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A STUDY ON PREVALENCE OF IRON DEFICIENCY ANEMIA IN SCHOOL AGED CHILDREN 5 – 12 YEARS OLD IN BELIZE

By

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PREVALENCE OF IRON DEFICIENCY ANEMIA AMONG SCHOOL AGED CHILDREN 5 TO 12 YEARS OLD IN BELIZE

ABSTRACT

This study investigated the presence of iron deficiency anemia among school aged children 5 to 12 years old in the country of Belize. Data previously collected, but not compiled and analyzed by the Belize Ministry of Health was used in this analysis. Belize has been classified as a low-middle income country by the World Bank. A poverty assessment in 2009 found that 43% of the population of Belize was living in poverty. This indicated that almost half of the population could not afford to buy the proper nutritional foods that would allow them to have a healthy diet. As such iron deficiency, a micronutrient deficiency and its anemia could develop due to poor nutrition. Although the Toledo district has a documented malnutrition rate of 43.7% among its children, the highest rate in the entire country, and it has the highest poverty rate (67.3%), it was not the district with the highest rate of IDA. The highest prevalence of 47% was found in the Stann Creek district. The findings of this study revealed that IDA is a moderate public health problem with an average of 30% iron deficiency anemia rate among children 5-12 years old in the country of Belize over a five year period. There was no statistical significance found between male and females overall years. The rate of IDA decreased as the age increased except in 12 year olds. Thus the highest prevalence was found in 5 year olds consistently and 11 year olds had the lowest prevalence. With the exception of 2008, no statistical difference was seen in the prevalence of IDA from 2009 to 2012.

CHAPTER 1
INTRODUCTION

This paper is structured so that the reader could get an understanding of what IDA is and its effect on the population globally and in Belize. It commences with a statement of the problem in which the effects are presented and the implications for a poverty stricken country such as Belize which provides the rationale for undertaking this study. The second chapter deals with the current literature regarding IDA and the factors that contribute to its prevalence. It also elaborates the impact of IDA on different systems of a country. Chapter three discusses the BHIS system, the laboratories in Belize and the selection criteria for including and/or excluding data from the study. The results of the study are presented in chapter four in the form of tables and graphs. The final chapter is discusses the results particularly looking at trends across years in the data and comparison analysis of other low-middle socioeconomic countries similar to Belize. The conclusions about the study and areas for further research are also included in this last chapter. A list of the references is included next followed by the appendices.

Statement of Problem

Definition of Iron Deficiency Anemia

Iron Deficiency Anemia (IDA) is a non malignant hematological disorder that has a high global prevalence of 24.8% which has made it a significant contributor to the disease burden globally (WHO 2008). This hematological disorder has serious health implications for its sufferers. IDA is characterized as a red cell disorder due to insufficient iron resulting in defective and insufficient hemoglobin which impairs normal functions in oxygen transportation, cellular growth and red cell proliferation (Harmening, 2009, Chapter 6). The defective hemoglobin results from reduced amounts of iron available for insertion into the protoporphyrin-IX molecule of the two alpha and two beta chains of the hemoglobin molecule. Therefore, the body produces red blood cells that are smaller and paler due to the reduced production of hemoglobin. The oxygen transport function of hemoglobin is affected and patients develop anemia. Harmening (2009) defines anemia as "A condition in which there is reduced oxygen delivery to the tissues." In iron deficient anemia the root cause of this is a severe lack of iron caused by depleted iron stores which prevents normal hemoglobin synthesis.

Iron deficiency anemia could result from inadequate intake of iron in the diet, loss of iron due to hemolysis or blood loss either due to hemorrhagic conditions or infection with hookworms. Anemia can also result when the body fails to properly metabolize and utilize iron as is seen in some congenital defects such as glucose-6-phosphate dehydrogenase deficiency (WHO, 2001). The World health Organization (2001) also indicated that hemolysis due to malaria and deficits in other nutrients, e.g. vitamins A, B12, and C, and folic acid could also result in iron deficiency which could result in anemia.

Iron Absorption and Regulation

Iron is only obtained through diet and since the body does not have a mechanism to get rid of excess iron, the absorption of iron from food is highly regulated. This is a critical factor in maintaining iron homeostasis in the body. Iron absorption occurs in the duodenum by enterocytes which have ferroportin molecules embedded in the cell membranes. The ferroportin picks up the iron and transfers it to transferrin molecules in the plasma. Transferrin molecules then transport the iron to the cells that express transferrin receptor 1 molecules such as the erythroid precursor cells and hepatocytes (Li,

H. and Ginzburg, Y., 2010). These receptors are needed to bind the transferrin molecule in order for the iron to be exported across the cell membrane by divalent metal transporter 1 (DMT1) molecules. Mitoferrin then takes up the iron molecule once it is in the cell cytoplasm and transports it to the mitochondria in erythroid precursor cells. Once the iron is taken up in the mitochondria it is added to the protoporphyrin IX molecule, a hemoglobin precursor compound, to form heme (Munoz, M. et. al. 2012). In tissue cells a similar process takes place but the iron is used to form myoglobin instead of hemoglobin.

Iron absorption is highly regulated by the hormone hepcidin, systemically, and by iron responsive elements (IRE) with iron regulatory proteins (IRP) at the cellular molecular level. Hepcidin regulates iron absorption by binding to the iron export protein ferroportin to cease iron absorption from food by degrading the ferroportin (Hentze, M., Muckenthaler, M. Galy, B. and Camaschella, C. (2010). The IRE/IRP system regulate iron uptake posttranscriptionally by preventing translation of the mRNA for ferroportin and ferritin among other molecules while increasing the stability of the transferrin receptor 1 mRNA 3' region. Hence the IRE/IRP system is directly influenced by iron to decrease iron storage and transport in iron deficient situations and increase iron uptake by cells (Hentze, M., Muckenthaler, M. Galy, B. and Camaschella, C. (2010). Although systemic hepcidin regulation and cellular IRE/IRP system regulation are better understood, the mechanisms of iron regulation in mitochondria still require further study.

Function of Iron in the Body

According to the Centers for Disease Control (CDC) the recommended daily allowance of iron in children 4 to 8 years old is 10mg/day and for children 9 to 13 years old it is 8mg/day (http://www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html).

