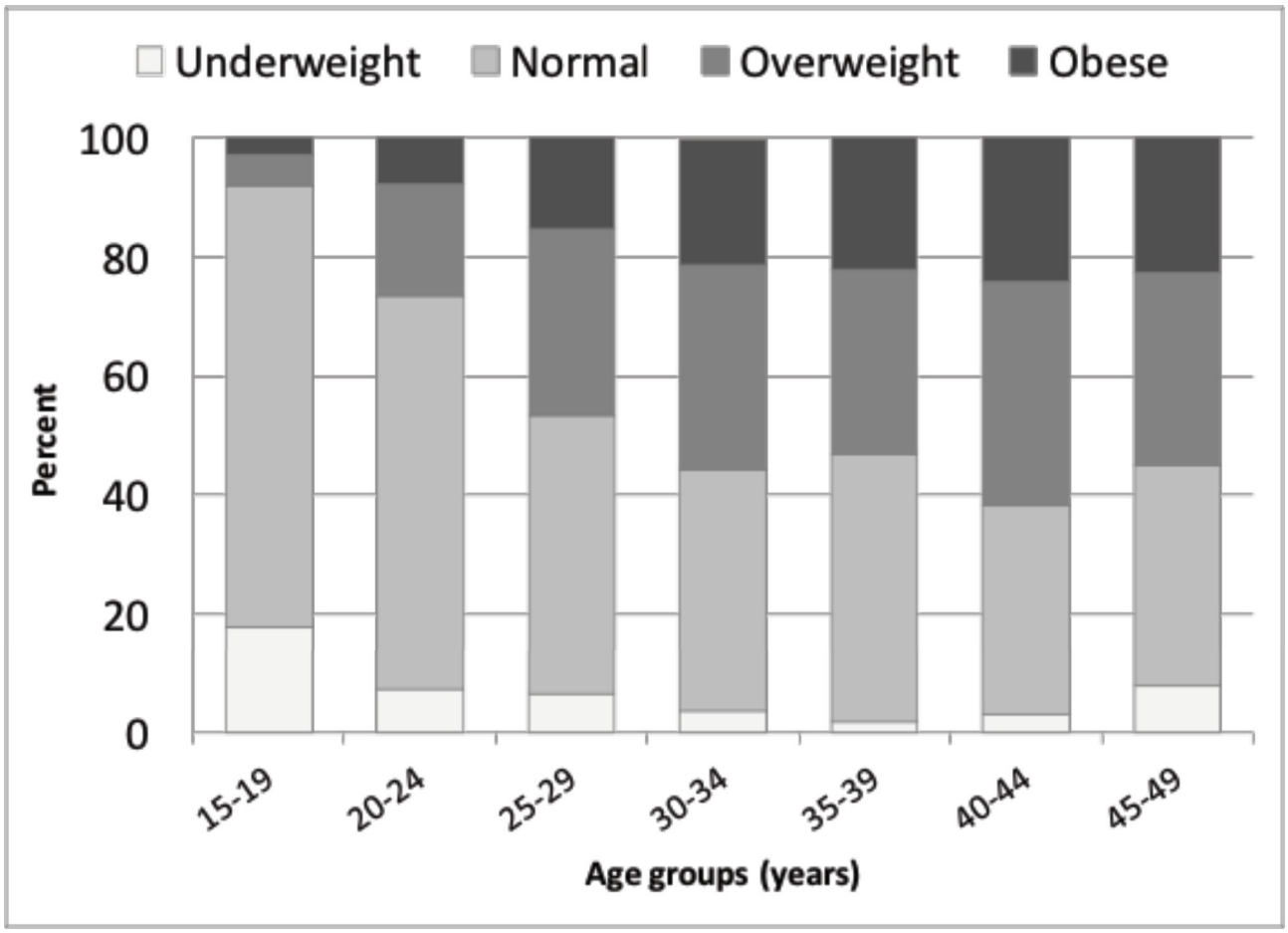


Table 35. Mean Body Mass Index (BMI) and percentage of specific BMI levels in non-pregnant women (15-49 years), Ghana 2017

Characteristic	Mean BMI	n	Severe chronic energy def. (BMI: <16) [a] % [a]	95 CI [b]	Mod. chronic energy def. (BMI:16.0-16.9) [a] % [a]	95 CI [b]	At risk (BMI: 17.0-18.4) [a] % [a]	95 CI [b]	Normal (BMI: 18.5-24.9) [a] % [a]	95 CI [b]	Overweight (BMI: 25.0-29.9) [a] % [a]	95 CI [b]	Obese (BMI: ≥30.0) [a] % [a]	95 CI [b]	P value [c]
Age Group (in years)															
15-19	21.3	210	1.0	(0.2; 4.3)	3.1	(1.3; 7.1)	13.9	(8.9; 21.0)	73.9	(65.8; 80.6)	5.4	(2.8; 10.0)	2.7	(0.9; 7.6)	<0.0001
20-24	23.2	169	-		0.5	(0.1; 3.6)	6.8	(4.0; 11.6)	66.1	(57.0; 74.1)	18.8	(12.6; 27.1)	7.8	(3.9; 14.9)	
25-29	25.1	178	1.2	(0.3; 4.8)	1.0	(0.3; 2.9)	4.4	(1.9; 10.0)	46.7	(39.2; 54.4)	31.4	(25.0; 38.7)	15.3	(9.2; 24.1)	
30-34	26.3	169	-		0.5	(0.1; 3.6)	3.2	(1.4; 7.5)	40.7	(30.5; 51.9)	34.2	(26.7; 42.6)	21.3	(14.9; 29.4)	
35-39	26.4	115	-		-		1.9	(0.6; 6.1)	45.0	(34.0; 56.4)	31.0	(22.3; 41.3)	22.1	(14.5; 32.3)	
40-44	26.7	102	-		0.5	(0.1; 3.5)	2.5	(0.5; 11.2)	35.3	(24.6; 47.7)	37.5	(26.4; 50.0)	24.3	(16.6; 34.0)	
45-49	26.8	46	1.2	(0.2; 8.2)	3.6	(0.5; 22.1)	3.0	(0.4; 18.1)	37.3	(22.3; 55.1)	32.4	(19.7; 48.4)	22.6	(12.3; 38.0)	
Residence															
Urban	25.8	437	0.6	(0.2; 1.9)	0.9	(0.4; 2.3)	4.3	(2.8; 6.7)	44.6	(38.9; 50.4)	29.7	(23.5; 36.9)	19.8	(15.4; 25.2)	<0.0001
Rural	23.3	565	0.4	(0.1; 1.7)	1.7	(0.9; 3.1)	8.0	(5.6; 11.2)	61.1	(55.2; 66.7)	19.8	(16.2; 24.0)	9.0	(6.9; 11.7)	
Stratum															
Southern Belt	25.4	307	0.3	(0.0; 1.9)	1.3	(0.5; 3.5)	4.9	(3.0; 7.9)	46.5	(39.8; 53.2)	28.0	(22.0; 34.8)	19.1	(13.0; 27.1)	<0.0005
Middle Belt	24.7	405	0.8	(0.2; 2.4)	0.8	(0.2; 2.6)	6.1	(3.7; 9.9)	51.2	(44.5; 57.8)	26.3	(20.5; 33.1)	14.9	(12.5; 17.7)	
Northern Belt	22.4	290	0.3	(0.0; 2.0)	2.6	(1.3; 5.1)	8.9	(5.7; 13.5)	69.8	(62.8; 75.9)	14.6	(9.6; 21.7)	3.9	(1.8; 7.9)	
Woman's Education															
Never attended	24.0	241	0.3	(0.0; 2.0)	1.5	(0.6; 3.9)	7.3	(4.3; 12.0)	56.7	(47.8; 65.2)	23.3	(17.5; 30.3)	10.9	(6.8; 17.2)	0.93
Comp PS or less	24.7	161			2.0	(0.5; 7.6)	6.1	(3.2; 11.5)	52.4	(43.2; 61.4)	22.8	(16.1; 31.1)	16.8	(11.1; 24.7)	
Attend or comp JSS	24.5	411	0.5	(0.1; 2.2)	1.1	(0.5; 2.6)	6.0	(4.1; 8.6)	53.3	(46.8; 59.6)	25.5	(20.1; 31.8)	13.7	(10.9; 17.0)	
Attend SSS or more	25.0	188	1.0	(0.2; 4.0)	1.1	(0.3; 4.6)	5.8	(3.2; 10.3)	50.0	(42.4; 57.5)	25.2	(18.5; 33.4)	16.9	(10.9; 25.3)	
Wealth Quintile															
Lowest	22.1	278	0.3	(0.0; 1.9)	1.8	(0.8; 4.0)	9.7	(6.4; 14.4)	71.8	(66.3; 76.7)	12.6	(9.0; 17.4)	3.8	(1.8; 7.9)	<0.0001
Second	24.0	213	0.7	(0.1; 4.4)	1.1	(0.3; 4.2)	5.3	(3.1; 9.0)	60.5	(53.3; 67.3)	20.0	(15.0; 26.1)	12.4	(8.9; 16.9)	
Middle	24.5	187	0.6	(0.1; 4.2)	1.8	(0.6; 5.6)	7.8	(4.0; 14.7)	48.8	(42.7; 54.9)	28.0	(22.1; 34.7)	13.1	(8.3; 20.1)	
Fourth	25.5	162	1.0	(0.2; 3.8)	0.9	(0.1; 5.6)	4.9	(2.3; 10.2)	44.7	(35.7; 54.0)	29.6	(21.5; 39.1)	19.0	(13.7; 25.8)	
Highest	26.9	162	--		0.8	(0.2; 3.5)	2.8	(1.0; 7.6)	38.0	(32.2; 44.1)	33.9	(24.6; 44.6)	24.5	(17.2; 33.6)	
TOTAL RESPONDING	24.5	1002	0.5	(0.2; 1.2)	1.3	(0.8; 2.2)	6.2	(4.6; 8.2)	53.0	(48.6; 57.4)	24.7	(21.0; 28.8)	14.3	(11.5; 17.7)	

Note: The n's are un-weighted denominators for each subgroup; subgroups that do not sum to the total have missing data.
a Percentages weighted for non-response and survey design.
b CI=confidence interval, adjusted for cluster sampling design.
c Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly

3.5.4. Hemoglobinopathies

As shown in Table 36 the prevalence of sickle cell disease in non-pregnant women is less than 1%. The proportion of women with sickle cell trait is 13.0%. Similar to this, the prevalence of homozygous α-thalassemia is low (4.4%), whereas almost one- third of the women possessed the heterozygous α-thalassemia.

Table 36. Prevalence of blood disorders in participating non-pregnant women, Ghana 2017[1]

Characteristic	n	% [a]	(95% CI)[b]
Sickle cell disorder (N=479)			
Normal	419	86.5	(82.9; 89.4)
SS (disease)	2	0.5	(0.1; 0.9)
AS (trait)	58	13.0	(10.1; 16.7)
α-thalassemia (N=474)			
Normal	311	65.4	(60.3; 70.3)
Homozygous	19	4.4	(2.7; 7.2)
Heterozygous	144	30.1	(25.4; 35.3)

1 Note that only half of the women samples were randomly selected and underwent analysis.
a Percentages weighted for non-response and survey design.
b CI=confidence interval, adjusted for cluster sampling design.

For sub group analyses (Table 37), women with sickle cell disease were excluded as so few women were affected. In addition, sickle cell disease results in severe anemia whereas sickle cell trait is protective against malaria and typically results in mild anemia. For α-thalassemia, women with homozygous and heterozygous α-thalassemia were merged.

The survey found no significant differences in the prevalence of sickle cell disorders or α-thalassemia by urban vs. rural residence, strata, regions, women's education and household living standards. Although not significantly different, the prevalence of sickle cell trait was lowest in the Northern Belt, and the prevalence of α-thalassemia was higher in the Southern Belt compared to the Middle and Northern Belts.

Table 37. Sickle cell trait and α-thalassemia (heterozygote and homozygote) in non-pregnant women, Ghana 2017

	Sickle cell trait[a]				α-thalassemia[b]			
Characteristic	n	% [c]	(95% CI)[d]	P value [e]	n	% [c]	(95% CI)[d]	P value [e]
Age Group (in years)								
15-19	101	9.0	(4.5; 17.1)	0.12	100	37.1	(27.2; 48.1)	0.92
20-24	68	11.2	(4.6; 24.5)		66	37.2	(25.6; 50.5)	
25-29	91	9.9	(4.9; 19.2)		90	30.5	(21.4; 41.4)	
30-34	85	12.6	(7.0; 21.5)		82	37.5	(27.8; 48.2)	
35-39	56	16.0	(6.9; 32.8)		55	33.3	(20.4; 49.1)	
40-44	48	28.7	(15.1; 47.7)		49	36.4	(22.6; 52.9)	
45-49	25	8.6	(2.1; 29.2)		25	27.6	(14.3; 46.7)	
Residence								
Urban	214	14.9	(10.7; 20.4)	0.28	213	32.9	(26.0; 40.6)	0.53
Rural	263	11.3	(7.6; 16.5)		261	36.2	(29.5; 43.5)	
Stratum								
Southern Belt	141	13.8	(9.4; 19.9)	0.14	139	42.1	(32.4; 52.4)	0.07
Middle Belt	192	15.2	(10.3; 21.7)		192	30.0	(23.6; 37.4)	
Northern Belt	144	7.2	(3.8; 13.1)		143	31.6	(25.1; 38.9)	
Woman's Education								
Never attended school	120	15.1	(8.5; 25.4)	0.93	118	37.7	(28.3; 48.1)	0.61
Comp. PS or less	74	11.1	(5.1; 22.8)		74	40.4	(27.1; 55.2)	
Attend or comp. JSS	192	13.2	(8.8; 19.3)		191	32.7	(25.6; 40.8)	
Attended SSS or higher	90	12.7	(6.5; 23.1)		90	31.2	(21.7; 42.5)	
Wealth Quintile								
Lowest	126	10.5	(4.4; 22.7)	0.73	123	30.0	(23.2; 37.8)	0.64
Second	107	11.1	(5.4; 21.4)		106	38.1	(26.4; 51.3)	
Middle	85	11.6	(6.8; 19.1)		88	39.0	(30.6; 48.2)	
Fourth	78	15.9	(8.8; 27.0)		76	29.6	(18.4; 44.0)	
Highest	81	17.1	(9.5; 28.7)		81	34.2	(22.8; 47.8)	
TOTAL	477	13.1	(10.1; 16.7)		474	34.6	(29.7; 39.7)	

Note: The n's are un-weighted denominators for each subgroup; subgroups that do not sum to the total have missing data.

a Includes all women with sickle cell trait only.

b Includes all women with homozygote and heterozygote α-thalassemia.

c Percentages weighted for non-response and survey design.

d CI=confidence interval, adjusted for cluster sampling design.

e Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly

3.5.5. Malaria

As shown in Table 38, 8.4% of non-pregnant women tested positive for *P. falciparum* and other *Plasmodium* species at the time of the survey. Of the 93 women that tested positive for malaria, 91 were found with *P. falciparum*, 1 was found with concurrent *P.falciparum* and another malaria species, and only 1 was found with another malaria species and no *P. falciparum*. The prevalence of malaria did not differ significantly by age. It was significantly lower in urban areas ($p<0.001$) and women living in the Middle Belt ($p<0.05$). The survey also found that women's education was a predictor of malaria infection ($p<0.01$) and there is some indication that malaria infection has a lower prevalence in women in the wealthiest households, when compared to the women living in poorer households ($p<0.05$). The results show that hemoglobinopathies are not associated with malaria infection.

Table 38. Proportion testing positive on malaria rapid diagnostic test for *Plasmodium ssp.* in non- pregnant women, by various characteristics, Ghana 2017

Characteristic	n	Malaria %[a, b]	(95% CI)[c]	P value [d]
Age Group (in years)				
15-19	194	11.1	(7.2; 16.7)	0.43
20-24	156	11.1	(6.6; 18.1)	
25-29	171	5.9	(3.4; 9.9)	
30-34	163	8.6	(3.7; 18.8)	
35-39	105	4.1	(1.4; 11.6)	
40-44	98	9.0	(3.4; 21.8)	
45-49	46	7.4	(2.1; 23.3)	
Residence				
Urban	395	3.5	(1.8; 6.7)	<0.001
Rural	552	12.8	(8.7; 18.4)	
Stratum				
Southern Belt	303	5.9	(3.5; 9.8)	<0.05
Middle Belt	352	12.0	(7.0; 19.9)	
Northern Belt	292	5.5	(3.0; 9.9)	
Women's Education				
Never attended school	239	8.9	(4.9; 15.4)	<0.01
Completed primary school or less	147	6.0	(2.9; 12.0)	
Attend or completed JSS	386	11.6	(7.8; 17.0)	
Attended SSS or higher	174	2.9	(1.1; 7.6)	
Sickle cell e				
Sickle cell disease (SS)	2	-		0.12
Sickle cell trait (AS)	53	1.9	(0.3; 12.4)	
Normal (AA)	391	10.6	(6.4; 17.0)	
α-thalassemia e				
Homozygous	18	17.2	(5.3; 43.8)	0.58
Heterozygous	135	9.9	(4.0; 22.6)	
Normal	288	9.1	(5.3; 15.3)	
Wealth Quintile				
Lowest	277	10.4	(6.6; 16.2)	<0.05
Second	200	13.9	(8.4; 22.1)	
Middle	178	8.2	(4.6; 14.5)	
Fourth	152	6.3	(2.9; 13.2)	
Highest	140	2.0	(0.5; 7.5)	
TOTAL RESPONDING	947	8.4	(5.7; 12.2)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b Malaria %= % of women identified as malaria positive using rapid diagnostic tests for plasmodium falciparum and other plasmodium species
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups
e Hemoglobinopathies analyzed in a subsample of women

3.5.6. Anemia, iron deficiency, and iron deficiency anemia

Nearly 22% of non-pregnant women were anemic (see Table 39). Less than 1% of non-pregnant women were severely anemic, whereas moderate and mild anemia was present in 7.0 % and 14.3% of women, respectively (see Table A15 - 1). The distribution of hemoglobin concentration is shown in Figure 14, showing that the majority of measurements are right of the anemia cutoff.

ID and IDA affected about 14% and 9% of non-pregnant women, respectively. There is a considerable overlap of anemia and ID (see Figure 15), and among women with anemia, 41.1% had concurrent ID (data not shown).

No significant differences in the prevalence of anemia, ID, or IDA were observed by age, residence, educational status, or household wealth. Women living in the Middle Belt had a lower anemia prevalence than in other strata, women with sickle cell trait had a slightly higher prevalence of anemia ($p<0.05$) compared to women with a normal allele of the hemoglobin beta gene. Alpha-thalassemia was not associated with anemia, ID or ID anemia.

The survey did not find any significant differences in the prevalence of anemia, ID and ID anemia for folate status and the consumption of folic acid tablets and multivitamin tablets or syrup in the last 6 months prior to the survey (see Table 40). Although not statistically significant, it appeared that women who had taken iron tablets or syrup in the prior 6 months had a slightly lower prevalence of ID.

The prevalence of anemia was significantly higher in women that were iron deficient ($p<0.01$) and vitamin A deficient ($p<0.05$) compared to women sufficient for each micronutrient. Surprisingly, in women who were vitamin B12 deficient the prevalence of anemia was significantly lower ($p<0.01$) compared to vitamin B12 replete women. Women who had been tested positive for malaria had a substantially lower prevalence of ID ($p<0.05$).

