

Introduction

Anemia is a condition characterized by decreased oxygen-carrying capacity of the blood and confirmed by measuring blood hemoglobin, erythrocyte count, and/or hematocrit. Mild anemia causes weakness, fatigue, headaches, and pallor. As anemia worsens, patients experience dyspnea, tachycardia, and dizziness. Severe anemia has been linked to poor cognitive function,¹ congestive heart failure,² and chronic kidney disease.³ Severe anemia can also have devastating consequences on both mother and fetus during pregnancy, including increased risks for maternal morbidity,⁴ low birth weight, preterm birth, perinatal morbidity, and neonatal morbidity.⁵

Anemia is a serious health concern worldwide, affecting about 25% of the world's population. Virtually every country reports anemia to some degree.⁶ Much of this burden is concentrated in financially underdeveloped countries. For example, 1.4% of all deaths from iron deficiency anemia worldwide occur in North America (developed), whereas 71% of deaths due to iron deficiency anemia occur in Africa and parts of Asia (underdeveloped).⁷

The cause of anemia in underdeveloped countries is multifactorial but linked to poverty. Low family income reduces the frequency and quality of food consumption leading to nutritional deficiencies of iron, vitamin B₁₂, folic acid, and protein, all of which may cause anemia. Iron deficiency anemia is responsible for about 50% of anemia cases worldwide.⁸ Insufficient funds within families and governments leads to improper sanitation causing frequent and cyclical bacterial and parasitic infections resulting in anemia due to diarrhea, blood loss, and consumption of nutrients by the infectious organism.⁸ Intestinal parasites contribute to anemia by causing intestinal bleeding resulting in blood loss. Vegetables and meats sold in markets of underdeveloped countries are often contaminated with intestinal parasites such as *Ascaris lumbricoides* and *Entamoeba histolytica*.⁹ Malaria is also a major etiology of anemia because the *Plasmodium* species cause increased destruction of parasitized and un-parasitized erythrocytes as well as decreased RBC production.¹⁰ In one study, 22.1% of the study population was severely anemic at the end of the high malaria transmission season compared to 1.4% at the end of the low transmission season.¹¹

Haiti, the poorest country in the Western hemisphere, has a population where 25% live in extreme poverty.¹² In 2017, Haiti was ranked as the 17th poorest country in the world based on per capita gross domestic product (GDP), adjusted for purchasing power parity (PPP).¹³ Many Haitians face both geographical and economic barriers in accessing health care.¹⁴ Some travel hours to reach a hospital only to be sent away for being unable to pay for the services. Others give all they have to pay for the doctor appointment and later are unable to afford the medication they are prescribed. Given the circumstances, many people wait until they are severely ill before they attempt to seek health care. This state of weakened health combined with lack of income makes them more susceptible to infections and nutritional deficiencies, all of which can lead to anemia.

Knowing the prevalence and severity of anemia in Haiti can motivate governments, organizations, and hospitals to improve testing, treatment, and preventative measures to help alleviate the burden of anemia. However, reports of anemia prevalence in Haiti are few, represent select communities, and focus mostly on children. Thus, the purpose of this study was

to analyze specimens from a wider population, including mostly adults, and from communities distributed across Haiti to determine the prevalence and severity of anemia.

Materials and Methods

Specimens:

Whole blood specimens (n=1500) were collected in EDTA over a 12-year period (2006-2018) from mostly adults visiting local clinics representing 15 communities distributed across most of Haiti. Hematocrit values were determined using the microhematocrit method by averaging the hematocrit values of two capillary tubes performed simultaneously. Hemoglobin values were determined using the MissionPlus Reflectance point-of-care instrument (ACON Laboratories, Inc., 10125 Mesa Rim Road, San Diego, CA 92121, USA). Results were reported as hemoglobin, so hematocrit values were converted to hemoglobin values using the Rule of Three ($3 \times \text{Hgb} = \text{HCT}$). In all cases, blood specimens analyzed in this study were collected for clinical purposes. After all clinical testing was completed, blood specimens were de-identified by Haitian laboratory staff prior to analysis qualifying the study as IRB exempted.

Determining normal reference interval:

De-identified blood specimens could not be segregated by gender so a single reference interval was generated as an average of male and female specific values. The hemoglobin reference interval of **12.4 – 14.6g/dL** was computed and applied using published reference intervals from African American children and adolescents¹⁵ (14.0-14.35 g/dL for males, 11.94-12.55 g/dL for females, 13.0-13.45g/dL - average), normal Nigerian adults,¹⁶ (14.0-14.4 g/dL for males, 12.4-13.1 g/dL for females, 13.2-13.75g/dL – average), healthy adults in Eastern and Southern Africa,¹⁷ (12.2-17.7 g/dL for males, 9.5 – 15.8 g/dL for females, 10.85-16.75g/dL – average), and the WHO criteria⁶ (<13.0 g/dL for males, <12.0 g/dL for females, 12.5g/dL - average).