Sight and Life (2007) reported that an average of 25% of heme iron and 2 to 20% of non-heme iron is absorbed from food daily. Approximately 35mg of iron is recycled daily by the macrophages in the catabolism of senescent red cells (Beard, 2001). It is imperative for iron to be utilized efficiently through recycling since it is needed for many important functions in the body. Majority of the iron in the body is used for erythropoeisis since they are a part of the hemoglobin structure. Iron is needed for the production of adequate hemoglobin for the transport of oxygen throughout the body. Iron also functions in oxidative metabolism by acting as electron transporters in the cytochrome molecules within the mitochondria (Beard, 2001). It is also a component of the enzyme, myeloproxidase, found in neutrophils and is responsible for respiratory burst reaction to kill pathogens. Cellular immune response is also dependent on iron availability as reduced proliferation and function is seen in iron deficiency (Mun˜oz, M., Garcı ´a-Erce, J., Remacha, A., (2012).

Effects of Iron Deficiency Anemia

Due to iron's role in oxygen transport, ATP synthesis and immune response it is an important element that is needed to maintain good health. When iron is unavailable for heme synthesis less hemoglobin is produced and erythropoeisis is increased to compensate for the reduced hemoglobin. As a result iron deficiency leads to a hypochromic and microcytic (paler and smaller) red blood cells (Li, H. and Ginzburg, Y., 2010). This progresses to anemia where the individual experiences symptoms such a shortness of breath, fatigue, dizziness, headaches, chest pains and pallor. Signs of anemia in infants and young children may present as poor appetite, delayed growth and development, and behavioral problems (National institute of Health, 2011). On the other hand high levels of free iron are toxic to cells which also have debilitating health consequences.

Due to iron's role in oxygen transport in the hemoglobin molecule, oxygen diffusion in tissue by the myoglobin molecule, myelination of the spinal cord and white matter of the cerebellar folds, electron transport in cytochrome molecules and its role in mediating immune reactions through various mechanisms, iron deficiency can result in subtle but damaging outcomes (Beard, J.L., 2001). There are significant functional consequences of IDA in both children and adults that have been investigated and established. Friere (1997) highlighted the retardation of growth and cognitive development of IDA in children and the irreversible effects on psychomotor skills. IDA, said Friere, leads to significantly diminished language and fine motor coordination skills. In adults it has been documented that IDA leads to low productivity, fatigue and effects neurological, muscular and thermo-regulation functions (Friere, 1997). Clark (2008) reiterated the same effects of IDA in both pregnant women and children under the age of five. Clark added immune dysfunction, GI disturbances and infection with *H. Pylori* are also attributed to IDA. Numerous studies have also indicated low birth rate. The effects of IDA in infants, preschool children and pregnant women are well documented. However, Nokes, C., Bosch, C. and Bundy, D. (1998) discussed several studies that found that school aged children with IDA had attention and behavioral disturbances as well as poor performance on achievement tests compared to their non-anemic peers. Performance in school is probably one of the greatest impacts that IDA has on school aged children.

Diagnosing Iron Deficiency Anemia

Because of the short and long term effects of IDA it is imperative that it be diagnosed properly and early to yield better outcomes for those afflicted by the disorder. The WHO has outlined what constitutes IDA and the factors that affect these parameters such as age, sex, altitude, pregnancy and even ethnicity. As such IDA will be diagnosed and effectiveness of treatment monitored using the WHO (2001) criteria. Hemoglobin or hematocrit can be used to confirm or diagnose iron deficiency anemia in resource poor countries according to the WHO's (2001), *Iron Deficiency Anaemia: Assessment, Prevention, and Control: A Guide for Programme Managers*. This is because more robust and sophisticated methods may be too costly for routine testing in the clinical setting in resource poor countries and even more impractical in remote areas. For example in Belize, a complete blood count which includes hemoglobin and hematocrit tests costs less than US $5.00 while a ferritin tests costs approximately US $50.00 or more which is unaffordable, especially, to those who utilize the public hospitals and are not covered by the National Health Insurance plan (CML prices) which is 80% of the population.. Subsequently, the WHO recommends that a hemoglobin concentration less than 11.5g/dL in children 5 to 11 years old and less than 12.0g/dL in 12 to 14 year olds be considered as having anemia. Those having a hematocrit of less than 34% at age 5 to 11 and less than 36% at age 12 to 14 are also classified as having anemia. These values are the same for both males and females in these age groups; however, males and females above the age of 15 have differences in hemoglobin level. Altitude is another factor that affects all age groups. The WHO provides correction factors for every 500 meters above sea level (see WHO, 2001).

Serum ferritin, in the absence of infection, is the most specific test for detecting iron stores depletion and thus is the best indicator of iron deficiency according to the WHO. Ferritin is an acute phase reactant and thus must be measured in the absence of any infection or inflammation. Other tests such as erythrocyte protoporphyrin and transferring receptor can also be used in conjunction with the ferritin level to determine iron deficiency. Erythrocyte protoporphyrin will be elevated while serum ferritin will be reduced in iron deficient people. It is critical that this test be done in the absence of lead poisoning and other hemolytic conditions since erythrocyte protoporphyrin is elevated in these conditions. Transferrin receptors will also be increased as iron decreases. However, this test can give a false increase in those who suffer from hemolytic diseases (WHO, 2001). Transferrin saturation (Total Iron Binding Capacity) and mean corpuscular volume (MCV) can also provide more information in assessing iron status and anemia. Transferrin saturation decreases as iron availability is reduced while the MCV will be reduced as the red blood cells decrease in size. Furthermore, microscopic morphology of red blood cells of an IDA individual will reveal microcytic and hypochromic red cells.

Global Situation

Iron remains the most common nutrient deficiency globally (Clark, 2008). Iron deficiency anemia (IDA) is one of the most critical health disorders due to inadequate iron supply to meet the body's need.   IDA is considered a public health problem throughout the world (Stoltzfus, 2001). There have been countless studies conducted globally investigating IDA and its effects on the health of particular groups in the population. According to a report by the World Health Organization (WHO) and the Pan

American Health Organization (PAHO) in 1999, as cited in Stoltzfus (2001), over 2 billion people in the world are considered iron deficient of which over half suffer anemia. Stoltzfus (2001) stated "applying the 30% prevalence figure of DeMaeyer and Adiels-Tiegman to a new global population of >6 billion" estimated that "the number of iron-deficient people could be as high as 5 billion, or 80% of the world's population." This speaks to the magnitude of this global public health problem. Using this information it is likely that the prevalence of IDA will increase as world population grows.