Women in early convalescent phase, with elevation of CRP and AGP as well as women in the late convalescence phase, with elevated AGP only, had a substantially elevated prevalence of anemia compared to other women. On the other hand, neither ID nor ID anemia were significantly associated with markers of inflammation.

Figure 14. Histogram of hemoglobin concentration (g/L) in non-pregnant women of reproductive age, Ghana 2017

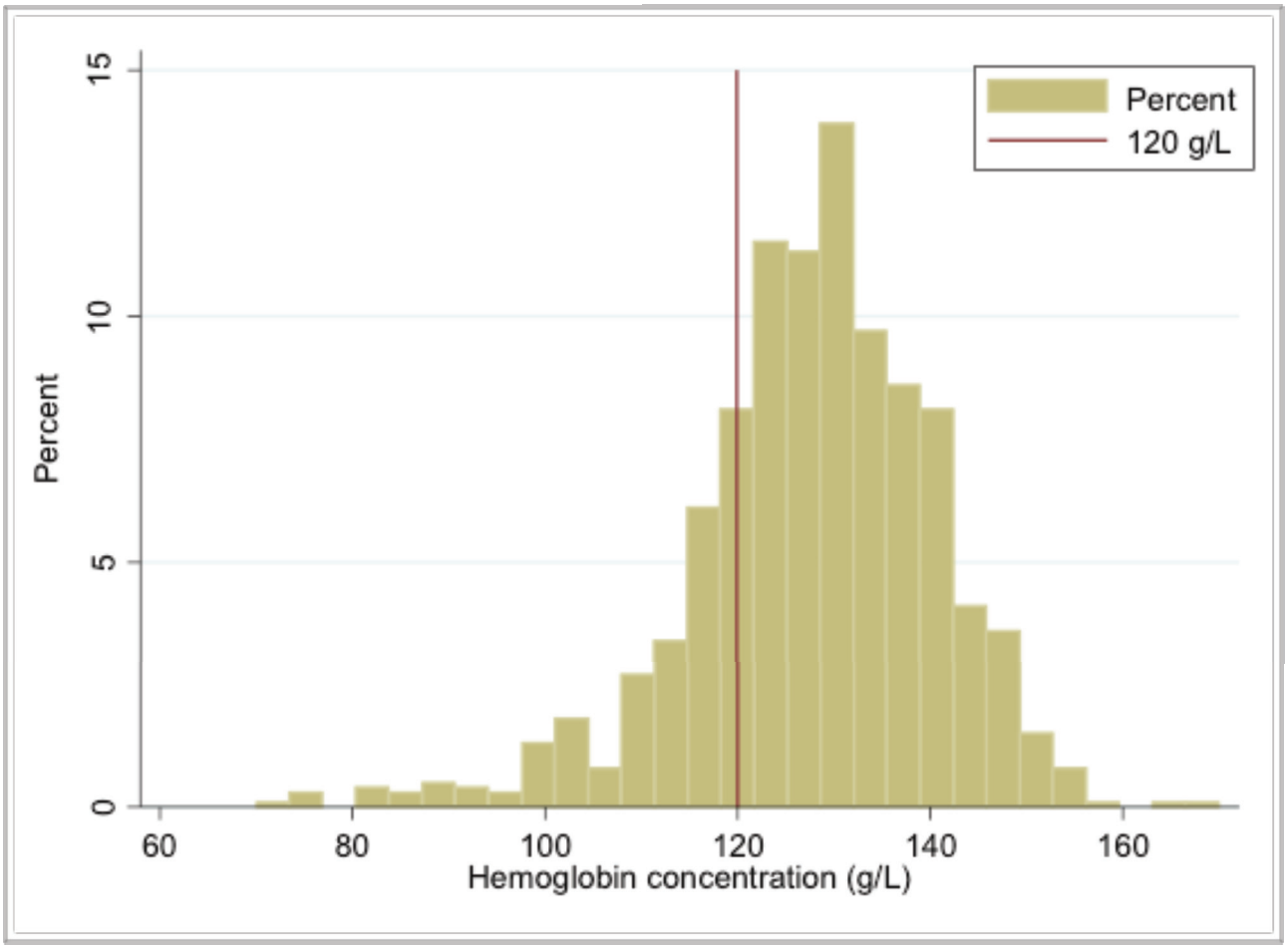


Figure 15. Venn diagram showing overlap between anemia and iron deficiency in non-pregnant women of reproductive age, Ghana 2017

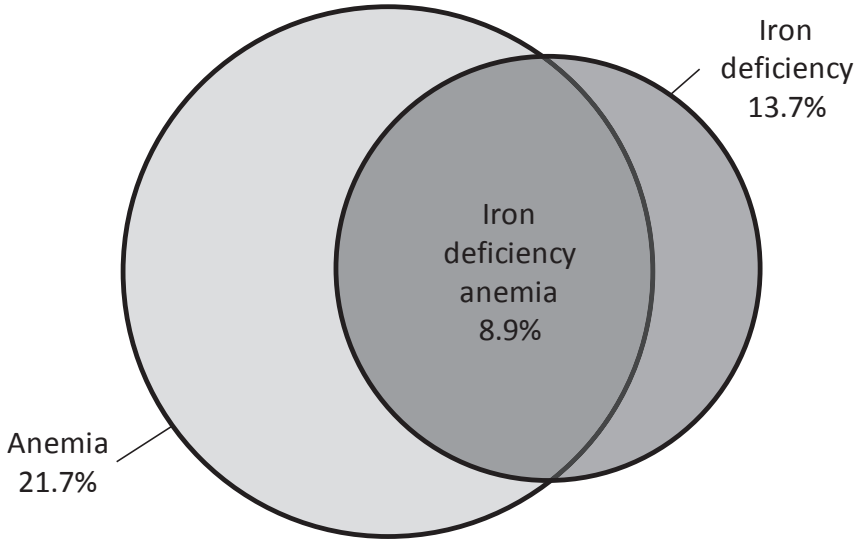


Table 39. Anemia, iron deficiency, and iron deficiency anemia in non-pregnant women (15-49 years), Ghana 2017

Characteristic	n	Anemia [b] %[a]	Anemia [b] (95% CI)[c]	Anemia [b] P value[d]	n	Iron deficiency [e] %[a]	Iron deficiency [e] (95% CI)[c]	Iron deficiency [e] P value[d]	n	Iron deficiency anemia [f] %[a]	Iron deficiency anemia [f] (95% CI)[c]	Iron deficiency anemia [f] P value[d]
Age group (in years)												
15-19	207	26.4	(19.1; 35.2)	0.58	205	20.9	(15.0; 28.3)	0.10	206	14.5	(9.1; 22.4)	0.12
20-24	169	20.9	(14.2; 29.6)		167	15.2	(10.7; 21.2)		169	7.3	(4.2; 12.4)	
25-29	178	23.1	(17.0; 30.5)		179	11.1	(6.9; 17.5)		179	9.0	(5.3; 14.9)	
30-34	169	23.0	(16.4; 31.3)		165	9.7	(5.8; 15.8)		166	3.6	(1.7; 7.5)	
35-39	113	15.5	(7.8; 28.5)		115	12.5	(5.5; 25.9)		113	10.2	(3.8; 25.0)	
40-44	103	16.9	(10.0; 27.1)		104	13.2	(8.3; 20.4)		103	8.9	(4.5; 16.8)	
45-49	46	20.0	(9.3; 37.9)		44	5.1	(1.1; 20.3)		45	5.0	(1.1; 19.7)	
Residence												
Urban	436	21.6	(17.5; 26.4)	0.96	438	15.7	(12.5; 19.7)	0.15	435	9.8	(7.2; 13.2)	0.48
Rural	563	21.8	(17.4; 26.8)		549	11.7	(8.3; 16.1)		554	8.0	(4.8; 12.9)	
Strata												
Southern Belt	303	23.9	(18.9; 29.8)	<0.05	302	13.6	(9.9; 18.5)	<0.01	301	9.2	(6.0; 13.8)	<0.05
Middle Belt	404	17.5	(14.1; 21.5)		400	10.5	(7.9; 13.9)		398	5.9	(4.0; 8.5)	
Northern Belt	292	27.6	(20.4; 36.2)		285	21.5	(15.1; 29.7)		290	15.4	(9.1; 24.9)	
Sickle cell g												
Sickle cell disease (SS)	2	0.0	--	<0.05	2	0.0	--	0.66	2	0.0	--	0.88
Sickle cell trait (AS)	57	25.7	(16.1; 38.4)		58	11.0	(5.0; 22.7)		57	10.0	(4.3; 21.8)	
Normal (AA)	413	21.2	(16.9; 26.2)		414	14.6	(11.3; 18.6)		412	9.0	(6.1; 13.2)	
α-thalassemia g												
Homozygous	18	25.0	(8.4; 55.0)	0.95	308	14.5	(10.6; 19.7)	0.54	307	8.9	(5.6; 14.0)	0.25
Heterozygous	142	22.1	(15.5; 30.5)		142	10.3	(6.0; 17.2)		141	8.3	(4.7; 14.2)	
Normal (AA)	307	21.8	(17.0; 27.5)		19	16.0	(4.4; 44.1)		18	11.6	(2.3; 42.3)	
Woman's education												
Never attended school	242	24.3	(16.9; 33.7)	0.36	237	15.6	(9.2; 25.0)	0.70	240	12.2	(6.3; 22.3)	0.48
Completed primary school or less	160	16.9	(11.9; 23.5)		162	10.6	(6.3; 17.3)		160	7.5	(4.0; 13.7)	
Attend or completed JSS	406	23.0	(18.8; 27.9)		402	13.9	(10.8; 17.6)		400	8.1	(5.9; 11.0)	
Attended SSS or higher	190	20.2	(15.4; 25.9)		185	13.5	(9.1; 19.7)		188	8.6	(5.3; 13.6)	
Wealth quintile												
Lowest	278	21.2	(14.7; 29.5)	0.45	273	14.6	(9.2; 22.3)	0.44	276	10.6	(5.7; 18.7)	0.61
Second	211	22.4	(16.8; 29.2)		207	10.6	(6.5; 16.9)		209	6.8	(3.8; 11.9)	
Middle	187	25.8	(18.6; 34.6)		186	14.4	(10.1; 20.2)		186	9.8	(5.9; 15.8)	
Fourth	161	21.4	(15.8; 28.4)		160	17.9	(12.6; 24.8)		158	10.3	(6.6; 15.8)	
Highest	162	17.0	(12.1; 23.3)		161	11.3	(6.4; 19.1)		160	6.8	(3.7; 12.4)	
TOTAL RESPONDING	999	21.7	(18.7; 25.1)	--	987	13.7	(11.2; 16.6)	--	989	8.9	(6.7; 11.7)	--

a Percentages weighted for unequal probability of selection.
b Anemia defined as hemoglobin < 120 g/L adjusted for smoking.
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups.
e Iron deficiency defined as serum ferritin < 15.0 µg/l, values are adjusted for inflammation using the Thurnham approach.
f Iron deficiency anemia defined as low Hb (< 120 g/L) with low serum ferritin (< 15.0µg/L).
g Hemoglobinopathies measured in a sub sample.

Table 40. Anemia, iron deficiency, and iron deficiency anemia in non-pregnant women (15-49 years) by micronutrient status, supplement consumption, malaria status and inflammation, Ghana 2017

Characteristic	n	Anemia [b] %[a]	Anemia [b] (95% CI)[c]	Anemia [b] P value[d]	Iron deficiency [e] n	Iron deficiency [e] %[a]	Iron deficiency [e] (95% CI)[c]	Iron deficiency [e] P value[d]	Iron deficiency anemia [f] n	Iron deficiency anemia [f] %[a]	Iron deficiency anemia [f] (95% CI)[c]	Iron deficiency anemia [f] P value[d]
Iron status [e]												
Deficient (<15 µg/l)	131	64.8	(55.1; 73.4)	<0.0001	--	--	--	--	--	--	--	--
Sufficient (≥15µg/L)	845	13.9	(11.4; 17.0)		--	--	--		--	--	--	
Vitamin A status [g]												
Deficient (<0.7nmol/L)	13	46.6	(20.7; 74.4)	<0.05	13	22.1	(8.4; 46.8)	0.32	13	22.1	(8.4; 46.8)	0.07
Sufficient (≥0.70nmol/L)	963	20.6	(17.6; 23.9)		974	13.6	(11.0; 16.6)		963	8.8	(6.5; 11.7)	
Folate status [h]												
Deficient (<10 ηmol/L)	257	23.5	(18.2; 29.9)	0.74	256	16.8	(12.3; 22.5)	0.06	256	10.7	(7.1; 15.7)	0.15
Sufficient (≥10ηmol/L)	210	22.1	(16.6; 28.9)		212	11.0	(7.6; 15.8)		210	7.3	(4.4; 12.1)	
B12 status [h]												
Deficient (<150pmol/L)	39	6.1	(1.8; 18.6)	<0.01	40	9.8	(3.3; 25.8)	0.45	39	6.1	(1.8; 18.6)	0.47
Sufficient (≥150pmol/L)	426	23.9	(19.7; 28.8)		426	14.5	(11.3; 18.5)		425	9.4	(6.4; 13.5)	
Consumed iron tablets or syrup in past six months												
No	769	22.0	(19.0; 25.4)	0.68	759	15.0	(12.4; 18.1)	0.04	761	9.4	(7.1; 12.3)	0.16
Yes	211	20.1	(12.8; 30.1)		209	9.1	(5.4; 15.0)		209	6.7	(3.8; 11.5)	
Consumed folic acid tablet in past six months												
No	865	21.2	(18.2; 24.6)	0.24	859	14.2	(11.5; 17.4)	0.54	858	9.1	(6.7; 12.2)	0.91
Yes	117	27.6	(17.8; 40.1)		111	11.8	(6.7; 20.0)		114	8.7	(4.4; 16.5)	
Consumed multi-vitamin tablets or syrup in past six months												
No	825	22.2	(18.9; 26.0)	0.20	815	14.5	(11.7; 17.9)	0.09	817	9.0	(6.6; 12.3)	0.39
Yes	152	16.6	(10.4; 25.5)		151	8.8	(4.9; 15.2)		150	6.8	(3.6; 12.4)	
Malaria status [i]												
Negative	869	21.4	(17.8; 25.5)	0.94	848	14.8	(12.1; 18.0)	<0.05	860	9.7	(7.3; 12.8)	0.02
Positive	78	21.9	(12.9; 34.7)		77	3.8	(0.9; 14.5)		77	2.5	(0.7; 8.3)	
Inflammation [j]												
None	798	19.3	(15.9; 23.2)	<0.001	806	14.2	(11.3; 17.8)	0.50	798	9.3	(6.6; 12.9)	0.58
Incubation	63	8.3	(3.3; 19.4)		65	7.5	(2.9; 17.8)		63	3.8	(0.9; 15.0)	
Early convalescence	56	40.1	(27.8; 53.7)		56	10.8	(5.3; 20.8)		56	8.1	(3.1; 19.5)	
Late convalescence	59	33.0	(21.3; 47.2)		60	16.4	(7.4; 32.6)		59	11.2	(5.1; 22.6)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b Anemia defined as hemoglobin < 120 g/L adjusted for smoking.
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups.
e ID= Iron deficiency defined as serum ferritin < 15.0 µg/l, values adjusted for inflammation using the Thurnham approach.
f IDA= Iron deficiency anemia, defined as low Hb (< 120 g/L) with low serum ferritin (< 15.0µg/L).
g VAD= Vitamin A deficiency, defined as low retinol binding protein (<0.7 nmol/L) , values adjusted for inflammation using the Thurnham approach.
h Analyses done in a sub sample of non- pregnant women.
i Malaria status identified using rapid diagnostic tests during GMS data collection.
j Incubation=CRP only; early convalescence=CRP and AGP; late convalescence=AGP only.

3.5.7. Vitamin A deficiency

Only 1.5% of non-pregnant women had vitamin A deficiency when using RBP as the indicator. A higher proportion of women residing in the Northern Belt were vitamin A deficient, and women in the lowest and fourth wealth quintile had a higher deficiency prevalence than in other household wealth categories. There were no differences in the prevalence of vitamin A deficiency by age, urban vs. rural residence, or the fortification adequacy of vegetable oil sampled from the household.

Table 41. Vitamin A deficiency in non-pregnant women (15-49 years), Ghana 2017

Characteristic	n	%[a, b]	(95% CI)[c]	P value[d]
Age Group (in years)				
15-19	205	0.6	(0.1; 4.4)	<0.05
20-24	167	1.7	(0.6; 5.1)	
25-29	179	4.7	(1.9; 11.1)	
30-34	165	1.0	(0.2; 4.2)	
35-39	115	0.0	--	
40-44	104	0.5	(0.1; 3.5)	
45-49	44	0.0	--	
Residence				
Urban	438	1.1	(0.4; 2.8)	0.40
Rural	549	1.9	(0.8; 4.4)	
Stratum				
Southern Belt	302	1.1	(0.3; 3.6)	<0.05
Middle Belt	400	0.7	(0.2; 3.2)	
Northern Belt	285	4.1	(1.9; 8.6)	
Women's Education				
Never attended school	237	2.4	(0.7; 7.3)	0.61
Completed primary school or less	162	0.4	(0.1; 3.1)	
Attend or completed JSS	402	1.4	(0.4; 4.5)	
Attended SSS or higher	185	1.9	(0.6; 5.8)	
Wealth Quintile				
Lowest	273	3.2	(1.2; 8.1)	<0.05
Second	207	0.3	(0.0; 1.9)	
Middle	186	0.9	(0.2; 3.7)	
Fourth	160	3.0	(1.1; 7.6)	
Highest	161	0.5	(0.1; 3.5)	
Adequately fortified vegetable oil				
No	303	1.5	(0.5; 3.9)	0.77
Yes	341	1.2	(0.3; 3.9)	
TOTAL RESPONDING	987	1.5	(0.8; 2.9)	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

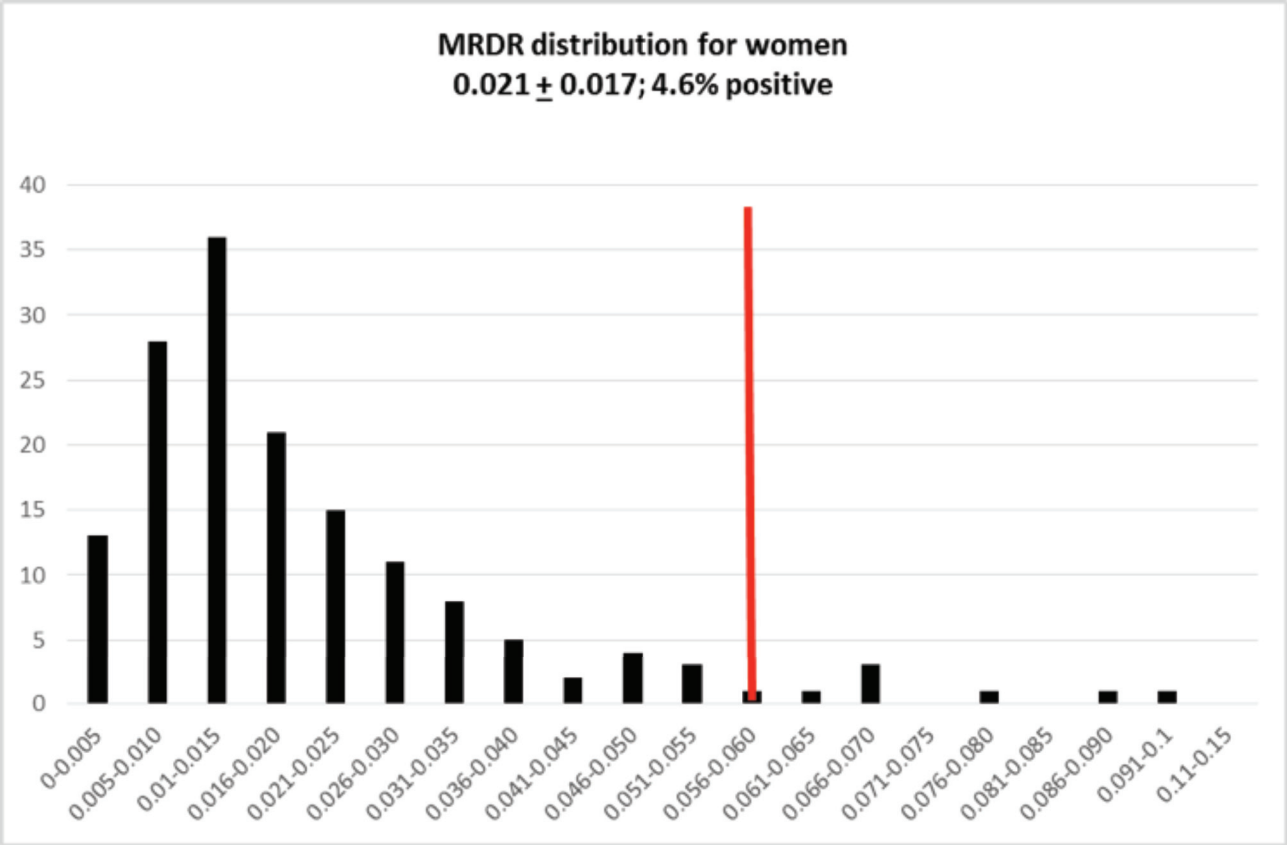
b Vitamin A deficiency defined as retinol binding protein (RBP) <0.70 µmol/L; RBP concentrations adjusted for inflammation.

c CI=confidence interval, calculated taking into account the complex sampling design.

d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Using the MRDR test in a subsample of 153 women, 4.6 % of women had vitamin A deficiency (MRDR ≥ 0.060). The mean MRDR value in the women was 0.021 indicating adequate liver stores (Figure 16).