Determining anemia stratification criteria:

To stratify anemia into mild, moderate, and severe, a modification of WHO criteria was used (Table 1).¹⁸ Since our data did not distinguish males and females, we used the values for non-pregnant women and men to determine anemia cut-offs as follows: **mild anemia (11.0 – 12.3g/dL)**, **moderate anemia (8.0 – 10.9g/dL)**, and **severe anemia (<8.0g/dL)**.

Data analysis:

Descriptive statistics were calculated and a frequency polygon was constructed using Microsoft Excel version 14.7.2.

Results

Based on the hemoglobin reference intervals used in this study, these data indicate that 49.27% of the population was anemic with 30.67% being mild (N=460), 15.73% being moderate (N=236), and 2.87% (N=43) showing severe anemia (Figure 1). Based on WHO criteria to determine public health significance (Table 2), these data suggest that anemia at a rate of 49.27% of the study population represents a severe public health problem in Haiti.

Discussion

Other studies have been conducted on the prevalence of anemia in Haiti, but prevalence varied based on the context of the study. One study on school-aged children in north Haiti found 70.6%

were anemic, with 2.6% being severely anemic.¹⁹ Another study performed on children 6-59 months old in south Haiti found 38.8% to be anemic, with 23.9% being mild, 14.7% being moderate, and 0.2% showing severe anemia.²⁰ One study focused on children 6-59 months old and adults ≥ 16 years in the Central Plateau of Haiti. For children 6-59 months old, 80.1% were anemic, with 51.8% being mild, 25.0% being moderate, and 3.3% being severely anemic.²¹ For adults ≥ 16 years old, 63.6% were anemic, with 53.8% being mild, 8.0% being moderate, and 1.5% showing severe anemia.²¹ All three published studies involved mostly or exclusively children. While important, these reports did not address anemia in the adult population. In addition, all reports cited took place in a single area of Haiti reflecting anemia prevalence locally. This study evaluated all patients, regardless of age, seeking medical attention in clinics scattered across the country of Haiti. Therefore, these data represent a more balanced snapshot of anemia across Haiti where bias, due to age or geographic location, has been minimized.

Clinic patients were used in this study because obtaining volunteer research subjects in Haiti is difficult. Research is a foreign concept that many do not understand. Haitian people are reluctant to donate blood because giving blood is perceived as a health risk. In addition, subjects are unwilling to walk long distances or spend money to travel to the location of blood collection and this study did not provide remuneration.

A combination of hematocrit and hemoglobin measurements were used. Hematocrit was the preferred anemia measurement because it is accurate and low cost; however, it requires electricity for the microhematocrit centrifuge. In the presence of electricity, hematocrit was measured; in the absence of electricity, hemoglobin was measured using the battery-powered MissionPlus reflectance instrument. The authors are aware that converting hematocrit to hemoglobin using the rule of three has the potential to introduce anemia classification errors for specimens whose values fall close to the anemia cut-points. Microcytic RBCs would decrease and macrocytic RBCs would increase hemoglobin levels calculated from hematocrit values. The absence of MCV values made it impossible to determine the presence and magnitude of potential classification errors. Assuming the probability of both microcytic and macrocytic anemias being present among the subjects tested, the degree of underestimation from microcytic anemias could be counterbalanced by the overestimation contributed by macrocytic anemias making the final estimation reflective of the Haitian population throughout the country. In addition, the magnitude of anemia and distribution of anemia severity was similar to the cited report where Haitian adults were also evaluated.²¹

The average of published male and female reference intervals were used in this study to generate the reference intervals because the study did not distinguish males and females. Papers that determined reference intervals using African populations were selected because Haitians are of African descent²² and some reports claim hemoglobin reference intervals differ between certain ethnic groups. Gender could not be distinguished from the de-identified specimens, so the reference interval represents the mean of the male and female reference intervals cited. The WHO criteria used to stratify anemia based on severity was the same for both males and non-pregnant females, so the cut-off values were applied directly from Table 1. The only exception to this was the interface between the upper end of the mild anemia reference interval (12.3g/dL) and the lower end of the non-anemia (normal) interval (12.4g/dL). The lower end of the reference interval used to determine mild anemia, created from published data, was greater than

the anemia cut-off value for each of the groups published by WHO (Table 1) except for men. We realize that men with hemoglobin values between 12.4-13.0g/dL could be erroneously classified as having mild anemia, but we believe an equal number of women and children with mild anemia may be classified as being non-anemic. Thus, these intervals represent a conservative estimate of mild anemia because women and children in Haiti seek medical attention more often than men.

We hypothesize that the group above the upper end of the reference interval (14.6g/dL) in Figure 1 may represent three distinct subgroups. First, the reference interval was averaged for gender, creating a falsely lowered upper end of the reference interval resulting in some normal males appearing to have elevated hemoglobin levels. Second, dehydrated individuals have a smaller plasma volume, causing a false increase in hemoglobin and hematocrit. Dehydration caused by limited potable drinking water and excessive sweating in a tropical climate are chronic situations that may result in overestimation of relative polycythemia and underestimation of anemia. Third, some in this group may represent primary polycythemia.