Friere (1997) showed prevalence of IDA in over 50% of pregnant women, infants and children under the age of 2 years in poor countries. Stoltzfus (2001) referenced DeMaeyer and Adiels-Tegman (1985) saying "The authors tentatively estimated that ~50% of anemia in women and children is attributable to iron deficiency. Thus it has been empirically established that there is IDA problem among pregnant women and infants under the age of 2 years. Studies conducted in the Americas (North, South and Central America) have found that approximately 94 million people suffer from iron deficiency and or IDA (Friere, 1997). Although young infants and pregnant women are the most effected group for IDA, Friere (1997) also commented on the fact that there is a significant prevalence of anemia among preschool children aged 3 to 5 years, school-age children, and women of childbearing age.

Potential Contributing Factors to IDA in Belize

According to the *Living Standards Measurement Survey (LSMS)* report (2002), 33.5% of the population of Belize was below the poverty line and 10.8% were indigent and could not afford their basic food cost which was estimated at $1.73 USD/day. The report goes on to highlight the fact that 2 out of every 5 children (40%) do not have their basic food needs met. Not getting basic food requirements is one of the factors that lead to malnutrition and subsequently micronutrient deficiencies such as iron deficiency. A study of preschool aged children in Toledo in 1997 by the Ministry of Health (MOH) and Ministry of Education (MOE) found that 16.2% of these children were under nourished due to various contributing factors leading to nutrition insecurity.

Long term malnutrition according to WHO Working group (1986) as cited in MOH (2006) is reflected in low height for age or stunting. A national height census in 1996 for 6 to 9 year olds revealed that a 15.4% prevalence of stunting or retarded growth existed for the country. In some instances parts of the county such as the Toledo District found a 39% stunting among school children. However in 2002 the *LSMS* report indicated that the country of Belize had an 18% stunting rate in children less than 5 years of age with the district of Toledo reportedly having a 43.7% stunting rate in this age group (MOH, 2006). This is an increase from the 1996 study.

High country poverty rate, high malnutrition rate among children as evidenced by high prevalence of stunting nationally along with poor living conditions are major contributing factors for developing IDA. Thus it was expected that children in this study will also show a high prevalence of IDA, i.e. exceeding the 5% threshold set by the WHO.

Belize Health Information System and Lab Services

According to the *Basic Health Indicators of Belize 2010* there are a total of 126 Medical Technologists in the country who performed over 800,000 tests in that year. The Ministry of Health has on record 9 government (public) and 30 private laboratories operating in the country. The Cayo District had the highest number of private labs and the Toledo District did not have any recorded private lab. The Central Medical Laboratory (CML), the referral laboratory in Belize, and the STAT Lab at Karl Heusner Memorial Hospital (KHMH) were the only two public labs that utilized automated systems for hematology and chemistry testing at the time of data collection. All other public district labs used manual methods to carry out these tests. Unlike the differences in testing, all public laboratories were connected to and reported results using the Belize Health information System (BHIS). The BHIS system was implemented in all public health facilities including the laboratories in all districts across the country in 2008. Data was retrieved from all six districts for the period June 2008 to December 2012.

Purpose

This project was carried out to determine the prevalence of iron deficiency anemia in children aged 5 to 12 years old in Belize who utilized health services in the past five years. Although iron deficiency anemia (IDA) is a worldwide problem and has been well documented among pregnant women and infants throughout the world, there is very limited data in the country of Belize concerning the prevalence of the disorder. "With isolated exceptions, few countries have detailed national information on the prevalence of anemia" (Friere, 1997). This was highlighted in the article, *Strategies of the Pan American Health Organization/World Health Organization for the Control of Iron Deficiency in Latin America* by Friere (1997). This is true for the country of Belize. It has been shown that among lower socioeconomic classes the problem of iron deficiency with or without anemia is significant even among those who are not normally affected such as older children and adolescents (Odeh, 2006).

A study on prevalence of anemia among pregnant women in Belize in 1996 found that 51.7% of pregnant women were anemic. Anemia was defined as having a hemoglobin level less than 11g/dL of blood. This was an increase from 40.2% in 1988. In both of these studies it showed that Belize had a severe IDA among its pregnant women. The Food and Agricultural Organization (FAO) in 2003 published a report, "*Nutrition Country Profile*" for Belize in which they cited that Makdani, et. al. (1996) reported a national anemia prevalence of 19% among children between the ages of 2 and 8 years old. Although it did not indicate a severe problem of IDA in this age group, this study did show that 2 to 8 year olds were being afflicted with IDA. These are the only published data on iron deficiency anemia in Belize.

In an effort to gather more information on children in Belize as it relates to IDA this research investigated the prevalence of IDA among 5 to 12 year olds and sought to determine whether this prevalence is significant, exceeds 5% of the target population, according to WHO (2001) criteria for treating IDA as a public health problem. This study is important in light of the lack of data on IDA among this targeted age group and the need to implement interventions if there is a significant prevalence of the condition. Thus this study investigated the presence of this disorder among school aged children in the country of Belize using laboratory data of hemoglobin concentration results recorded in the BHIS for the past five years.

Assumptions/Hypothesis

In order to utilize the data from the BHIS in this study several assumptions must be made for the acceptability of the results. Thus the researcher made the following assumptions regarding the data in BHIS. Testing methods in all districts did not negatively impact results. Inaccuracies in protocol were minimal and did not affect lab results. Automated and manual methods produced statistically similar results. Recording and reporting in BHIS was accurate. Hemoglobin level was the most accurate measure to determine IDA in Belize. Preanalytical, analytical and post analytical factors were dealt with and did not impact results recorded in BHIS. All encounters for hemoglobin tests were recorded in BHIS and data was representative of the target population. Data was representative for all years analyzed. The researcher also made the assumption that iron deficiency anemia was the only cause for low Hemoglobin concentrations in the tested individuals.