Figure 16: The distribution of MRDR values from women in Ghana



3.5.8. Folate deficiency

The prevalence of folate deficiency was high with over 50%. There were no differences in the deficiency prevalence by age, urban/rural residence, stratum, educational attainment, or household wealth. Although not significant, it appears that taking folate in past 6 months slightly reduces the likelihood of developing folate deficiency (see Table 42). The distribution of folate deficiency is provided in APPENDIX 15.

Table 42. Serum folate deficiency in non-pregnant women (15-49 years), Ghana 2017 [a]

Characteristic	n	Folate deficiency %[b, c]	(95% CI)[d]	P Value [e]
Age Group (in years)				
15-19	102	57.3	(44.5; 69.2)	0.40
20-24	69	56.7	(41.8; 70.5)	
25-29	87	57.9	(46.4; 68.6)	
30-34	83	58.3	(45.5; 70.1)	
35-39	56	39.9	(26.0; 55.7)	
40-44	46	46.3	(33.1; 60.0)	
45-49	23	54.3	(34.5; 72.8)	
Residence				
Urban	211	55.5	(48.4; 62.3)	0.60
Rural	262	52.2	(42.3; 62.0)	
Stratum				
Southern Belt	141	53.0	(43.1; 62.8)	0.82
Middle Belt	191	55.8	(46.0; 65.1)	
Northern Belt	141	50.8	(37.5; 64.0)	
Women's Education				
Never attended school	114	56.2	(44.7; 67.1)	0.50
Completed primary school or less	71	44.2	(31.2; 58.1)	
Attend or completed JSS	196	55.6	(45.8; 64.9)	
Attended SSS or higher	91	54.7	(42.8; 66.1)	
Wealth Quintile				
Lowest	126	36.9	(28.0; 46.9)	0.07
Second	100	59.7	(45.6; 72.4)	
Middle	84	59.9	(45.1; 73.1)	
Fourth	79	55.2	(42.7; 67.1)	
Highest	84	56.2	(44.3; 67.4)	
Consumed folic acid supplements in past 6 months				
No	412	56.3	(49.4; 62.9)	0.05
Yes	53	39.5	(25.7; 55.3)	
TOTAL RESPONDING [a]	473	53.8	(47.6; 60.0)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Folate analysis conducted in a sub sample of non- pregnant women

b Percentages weighted for unequal probability of selection.

c Folate deficiency defined as serum folate <10 nmol/L.

d CI=confidence interval, calculated taking into account the complex sampling design.

e Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

3.5.9. B12 deficiency

As shown in Table 43, the overall prevalence of vitamin B12 deficiency in non-pregnant women was only 6.9%. No significant differences in the prevalence of B12 deficiency were found by age, residence, or household wealth. Women living in the Northern Belt had significantly ($p<0.05$) higher prevalence compared to those in the other strata. B12 deficiency prevalence was also significantly higher ($p<0.05$) in women that had attended or completed primary school. Combined marginal and deficiency status (i.e. B12<220 pmol/L) was observed in 18.8% (95% CI: 15.4; 22.7) of women (data not shown).

Table 43. Vitamin B12 deficiency in non-pregnant women (15-49 years), Ghana 2017 [a]

Characteristic	n	Vitamin B12 deficiency %[b, c]	(95% CI)[d]	P Value[e]
Age Group (in years)				
15-19	102	8.4	(3.6; 18.4)	0.95
20-24	68	8.2	(3.5; 18.2)	
25-29	87	6.4	(2.4; 16.1)	
30-34	83	6.0	(2.7; 12.6)	
35-39	56	6.6	(2.8; 14.8)	
40-44	45	4.0	(1.2; 12.4)	
45-49	23	7.8	(2.4; 22.2)	
Residence				
Urban	210	6.4	(3.8; 10.7)	0.70
Rural	261	7.4	(4.5; 11.9)	
Stratum				
Southern Belt	140	3.9	(1.7; 8.9)	<0.05
Middle Belt	191	6.3	(3.6; 10.8)	
Northern Belt	140	13.5	(7.4; 23.3)	
Women's Education				
Never attended school	114	6.5	(3.5; 11.8)	<0.05
Completed primary school or less	70	14.6	(7.7; 26.0)	
Attend or completed JSS	196	5.6	(3.0; 10.1)	
Attended SSS or higher	90	4.5	(1.9; 10.4)	
Wealth Quintile				
Lowest	125	8.8	(4.0; 18.3)	0.76
Second	100	9.3	(4.7; 17.5)	
Middle	84	5.2	(2.1; 12.6)	
Fourth	79	5.5	(2.1; 13.5)	
Highest	83	5.7	(2.2; 13.9)	
TOTAL RESPONDING [a]	471	6.9	(4.8; 9.8)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Vitamin B12 analysis conducted in a sub sample of non- pregnant women
b Percentages weighted for unequal probability of selection.
c Vitamin B12 deficiency defined as serum B12 <150pmol/L.
d CI=confidence interval, calculated taking into account the complex sampling design.
e Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

3.6. Pregnant women

3.6.1. Characteristics

In Table 44, the characteristics of the pregnant women participating in the survey are described. No age restriction was used for the recruitment of pregnant women, and the age range of pregnant women surveyed was 15 to 49 years. Most pregnant women included in the survey sample were between 20-39 years. Almost one-quarter had never attended school, and 1 in 4 was illiterate. A large majority were currently married or living with a man. More than half had no job outside the home.

Table 44. Description of pregnant women, Ghana 2017

	Survey Sample		
Characteristic	n	% [a]	(95% CI)[b]
Age (in years)			
15-19	15	8.4	(4.8; 14.3)
20-29	68	44.5	(35.2; 54.2)
30-39	63	41.9	(33.3; 51.0)
40-49	7	5.3	(2.3; 11.4)
Residence			
Urban	50	39.9	(27.4; 53.9)
Rural	103	60.1	(46.1; 72.6)
Stratum			
Southern Belt	46	37.6	(29.9; 45.9)
Middle Belt	53	36.8	(30.2; 43.8)
Northern Belt	54	25.7	(20.3; 31.9)
Woman's education			
Never attended school	46	23.3	(16.8; 31.3)
Completed primary school or less	24	15.7	(10.5; 22.9)
Attend or completed JSS	57	41.2	(32.8; 50.3)
Attended SSS or higher	25	19.8	(12.2; 30.5)
Woman's literacy			
Illiterate	32	26.9	(17.8; 38.5)
Partly or fully literate	72	73.1	(61.5; 82.2)
Marital status			
Never married, never lived with man	8	5.8	(2.8; 11.5)
Currently married or living with man	142	93.3	(87.6; 96.5)
Widowed	2	0.9	(0.2; 4.8)
Occupation			
No job	87	58.2	(47.0; 68.6)
Agriculture or unskilled labor	24	15.2	(9.5; 23.6)
Skilled labor or professional	41	26.6	(18.6; 36.4)
TOTAL RESPONDING	152	100	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.

3.6.2. Dietary diversity and consumption of vitamins and supplements

Most pregnant women had consumed foods from 4-5 food groups in the past 24 hours (see Table 45) and the mean number of food groups consumed the day before the survey was 4.4. About half of the women consumed iron or folic acid supplements in the 6 month prior to the survey and three-quarters consumed iron folic acid tablets for at least 90 days during their last pregnancy. Only one-third of the women consumed multivitamin supplements in the past six month and less than 20% took vitamin A capsules for at least 90 days during their last pregnancy.

Table 45. Food and vitamin supplement consumption in pregnant women, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Proportion with minimal dietary diversity	152	45.2	(35.1; 55.6)
Mean number of food groups	152	4.4	(4.2; 4.7)
Consumed iron tablets or syrup in past six months			
No	77	49.4	(40.9; 58.0)
Yes	69	46.9	(37.8; 56.2)
Consumed folic acid tablets in past six months			
No	66	38.4	(29.8; 47.7)
Yes	79	57.4	(47.9; 66.4)
Consumed multi-vitamin supplements in past six months			
No	91	59.1	(49.7; 67.8)
Yes	52	35.5	(27.0; 45.1)
Consumed iron or folic acid supplements during last pregnancy for 90 days or more			
No	25	18.5	(11.1; 29.2)
Yes	91	73.4	(62.6; 82.0)
Consumed vitamin A capsule after last delivery [c]			
No	80	63.9	(51.2; 74.8)
Yes	24	18.9	(11.0; 30.6)

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b CI=confidence interval, calculated taking into account the complex sampling design.

c Does not include women who have never been pregnant.

3.6.3. Mid-upper arm circumference

As shown in Table 46 the mean MUAC in surveyed pregnant women was 28.6 cm. Only 3.6% had a MUAC <23 cm and were therefore considered undernourished. The prevalence of undernourishment did not differ by age, urban/rural residence, stratum, women´s education and household living standards.

Table 46. Mean mid-upper arm circumference (MUAC) and percentage undernourished by various characteristics in pregnant women, Ghana 2017

Characteristic	Mean MUAC	n	% under-nourished [a, b]	(95% CI)[c]	P Value[d]
Residence					
Urban	30.0	44	4.5	(1.0; 17.7)	0.66
Rural	27.7	98	3.0	(1.0; 8.5)	
Stratum					
Southern Belt	29.6	42	5.0	(1.4; 16.6)	0.49
Middle Belt	28.7	49	3.2	(0.6; 14.3)	
Northern Belt	27.0	51	2.3	(0.3; 15.3)	
ALL PREGNANT WOMEN	28.6	142	3.6	(1.5; 8.5)	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b %Undernourished= % of women with MUAC < 23 cm

c CI=confidence interval, calculated taking into account the complex sampling design.

d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

3.6.4. Malaria

Nearly 10% of all pregnant women surveyed tested positive for malaria infection (see Table 47). All of those testing positive resided in rural areas and living in households of the lowest and the middle wealth quintiles. The results showed no differences in malaria infection by age or stratum.

Table 47. Malaria infection in pregnant women, Ghana 2017

Characteristic	n	% Malaria [a, b]	(95% CI)[c]	P Value[d]
Residence				
Urban	40	-		
Rural	94	15.2	(8.9; 24.7)	<0.01
Stratum				
Southern Belt	42	9.7	(3.6; 23.7)	0.88
Middle Belt	41	8.0	(2.3; 23.7)	
Northern Belt	51	11.2	(5.1; 22.8)	
ALL PREGNANT WOMEN	134	9.5	(5.4; 16.4)	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b % Malaria= % of women identified as malaria positive using rapid diagnostic tests for P. falciparum and any other Plasmodium species
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

3.6.5. Anemia

As shown in Table 48, over 40% of pregnant women were diagnosed anemic, posing a severe public health problem according to WHO classification [28]. Although not significantly different, data suggest that pregnant women between 20-39 years of age had a higher prevalence of anemia compared to women of other age groups. Household wealth was associated with anemia prevalence (p<0.05; data not shown) and it appears that women from the wealthiest households have the highest prevalence of anemia. No significant effects of urban vs. rural residence, stratum and women´s education on anemia prevalence were observed.

Table 48. Anemia in pregnant women, Ghana 2017

Characteristic	n	Anemia %[a, b]	(95% CI)[c]	P Value[d]
Residence				
Urban	50	41.3	(29.7; 54.1)	0.89
Rural	103	42.5	(32.9; 52.7)	
Stratum				
Southern Belt	46	50.8	(38.4; 63.0)	0.11
Middle Belt	53	32.1	(22.0; 44.2)	
Northern Belt	54	43.5	(28.6; 59.7)	
ALL PREGNANT WOMEN	153	42.0	(34.6; 49.9)	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b Anemia defined as hemoglobin < 110 g/L adjusted for smoking.
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

4. Discussion and Conclusions

The GMS 2017 has been stratified to yield representativeness for each of three agro-ecological zones – the Southern Belt, the Middle Belt and the Northern Belt, and aimed at providing representative data on micronutrient status among children aged 6-59 months and women of reproductive age. Additionally, it was used to update certain data on under- and overnutrition, which was collected by the most recent DHS in 2014 [5]. In addition, the GMS was used to update the coverage of fortified wheat flour and refined vegetable oil; estimate the prevalence of certain hemoglobinopathies; and assess risk factors leading to the high proportions of anemia in Ghana in the past. Very high household and individual response rates indicate that the sampling frame of the GMS 2017 is a good reflection of the Ghanaian population, as identified in the 2010 Population census [13], although there is a trend towards a larger urban population in the country. The urban population has increased from 50.9% to 52.1%, and Greater Accra and Ashanti regions are representing a considerably larger proportion than in 2010.

Household-level findings

At the household level, although 9 out of 10 households have access to safe drinking water, only 1 out of 10 households have adequate sanitary facilities in place or can access them. Handwashing proxies revealed that in the vast majority of households, there was handwashing soap available, and in 6 out of 10 households, there was water for handwashing at the time of the survey. It would seem from these results, that access to adequate sanitation facilities should be increased, since access to safe drinking water alone is insufficient to reduce diarrhea in children.

At the time of the survey, only about 70% of households reported purchasing refined vegetable oil, illustrating that a sizeable proportion of households (30%) does not routinely consume vegetable oil. Among the households that consume vegetable oil and provided an oil sample, only 56% were adequately fortified with vitamin A (i.e., having ≥ 10 µg RE/mL oil). This means that at the time of the survey, only 4 out of 10 households consumed adequately fortified oil nationally. That said, there are marked differences in proportions of adequately fortified oil by region and by agro-ecological zones, driven by the fact that the different oil brands reach different market segments and have varying vitamin A concentrations.

For wheat flour, the GMS found that less than 6% of flour samples were adequately fortified, as measured by the iron concentrations found in the wheat flour samples. This prevalence is lower than 13% estimate reported by Ghana's Food and Drug Board in 2011 [1]. While wheat flour fortification is mandatory in Ghana, wheat flour milling companies have been reluctant to comply with national standards citing organoleptic changes following fortification [1]. As iron (ferrous fumarate) is one of the eight micronutrients included in Ghana's wheat fortification standards, the GMS 2017 findings indicate that other levels of other micronutrients that should be included in the premix added to wheat flour (i.e. zinc, niacin, riboflavin, thiamine, vitamin B12, folic acid, and retinol palmitate) were also only found in adequate levels in about 6% of samples.

Because globally, recent iron deficiency assessments found lower prevalence than expected [9,34], the GMS 2017 also collected drinking water samples to semi-quantitatively measure the content of ferrous iron, the more soluble form of iron. Ferrous iron was found in only a small number of water samples, suggesting that drinking water does not contribute to iron intakes. As water samples were collected from households and measured at the end of the day in each EA, it is possible that some proportion of the ferrous iron may have been oxidized to insoluble ferric iron, which the test could not measure. Thus, it is possible that greater quantities of iron would have been found in water samples had the measurement been done at the household or if the test also measured ferric iron. However, ferric iron is less well absorbed than ferrous iron, and thus would not likely contribute to iron intakes in a meaningful way.

Preschool-age children

Infant and young child feeding practices are mostly adequate with regard to early initiation and continued breastfeeding, but clearly need improving with regard to minimum acceptable diet, both with regard to dietary diversity and food frequency. Although it is known that a minimum acceptable diet alone is not sufficient to avoid stunting, it has been described recently to affect linear growth faltering [35]. Also, vitamin A supplementation and deworming in the six months preceding the survey is quite low with only about one-third of the children receiving either of those interventions. Not surprisingly, consumption of iron supplements is even lower, since there is no routine distribution of iron supplements to pre-school children by the Ghanaian health system. The low coverage (27%) with vitamin A supplementation is comparable to the 24% figure reported by UNICEF in 2014 [36].

Child stunting affects close to 20% of the children under 5 years of age, a prevalence that is slightly lower but comparable to the 2014 DHS. Also similar to the DHS, the prevalence of overweight among pre-school children was quite low, affecting less than 1% of children. For stunting, the stunting prevalence was higher in rural children, and stunting prevalence decreased with increasing household wealth. A slightly higher proportion of children in the GMS were diagnosed as wasted than in the DHS 2014, 7.1% versus 4.7%. The difference in wasting may be partly explained by seasonality: the DHS 2014 was conducted from September to December – after the rainy season, when local foodstuffs are more abundant, while the GMS 2017 field work ended in May, towards the very end of the dry season with limited food availability.

A quarter of children 6-59 months of age reportedly had diarrhea during the two weeks preceding the interview, and a third or more reportedly had fever or cough during the same period. This high occurrence of illness is reflected by the high prevalence of elevated markers inflammation (AGP, CRP, or both) among the children. Positive malaria RDT was observed in 20% of children, with lower prevalences among children in urban areas and in households in the highest wealth quintile. In the DHS 2014, higher prevalence (36%) of positive malaria RDT was observed. This differences could most likely be explained by the different transmission patterns; the GMS 2017 was conducted before the rainy season and the DHS 2014 was undertaken after the rainy season.

Sickle cell disorders are present in about 14% of the children 6-59 months of age, with 1.3% showing sickle cell disease (SS) and 12.7% showing sickle cell trait (AS). One-third of children are affected by any form (hetero- or homozygous) of α-thalassemia, with 3.3% carrying the homozygous form.