Conclusion

These findings corroborate the high prevalence of anemia in Haiti reported by others in the scientific literature¹⁹⁻²¹ and extend those findings to include adult subjects living in areas across Haiti. A total of 49.27% of our study population was anemic, classifying it as a severe public health problem in Haiti by WHO standards (Table 2).⁶ These findings contribute to the small library of existing knowledge about anemia prevalence in Haiti.

Future studies would involve determining the major causes of anemia in Haiti to include nutritional (iron deficiency, B₁₂/folate deficiency, protein deficiency); infections (parasitic, bacterial, malaria, TB, HIV); hemoglobinopathies; or hemolytic anemias.

Table 1. WHO criteria to stratify anemia based on hemoglobin levels (in g/dL).¹⁸ Criteria varies based on age of the individual. To form the criteria to stratify mild, moderate, and severe anemia for the study, we took the average of the reference values for non-pregnant women and men 15+ years old.

Population	NON-ANEMIA	ANEMIA		
		Mild	Moderate	Severe
Children 6-59 months	11.0 or higher	10.0 – 10.9	7.0 – 9.9	lower than 7.0
Children 11-15 years	11.5 or higher	11.0 – 11.4	8.0 – 10.9	lower than 8.0
Children	12.0 or higher	11.0 – 11.9	8.0 – 10.9	lower than 8.0

12-14 years				
Non-pregnant women 15+ years	12.0 or higher	11.0 – 11.9	8.0 – 10.9	lower than 8.0
Pregnant women	11.0 or higher	10.0 – 10.9	7.0 – 9.9	lower than 7.0
Men 15+ years	13.0 or higher	11.0 – 12.9	8.0 – 10.9	lower than 8.0
STUDY	12.4 - 14.6	11.0 – 12.3	8.0 – 10.9	lower than 8.0

Figure 1. Hemoglobin frequency and anemia stratification within Haitian study population. The graph is divided into severe, moderate, mild, normal, and polycythemic, with N being the number of individuals that fall into each category, and the percent being the percentage of the study population that falls into each category.

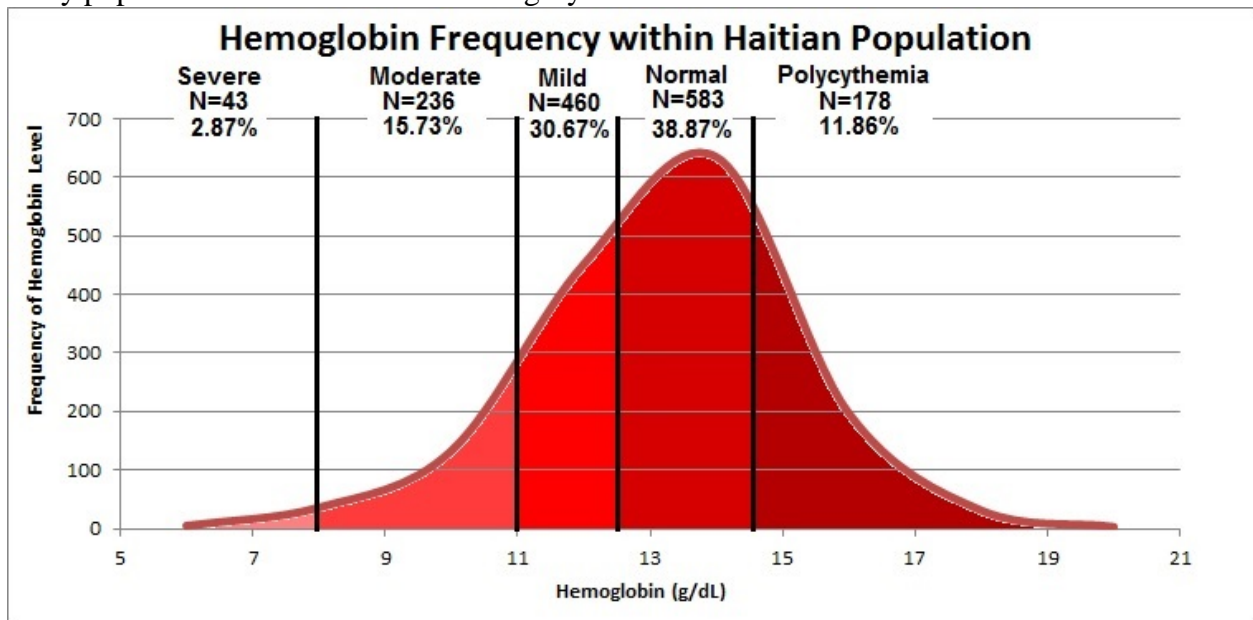


Table 2. WHO criteria for public health significance of anemia.⁶ The more prevalent the condition, the more severe it is seen as a public health problem within a population.

Prevalence of anemia (%)	Category of public health significance

≤ 4.9	No public health problem
5.0 – 19.9	Mild public health problem
20.0 – 39.9	Moderate public health problem
≥ 40.0	Severe public health problem