Many of the studies done in the past used anthropometric data to make deductions about nutrition status. These studies were conducted on infants, mostly under 5 years old, and women. However, I believe that IDA is prevalent among children of Belize ages 5-12 years despite that they are not the expected susceptible group. There might be a significant prevalence exceeding 5% of the target population. This prediction is based on the reported statistics of malnutrition in the country based on anthropometric data as well as reports of poverty rate in Belize.

Limitations

Data were retrieved aggregated by type of tests from BHIS. As such no patient identifying information was used and unique patient codes were developed and used to identify duplicate test result in a day and in the year. The total clinical picture could not be assessed for each individual patient appropriately although attempts were made to compare the hematocrit and hemoglobin results. Also there was missing information since not all labs were utilizing the BHIS at the inception of the system. Quality of data may be affected due to deficiencies in the set up of the system and the misuse of the system beyond the control of the administrators of BHIS. Also there were a lot of missing data that could impact the value of the results. There was a lack of empirical data to use as cross reference for IDA in children in Belize; this was a major limitation to the study. There were no established national hemoglobin or hematocrit levels for children based on the population of Belize. Altitude differences across the country as well as ethnicity were not factored into the analysis of hemoglobin levels in this study. Generalizations must be made with caution since the data was for those children who utilized the public health facilities and may not be representative of healthy children.

Significance

This study is important to determine the prevalence of IDA in school-aged children in Belize because it will act as baseline data to identify the magnitude of the problem in this age group in Belize based on laboratory test data. With this information iron fortification programs can be assessed, decisions for allocations of funds can be made and policies regarding nutrition programs, health care facilities and other factors with far reaching implications on the health of the children can be implemented. Future research that may result from this study is to determine the impact of IDA on student's performance on the annual Primary School Examinations (PSE) which is taken by children age 12-14 years old.

CHAPTER 2

LITERATURE REVIEW

Economics and Iron Deficiency Anemia

WHO (2005) reported a world prevalence of IDA as 1.6 billion people which equates to a global rate of 24.8%. Twenty five percent (25.4%) of those suffering from IDA globally are from the category classified as school aged children. The WHO considers these rates to signify a moderate public health problem. For the categories of preschool and women of child bearing age, Belize has been classified as having a moderate public health problem. However, there are regions such as Africa whose pre-school age children are classified as having a severe problem due to prevalence of anemia exceeding 40% of the age group. In the case of Belize, only the subgroup of pregnant women falls in the severe category for IDA which is a result of 51.7% being identified as IDA sufferers (MOH, 1996).

With such high prevalence the global economic burden of IDA is significant and has far reaching implications for countries in terms of funding healthcare systems to diagnose and treat IDA patients. This task is made even more complex due to the various causes of IDA besides inadequate nutrition. These are documented in Clark (2008). Clark stated, "From a clinical perspective, IDA can be relatively isolated … or it can be a by-product of chronic disease … the actual diagnosis of IDA can be problematic." Therefore, it is critical to identify the cause of IDA in order to execute proper treatment (Clark, 2008). From an economic stand point this is imperative to reduce the cost of diagnosing and treating IDA patients.

Costs of IDA also comes indirectly to provide services to diagnose and treat slow cognitive development in children as well as days lost from work or decreased productivity due to the effects of IDA, whether it is a primary or secondary clinical condition (Horton and Ross, 2003). Horton and Ross (1998) estimated an annual economic loss of 4 billion dollars in South Asia attributed to iron deficiency. Belize, as a developing country, cannot sustain economical losses due to the various impacts of iron deficiency and its anemia which according to Horton and Ross (1998) can be as high as 0.9% of annual GDP in some countries.

Although there are no direct figures to correlate the economic cost to Belize's economy due to IDA there are general observations of low productivity and economic losses due to "sick" days that also provide useful information. The *LSMS* (2002) reported that people were ill on an average of 8 days and could not perform regular duties for an average of 4 days in a 30 day period. The *Country Cooperation Strategy 2008-2011* Report by PAHO (2009) showed that productivity lost days doubled from 1995 to 2003 from 35,430 to 70,000 days indicating high rates of injuries and/or disease. However fast forward to 2011 and the *Social Security Board Annual Report* (2011) recorded 237,741 days claimed for sick benefits. Although these statistics do not identify IDA as a cause of the recorded loss of productivity and reason for sick claims it is not far reaching to attribute some of these to IDA since the effects of the condition is fatigue, weakness and tiredness which leads to unproductivity.

Indirect cost of IDA due to low productivity and sick claim benefits is something to be further investigated in Belize. On the other hand there are direct costs that can be attributed to IDA in that the GOB is spending directly on iron supplement to prophylactically address the problem after the study on *Iron Deficiency Anemia in*

Pregnant Women in Belize (1996) determined a rate of 51.7% in this group. This proactive approach was in accordance with the recommendations from *Strategies of the Pan American Health Organization/World Health Organization for the Control of Iron Deficiency in Latin America* (1997). Other countries that are classified as lower middle income economy like Belize have also implemented supplemental programs to address the problem of IDA. Countries such as Tanzania with a 77% prevalence, Ghana with 41% and Indonesia with 28% IDA prevalence have also implemented supplemental programs to reduce the prevalence of IDA (Partnership for Child Development, 2002).

Partnership for Child Development (2002) estimated the cost of such programs at US $0.70 per child per school year for fortified biscuits for children in South Africa. Bundy, D. et. al. (n.d.) estimated an annual per capita cost of US $0.10 for iron folate supplementation alone in a school based intervention program. Both reports expressed that the outcomes of such school based programs, i.e. improvement in academic performance and attendance at school, make them very cost effective. As mentioned before, Belize has an iron supplement program for infants and pregnant mothers that was implemented in 1999 and a flour fortification program that was legislated in 2006, however the cost of these programs were not documented in the sources which reported them (PAHO, 2009). Belize also has annual school based deworming and vitamin A programs, which improve iron status as well, however the sources consulted did not provide the estimated cost of these programs. Nonetheless, they are a direct financial burden to the government.

The economic problem of IDA is not unidirectional in terms of costs for diagnosis, treatment and prevention. The economic status of a country or a family can also have a direct impact on the prevalence of IDA, making this a vicious cycle for under developed and developing countries. Alaimao et. al. (2001) investigated food insufficiency, family income and the impact on the health of preschool and school aged children in the United States. The outcome of this study revealed that children from low income families were more likely to have food insufficiency and therefore had iron deficiency. It is established that children of any age group from low income families are more likely to suffer nutritional deficiencies.