Anemia was markedly higher in the Northern belt (53.2%) compared to the Middle (28.2%) and Southern (32.3%) belts. A similar disparity was observed with ID and IDA as the prevalence in the Northern belt was substantially higher than in the other strata. To illustrate, IDA was nearly 30% in the Northern belt, but less than 8% in the Middle and Southern Belts. About 35% of anemic children had concurrent iron deficiency (i.e. IDA), which is slightly higher than the 28% estimate in a recent meta-analysis for countries in sub-Saharan Africa [37] and indicates that iron deficiency continues to play an important role in the etiology of anemia in Ghanaian children. Additionally, bivariate analyses reveal highly significant associations between anemia and iron deficiency. Bivariate analyses also suggest that there are multiple factors associated with anemia in children, as anemia prevalence is significantly higher in those with malaria, recent diarrhea, inflammation, and vitamin A deficiency. Additional multivariate analyses and calculation of population attributable fractions for the various risk factors of anemia would be useful to determine the extent to which each risk factor contributes to anemia in Ghanaian children.

Nonetheless, the current analysis clearly suggests that there are multiple factors contributing to anemia. The GMS also illustrates that improving iron status may not always result in improved anemia prevalence. For example, children receiving deworming tablets had a significantly lower prevalence of ID and IDA, but no difference in the anemia prevalence was found. While children that consumed iron-fortified foods the day prior to the survey had very low levels of anemia (<2%), this finding may be a proxy for household wealth. About 10% and 30% of children in the fourth and wealthiest wealth quintile consumed iron-fortified foods, whereas these foods were consumed by 5% or less children in other wealth quintiles. As such, interventions focusing solely on reducing iron deficiency, although important, will not eradicate anemia.

The anemia prevalence found in children in the GMS is about one-half that reported in the DHS 2014 (36% vs. 66%), which is a surprisingly large difference considering the relatively short time interval between the two surveys. Malaria prevalence and presence of illness were higher in the DHS (after the rainy season), which could lead to higher anemia prevalence. On the other hand, the availability of a more diverse diet during the months (Sep-Dec) that the DHS 2014 was conducted could lead to higher hemoglobin concentrations. There are some technical differences that may partly explain the differences, although it is not known to what extent. For example, the GMS used the Hemocue Hb 301 device, which has been described to yield slightly higher hemoglobin readings [38] than the Hb 201+, although such a bias is not described consistently [39]. However, even with an increased hemoglobin cutoff of +5g/L (i.e., 115 g/L) for the GMS, the estimated anemia prevalence in children would be 51%, still considerably lower than the prevalence found in the DHS. The GMS used capillary blood samples in the majority of children (except the subsample included for MRDR analysis) and thus, the sampling technique is comparable between GMS and DHS; and even if the field workers in the DHS were 'milking' the participants' fingers heavily, this would not likely explain the massive differences. For the GMS, daily quality control

of the devices using quality control blood obtained from the supplier-recommended manufacturer was done.

Due to concerns about the usefulness of serum retinol and retinol-binding protein (RBP) to assess vitamin A status, we have complemented this biomarker with the modified relative-dose response test. This combined approach is in line with recent literature [40] and being discussed by the WHO to be more widely adopted as published in 1996 [29]. The Global Alliance for Vitamin A and the Centers for Disease Control are currently developing statements on vitamin A biomarkers. Using RBP concentrations adjusted for inflammation, approximately 20% of children 6-59 months are vitamin A deficient. While this prevalence is classified as a 'severe public health problem' by WHO [33], it is at the lower end of the range of the "severe" category. Nonetheless, the GMS 2017 shows that vitamin A deficiency is widespread, and more present in Ghana's northern regions. Importantly, since the coverage of vitamin A supplements are low in Ghana, children likely have a higher risk of mortality due to compromised immune function [41]. In addition, the GMS 2017 illustrated that vitamin A deficiency is markedly less prevalent in children residing in wealthier households, illustrating that household-level socio-economic factors could influence factors, such as dietary diversity, that influences vitamin A deficiency in children.

Of note the prevalence found in the GMS 2017 is considerably lower than that found in a 1998 survey [42] representing 7 regions (76% VAD). Importantly, however, the 1998 survey made no adjustments for inflammation, so a recalculation would likely reduce the prevalence. Furthermore, receipt of vitamin A supplements in the six months preceding the survey did not importantly modify the prevalence of VAD. This finding makes sense as the overall coverage is vitamin A supplements is quite low. Furthermore, this finding corresponds with the scientific evidence documenting that a high-dose vitamin A supplement only results in elevated vitamin A blood levels for 2-3 months [43].

The reduced severity of the public health problem of vitamin A in preschool-age is corroborated by the results from the MRDR test. The GMS found that 6.7% of the children had a MRDR value ≥0.060. A longitudinal study of vitamin A status of infants in Ghana published in 2002 found that the prevalence of MRDR values ≥0.060 ranged from 39.3% to 53.8% in infants aged 6 and 9 months who either received vitamin A or placebo [44]. A small scale intervention study conducted in 2009 in the Kintampo North municipality among children 6-24 months of age found an extremely high prevalence of elevated MRDR values of approximately 90% [45]. Finally, a study conducted in 2010, again in the Kintampo region and including children 7-9 months at baseline reported less than 10% VAD based on MRDR [46]. The mean MRDR values in the current study for the children are much lower than those conducted in 2000 and 2009, and the current values are very similar with the 2010 study.

Women of reproductive age (non-pregnant)

Women's knowledge about fortified vegetable oil and wheat flour is very limited according to the findings in this report: only a quarter of respondents have ever heard about fortified oil and only one out of ten of fortified flour. Of the women interviewed, one out of ten was pregnant and one out of three was lactating. For presentations of the biological indicators, the pregnant women are presented separately in this report,

because their physiological needs are very different and not the same variables were collected.

About half of the responding non-pregnant women 15-49 years of age consumed 5 or more food groups the day preceding the survey interview. Vitamin or mineral supplement intake when not pregnant was relatively rare, although a fifth of women stated having taken iron tablets in the previous six months. Almost seven out of ten women reported having consumed iron supplements during their last pregnancy; this coverage estimate is slightly higher compared to the 2014 DHS [5], where the corresponding coverage was 59%. In contrast, the GMS found that only one third was given postpartum vitamin A supplements compared to 68% reported in the 2014 DHS. The GMS had a large proportion of respondents who stated 'don't know', which may partly explain the lower coverage.

With 8% underweight, undernutrition is somewhat present in Ghanaian women, but the majority of underweight women had BMIs between 17.0 kg/m2 and 18.4 kg/m2, and as such were only at risk for chronic energy deficiency. On the other hand, 39% of the Ghanaian women were overweight (25%) or obese (14%). Furthermore, prevalence of overweight/obesity is almost double in urban areas compared to rural areas, and is strongly positively associated with socio-economic status.

While overweight and obesity increases with age, age likely serves as a proxy for parity. The overweight and obesity prevalence significantly increased ($p<0.01$) from 12.2% in women with no births, to 28.6% in those with one birth, to 51.5% in those with two or more births (data not shown). This suggests that following pregnancy, women may fail to return to their pre-pregnancy weight. This same association has been seen in other countries [47].

Underweight and overweight/obesity prevalence compare relatively well with the 2014 DHS. The findings that women from urban and wealthier households are more likely to be overweight/obese are consistent with a recent meta-analysis [48]. Based on data herein, Ghana is likely to experience a further increase in overweight/obesity prevalence unless effective measures are taken. The well-documented link between overweight/obesity and type 2 diabetes, blood pressure, cardiovascular diseases and all-cause mortality highlights the importance of tackling the problem [49,50]. Over and above, there is growing evidence of an intergenerational effect in that children born to overweight/obese mothers are more likely to be stunted or to also become overweight later in life [51].

Malaria parasitemia was present in 8% of surveyed women, with more women from rural or poorer dwellings having a positive test result. There were also stratum-specific differences and by woman's educational status, but no pattern emerged.

Sickle cell disorders are present in 13% of the women, but only in 0.5% is the SS form present. Close to 35% of women are affected by any form (hetero- or homozygous) of α-thalassemia, with 4.4% carrying the homozygous trait. Not surprisingly, these prevalence estimates are highly comparable to those of children, since this a genetic disorder and no treatment is available.

One in five women was anemic, and only about 14% and 9% had ID and IDA, respectively. Among anemic women, 40% had concurrent ID. Although there are no urban/rural differences for anemia, ID is more prevalent in urban areas; there are differences by stratum for anemia and IDA, and a marginal difference for ID, with the Middle belt having higher values. Sickle cell trait (AS) is also associated with slightly higher anemia prevalence, but it has to be noted that the numbers are small. Elevated inflammatory markers are highly and positively associated with anemia (but not iron deficiency). Interestingly, many known risk factors for anemia were not significantly associated in the GMS 2017, such as current or recent malaria parasitemia, folate deficiency, recent iron supplement intake, folic acid supplement intake or multivitamin intake. In the case of vitamin B12 deficiency, the association was significant but in the opposite direction than expected: vitamin B12 deficiency was associated with a lower anemia prevalence; of note though, the number of deficient women is low. The significance and direction of association is consistent when examining the association between anemia and combined vitamin B12 marginal and deficient status, with 24.7% anemia in B12-replete women, and 13.6% in women with deficiency (data not shown).

As for preschool-aged children, the anemia prevalence found in the GMS 2017 is about half that reported in the DHS (20% vs. 42%). As discussed above, this difference is hard to explain by methodological differences. The only major difference to children is that for women, the GMS collected venous blood from all participants. Even when using a 5 g/L higher cutoff to define anemia (i.e., 125 g/L), the prevalence estimate increased to 36 %, closer to the 2014 DHS but still at lower levels.

Vitamin A deficiency is hardly present in Ghanaian women, both when assessed using RBP and MRDR. The MRDR value in the GMS for the women is much lower than either of the other values previously published for Ghana [52,53]. We can conclude that the vitamin A status in Ghana appears to have improved over time and is likely due to diligent public health interventions. It is worth noting that in the Northern Belt, considerably more women are affected by VAD although the prevalence remains relatively low with 5%. Folate deficiency affects a bit over half of the women and although no prevalence thresholds for determining the public health severity exist, can be considered highly prevalent. In contrast, vitamin B12 deficiency affects only 7% of women. Folic acid and vitamin B12 is added to flour in Ghana, but the flour sampling approach taken in the GMS does unfortunately not allow for regression analyses, since flour samples were not collected from household but from bakeries or shops.

Pregnant women

For pregnant women, because their number is limited, the GMS 2017 could only provide sub-group analyses for residence and stratum. Dietary diversity is comparable to non-pregnant women, yet supplement consumption is considerably higher. A small proportion of pregnant women has low MUAC, rendering any sub-group analysis difficult.

With regard to anemia, 45% of pregnant women are affected; this prevalence for once is very comparable to the DHS 2014, where 45% of pregnant women were reported to be affected. One in ten pregnant women tested positive for malaria parasitemia, with all positive cases found in the rural dwellers.

5. Recommendations

Using the findings presented in this report and an understanding of Ghana's programmatic and research environment, the University of Ghana and GroundWork developed the following programmatic and research recommendations. These recommendations have been structured by health problem or deficiency and ordered by priority based on the magnitude of the health problem as measured by the GMS.

1. Reduce anemia in children and women

The GMS contained nearly all the major anemia risk factors, and the results suggest that multiple risk factors contribute to anemia in children, including iron and vitamin A deficiencies, malaria, and inflammation. Programs to reduce anemia in Ghana should prioritize activities in regions in the Northern belt, as the anemia prevalence here is markedly higher than in the Middle and Southern strata. Interventions should include the promotion of age-appropriate infant and young child feeding practices, including the promotion of foods (fortified or unfortified) rich in iron and vitamin A. In women, iron deficiency and inflammation appear to be main drivers of anemia, and programs to promote the consumption of iron-rich foods and iron supplements can be considered. However, the GMS found that ID prevalence is significantly lower in women with malaria (Table 40), suggesting that ID may have some protective effect against malaria.

2. Reduce malaria infections

Targeted programs to reduce the exposure to malaria should be continued and strengthened. These programs should particularly address malaria infection in children from low-income households in rural areas, as the malaria prevalence is highest amongst this population group. Programs that reduce the prevalence of malaria in children will both help to reduce mortality and morbidity associated with malaria directly, and will also help to reduce anemia in children.

3. Reduce vitamin A deficiency in children

While vitamin A deficiency affects about 20% of children in Ghana, the severity of this deficiency is significantly higher in Ghana's northern regions. To address this severe public health problem, multiple approaches should be used. First, Ghana's vitamin A supplementation program should be improved to strengthen childrens' immune systems and reduce the risk of mortality due to measles, diarrhea, and other illnesses. As Ghana's vitamin A supplementation program is implemented as component as part of Ghana's immunization program, greater promotion is required to encourage caretakers of children 6-59 months to bring their children every 6 months to the local health posts and health facilities. Secondly, to increase the vitamin A stores, the vitamin A fortification program should be strengthened. More rigorous surveillance programs that increase the coverage of adequately fortified vegetable oil would increase quantity of retinol consumed by children on a daily basis. Thirdly, programs to improve consumption of vitamin A-rich foods, other than fortified vegetable oil, should be pursued. This is particularly relevant in Ghana's Upper East and Upper West regions, where the proportion of households consuming vegetable oil is low. This

type of intervention could include promoting local food products rich in vitamin A, or introducing vitamin A-biofortified staple foods that could be readily cultivated in these regions of Ghana.

4. Reduce the prevalence of overweight and obesity in women

Nearly 40% of non-pregnant women were classified as either overweight or obese, with the highest proportions in urban areas, the Southern belt, and among women residing in wealthier households. As the prevalence of overweight and obesity has risen nearly 10 percentage points in the past decade - Ghana's 2008 DHS estimated about 30% of women were overweight or obese - there is an imperative need to educate urban women about approaches to maintaining healthy weight to prevent the prevalence of overweight and obesity from rising further. Due to the association between increased parity and increased overweight and obesity prevalence, it is recommended that antenatal and postnatal care provided by doctors and nurses be expanded to include behavior change messages and counseling for mothers.

5. Reduce folate deficiency in women of reproductive age

The GMS found a very high prevalence of folate deficiency among women. Moreover, many women had extremely low levels of folate that were below the detection limit of laboratory equipment utilized (see APPENDIX 15). While folate deficiency was not associated with anemia, such low levels of folate deficiency can result in neural tube defects and other adverse health outcomes. While the only study from Ghana documenting the incidence of neural tube defects was conducted in Accra in 1993 [54], it nonetheless concluded that neural tube defects were common. Systematic reviews have shown that fortification of wheat flour with folic acid [55] and folic acid supplementation are successful approaches to reduce birth defects [56]. In addition, a recent Cochrane review found that consumption of iron and folic acid supplements results in decreases in low birthweight [57]. As folic acid supplement were consumed by less than 20% of non-pregnant women, it is recommended that Ghana's health system promote the consumption of these supplements among women of reproductive age. General awareness campaigns can also be considered, but should only be conducted when distribution channels are in place guaranteeing access to supplements. In addition, the implementation of Ghana's wheat flour fortification program should be improved. Lastly, campaigns that raise the awareness of folate deficiency and promote the consumption of foods rich in folate should be considered.

6. Measure fortification compliance of flour and vegetable oil

The GMS and previous assessments suggest that wheat flour fortification is poorly implemented in Ghana, documented by low coverage of adequately fortified flour. To address implementation challenges to wheat flour fortification, it is recommended stakeholders within the national fortification program take steps to address mill compliance. To ensure compliance, additional efforts to monitor the fortification program should be strengthened. Regarding vegetable oil, fortification improvements to fortification monitoring have resulted in a well-functioning program in the past, with 95% of oil samples adequately fortified in 2012. As the GMS data indicate lower levels of adequately fortified oil, monitoring efforts may need to be strengthened again to ensure that vitamin A is added vegetable oil in the appropriate levels.

6. References

1. Nyumuah RO, Hoang TCC, Amoaful EF, Agble R, Meyer M, Wirth JP, et al. Implementing large-scale food fortification in Ghana: lessons learned. Food Nutr Bull. 2012;33.
2. Food Fortification Initiative. Country Profile - Ghana [Internet]. 2018 [cited 10 Mar 2018]. Available: http://www.ffinetwork.org/country_profiles/country.php?record=81
3. Muthayya S, Rah JH, Sugimoto JD, Roos FF, Kraemer K, Black RE. The Global Hidden Hunger Indices and Maps: An Advocacy Tool for Action. PLoS One. 2013;8. doi:10.1371/journal.pone.0067860
4. Jones AD, Acharya Y, Galway LP. Urbanicity Gradients Are Associated with the Household- and Individual-Level Double Burden of Malnutrition in Sub-Saharan Africa. J Nutr. 2016;146: 1257–1267. doi:10.3945/jn.115.226654
5. Ghana Statistical Service. Ghana Demographic and Health Survey 2014: Ghana Statistical Service, Ghana Health Service,. Ghana Statistical Service (GSS) Ghana Demographic and Health Survey. 2014. doi:10.15171/ijhpm.2016.42
6. Ghana Statistical Service, Macro International. Ghana Demographic and Health Survey 1993. Calverton, Maryland, USA; 1994.
7. Ghana Statistical Service, Noguch Memorial Institute for Medical Research, ORC Macro. Ghana Demographic and Health Survey 2003. Calverton, Maryland, USA; 2004.
8. Rohner F, Northrop-Clewes C, Tschannen AB, Bosso PE, Kouassi-Gohou V, Erhardt JG, et al. Prevalence and public health relevance of micronutrient deficiencies and undernutrition in pre-school children and women of reproductive age in Cote d'Ivoire, West Africa. Public Health Nutr. 2014;17: 2016–2028. doi:10.1017/S136898001300222X
9. Wirth JP, Rohner F, Woodruff BA, Chiwile F, Yankson H, Koroma AS, et al. Anemia, Micronutrient Deficiencies, and Malaria in Children and Women in Sierra Leone Prior to the Ebola Outbreak - Findings of a Cross-Sectional Study. PLoS One. 2016;11: e0155031. doi:10.1371/journal.pone.0155031
10. Karakochuk CD, Murphy HM, Whitfield KC, Barr SI, Vercauteren SM, Talukder A, et al. Elevated levels of iron in groundwater in Prey Veng province in Cambodia: A possible factor contributing to high iron stores in women. J Water Health. 2015;13: 575–586. doi:10.2166/wh.2014.297
11. Merrill RD, Shamim AA, Ali H, Jahan N, Labrique AB, Schulze K, et al. Iron status of women is associated with the iron concentration of potable groundwater in rural Bangladesh. J Nutr. 2011;141: 944–949. doi:10.3945/jn.111.138628
12. GAIN, GHS, UNICEF. National Iodine Survey Report Ghana - 2015. Accra, Ghana; 2017.
13. Ghana Statistical Service. 2010 Population and Housing Census: National Analytical Report. Accra, Ghana; 2013.
14. United Nations Department of Technical Co-operation for Development and Statistical Office National Household Survey Capability Programme. Assessing the nutritional status of young children in household surveys: Annex I Summary procedures, how to weight and measure children. New York: United Nations; 1986.
15. WHO Multicentre Growth Reference Study Group. WHO Child Growth Standards based on length/height, weight and age. Acta Paediatr Suppl. 2006/07/05. 2006;450: 76–85.