Belize has been described as a lower middle income country by the World Bank (http://data.worldbank.org/country/belize). However, the *2009 Country Poverty Assessment Report* for Belize showed that the country has a 43% poverty rate. This is a 10% increase from that reported in the *LSMS* (2002). Therefore this proves that there are many people who cannot adequately provide their minimal needs such as a basic food basket. This then leads to malnutrition of children and adults which has been correlated with higher prevalence of iron deficiency anemia (Alaimo, Olson, Frongillo and Briefel, 2001). The socioeconomic status and the few national data that has been compiled showed that the children in District of Toledo have the highest rate of malnutrition, 43.7%, which is higher than some countries of similar economic status as Belize. There are studies in countries with similar economic classification as Belize which has found increased prevalence of IDA among school aged children. For example, Leenstra,T., Kariuki, S.K., Kurtis, J.D., Oloo, A.J., Kager, P.A. and Kuile, F. (2004) conducted a study on school girls in Kenya ages 12 -18 years old and found that there was a 30.4% iron deficiency anemia rate among those study participants.

Odeh (2006) also conducted a study in similar age groups and found a significant prevalence (14%) of IDA among school children between the ages of 6 and 18 years. Alaimo, K., Olson, C.M., Frongillo, E.A. and Briefel, R.R. (2001) found that school age children from low socioeconomic background had a higher prevalence of iron deficiency (5.6%) compared to those of middle (2.9%) and high (0.7%) income levels. Food insufficiency did not show a significant difference (3.9%) in iron deficiency compared to those who had sufficient food (3.4%). Parasitic infections, chronic inflammation or illness and food insecurity are realities of low socioeconomic classes and they contribute to the development of IDA (Clark, 2008).

Based on model presented in: *Strategy for Improved Nutrition of Children and Women in Developing Countries*, a UNICEF Policy Review, low-income means not being able to access fortified foods which is compounded by poor sanitary conditions and improper disposal of human waste which increases the likelihood of bacterial and parasitic infections due to contamination of freshwater with infectious larvae. Poor healthcare access and infrastructure may also add the problem of IDA (Pasricha et. al., 2013).

Health and Iron Deficiency Anemia

As with the economic aspect of IDA, the health factors of IDA are also a bidirectional phenomenon. IDA is caused by health risk factors and it in turn impacts the health status of an individual. IDA is caused by nutritional deficiencies when adequate amounts of iron rich foods are not consumed due to the factors that lead to malnutrition such as economic status as discussed above. The health of an individual is directly impacted by the types of food that they consume. Therefore, the type of iron, whether heme or non-heme available in the food source; the presence of inhibitors such as phytates that are found in whole grains and legumes; and polyphenols found in tea, coffee and spices as opposed to enhancers such as ascorbic acid; all influence the absorption of iron from food sources and thus affects the health of the individual by lowering their iron level (Balarajan, Y., Ramakrishnan, U., Özaltin, E., Shankar, A., Subramanian, S., 2011).

Furthermore, IDA can be a result of poor health within the individual as discussed before. For example, deficiency of iron can occur due to physiological problems within the intestines. The presence of hemoglobinopathies and defects in the regulation of iron by TMPRSS6 can also affect the iron availability for erythropoeisis.

While poor nutrition leads to poor health, probably the single highest contributing factor to IDA is parasitism and other infectious diseases. Chronic blood loss is experienced due to GI tract bleeding in hookworm infestation while intestinal and genitourinary bleeding results from infection with some Schistosomes. Leenstra (2004) documented the significance of IDA in young females -12 to 14 years old-with *S. mansoni* infection while Haidar (2010) found no effect of mild parasitic infection on IDA in women 15 to 49 years old. Resistance to iron absorption may be seen in Helicobacter pylori infection which produces peptic ulcers. Other chronic infections lead to unavailable iron stores that are accumulated in macrophages. It is believed that during malarial infection iron absorption and utilization for erythropoeisis is impaired (Pasricha, S.R., Drakesmith, H., Black, J., Hipgrave, D. and Biggs, B.A., 2013).

Besides poor health conditions, physical changes in children as they develop also affect their iron level. Iron stores also quickly deplete in growing children and adolescents who undergo physiological and physical changes which demand higher levels of iron. For example Pasricha, S. et. al.(2013) reported that adolescent males experience an expansion in hemoglobin and muscle mass while girls have their menarche both of which increase iron requirements and potentially lead to low iron levels.

While preexisting health conditions and developmental demands can create an environment conducive to the progression of IDA, IDA in itself has its own deleterious effects on the health of its sufferers. There are significant functional consequences of IDA in both children and adults that have been investigated and established. Friere (1997) highlighted the retardation of growth and cognitive development of IDA in children and the irreversible effects on psychomotor skills. IDA, said Friere, leads to significantly diminished language and fine motor coordination skills. In adults it has been documented that IDA leads to low productivity, fatigue and effects neurological, muscular and thermo-regulation functions (Friere, 1997). Clark (2008) reiterated the same effects of IDA in both high risk populations. Clark added immune dysfunction, GI disturbances and infection with *H. Pylori* are also attributed to IDA. Numerous studies have also indicated low birth rate.

In a study done by Bandhu R., Shankar N., and Tandon O.P., (2003) they found that "… IDA children lagged behind the control children in terms of anthropometric parameters and they benefited relatively more in terms of anthropometric improvement and hematological improvement after iron supplementation." Children who received iron supplements (Ferrous iron 3-4 mg/kg body weight/day) for 90 days showed improvement in their hematological values. The anemic girls showed an increase in height, weight and body mass index greater than any other group. There was greater improvement in hematological factors for both the anemic girls and boys than for their respective control groups in this study. This study concluded that psychomotor skills are also adversely affected by IDA in children. Researchers used the Denver II Developmental Screening Test to detect early developmental delays, in infants who had iron deficiency and or iron deficiency anemia. They found a higher percentage, 67.3% of abnormal values in children suffering from IDA as compared to only 21.6% in children with iron deficiency alone (Pala E., Erguven M., Guven S., Erdogan M., and Balta T., 2010). Another study, Lozoff B., Armony-Sivan R., Kaciroti N., Jing Y., Golub M. and Jacobson SW. (2010), found that eye blinking rate is lower in IDA children due to reduced dopamine function. Dopamine has important functions in movement regulation, motivation, cognition, and hormone release. In rodent models it was discovered that iron deficiency affects the dopamine and the hippocampus systems.