16. Ververs M tesse, Antierens A, Sackl A, Staderini N, Captier V. Which Anthropometric Indicators Identify a Pregnant Woman as Acutely Malnourished and Predict Adverse Birth Outcomes in the Humanitarian Context? PLoS Curr. 2013; doi:10.1371/currents.dis.54a8b618c1bc031ea140e3f2934599c8
17. WHO/CDC. Assessing the iron status of a population, second edition including literature reviews. Geneva, Switzerland; 2007.
18. Thurnham DI, McCabe LD, Haldar S, Wieringa FT, Northrop-Clewes CA, McCabe GP. Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: a meta-analysis. Am J Clin Nutr. 2010/07/09. 2010;92: 546–555. doi:10.3945/ajcn.2010.29284
19. Thurnham DI, McCabe GP, Northrop-Clewes CA, Nestel P. Effects of subclinical infection on plasma retinol concentrations and assessment of prevalence of vitamin A deficiency: meta-analysis. Lancet. 2003;362: 2052–2058. doi:10.1016/s0140-6736(03)15099-4
20. Namaste SM, Rohner F, Huang J, Bhushan NL, Flores-Ayala R, Kupka R, et al. Adjusting ferritin concentrations for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr. 2017;106: 359S–371S. doi:10.3945/ajcn.116.141762
21. Larson LM, Namaste SM, Williams AM, Engle-Stone R, Addo OY, Suchdev PS, et al. Adjusting retinol-binding protein concentrations for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr. 2017;106: 390S–401S. doi:10.3945/ajcn.116.142166
22. Erhardt JG, Estes JE, Pfeiffer CM, Biesalski HK, Craft NE. Combined measurement of ferritin, soluble transferrin receptor, retinol binding protein, and C-reactive protein by an inexpensive, sensitive, and simple sandwich enzyme-linked immunosorbent assay technique. J Nutr. 2004/10/30. 2004;134: 3127–3132.
23. Valentine AR, Tanumihardjo SA. Adjustments to the modified relative dose response (MRDR) test for assessment of vitamin A status minimize the blood volume used in piglets. J Nutr. 2004;134: 1186–92.
24. Rohner F, Frey SK, Mothes R, Hurtienne A, Hartong S, Bosso PE, et al. Quantification of vitamin A in palm oil using a fast and simple portable device: method validation and comparison to high-performance liquid chromatography. Int J Vitam Nutr Res. 2011;81: 335–342. doi:10.1024/0300-9831/a000081
25. Laillou A, Icard-Vernière C, Rochette I, Picq C, Berger J, Sambath P, et al. Rapid quantification of iron content in fish sauce and soy sauce: a promising tool for monitoring fortification programs. Food Nutr Bull. 2013;34.
26. WHO, FAO. Guidelines on food fortification with micronutrients. Allen L, Benoist B de, Dary O, Hurrell R, editors. Geneva: World Health Organization; 2006.
27. Brito A, Mujica-Coopman MF, Olivares M, Lopez de Romana D, Cori H, Allen LH. Folate and Vitamin B12 Status in Latin America and the Caribbean: An Update. Food Nutr Bull. 2015;36: S109–S118. doi:10.1177/0379572115585772
28. World Health Organization. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Vitamin and Mineral Nutrition Information System (WHO/NMH/NHD/MNM/11.1) [Internet]. Geneva: World Health Organization; 2011. Available: http://www.who.int/vmnis/indicators/haemoglobin.pdf
29. WHO. Indicators for assessing Vitamin A Deficiency and their application in monitoring and evaluating intervention programs. Geneve, Switzerland; 1996.
30. Filmer D, Pritchett LH. Estimating Wealth Effects Without Expenditure Data---Or Tears: An Application To Educational Enrollments In States Of India*. Demography. 2001;38.

31. WHO, UNICEF, IFPRI. Indicators for assessing infant and young child feeding practices Part 2 Measurement. Geneva, Switzerland: World Health Organization; 2010.
32. WHO. Nutrition Landscape Information System (NLIS): Country Profile Indicators - Interpretation Guide. Organization WH, editor. Geneva, Switzerland: : World Health Organization; 2010.
33. WHO. Serum retinol concentrations for determining the prevalence of vitamin A deficiency in populations. In: Vitamin and Mineral Nutrition Information System [Internet]. Geneva: World Health Organization; 2011. Available: http://www.who.int/vmnis/indicators/retinol.pdf
34. Harvey-Leeson S, Karakochuk CD, Hawes M, Tugirimana PL, Bahizire E, Akilimali PZ, et al. Anemia and Micronutrient Status of Women of Childbearing Age and Children 6-59 Months in the Democratic Republic of the Congo. Nutrients. 2016;8. doi:10.3390/nu8020098
35. Onyango AW, Borghi E, de Onis M, Casanovas M del C, Garza C. Complementary feeding and attained linear growth among 6–23-month-old children. Public Heal Nutr. 2013; 1–9.
36. UNICEF. Data: Monitoring the Situation of Children and Women [Internet]. 2016 [cited 17 Feb 2017]. Available: http://data.unicef.org/nutrition/vitamin-a.html
37. Petry N, Olofin I, Hurrell RF, Boy E, Wirth JP, Moursi M, et al. The Proportion of Anemia Associated with Iron Deficiency in Low, Medium, and High Human Development Index Countries: A Systematic Analysis of National Surveys. Nutrients. 2016;8. doi:10.3390/nu8110693
38. Tayou Tagny C, Kouam L, Mbanya D. The new HemoCue system Hb 301 for the haemoglobin measurement in pregnant women. Ann Biol Clin (Paris). 2008;66: 90–4. doi:10.1684/abc.2008.0195
39. Sanchis-Gomar F, Cortell-Ballester J, Pareja-Galeano H, Banfi G, Lippi G. Hemoglobin Point-of-Care Testing:The HemoCue System. J Lab Autom. 2012; doi:10.1177/2211068212457560
40. Tanumihardjo SA, Russell RM, Stephensen CB, Gannon BM, Craft NE, Haskell MJ, et al. Biomarkers of Nutrition for Development (BOND)—Vitamin A Review. J Nutr. 2016;146: 1816S–1848S. doi:10.3945/jn.115.229708
41. Beaton G.H., Martorell R, Aronson K, Edmonston B, McCabe G, Ross A, et al. Effectiveness of Vitamin A Supplementation in the Control of Young Child Morbidity and Mortality in Developing Countries – Nutrition policy discussion paper No. 13. United Nations - Adm Comm Coord -Subcommittee Nutr. 1993; 1–166.
42. Quarshie K, Amoaful E. Proceedings of the workshop on dissemination of findings of vitamin A and anaemia prevalence surveys - 24-25 Nov 1998. Accra, Ghana; 1998.
43. Palmer AC, West Jr. KP, Dalmiya N, Schultink W. The use and interpretation of serum retinol distributions in evaluating the public health impact of vitamin A programmes. Public Health Nutr. 2012;15: 1201–1215. doi:10.1017/S1368980012000560
44. Bahl R, Bhandari N, Wahed MA, Kumar GT, Bhan MK, Arthur P, et al. Vitamin A supplementation of women postpartum and of their infants at immunization alters breast milk retinol and infant vitamin A status. J Nutr. 2002;132: 3243–3248.
45. Owusu-Agyei S, Newton S, Mahama E, Febir LG, Ali M, Adjei K, et al. Impact of vitamin A with zinc supplementation on malaria morbidity in Ghana. Nutr J. 2013;12: 131. doi:10.1186/1475-2891-12-131
46. Newton S, Owusu-Agyei S, Asante KP, Amoaful E, Mahama E, Tchum SK, et al. Vitamin A status and body pool size of infants before and after consuming fortified

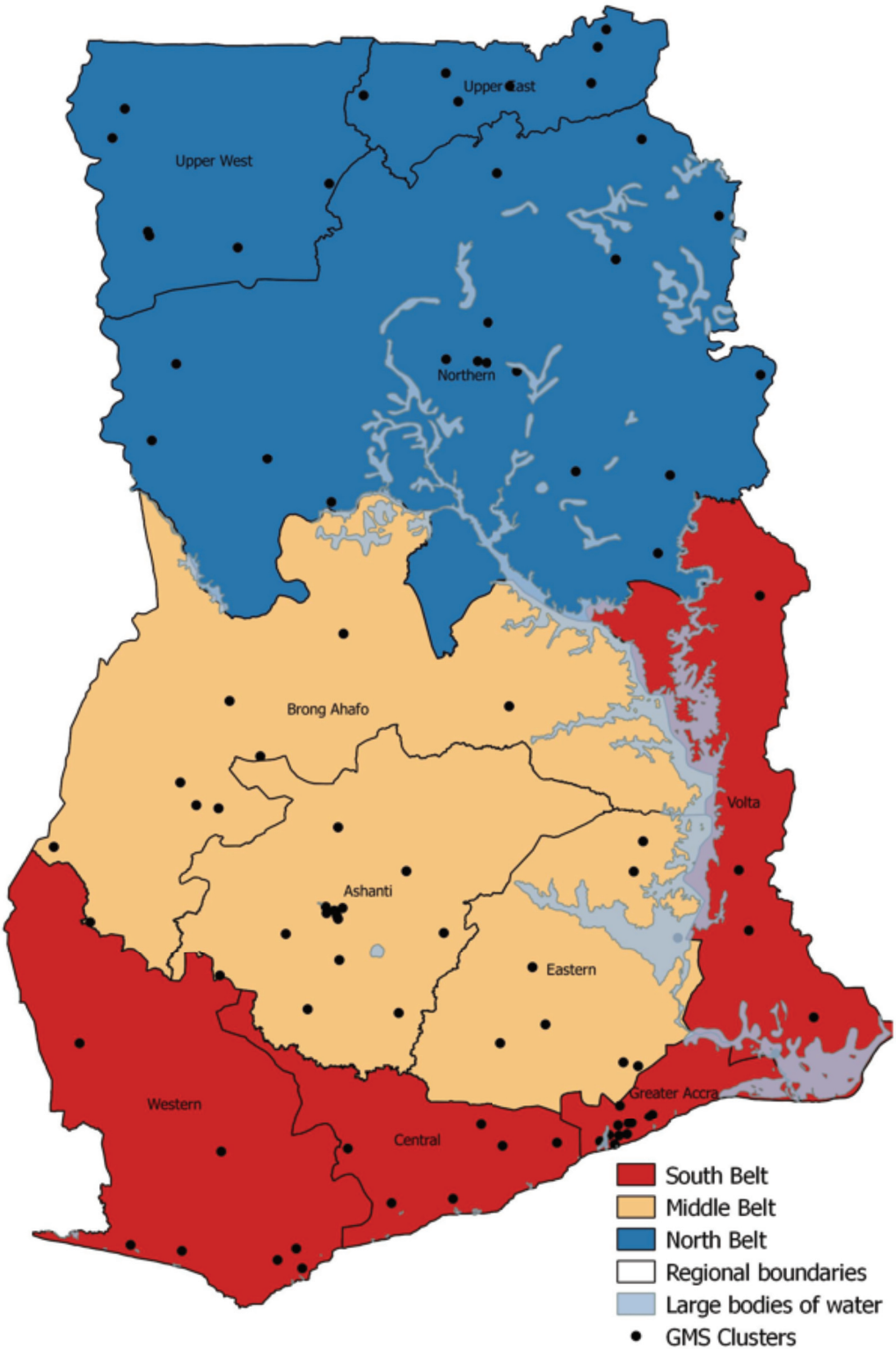
home-based complementary foods. Arch Public Heal. 2016;74: 10. doi:10.1186/s13690-016-0121-4
47. Wilkinson SA, van der Pligt P, Gibbons KS, McIntyre HD. Trial for Reducing Weight Retention in New Mums: a randomised controlled trial evaluating a low intensity, postpartum weight management programme. J Hum Nutr Diet. 2013/11/26. 2013; doi:10.1111/jhn.12193
48. Abarca-Gómez L, Abdeen ZA, Hamid ZA, Abu-Rmeileh NM, Acosta-Cazares B, Acuin C, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. Lancet. 2017; doi:10.1016/S0140-6736(17)32129-3
49. Saydah S, Bullard KM, Cheng Y, Ali MK, Gregg EW, Geiss L, et al. Trends in cardiovascular disease risk factors by obesity level in adults in the United States, NHANES 1999-2010. Obesity (Silver Spring). 2014;22: 1888–95. doi:10.1002/oby.20761
50. Global BMI Mortality Collaboration, Di Angelantonio E, Bhupathiraju S, Wormser D, Gao P, Kaptoge S, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. Lancet (London, England). 2016;388: 776–86. doi:10.1016/S0140-6736(16)30175-1
51. World Health Organization. The double burden of malnutrition. Policy brief. World Heal Organ. 2017; 1–12.
52. Tchum SK, Newton S, Tanumihardjo SA, Fareed KNA, Tetteh A, Owusu-Agyei S. Evaluation Of A Green Leafy Vegetable Intervention In Ghanaian Postpartum Mothers. African J Food, Agric Nutr Dev. 2009;9: 1294–1308. doi:10.4314/ajfand.v9i6.46260
53. Tchum SK, Tanumihardjo SA, Newton S, De Benoist B, Owusu-Agyei S, Arthur FKN, et al. Evaluation of vitamin A supplementation regimens in Ghanaian postpartum mothers with the use of the modified-relative-dose-response test. American Journal of Clinical Nutrition. 2006. pp. 1344–1349.
54. Anyebuno M, Amofa G, Peprah S, Affram A. Neural tube defects at Korle Bu Teaching Hospital, Accra, Ghana. East Afr Med J. 1993;70: 572–4.
55. Castillo-Lancellotti C, Tur JA, Uauy R. Impact of folic acid fortification of flour on neural tube defects: a systematic review. Public Health Nutr. 2013;16: 901–11. doi:10.1017/S1368980012003576
56. De-regil LM, Fernández-gaxiola AC, Dowswell T, Peña- JP. Effects and safety of periconceptional fotale supplementation for preventing birth defects. Cochrame Database Syst Rev. 2014;2: 1–135. doi:10.1002/14651858.CD007950.pub2.Effects
57. Haider BA, Bhutta ZA. Multiple-micronutrient supplementation for women during pregnancy. Cochrane Database Syst Rev. 2012/11/16. 2012;11: CD004905. doi:10.1002/14651858.CD004905.pub3
58. Atkinson SH, Rockett K, Sirugo G. Seasonal childhood anaemia in West Africa is associated with the haptoglobin 2-2 genotype. Plos Medicine 2006
59. Chong SS, Boehm CD, Higgs DR, Cutting GR. Single-tube multiplex-PCR screen for common deletional determinants of alpha-thalassemia. Blood 2000
60. Waterfall CM, Cobb BD. Single tube genotyping of sickle cell anaemia using PCR-based SNP analysis. Nucleic Acids Res 2001

Appendix 1 - List and Map of Selected Enumeration Areas

Strata	Region	District	Cluster (EA) name	EA Code	Urban/ Rural	GMS ID
South Belt	Western	Nzema East	AHUNYAME	0103200057	rural	1
	Western	Prestea/Huni Va	ANOKYEKROM	0109100060	rural	2
	Western	SEFWI AKONTOMBRA	AMANFOKROM	0113100053	rural	3
	Western	MPOHOR	BOTODWINA	0118100035	rural	4
	Western	JOMORO	HALF ASSINI	0101100035	urban	5
	Western	STMA	ANAJI	0105301224	urban	6
	Western	SHAMA	INCHABAN	0106100008	urban	7
	Central	Abura-Asebu-Kwamankese	PATOAKO	0203100126	rural	8
	Central	Ewutu Senya	BONTRASE	0209100159	rural	9
	Central	TWIFO ATI MARKWA	MMAADIMONO	0215100159	rural	10
	Central	Mfantsiman	MANKESSIM	0204200218	urban	11
	Central	Agona East	AGONA ASAFO	0210100012	urban	12
	Central	Awutu Senya East Municipal	ODUPONKPEHE-KASOA	0220200100	urban	13
	Greater Accra	Ga South Municipal	AKOTEAKU (GONORMAN AND KOLEKYE)	0301200678	rural	14
	Greater Accra	Ga South Municipal	NGLESHIE AMANFRO	0301200198	urban	15
	Greater Accra	GA EAST	TAIFA	0303200055	urban	16
	Greater Accra	AMA-ABLEKUMA CENTRAL Accra Metropolis	SUKURA	0304302040	urban	17
	Greater Accra	AMA-ASHIEDU KETEKE	KORLE DUDOR	0304303142	urban	18
	Greater Accra	AMA-AYAWASO CENTRAL	NEW TOWN	0304307062	urban	19
	Greater Accra	AMA-ABLEKUMA NORTH	DARKUMAN	0304309148	urban	20
	Greater Accra	AMA-ABLEKUMA CENTRAL	MEMPEASEM	0304311060	urban	21
	Greater Accra	Ashaiman Municipal	ASHAIMAN	0307200107	urban	22
	Greater Accra	Tema Metropolis	TEMA COMMUNITY 7	0308302154	urban	23
	Greater Accra	La Dade Kotopon Municipal	BURMA CAMP	0312200204	urban	24
	Volta	Ketu South	TUBLUKOPE SOMAXLEKOPE	0403100200	rural	25
	Volta	South Dayi	KPEVE (NEW TOWN)	0409100080	rural	26
	Volta	NKWANTA SOUTH	OBANDA	0417100003	rural	27
	Volta	AFADZATO SOUTH	TAFI ATOME	0423100064	rural	28
	Volta	SOUTH TONGU	SOGAKOPE	0401100135	urban	29
	Volta	HO MUNICIPAL	HO	0408200246	urban	30

Middle Belt	Eastern	Akwapem North	ADENYA	0506200088	rural	31
	Eastern	FANTEAKWA	NSUTEM	0512100013	rural	32
	Eastern	BIRIM NORTH	DOMEABRA (KORLETEI)	0516100069	rural	33
	Eastern	KWAHU AFRAM PLAINS NORTH	AGORDATOR KOPE	0521100241	rural	34
	Eastern	KWAHU AFRAM PLAINS SOUTH	NSOGYASO	0526100214	rural	35
	Eastern	Akwapem North	MAMFE	0506200040	urban	36
	Eastern	East Akim Municipal	APEDWA	0513200021	urban	37
	Eastern	Denkyembuor	TAKROWASE	0525100021	urban	38
	Ashanti	Amansie West	NWINISO	0602100058	rural	39
	Ashanti	ADANSI NORTH	AGOGOSO NO.1	0606100027	rural	40
	Ashanti	ASANTE AKIM SOUTH	ATWEDIE	0609100155	rural	41
	Ashanti	ATWIMA NWABIAGYA	JANKOBAA	0615100023	rural	42
	Ashanti	OFFINSO MUNICIPAL	AMOAWI	0618200066	rural	43
	Ashanti	Sekyere Afram Plains	BANKO	0624100107	rural	44
	Ashanti	BEKWAI MUNICIPAL	BEKWAI	0607200141	urban	45
	Ashanti	KMA- KWADASO	TANOSO	0614301182	urban	46
	Ashanti	KMA-SUBIN	AMAKOM	0614303117	urban	47
	Ashanti	KMA- OFORIKROM	AHINSAN	0614305078	urban	48
	Ashanti	KMAMANHYIA	SEPE APAMPRAM	0614307158	urban	49
	Ashanti	KMA-SUAME	BREMANG	0614309096	urban	50
	Ashanti	KMA - BANTAMA	OHWIM	0614310228	urban	51
	Ashanti	Sekyere Afram Plains	DADEASE	0624100021	urban	52
	Ashanti	Asokore Mampong Municipal	SEPE-TINPOM	0628200244	urban	53
	Brong Ahafo	Asunafo South	DIETWA	0701100017	rural	54
	Brong Ahafo	TANO NORTH	DUMAKWAE	0707100004	rural	55
	Brong Ahafo	WENCHI MUNICIPAL	AKROBI	0714200048	rural	56
	Brong Ahafo	PRU	KONKOMMA	0720100120	rural	57
	Brong Ahafo	SUNYANI MUNICIPAL	SUNYANI	0708200090	urban	58
	Brong Ahafo	TECHIMAN MUNICIPAL	TANOSO	0715200015	urban	59
	Brong Ahafo	DORMAA WEST	NKRANKWANTA	0724200060	urban	60