The effects of IDA in infancy and early childhood have lasting effects that are irreversible. Beard, J.L. (2008) reported that “the data in human infants are consistent with altered myelination of white matter, changes in monoamine metabolism in striatum, and functioning of the hippocampus.” During gestation and lactation persistent iron deficiency into adulthood was observed in rodent models despite restoration of iron status at weaning (Beard, J.L. 2008). These studies suggest that gestation and lactating periods are critical where long lasting effects of iron deficiency develop. This is evident in the neurocognitive impact that is seen in young adults who performed less well on frontostriatal-mediated executive functions, including inhibitory control, set-shifting, and planning who suffered chronic, severe iron deficiency in infancy. These subjects also exhibited impairment on a hippocampus-based recognition memory task (Lukowski, A.F., Koss, M., Burden, MJ., Jonides, J., Nelson, CA., Kaciroti, N., Jimenez, E. and Lozoff, B., 2010).

Peirano, P.D., Algarín, C.R., Chamorro, R., Reyes, S., Garrido, M.I., Duran, S., and Lozoff, B. (2009) also attributed iron deficiency to slower neural transmission in the auditory system in infants and slower transmission in both auditory and visual transmission at preschool age. These effects were seen after 1 year of iron therapy. Motor activity patterning and sleep states organization showed differences in all sleep-waking states in children with iron deficiency. This also highlights the irreversibility of the effects of iron deficiency and its anemia. Motor skills are also affected by IDA as was demonstrated in the study on infant motor development by Shafir, T., Angulo-Barroso, R., Jing, Y., Angelilli, M.L., Jacobson, S.W. and Lozoff, B., (2008). The study found poorer motor function among iron deficient infants with or without anemia compared to the iron sufficient groups. The researchers utilized the Gross motor developmental milestones, Peabody Developmental Motor Scale, Infant Neurological International Battery (INFANIB), motor quality factor of the Bayley Behavioral Rating Scale, and a sequential/bi-manual coordination toy retrieval task. In another study the same group of researchers found that iron deficiency also adversely impacted social and emotional behavior in infants.

Education and Iron Deficiency Anemia

Perhaps the most significant effect of IDA in the target population of this study is its impact on cognitive development and performance in school aged children. Insufficient iron intake leads to alterations in morphology, neurochemistry and bioenergetics which may delay the development of the central nervous system significantly (Beard, J.L. 2008). Numerous studies have shown that the effects are life-long even after iron levels have been restored. Therefore iron deficiency and IDA tremendously impacts school performance of children. Halterman, J.S., Kaczorowski, J.M., Aligne, C.A., Auinger, P. and Szilagyi, P.G. (2001), demonstrated lower standardized math scores among iron-deficient school-aged children and adolescents, including those with iron deficiency without anemia in the United States. A study done as far back as 1985 found statistically significant differences in achievement scores in children after iron treatment for IDA (Soemantri, A.G., Pollitt, E. and Kim, I., 1985). The poor performance of iron deficiency anemic children, not performing to their full potential, is a result of the neurological and cognitive effects of iron deficiency and its anemia.

Implication for Belize

Empirical data has shown that IDA is a global problem and it has far reaching economic impact for countries in terms of funding healthcare systems to diagnose and treat IDA patients according to the underlying cause of the clinical condition or conditions that result from IDA. Belize is no doubt making large investments addressing the healthcare needs of patients who are actually sufferings from IDA, in my opinion. However, due to lack of empirical data regarding the condition the exact cost cannot be calculated. The 2011 health statistics of Belize indicated that 1.9% of the country's GDP was spent on health (http://www.indexmundi.com/facts/belize/health-expenditure). It would benefit the policy makers to know the exact cost of IDA on the health system of Belize in all age ranges. The health burden of IDA can be a substantial economic burden across all public services. The problem may be exasperated in areas where the poverty rate is extremely high and malnutrition is also above national average.

The education sector is impacted the most for the targeted population of this study. In Belize the national Primary School Exam (PSE) has seen consistently low results in Math and English indicating that the children are not gaining the proficiency that they should in these subjects by the time they finish their primary education. The "Primary School Examination Preliminary Result" (2012) report shows that 60%, of the 6983 students who sat the exam country wide, performed below the satisfactory level of 60-69% for the math portion. Twenty nine percent of the students scored in the competent level (70-79%) or excellent (80-100%).   While for English only 20% of the students performed competently and a mere 6% did excellent. The report also indicates that there has been little change in the trend of the mean scores for Math and English over a 10 year period from 2002-2012. It is important to note that the district of Toledo, which has the highest reporting malnutrition rate and poverty rate, had the lowest mean scores out of all districts for the sections of the subject tests in Math, English and Social Studies. For Science the Stann Creek district, which has a 25% poverty rate, had the lowest average scores.

Given Belize's high poverty rate and the scientific research which supports the negative effects on cognitive development by IDA, the results of the PSE may be partially due to long term effects of IDA in these children. Therefore, further studies can be conducted to see if there is a correlation between IDA prevalence and performance on the PSE in Belize.

CHAPTER 3

METHODOLOGY

The data were from children who visited the health facilities and therefore there is an inherent bias in the results. The data analyzed was probably not indicative of the true situation in healthy children who did not seek medical services within the last five years. The data was analyzed to determine the prevalence of iron deficiency anemia among the total population of children who visited the health facilities and obtained a hemoglobin test within the last five years.

This study utilized information on test results from the Belize Health information System (BHIS). Both test orders and results are entered into BHIS for every encounter that a patient has at a public health facility which are available in all six districts. The Biostaticians at the Ministry of Health's Epidemiology Department entered data searches based on the criteria of age, test and year. Data on the hemoglobin level of the 5-12 year olds from 2008 to 2012 was compiled. Other test values such as hematocrit, mean corpuscular volume (MCV), iron levels, ferritin and CRP were evaluated where provided as additional or supporting information.