North Belt	Northern	SAWLA TUNA KALBA	KONKOROPE	0802100010	rural	61
	Northern	CENTRAL GONJA	KEKALE NO.4	0804100038	rural	62
	Northern	EAST GONJA	KAFOWURAPE	0805100123	rural	63
	Northern	KPANDAI	BAKAMBA	0806100123	rural	64
	Northern	NANUMBA NORTH	KALEGU	0808100062	rural	65
	Northern	YENDI MUNICIPAL	KUGA (KPATUYA)	0810200237	rural	66
	Northern	TOLON	NUABA	0812100180	rural	67
	Northern	GUSHIEGU	SAGULI	0815100010	rural	68
	Northern	CHEREPONI	CHOMBOSU (ANGOR)	0817100010	rural	69
	Northern	Bunkpurugu Yonyo	SINSABJINA	0818100140	rural	70
	Northern	WEST MAMPRUSI	SADUGU (SAGADUGO NO. 1)	0820100140	rural	71
	Northern	SAGNERIGU	GUMBIHINI	0823100044	rural	72
	Northern	TATALE	NAHUYILI	0825100116	rural	73
	Northern	BOLE	BOLE	0801100061	urban	74
	Northern	NANUMBA NORTH	BIMBILLA	0808100084	urban	75
	Northern	TMA	CHENGLI	0811302050	urban	76
	Northern	Savelugu Nanton	SAVELUGU	0813100078	urban	77
	Northern	WEST MAMPRUSI	WALEWALE	0820100152	urban	78
	Upper East	Kasena Nankana West	KALEVIO ABOENIA	0902100017	rural	79
	Upper East	Kasena Nankana East	SIRIGU AYAREGABISI	0903200140	rural	80
	Upper East	Talensi	NAMOORANTENG (NAMOO)	0905100092	rural	81
	Upper East	Bawku West	GUMBO NAGODI	0907100057	rural	82
	Upper East	Garu Tempane	BASYONDE/SABZUNDE	0908100189	rural	83
	Upper East	Binduri	MANGA NYORUGU	0912100146	rural	84
	Upper East	Bawku Municipal	BAWKU	0909200258	urban	85
	Upper West	Wa West	PONYONYIRI(PONYAMAYIRI)	1001100016	rural	86
	Upper West	Wa East	VIAHAA	1003100055	rural	87
	Upper West	Jirapa	TAMPALA	1006100014	rural	88
	Upper West	Lambussie Karni	KORRO-BOGMIO	1008100054	rural	89
	Upper West	Wa Municipal	WA	1002200039	urban	90


Upper East
Upper West
Northern
Brong Ahafo
Volta
Ashanti
Eastern
Western
Central
Greater Accra
South Belt
Middle Belt
North Belt
Regional boundaries
Large bodies of water
GMS Clusters

Appendix 2 -
A Priori Sample Size Calculations

Sample size for children (6-59 months of age), non-pregnant women (15-49 years of age) and pregnant women per stratum and in all three strata taking into account desired precision and assumed design effect and individual response rate

Target group and indicator	Estimated prevalence	Desired precision (percentage points)	Assumed design effect	Assumed individual response	Number of persons to select in one stratum	Number of persons to select in all three strata
Children						
Anemia	50%	±10	1.5	85%	170	510
Iron deficiency	50%	±10	1.5	85%	170	510
Vitamin A deficiency	25%	±5	1.5	85%	509	1,527
Wasting	5%	±3	1.5	95%	321	963
Stunting	20%	±5	1.5	95%	389	1,167
Non-pregnant women						
Anemia	50%	±10	1.5	90%	161	483
Iron deficiency	50%	±10	1.5	90%	161	483
Vitamin A deficiency	5%	±3	1.5	90%	338	1,014
Folate deficiency	50%	±10	1.5	90%	161	483
Vitamin B12 deficiency	10%	±5	1.5	90%	231	693
BMI <18.5	10%	±5	1.5	95%	219	657
Pregnant women						
Anemia	50%	±10	1.5	90%	161	483

Appendix 3 -
Average Household Size in Different Regions in Ghana

Population, number of households, and average household size, by region and various groups of regions

Stratum	Region	Population 2010 census	# HHs	Average household size		
	Western	2,307,395	553,635		4.2	
Southern Belt	Central	2,113,766	526,764	4.0	3.9	
	Greater Accra	3,888,512	1,036,426	3.8		
	Volta	2,086,567	495,603	4.2		4.1
Middle Belt	Eastern	2,574,549	632,048	4.1	4.2	
	Ashanti	4,671,982	1,126,216	4.1		
	Brong Ahafo	2,265,458	490,519	4.6		
	Upper East	1,034,704	177,631	5.8		
Northern Belt	Upper West	688,333	110,175	6.2	6.9	6.0
	Northern	2,445,061	318,119	7.7		7.7

Appendix 4 -

Average Household Size in Different Regions in Ghana

Number of households to select in each of various strata and regions to obtain equal numbers of women and children in each of the three strata

Target group	Number individuals needed with laboratory result	Total number of individuals to recruit	Number of individuals to recruit per stratum	Number of households to select			Total number of house-holds
				Southern Belt and Middle Belt strata	Northern Belt stratum excluding Northern Region	Northern Region	
Children	1000	1177	393	1709	239	268	2217
Women	900	1000	334	751	106	118	975

Appendix 5 -
Ethical Approval

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.

My Ref. GHS/RDD/ERC/Admin/App/17/418
Your Ref. No.

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra
Tel: +233-302-681109
Fax + 233-302-685424
Email: ghserc@gmail.com

Seth Adu-Afarwuah
Department of Nutrition and Food Sciences
University of Ghana
P. O. Box LG 134, Legon, Accra

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol.

GHS-ERC Number	**GHS-ERC: 15/01/2017**
Project Title	Ghana Micronutrient Survey 2017
Approval Date	29th March, 2017
Expiry Date	28th March, 2018
GHS-ERC Decision	**Approved**

This approval requires the following from the Principal Investigator

- Submission of yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months,
- Reporting of all serious adverse events related to this study to the ERC within three days verbally and seven days in writing.
- Submission of a final report **after completion** of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings.

Please note that any modification of the study without ERC approval of the amendment is invalid.

The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Kindly quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED.....
DR. CYNTHIA BANNERMAN
(GHS-ERC CHAIRPERSON)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra

Appendix 6 -
Information Sheet and Consent Form

INFORMATION SHEET (FOR THE PARTICIPANT TO KEEP)	
Title of Study:	**Ghana Micronutrient Survey 2017**
Principal Investigators:	Dr. Seth Adu-Afarwuah, Department of Food Science and Nutrition, University of Ghana Dr. Fabian Rohner, GroundWork, Switzerland
Certified Protocol Number	GHS-ERC: 15/01/2017

General Information
The Ghana Micronutrient Survey 2017 is conducted to understand the severity of various nutritional deficiencies, such as anemia, iron deficiency, vitamin A deficiency, and under- and overweight in women and children. The survey is done by the University of Ghana, Department of Food Science and Nutrition, GroundWork in Switzerland, and the University of Wisconsin-Madison in the United States. The survey is supported by the Ghana Health Service and UNICEF.

We will ask questions about your household, and if there are selected women or children living in the household, we will ask individual questions to better understand their person and their food habits.

We would very much appreciate your participation in this survey. This information will help the Government to plan health services. The questionnaire for you usually takes about 30 minutes to complete. Whatever information you provide will be kept strictly confidential and will not be shown to other persons.

Following the completion of the questionnaire, we will measure height and weight and request to draw a small amount of blood from all women 15 to 49 years of age and children 6 to 59 months of age in a dedicated place near your household. This small blood sample will be used to test if you have anemia or malaria, and these results will be provided to you directly. In addition, a small portion of blood will be collected to test for micronutrient deficiencies, such as iron, folate and vitamin A status. We will also test parts of your sample for hemoglobinopathies, or blood disorders.

Benefits/Risk of the study
For women, 5 mL of blood will be collected from the arm vein using a needle. For children, a small sample of blood (0.5 mL) will be collected from the finger and in a small sub-set of children, we will also draw 5 mL of blood from the vein for additional

vitamin A analyses. Blood will be collected by trained technicians. The blood draw should take less than 5 minutes, and the anemia and malaria results will be provided in less than 15 minutes following the taking of blood, and should you be diagnosed with severe anemia or malaria, we will provide you with a referral to a nearby health facility for further testing and treatment. This survey poses no serious risks to you or other participating family members.

Other than the information about your hemoglobin levels or malaria parasitemia and referral in case of diagnosis of severe anemia, we cannot promise that the survey will help you directly. But the information we get will help the Government to evaluate its nutrition and health services and if needed, adapt them.

Confidentiality
All information which is collected about you and your household during the course of the interview will be kept strictly confidential, and any information about you and the household address will not be included in the final report so that you cannot be recognized.

Only the personnel doing the interview and the principal researchers will have access to identifiable information and by providing your signature/thumbprint, you allow the research team in doing so.

Compensation
Your participation in this interview is important and we do appreciate the time made available. At the end of all interviews, I will offer the entire household two bars of soap to express our gratitude for the time taken and to compensate you for the food samples I have taken. Also, as mentioned earlier, should you/your child be diagnosed with severe anemia or malaria, I will let you know and fill in a referral form for you to seek treatment.

Withdrawal from Study
Participation in this survey is voluntary, and if we should come to any question you do not want to answer, just let me know and I will go on to the next question; or you can stop the interview at any time, without any consequences to you or your household. However, we hope that you will participate in this survey since your views are important. There will not be any negative effects on you, if you decide that you no longer want to continue with the interview.

If you are younger than 18 years, your legal parent will have to give signed consent for your participation. This information sheet will be for you/your caretaker to keep. If you have any question, do not hesitate to contact the principal researchers.

Contact for additional Information
If you have any questions about the study, you are welcome to call Dr. Seth Adu-Afarwuah at the University of Ghana, who is in charge of this study, on Tel. 024 914 9385 and he will be happy to answer your questions. You can also call Ms. Hannah Frimpong, the Ghana Health Service Ethical Review Committee Administrator, on Tel. 050 704 1223, if you have further concerns.

WRITTEN INFORMED CONSENT FORM

VOLUNTEER AGREEMENT

a. Child's participation

"I have read or have had someone read all information on the information sheet, have asked questions, received answers regarding participation in this study, and am willing to give consent for my child/ward to participate in this study. I have not waived any of my rights by signing this consent form. Prior to signing this consent form, I was given a copy of the information sheet for my personal records."

_____

Name of mother or legal caregiver (if respondent is a minor)

_____ _____

Signature or mark of mother or legal caregiver Date

b. Adult woman's own participation

"I have read or have had someone read all information on the information sheet, have asked questions, received answers regarding participation in this study, and am willing to give consent to participate in this study. I have not waived any of my rights by signing this consent form. Prior to signing this consent form, I was given a copy of the information sheet for my personal records."

_____

Name of participant

_____ _____

Signature or mark participant Date

CLUSTER ID: ☐☐		RESPONDENT Label: **C** ☐☐☐☐	
HH Label: **H** ☐☐☐☐		**W** ☐☐☐☐	

Appendix 7 -
Authorization Letter from the Ghana Health Service

In case of the reply the number and the date of this letter should be quoted.

My Ref.
No. GHS/NUT/ADMIN/23

Your Ref. No. .....

GHANA HEALTH SERVICE
PRIVATE MAIL BOX
ACCRA, GHANA.

nutrition@ghsmail.org

17th APRIL 2017

To Whom It May Concern

Introductory Letter for the Ghana Micronutrient Survey 2017

The Ghana Health Service in collaboration with UNICEF is supporting the conduct of 2017 national Micronutrient Survey for Ghana.

The purpose of the survey is to provide information on the current situation and increase the understanding of the severity of various nutritional deficiencies and malnutrition in women and children in Ghana. The information collected in this survey will be used for improved design and delivery of health services.

As part of the survey household-level interviews will be conducted using individual questionnaires. In addition children will be weighed and blood samples collected from children 6-59 months of age, non-pregnant women 15-49 years of age and pregnant women. The survey will also provide participating individuals with on-site results of their anemia or malaria status. Should an individual be identified with anemia, malaria, or severe acute malnutrition (children only), the survey teams will refer the individual to the nearest health facility for further testing and treatment.

The survey is being implemented by the University of Ghana, Department of Food Science and Nutrition, GroundWork (a Swiss-based organization), and the University of Wisconsin-Madison in the United States. The survey protocol has received ethical approval from the Ghana Health Service Ethical Review Committee.

We wish to request the kind support of regional and district health directorates, and community health teams to facilitate the work of the survey teams.

Counting on your collaboration and support.

DR PATRICK ABOAGYE
DIRECTOR FAMILY HEALTH

Appendix 8 -

Teams, Team Members, and Supervisors

STRATA	SUPERVISORS	TEAM #	REGION(S)	LANGUAGES	TEAM LEADER	INTERVIEWERS	ANTHROPOMETRISTS	PHLEBOTOMISTS
South Belt	Humphrey Thompson	1	Greater Accra	Ga/Twi	Juliet Vickar	Evelyn Danso	Patience Anku	Dennis Papa Acquah
						Amatus Amienu Baghri	Mensah Oppong Daniel	Grace Nkunsah
		2	Volta	Ewe/Twi	Emmanuel Kwabena Fumador	Wisdom Kodzo	Ignatius Great Sakada	Seyram Yaa Attivor
						Nyamedor Evans Courage		
		3	Western/Central	Fante	Obed Harrison	Daniel Armo-Annor	Sydney Phixon-Owoo	Frank Boadi
						Kofi Amissah Appiah		
Middle Belt	William Ekow Spio Donkor	4	Brong-Ahafo	Twi	Felix Kweku Kyereh	Atta Boakye JNR	Michael Wiafe Akenteng	Joyce Antwi
						Salomey Boakye		
		5	Ashanti	Twi	Isaac Boadu	Silas Appiah	Barbara Boye	Lawrence Ohuapo-Agyemang
						Prosper Gbafa		
		6	Eastern	Twi	Elizabeth Duah	Olivia Anokye	Frederick Gyimah Yeboah	Samuel KofiTchum
						Eric Annor		Samuel Boafo Budu
North Belt	Joe Nyefene Dare	7	Upper West	Dagaare/Waale	Naapong Kuubeme Edward	Abu-Naa Zahari Aminbo	James BoyeleDakurah	Nestor Kukpieng
						Mohammed Awal		
						Gyekua-Der Nichodemus		
		8	Upper East	Frafra	Richard Apini	Ebenezer Alangura	Koblaji Florence Akua	Obed Sarfo
						John Adatcesi Aganah		
		9	Northern	Dagbani	Prosper Chapu	Alhassan Ridwan	Ishawu Iddrisu	Solomon Okyere Koi
						Ibrahim Abdul-Rahman		
		10	Northern	Dagbani	Yvon Galaa	Alidu Ismael Atote	Sulemani Bapula Herrick	Adams Batiadan Abdul-Hanif
						Zuberu Osman		
						Hudu Alhassan		

Appendix 9 -
Survey Questionnaires and Tools

PDF versions of all questionnaires and survey tools can be download from GroundWork's website using the URL hyperlinks provided below:

Household Questionnaire:
http://groundworkhealth.org/wp-ontent/uploads/2017/12/GMS_household_questionnaire.pdf

Child Questionnaire:
http://groundworkhealth.org/wp-content/uploads/2017/12/GMS_children_questionnaire.pdf

Child Biological Form:
http://groundworkhealth.org/wp-content/uploads/2017/12/GMS_children_biological_form.pdf

Woman Questionnaire:
http://groundworkhealth.org/wp-content/uploads/2017/12/GMS_women_questionnaire.pdf

Woman Biological form:
http://groundworkhealth.org/wp-content/uploads/2017/12/GMS_women_biological_form.pdf

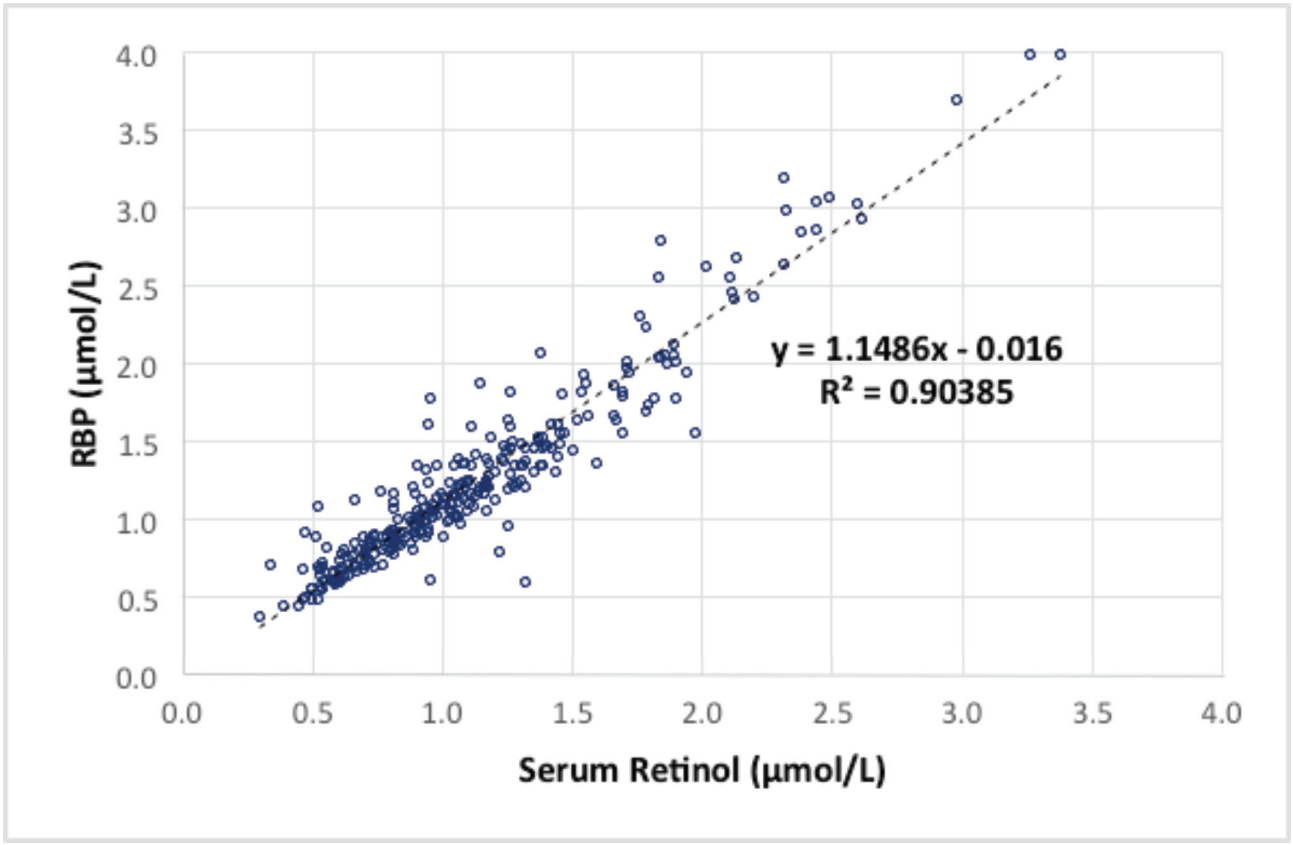
Referral Form:
http://groundworkhealth.org/wp-content/uploads/2017/12/GMS_Referral-sheet.pdf

Appendix 10 -

Comparison of Serum Retinol and Retinol Binding Protein

Because RBP is not a WHO-recommended biomarker for the assessment of vitamin A status, extra serum specimens from children and non-pregnant women were analyzed for serum retinol as a comparison and validations of RBP measurements. Serum retinol was analyzed using HPLC at the University of Wisconsin-Madison, USA, and RBP was measured using the ELISA technique at the VitMin Lab, Freiburg, Germany.