Identification information was not retrieved nor used in the analysis of the results. However, special codes were developed by the Biostaticians for each patient so as to be able to clean the data of duplicate cases. Therefore, the data was evaluated and subsequently cleaned of duplicated tests per patient code. The data was analyzed using the Statistical Package for Social Sciences (SPSS) version 19, 2010. The first test for hemoglobin and hematocrit for the year was selected for the analysis for IDA. This was done by aggregating the data by patient code and result date and year and choosing the minimum date and the first result. This was to ensure that only one patient is counted for the year in order to determine prevalence for the year. Results that were outliers were excluded. For hemoglobin any value below 1 and above 18 g/dL were excluded while for the hematocrit any value below 5% (0.05L/L) and above 54% (0.54 L/L) were excluded. The exclusion criteria were set at the upper limit of normal for adult males due to wide variation in the results recorded.

The data was then analyzed to determine IDA prevalence by selecting all the cases that had a hemoglobin result of <11.5g/dL for children between the ages of 5-11 years old and <12.0g/dL for 12 year olds according to WHO recommendations for classification of IDA. Once these IDA cases were selected they were further analyzed to find out the prevalence for each year. This was done by determining the frequency of results that satisfied the IDA criteria for the year and divide it by the total number of hemoglobin tests for the year multiplied by 100. A trend analysis was done using line graphs. The relationship between gender, age and district was determined by conducting a chi square test analysis on disaggregated data. This showed the likelihood and the statistical significance between the children suffering from IDA and these variables. Furthermore, those identified as having IDA by hemoglobin concentration results were further categorized into levels, mild, moderate or severe, using the WHO (2011) recommended values (see appendices Table I).

The hematocrit test results were also cleaned and analyzed to see if it would reflect the same prevalence rate as those classified as IDA based on hemoglobin cut-off values and those who had a low hematocrit value. A hematocrit value of <34% (0.34 L/L) for 5-11 year olds and <36% (0.36 L/L) for 12 year old was used to determine the fit of the two tests for those who were classified as IDA. A correlation was also done between the two tests using all results.

The percentage of target population identified with IDA in this study could not be applied to the total population of Belize for the age group 5-12 years old to determine the prevalence of IDA in the country because the sample was not randomly chosen among healthy school-age population.

Sample

The sample is a convenient sample using secondary data reported in the BHIS system. Children ages 5-12 years old in the Belize who visited the public health facilities, where BHIS is available and being utilized, over the past five years and who have had a hemoglobin test result reported in BHIS. The age group between the ages of 5 and 12 years was chosen because there is virtually no information on this group for any nutritional deficiency in Belize. This age group has also had little attention in global studies for IDA and therefore, it is intriguing to find out if they are just as susceptible as young infants and pregnant mothers to developing IDA in poor developing countries like Belize. Therefore to be included in the sample the child had to be between the ages of 5 and 12 years old and had to have a hemoglobin test done between 2008 and 2012 at a public health facility which utilized the BHIS system to report results. The same is true for other tests that were retrieved as supporting data such as the hematocrit, MCV, CRP, Ferritin and Serum iron. Children outside the age group were not included as well as children who visited private health facilities. Children who visited the public health facilities and who did not have a hemoglobin test done, or any of the supporting tests, were not included in the study. Children who visited a public health facility where BHIS was not in use in the years analyzed were not included in the study.

Location

Belize is a third world developing country, as assessed by the World Bank. Geographically it is in Central America but is also included in the Caribbean demographically and historically. Geologically, Belize is below the Tropic of Cancer but above the equator (Cubola Productions, 2011). Hence, the country experiences tropical climates and have the dry season from March to May and the wet season from June to November (Cubola Productions 2007). The hurricane season starts June 1st and ends November 30th. The political map of Belize shows that the country is divided into six districts; From North to South there is Corozal, Orange Walk, Belize, Cayo, Stann Creek and Toledo. The people of Belize are a mixture of Mestizo, Mayan, Creole, Garifuna and other minor groups such as the Mennonites, Chinese and East Indians.

Each district has a unique blend of different ethnic groups. For example in the Belize district it is mostly Creole people while in the Cayo, Orange Walk and Corozal districts there are mostly Mestizos. In the Stann Creek district there is also the majority being Mestizos, however, this district also has the highest population of the Garifuna ethnic group. The Toledo district is mostly made up of Maya ethnicity followed by the Mestizos (SIB, 2013). The culture of each ethnic group greatly influences the type of food that they eat. For example In the Belize district the main food is rice and beans with chicken and potato salad or coleslaw. Ground food such as yam, cassava and sweet potato are also a part of the Creole culture. In the districts where the Mestizos are majority the main foods are corn based such as tamales, panades, salbutes, tacos, corn tortillas and beans, escabeche, bollos, and relleno. Where Garifuna people are a large part of the population there will be foods such as fish, plantains, cassava, coconut and other ground foods. The Mayas main diet consists of corn which is used to make tortillas, tamales, and porridge, beans, game meat, chicken and pork. (Cubola Productions, 2007)

Agriculture is Belize's most important industry since it brings in income for the country and provides food as well. Therefore, the major industries in Belize are agriculture based. The type of agriculture is influenced by the landscape of Belize as some areas are flat and others are high as in the Mountain pine Ridge area in the Cayo district. For example in the Corozal district the sugar cane and papaya industries are the main source of income while in the Orange Walk district the sugar cane is also the main export crop produced. For this reason, Orange Walk is called the "Sugar city". The Belize district has a variety of industries such as cattle, fisheries, tourism and manufacturing goods (Cubola publications, 2011).

Belize City has the highest population of people living in urban areas compared to other districts where the majority of the population lives in rural areas, Cayo district being split 50-50 (SIB, 2013). In Cayo district the main industry is cattle and citrus while in the Stann Creek district citrus and banana are the main income earners. The Toledo district produces a lot of rice, cocoa and some banana (Cubola, 2011). This Toledo district also has the highest proportion of its population living in rural areas and it is seconded by the Corozal district (SIB, 2013). Tourism is an important service industry in Belize and earned approximately 21.4% of the country's GDP in 2006 (Cubola

Productions, 2007). Tourism has consistently brought in more revenue than agriculture (13% of 2012 GDP) industry. The establishment of the Belize Natural Energy company and its revenue (3.1% of GDP for FY 2011/12) from oil found in Belize was also a major income earner for the country in recent years (Central Intelligence Agency, 2013; Ministry of Finance and Economic Development, 2012).