The figure below presents the correlation plot and regression equation comparing retinol and RBP for both children and women combined. Using 300 cases, we found a strong correlation between RBP and serum retinol values (R2=0.9). The estimated slope was 1.15, showing that RBP values were slightly higher than their serum retinol counterparts.



Appendix 11 -
Description of Survey Weights

Survey weights for the GMS 2017 were calculated using a multi-step process. First, using projected population estimates for 2017 provided by the Ghana Statistical Service, the probability of selection of surveyed households from within each stratum was calculated. This stratum-specific probability was divided by the probability of selection of households from the entire Ghanaian population to calculate the standardized stratum-specific weights. Second, the probability of selecting households from within each strata was calculated by dividing the number of households listed in Ghana's 2010 census by the total number of households in each strata in 2010. The probability of selection was then calculated separately for based on the number of households listed in each PSU by the GMS 2017. Standardized PSU weights were then calculated by dividing the corrected probability of selection by the actual probabiliy of selection, which used Ghana's 2010 census data. Third, the final survey weights for each PSU were calculated by multiplying the standardized PSU weights by the standardized stratum weights.

Region	Strata	PSU Number	Number of household based on 2010 Ghanaian Census	Number of households LISTED in each PSU by GMS	Actual probability of section using 2010 Census (by each stratum)	Corrected probability of selection based on household listing and projected number of households	Standardized PSU weights	Standardized PSU weight * Standardized Stratum weight
Western	South	1	148	139	0.000071	0.0000666	0.939	0.923
Western	South	2	95	35	0.000046	0.0000168	0.368	0.362
Western	South	3	169	48	0.000081	0.0000230	0.284	0.279
Western	South	4	182	97	0.000087	0.0000465	0.533	0.524
Western	South	5	56	126	0.000027	0.0000604	2.250	2.211
Western	South	6	397	66	0.000190	0.0000316	0.166	0.163
Western	South	7	319	327	0.000153	0.0001568	1.025	1.007
Central	South	8	162	137	0.000078	0.0000657	0.846	0.831
Central	South	9	95	84	0.000046	0.0000403	0.884	0.869
Central	South	10	56	44	0.000027	0.0000211	0.786	0.772
Central	South	11	226	146	0.000108	0.0000700	0.646	0.635
Central	South	12	194	341	0.000093	0.0001635	1.758	1.727
Central	South	13	209	167	0.000100	0.0000801	0.799	0.785
Greater Accra	South	14	214	187	0.000103	0.0000897	0.874	0.859
Greater Accra	South	15	47	89	0.000023	0.0000427	1.894	1.861
Greater Accra	South	16	175	232	0.000084	0.0001112	1.326	1.303
Greater Accra	South	17	396	344	0.000190	0.0001649	0.869	0.854

Region	Strata	PSU Number	Number of household based on 2010 Ghanaian Census	Number of households LISTED in each PSU by GMS	Actual probability of section using 2010 Census (by each stratum)	Corrected probability of selection based on household listing and projected number of households	Standardized PSU weights	Standardized PSU weight * Standardized Stratum weight
Greater Accra	South	18	464	643	0.000222	0.0003083	1.386	1.362
Greater Accra	South	19	295	256	0.000141	0.0001227	0.868	0.853
Greater Accra	South	20	365	344	0.000175	0.0001649	0.942	0.926
Greater Accra	South	21	293	654	0.000140	0.0003136	2.232	2.193
Greater Accra	South	22	255	418	0.000122	0.0002004	1.639	1.611
Greater Accra	South	23	168	167	0.000081	0.0000801	0.994	0.977
Greater Accra	South	24	322	212	0.000154	0.0001016	0.658	0.647
Volta	South	25	137	246	0.000066	0.0001179	1.796	1.765
Volta	South	26	149	226	0.000071	0.0001084	1.517	1.491
Volta	South	27	109	101	0.000052	0.0000484	0.927	0.911
Volta	South	28	214	160	0.000103	0.0000767	0.748	0.735
Volta	South	29	155	198	0.000074	0.0000949	1.277	1.255
Volta	South	30	83	57	0.000040	0.0000273	0.687	0.675
Eastern	Central	31	113	45	0.000041	0.0000162	0.398	0.536
Eastern	Central	32	200	156	0.000072	0.0000562	0.780	1.050
Eastern	Central	33	109	42	0.000039	0.0000151	0.385	0.518
Eastern	Central	34	138	38	0.000050	0.0000137	0.275	0.371
Eastern	Central	35	210	92	0.000076	0.0000331	0.438	0.590
Eastern	Central	36	249	167	0.000090	0.0000602	0.671	0.902
Eastern	Central	37	99	131	0.000036	0.0000472	1.323	1.781
Eastern	Central	38	172	119	0.000062	0.0000429	0.692	0.931
Ashanti	Central	39	89	132	0.000032	0.0000476	1.483	1.996
Ashanti	Central	40	125	114	0.000045	0.0000411	0.912	1.227
Ashanti	Central	41	228	160	0.000082	0.0000576	0.702	0.944
Ashanti	Central	42	103	144	0.000037	0.0000519	1.398	1.881
Ashanti	Central	43	71	68	0.000026	0.0000245	0.958	1.289
Ashanti	Central	44	113	96	0.000041	0.0000346	0.850	1.143
Ashanti	Central	45	187	161	0.000067	0.0000580	0.861	1.159
Ashanti	Central	46	171	113	0.000062	0.0000407	0.661	0.889
Ashanti	Central	47	338	168	0.000122	0.0000605	0.497	0.669
Ashanti	Central	48	202	80	0.000073	0.0000288	0.396	0.533
Ashanti	Central	49	220	138	0.000079	0.0000497	0.627	0.844
Ashanti	Central	50	110	151	0.000040	0.0000544	1.373	1.847
Ashanti	Central	51	186	91	0.000067	0.0000328	0.489	0.658
Ashanti	Central	52	121	106	0.000044	0.0000382	0.876	1.179
Ashanti	Central	53	416	290	0.000150	0.0001045	0.697	0.938
Brong Ahafo	Central	54	121	60	0.000044	0.0000216	0.496	0.667
Brong Ahafo	Central	55	133	57	0.000048	0.0000205	0.429	0.577
Brong Ahafo	Central	56	228	131	0.000082	0.0000472	0.575	0.773
Brong Ahafo	Central	57	124	114	0.000045	0.0000411	0.919	1.237

Region	Strata	PSU Number	Number of household based on 2010 Ghanaian Census	Number of households LISTED in each PSU by GMS	Actual probability of section using 2010 Census (by each stratum)	Corrected probability of selection based on household listing and projected number of households	Standardized PSU weights	Standardized PSU weight * Standardized Stratum weight
Brong Ahafo	Central	58	104	99	0.000037	0.0000357	0.952	1.281
Brong Ahafo	Central	59	150	83	0.000054	0.0000299	0.553	0.745
Brong Ahafo	Central	60	485	423	0.000175	0.0001524	0.872	1.174
Northern	North	61	162	160	0.000267	0.0002641	0.988	0.466
Northern	North	62	169	114	0.000279	0.0001881	0.675	0.318
Northern	North	63	154	60	0.000254	0.0000990	0.390	0.184
Northern	North	64	98	10	0.000162	0.0000165	0.102	0.048
Northern	North	65	104	115	0.000172	0.0001898	1.106	0.522
Northern	North	66	119	103	0.000196	0.0001700	0.866	0.408
Northern	North	67	70	68	0.000116	0.0001122	0.971	0.458
Northern	North	68	71	92	0.000117	0.0001518	1.296	0.611
Northern	North	69	98	132	0.000162	0.0002178	1.347	0.635
Northern	North	70	83	94	0.000137	0.0001551	1.133	0.534
Northern	North	71	65	83	0.000107	0.0001370	1.277	0.602
Northern	North	72	367	655	0.000606	0.0010810	1.785	0.842
Northern	North	73	178	263	0.000294	0.0004340	1.478	0.697
Northern	North	74	122	226	0.000201	0.0003730	1.852	0.874
Northern	North	75	61	57	0.000101	0.0000941	0.934	0.441
Northern	North	76	176	175	0.000290	0.0002888	0.994	0.469
Northern	North	77	49	44	0.000081	0.0000726	0.898	0.423
Northern	North	78	198	285	0.000327	0.0004704	1.439	0.679
Upper East	North	79	90	168	0.000149	0.0002773	1.867	0.880
Upper East	North	80	47	226	0.000078	0.0003730	4.809	2.268
Upper East	North	81	160	120	0.000264	0.0001980	0.750	0.354
Upper East	North	82	125	314	0.000206	0.0005182	2.512	1.185
Upper East	North	83	178	133	0.000294	0.0002195	0.747	0.352
Upper East	North	84	202	324	0.000333	0.0005347	1.604	0.756
Upper East	North	85	192	324	0.000317	0.0005347	1.688	0.796
Upper West	North	86	95	126	0.000157	0.0002079	1.326	0.626
Upper West	North	87	112	114	0.000185	0.0001881	1.018	0.480
Upper West	North	88	114	97	0.000188	0.0001601	0.851	0.401
Upper West	North	89	91	95	0.000150	0.0001568	1.044	0.492
Upper West	North	90	259	259	0.000427	0.0004274	1.000	0.472
TOTAL			15473	15096				

Appendix 12 -
Design Effects of Major Outcomes

Variable	Number in analysis	Design effect
Households		
Improved water source	2123	12.9
Improved sanitation	2123	5.3
Water at handwashing place	1752	8.8
Household uses vegetable oil	2036	6.3
Vegetable oil fortified >10 ppm	1218	7.0
Household uses bread	2123	9.0
Children		
Low birth weight	583	1.9
Early initiation of breastfeeding (within first hour)	357	1.6
Minimum dietary diversity	414	1.7
Minimum meal frequency	415	1.1
Minimum acceptable diet	415	1.4
Took iron supplementation in past 6 months	1200	2.2
Took vitamin A supplement in past 6 months	1087	2.1
Had diarrhea in past 2 weeks	1234	1.4
Had fever in past 2 weeks	1232	2.7
Had cough in past 2 weeks	1231	2.8
Had lower respiratory infection	1234	2.0
Positive malaria rapid test kit	1113	5.6
Sickle cell trait	1128	2.2
α-thalassemia trait	1046	1.4
Anemia	1172	2.0
Iron deficiency	1165	1.9
Vitamin A deficiency	1165	1.5
Non-pregnant women		
Heard of fortified vegetable oil	1002	1.9
Heard of fortified wheat flour	992	1.8
Took folic acid supplement in past 6 months	1035	2.2
Took iron supplement in past 6 months	1033	1.3
Positive malaria rapid test kit	947	3.2
Sickle cell trait	477	1.1
α-thalassemia trait	455	1.4
Anemia	999	1.5
Iron deficiency	987	1.5
Vitamin A deficiency	987	1.6
Folate deficiency	473	1.9
Vitamin B12 deficiency	471	1.1
Pregnant women		
Took folic acid supplement in past 6 months	145	1.3
Took iron supplement in past 6 months	146	1.2
Positive malaria rapid test kit	134	1.1
Anemia	153	0.9

Appendix 13 -
Additional Household Tables

Table A12 - 1. Number and % of most often consumed breads in participating households, Ghana 2017

Characteristic	Factory white bread		Factory brown bread		Other bread from bakery or factory		P value [b]
	n	% [a]	n	% [a]	n	% [a]	
Residence							
Urban	626	84.0	97	14.2	17	1.8	<0.001
Rural	651	96.7	11	1.8	14	1.6	
Stratum							
Southern Belt	533	85.0	80	14.7	3	0.3	<0.001
Middle Belt	556	93.5	26	4.3	15	2.2	
Northern Belt	188	91.7	2	1.2	13	7.0	
Wealth quintile							
Lowest	283	96.0	3	1.2	8.0	2.8	<0.001
Second	279	96.3	5	1.7	7.0	2.0	
Middle	244	95.8	9	2.7	5.0	1.5	
Fourth	231	86.0	31	11.6	8.0	2.3	
Highest	240	76.8	60	22.8	3	0.4	

Note: The n's are un-weighted numbers in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Appendix 14 -
Additional Child Tables and Figures

Table A14 - 1. Distribution of birth weight variables in pre-school age children, Ghana 2017

Characteristic	n	% [a]	(95% CI)[b]
Child weighed at birth			
No	326	23.3	(18.4; 29.0)
Yes	802	67.2	(61.1; 72.7)
Unknown	106	9.5	(7.6; 11.8)
Birthweight category			
Low birthweight	123	14.9	(11.8; 18.7)
Normal birth weight	460	59.6	(54.0; 64.9)
Don´t remember	219	25.5	(20.7; 31.0)
Source of birthweight information [c]			
From health card	444	73.8	(67.4; 79.4)
From recall	139	26.2	(20.6; 32.6)

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.
c Benefits of fortified vegetable oil and wheat flour only asked of women who had heard of fortified vegetable oil or wheat flour previously. Respondents could report more than one benefit.

Table A14 - 2. Proportion of children with low birth weight (<2.5 kg), Ghana 2017

Characteristic	n	%[a]	(95% CI)[b]	P value[c]
Sex				
Male	299	16.9	(12.5; 22.4)	<0.05
Female	284	23.4	(17.8; 30.1)	
Residence				
Urban	340	20.1	(14.8; 26.9)	0.96
Rural	279	19.9	(14.0; 27.5)	
Stratum				
Southern Belt	180	17.2	(10.2; 27.3)	0.60
Middle Belt	221	22.7	(18.0; 28.1)	
Northern Belt	182	19.9	(11.3; 32.5)	
Wealth quintile				
Lowest	160	18.7	(10.2; 31.7)	0.18
Second	99	25.5	(17.6; 35.5)	
Middle	105	10.8	(5.4; 20.5)	
Fourth	102	23.9	(16.4; 33.3)	
Highest	117	22.8	(14.7; 33.6)	
ALL CHILDREN	802	14.9	(11.8; 18.7)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b CI=confidence interval, calculated taking into account the complex sampling design.

C Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Table A14 - 3. Distribution of various times of breastfeeding initiation after birth, children 6-24 months of age, Ghana 2017. (WHO/UNICEF recommendations - Indicator #1: Early initiation of breastfeeding

Characteristic	n	<1 hour %[a]	<1 hour (95% CI)[b]	1-12 hours %[a]	1-12 hours (95% CI)[b]	>12 hours %[a]	>12 hours (95% CI)[b]	P value
Age Group (in months)								
6-11	112	81.3	(69.9; 89.1)	14.8	(7.4; 27.5)	3.9	(1.4; 10.0)	0.25
12-23	231	80.8	(73.3; 86.6)	10.1	(6.6; 15.3)	9.1	(4.8; 16.4)	
Sex								
Male	179	81.3	(73.4; 87.3)	9.0	(5.4; 14.6)	9.7	(5.2; 17.5)	0.13
Female	166	80.8	(71.6; 87.5)	14.4	(8.3; 23.8)	4.8	(2.2; 10.0)	
Residence								
Urban	130	84.2	(72.9; 91.4)	10.9	(5.2; 21.4)	4.9	(1.9; 12.0)	0.47
Rural	215	78.5	(71.4; 84.3)	12.1	(7.5; 18.7)	9.4	(5.0; 17.2)	
Stratum								
Southern Belt	90	82.3	(67.7; 91.1)	12.3	(4.8; 28.1)	5.5	(2.6; 11.0)	0.14
Middle Belt	141	86.8	(77.8; 92.5)	7.1	(3.6; 13.5)	6.2	(2.6; 13.7)	
Northern Belt	114	68.6	(58.2; 77.3)	19.3	(10.7; 32.2)	12.2	(4.5; 28.9)	
Wealth Quintile								
Lowest	126	75.6	(46.1; 84.3)	10.3	(4.6; 21.5)	14.0	(6.6; 27.3)	<0.05
Second	71	70.4	(57.0; 80.9)	21.8	(13.2; 33.9)	7.8	(3.1; 18.1)	
Middle	51	92.9	(82.2; 97.3)	5.9	(2.0; 16.3)	1.3	(0.2; 8.8)	
Fourth	48	84.2	(66.6; 93.5)	7.9	(2.0; 26.3)	7.8	(2.4; 22.3)	
Highest	49	86.1	(70.1; 94.3)	11.8	(4.4; 27.9)	2.1	(0.4; 11.1)	
ALL CHILDREN								

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b CI=confidence interval, calculated taking into account the complex sampling design.

Table A14 - 4. Proportion of children breastfed the day before the interview, children 12-15 months of age, Ghana 2017. (WHO/UNICEF recommendations - Indicator #3: Continued breastfeeding at 1 year)

Characteristic	n	%[a]	(95% CI)[b]	P value
Sex				
Male	49	100		
Female	48	86.1	(68.5; 94.6)	<0.05
Residence				
Urban	33	88.0	(68.2; 96.2)	0.18
Rural	64	96.6	(83.4; 99.4)	
Stratum				
Southern Belt	21	90.8	(63.4; 98.2)	0.40
Middle Belt	36	90.7	(68.1; 97.8)	
Northern Belt	40	98.7	(90.6; 99.8)	
Wealth Quintile				
Lowest	33	98.7	(90.1; 99.8)	0.35
Second	24	83.3	(51.6; 95.9)	
Middle	16	86.9	(43.2; 98.3)	
Fourth	16	100		
Highest	8	100		
ALL CHILDREN				

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.

Table A14 - 5. Proportion of children eating complementary food the day before the interview, children 6-8 months of age, Ghana 2017. (WHO/UNICEF recommendations - Indicator #4: Introduction of solid, semi-solid or soft foods)

Characteristic	n	%[a]	(95% CI)[b]	P value
Sex				
Male	30	92.4	(75.8; 97.9)	0.24
Female	26	97.9	(85.0; 99.7)	
Residence				
Urban	23	95.3	(71.8; 99.4)	0.86
Rural	33	94.1	(78.2; 98.6)	
Stratum				
Southern Belt	15	90.8	(70.8; 97.6)	0.32
Middle Belt	23	95.9	(70.5; 99.6)	
Northern Belt	15	94.7	(83.8; 98.4)	
Wealth Quintile				
Lowest	21	100		0.37
Second	11	80.7	(41.0; 96.2)	
Middle	9	100		
Fourth	7	84.0	(35.3; 98.0)	
Highest	8	100		
ALL CHILDREN	56	94.7	-	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.

Table A14 - 6. Proportion of children with minimum dietary diversity the day before the interview, children 6-23 months of age, Ghana 2017. (WHO/UNICEF recommendations - Indicator #5: Minimum dietary diversity)

Characteristic	n	%[a]	(95% CI)[b]	P value
Age Group (in months)				
6-11	124	30.3	(20.5; 42.3)	<0.05
12-23	289	46.9	(40.1; 53.9)	
Sex				
Male	207	44.0	(35.5; 52.8)	0.56
Female	203	40.6	(32.2; 49.5)	
Residence				
Urban	163	50.2	(41.7; 58.6)	<0.05
Rural	247	35.4	(26.4; 45.7)	
Stratum				
Southern Belt	108	32.7	(23.1; 43.9)	<0.0001
Middle Belt	17	56.2	(46.8; 65.2)	
Northern Belt	125	24.9	(17.0; 34.8)	
Wealth Quintile				
Lowest	138	23.6	(16.3; 32.8)	<0.001
Second	87	40.2	(29.2; 52.4)	
Middle	67	41.8	(28.7; 56.1)	
Fourth	61	51.2	(36.2; 65.9)	
Highest	57	66.2	(54.2; 76.4)	
ALL CHILDREN	410	42.3	-	

Note: The n's are un-weighted numbers in each subgroup; subgroups that do not sum to the total have missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.

Table A14 - 7. Distribution of children with minimal meal frequency the day before the interview, children 6-23 months of age, Ghana 2017. (WHO/UNICEF recommendations - Indicator #6: Minimum meal frequency)

Characteristic	n	%[a]	(95% CI)[b]	P value
Age Group (in months)				
6-11	124	54.5	(44.1; 64.5)	<0.0005
12-23	288	30.9	(25.7; 36.6)	
Sex				
Male	207	43.1	(35.8; 50.8)	0.12
Female	202	33.5	(26.2; 41.8)	
Residence				
Urban	162	38.8	(32.2; 45.9)	0.89
Rural	247	38.1	(31.1; 45.6)	
Stratum				
Southern Belt	108	41.7	(31.7; 52.5)	<0.005
Middle Belt	176	29.7	(23.6; 36.7)	
Northern Belt	125	53.3	(45.5; 61.0)	
Wealth Quintile				
Lowest	138	52.9	(44.2; 61.4)	<0.05
Second	87	31.4	(22.4; 42.0)	
Middle	67	31.0	(20.8; 43.5)	
Fourth	60	41.5	(27.1; 57.5)	
Highest	57	31.2	(22.0; 42.3)	
ALL CHILDREN				

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.

Table A14 - 8. Proportion of children with minimum acceptable diet the day before the interview, children 6-23 months of age, Ghana 2017. (WHO/UNICEF recommendations - Indicator #7: Minimum acceptable diet)

Characteristic	n	%[a]	(95% CI)[b]	P value
Age Group (in months)				
6-11	124	5.9	(3.2; 10.5)	
12-23	288	7.9	(5.3; 11.5)	
Sex				
Male	207	18.0	(13.2; 24.0)	0.1
Female	202	10.5	(5.9; 18.2)	
Residence				
Urban	162	19.2	(13.9; 25.8)	<0.05
Rural	247	10.1	(6.4; 15.6)	
Stratum				
Southern Belt	108	18.0	(10.7; 28.6)	0.44
Middle Belt	176	12.6	(8.4; 18.6)	
Northern Belt	125	12.8	(7.4; 21.3)	
Wealth Quintile				
Lowest	138	10.7	(5.6; 19.7)	0.3
Second	87	10.4	(5.7; 18.3)	
Middle	67	13.9	(7.5; 24.3)	
Fourth	60	18.0	(8.9; 32.9)	
Highest	57	21.7	(13.5; 33.0)	
ALL CHILDREN				

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b CI=confidence interval, calculated taking into account the complex sampling design.

Table A14 - 9. Proportion of mild, moderate and severe anemia in children 6-59 months of age, Ghana 2017

Characteristic	n	Mild anemia % [a, b]	Mild anemia (95% CI)[c]	Mild anemia P value[d]	Moderate anemia % [a, b]	Moderate anemia (95% CI)[c]	Moderate anemia P value[d]	Severe anemia % [a, b]	Severe anemia (95% CI)[c]	Severe anemia P value[d]
Age Group (in months)										
6-11	120	21.8	(15.4; 30.0)	<0.05	22.8	(16.1; 31.1)	<0.01	--		0.76
12-23	276	24.3	(19.4; 30.0)		21.1	(14.8; 29.1)		0.7	(0.2; 2.3)	
24-35	256	15.7	(11.8; 20.5)		19.8	(14.5; 26.4)		1.3	(0.4; 4.3)	
36-47	265	16.5	(11.3; 23.4)		12.7	(8.4; 18.8)		0.9	(0.2; 3.8)	
48-59	253	12.3	(8.5; 17.6)		10.9	(7.2; 16.1)		0.2	(0.0; 1.5)	
Sex										
Male	581	18.6	(15.2; 22.6)	<0.56	18.7	(14.9; 23.2)	0.13	1.1	(0.4; 2.6)	0.20
Female	589	17.1	(13.9; 20.8)		15.4	(12.0; 19.5)		0.3	(0.1; 1.6)	
Residence										
Urban	432	14.2	(10.9; 18.4)	<0.05	12.5	(8.5; 17.9)	<0.05	0.1	(0.0; 0.8)	<0.01
Rural	740	20.5	(17.6; 23.8)		20.4	(16.3; 25.2)		1.2	(0.5; 2.5)	
Stratum										
Southern Belt	323	13.7	(9.9; 18.8)	<0.0001	17.6	(11.6; 25.7)	<0.05	1.0	(0.2; 3.8)	0.61
Middle Belt	447	27.9	(23.7; 32.5)		12.6	(8.3; 18.7)		0.4	(0.1; 1.8)	
Northern Belt	402				24.4	(19.6; 30.0)		0.9	(0.3; 2.5)	
Wealth Quintile										
Lowest	420	24.2	(20.1; 28.9)	<0.005	21.6	(16.4; 27.8)	<0.0001	1.2	(0.3; 4.1)	0.58
Second	247	18.1	(13.3; 24.2)		17.8	(12.8; 24.1)		0.5	(0.1; 2.1)	
Middle	213	16.6	(13.3; 20.6)		21.2	(15.9; 27.7)		1.0	(0.2; 4.1)	
Fourth	154	14.0	(9.2; 20.9)		13.9	(8.7; 21.5)		0.3	(0.0; 2.3)	
Highest	138	11.0	(7.0; 16.9)		2.8	(1.2; 6.7)		--		
ALL CHILDREN	1172	17.8	(15.6; 20.3)		17.0	(14.0; 20.6)		0.7	(0.3; 1.5)	

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.
a Percentages weighted for unequal probability of selection.
b Mild, moderate, and severe anemia defined as hemoglobin 100-109 g/L, 70-99 g/L, and <70 g/L, respectively.
c CI=confidence interval, calculated taking into account the complex sampling design.
d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Figure A14 - 1. Distribution of ferritin and retinol binding protein with no inflammation adjustment (A), Thurnham inflammation adjustment (B), and BRINDA inflammation adjustment (C) in children 6-59 months of age, Ghana 2017

Ferritin concentrations decreased after the Thurnham and BRINDA adjustments. The prevalence of ID was 16.5%, 21.5%, and 29.5% using no adjustment, Thurnham, and BRINDA adjustments, respectively. ID prevalence was 58.1% calculated using unadjusted TfR (>8.3 mg/L) (data not shown). For RBP, the Thurnham adjustment increased concentrations, but greater increases occurred when the BRINDA adjustment was used. The prevalence of vitamin A deficiency was 28.9%, 20.8%, and 13.1% using no adjustment, Thurnham, and BRINDA adjustments, respectively.

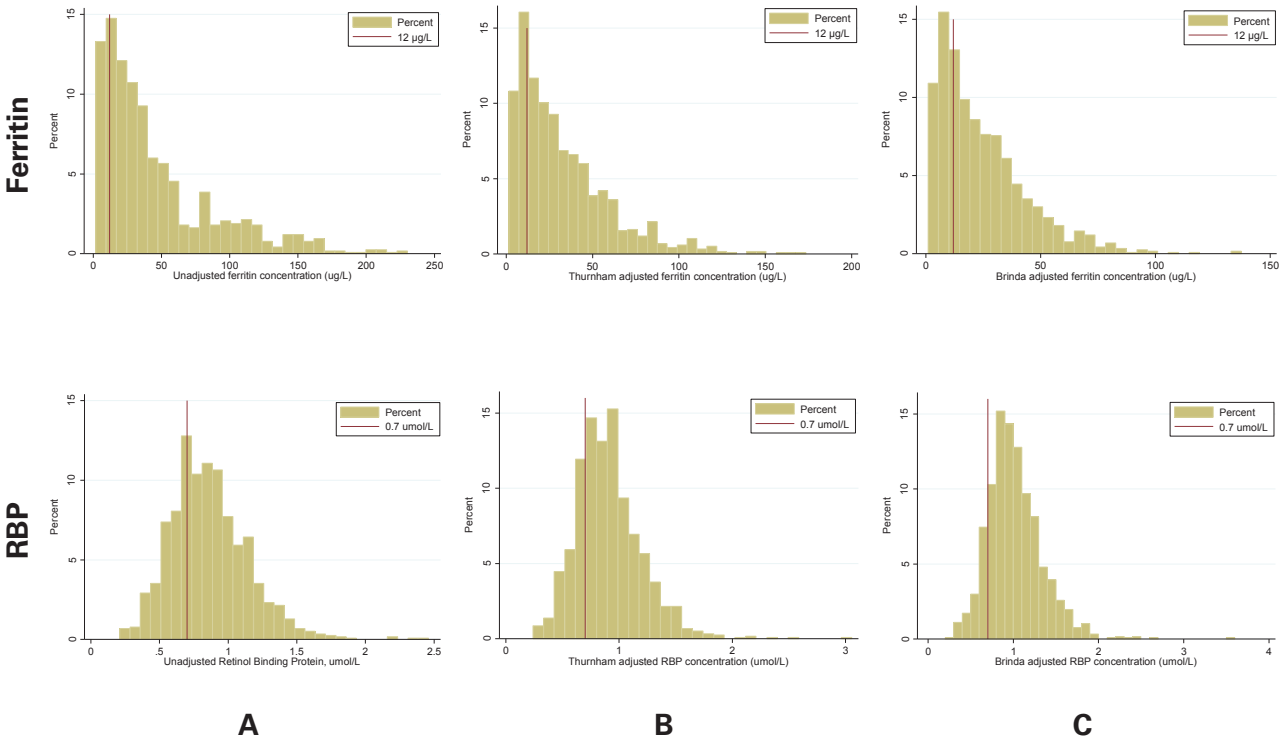


Table A15 - 1. Proportion of mild, moderate, and severe anemia in non-pregnant women (15-49 years), Ghana 2017

Characteristic	n	Mild anemia [b] %[a]	Mild anemia [b] (95% CI)[c]	Mild anemia [b] P value[d]	Moderate anemia %[a]	Moderate anemia (95% CI)[c]	Moderate anemia P value[d]	Severe anemia %[a]	Severe anemia (95% CI)[c]	Severe anemia P value[d]
Age group (in years)										
15-19	207	19.0	(12.9; 27.2)	0.38	7.4	(4.0; 13.1)	0.27	0.0	--	0.73
20-24	169	14.1	(8.6; 22.1)		5.8	(3.2; 10.1)		1.1	(0.2; 7.1)	
25-29	178	11.5	(7.3; 17.7)		10.9	(6.4; 18.0)		0.7	(0.1; 4.7)	
30-34	169	17.4	(12.1; 24.4)		5.3	(2.4; 11.1)		0.3	(0.0; 2.3)	
35-39	113	11.6	(6.1; 21.0)		3.9	(1.1; 12.6)		0.0	--	
40-44	103	11.8	(5.6; 23.2)		4.4	(1.5; 12.0)		0.7	(0.1; 5.0)	
45-49	46	7.3	(2.7; 18.0)		12.7	(4.1; 33.0)		0.0	--	
Residence										
Urban	436	12.5	(10.4; 14.9)	0.10	8.2	(5.7; 11.7)	0.29	0.9	(0.3; 2.5)	0.05
Rural	563	15.9	(12.6; 20.0)		5.8	(3.4; 9.8)		-		
Province										
Southern Belt	303	13.2	(11.0; 15.8)	0.08	9.9	(6.7; 14.5)	0.05	0.7	(0.2; 3.0)	0.55
Middle Belt	404	12.8	(10.0; 16.2)		4.4	(2.4; 8.0)		0.3	(0.0; 2.1)	
Northern Belt	292	19.6	(13.3; 27.9)		7.8	(4.4; 13.5)		0.3	(0.0; 2.0)	
Woman's education										
Never attended school	242	17.0	(11.3; 24.8)	0.21	7.1	(4.1; 12.0)	0.92	0.3	(0.0; 2.0)	0.09
Completed primary school or less	160	9.3	(5.9; 14.6)		7.6	(4.2; 13.2)		-		
Attend or completed JSS	406	15.6	(12.2; 19.7)		7.3	(4.8; 10.9)		0.2	(0.0; 1.2)	
Attended SSS or higher	190	12.8	(9.2; 17.4)		5.9	(3.1; 11.1)		1.5	(0.4; 5.9)	
Wealth quintile										
Lowest	278	17.6	(11.9; 25.0)	0.66	3.6	(1.7; 7.7)	0.09	-		0.76
Second	211	13.7	(9.5; 19.4)		7.7	(4.8; 12.2)		0.9	(0.1; 6.1)	
Middle	187	14.2	(9.4; 20.9)		11.1	(6.7; 17.8)		0.6	(0.1; 4.2)	
Fourth	161	14.0	(9.3; 20.6)		6.6	(3.5; 12.2)		0.7	(0.2; 3.0)	
Highest	162	11.7	(8.5; 15.9)		5.3	(2.3; 11.4)		-		
ALL NON-PREGNANT WOMEN	999	14.3	(12.2; 16.6)	--	7.0	(5.1; 9.5)	--	0.4	(0.2; 1.3)	--

Note: The n's are un-weighted denominators in each subgroup; the sum of subgroups may not equal the total because of missing data.

a Percentages weighted for unequal probability of selection.

b Mild, moderate, and severe anemia defined as hemoglobin 110-119 g/L, 80-109 g/L, and <80 g/L, respectively; after adjusting hemoglobin for smoking.

c CI=confidence interval, calculated taking into account the complex sampling design.

d Chi-square p-value <0.05 indicates that the proportion in at least one subgroup is statistically significantly different from the values in the other subgroups

Figure A15-1. Distribution of ferritin and RBP with no inflammation adjustment (A), Thurnham inflammation adjustment (B), and BRINDA inflammation adjustment (C) in non-pregnant women 15-49 years of age, Ghana 2017

Ferritin concentrations decreased after the Thurnham and BRINDA adjustments. The prevalence of ID was 13.0%, 13.8%, and 20.5% using no adjustment, Thurnham, and BRINDA adjustments, respectively. ID prevalence was 26.0% calculated using unadjusted TfR (>8.3 mg/L) (data not shown). For RBP, the Thurnham adjustment only slightly increased concentrations, resulting in a vitamin A deficiency prevalence of 1.7% and 1.5% using no adjustment and Thurnham adjustment, respectively. The Brinda project does not recommend adjusting RBP for adult women.

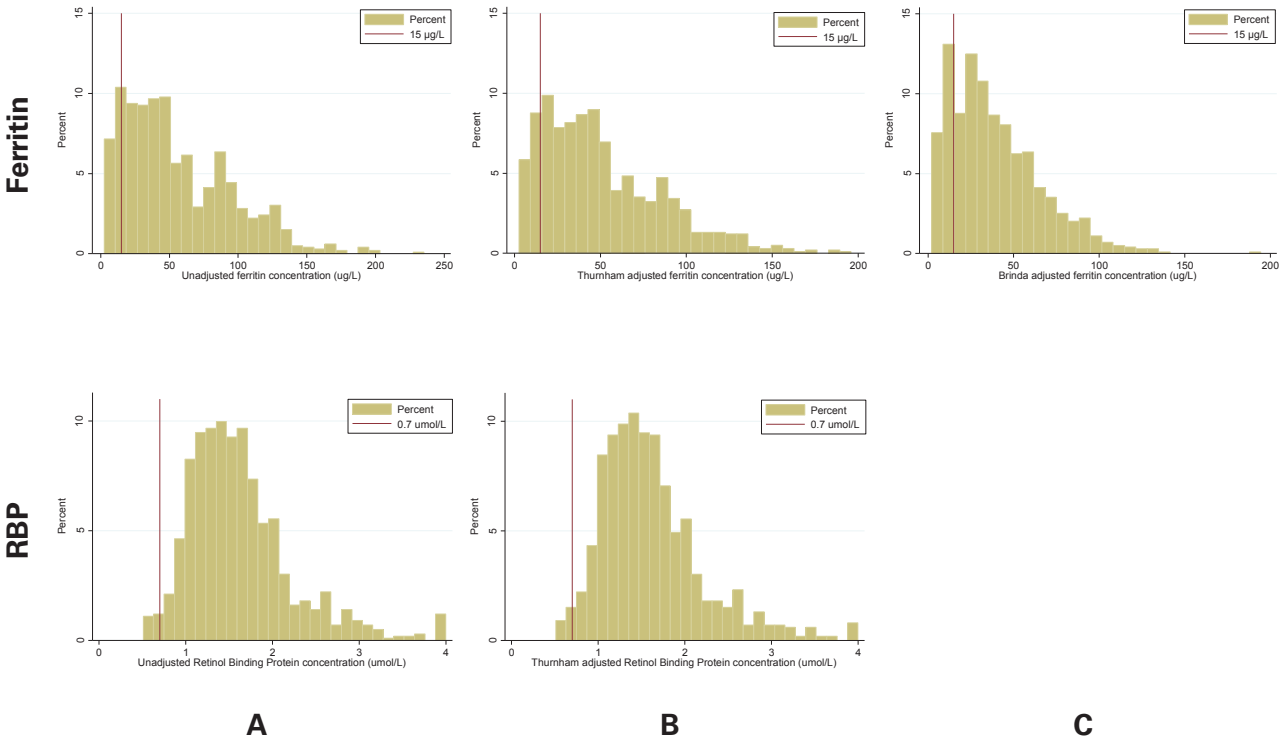


Figure A15-2. Distribution of folate and vitamin B12 in non-pregnant women 15-49 years of age, Ghana 2017

The distribution of folate and vitamin B12 are presented below. Notably, while the distribution of vitamin B12 is close to a normal distribution, folate concentrations are highly skewed to the left. This skewness is due to that fact that 93 women had folate concentrations below the level of detection by the Cobas e411 analyzer (Roche Diagnostics, Indianapolis, IN, USA), and thus were given the concentration of 4.54 nmol/L, the lowest measurable concentration of this analyzer.