The health sector also differs from district to district. Belize district still has the most medical centers with 14 reported in 2010 while the Toledo district had only 4 health centers (MOH 2010). The other districts reported 5 public health centers with the exception of Stann Creek which had 7. Medical testing in the districts also varies due to the lack of automated analyzers to determine hemoglobin concentration. The Central Medical Lab was the only facility that did automated testing; all others carried out hemoglobin test manually using the cyanmethemoglobin method and determined results spectrophotometrically. The difference in test methodology is a significant factor in the quality and reliability of the results.

Design

The study was designed to be a prevalence study for the entire country of Belize. It is reported that the BHIS covers 80% of the population of Belize. Thus data in BHIS was compiled from laboratories across the six Districts in the country. This research was a population study to determine the prevalence of IDA in children who visited the health facilities 2008-2012 which will be applied to the entire population of Belize's children who are ages 5 to 12 years old.

Procedure

The data was limited to June 2008 to December 2012. The age of the participant was the primary filter and test result for hemoglobin was the primary criteria for determining IDA. Hematoctrit, iron and/or ferritin and/or CRP were extrapolated to support the data. Iron deficiency anemia was diagnosed using the WHO (2001) criteria. Therefore, those children who had a reported hemoglobin level below 11.5g/dL in 5 to 11 year olds or 12.0 g/dL in 12 year olds were assessed as having IDA. Results that fell below 8.0g/dL were classified as having severe IDA, those between 8.0 and 10.9g/dL were classified as having a moderate IDA, while values between 11.0 and 11.4 for 5 to 11 year olds or 11.9 for 12 year olds were classified as mild IDA. Those with hematocrit levels below 34% in 5 to 11 year olds and 36% in 12 year olds (0.34 L/L and (0.36 L/L), respectively, were classified as having iron deficiency anemia. Other indicators in the target group were assessed where available such as serum iron level <50ug/dL, ferritin level, MCV <80fL and CRP positive test results.

Data analysis was done in SPSS. Frequency tables were produced and Chi square analysis was performed to find out statistical significance between variables, i.e. whether those identified as having IDA were more likely to come from a particular group or area. Time series analysis using line graphs was done to determine yearly trends. Correlation test was done to determine the correlation of results between hemoglobin and hematocrit test results for the same patient. Missing data were not included in the analysis.

Instrumentation and Analysis

The Central Medical Laboratory (CML) in Belize City, Belize District, utilized the Abbot Laboratories', Cell-Dyn Ruby 3700 hematology analyzer to conduct hemoglobin testing and all other red cell indices such as hematocrit and MCV. CML also utilized the

SelectraE to carry out chemistry analysis on serum specimens. The Beckman Coulter Ac- T diff^{TM} counter was used at the Karl Heusner Memorial Hospital (KHMH) STAT laboratory. This laboratory carries out all hematological testing and chemistry testing for inpatients and accident and emergency patients. Outpatients are referred to the CML for lab testing. Harmening (2009), reports that the Cell-Dyn Ruby 3700 analyzes hemoglobin by a modified hemoglobin cyanide method which measures light absorbance at 540nm. The result is a direct measure of hemoglobin and hematocrit is calculated from the measured parameters.

The Beckman Coulter hematology instrument utilizes the cyanmethemoglobin method and measures hemoglobin concentration directly by light transmittance at 525nm wavelength. The hematocrit is also calculated based on measured parameters on the Beckman Coulter instrument. In all other districts hemoglobin was measured manually using Drabkin's reagent (cyanmethemoglobin method). Hemactocrit was derived manually as well in all other district laboratories using the spun hematocrit and hematocrit card reader. Serum iron and ferritin were analyzed using the SelectraE chemistry analyzer by spectrophotometric methods. No other district lab provided serum iron and ferritin tests due to the lack of chemistry analyzer. Chemistries were done by manual spectrophotometric methods in all other district labs.

CHAPTER 4

RESULTS

This section shows the results of the analyses done on the data gathered from MOH. It was observed that for all analyses, 2008 data, and to some degree 2009 also, deviated from the other years and this could be attributed to the incompleteness of the data that was available for that year. The results showed that there was an increase in the number of tests done from year to year for all tests. Below (Table 1) is a summary of the total number of tests for each test done by year and it depicts the observations mentioned above. This table was included to indicate the volume of tests that were done each year in the public health laboratories in Belize for the time frame of this study. However, the primary test for identifying possible cases of iron deficiency anemia was the hemoglobin test. Therefore, subsequent tables and graphs will focus on the hemoglobin test.

Table 1

Number of Tests Reported for Each Year 2008-2012

	Year					
Test	2008	2009	2010	2011	2012	Total
CRP	8	25	44	56	52	185
Ferritin	0	0	0	1	1	2
Hematocrit	184	1227	2935	3400	3850	11596
Hemoglobin	**184**	**1222**	**2887**	**3327**	**3881**	**11501**
MCV	21	34	23	5	24	107
Serum Iron	0	1	1	2	3	7

Of the 11501 hemoglobin tests that were done over the 5 year period, 9130 were found to be first hemoglobin test for the year and these tests were used for analysis. Therefore, 2347 tests were repeated tests within the year for existing patients, 165 of these were repeated on the same day. A small number, approximately 24 tests results fell outside the cutoff value of 1-18g/dL of hemoglobin across the 5 years and thus were excluded from analysis. Fourteen percent (14%) or 1307 of the 9130 first visits for the year were patients who had a hemoglobin test done more than one year -returning patients- they were identified as duplicated across years. Out of the 9130 first hemoglobin test for the year, 31.3% - 2859 cases over 5 years combined- were found to be below the normal hemoglobin value. Thus these were classified as having iron deficiency anemia. Sixty eight point seven percent (68.7%) of the total did not meet the requirements to be classified as having IDA.

Table 2

Frequency of IDA and Non-IDA cases for Each Year 2008-2012

Classification	Year				
	2008	2009	2010	2011	2012
IDA (*n* = 2859)	49	255	804	721	1030
IDA (%)	28.5	24.1	33.9	28.8	34.1
Non- IDA(*n* = 6271)	123	801	1568	1785	1994
Non-IDA (%)	71.5	75.9	66.1	71.2	65.9
N = 9130	172	1056	2372	2506	3024

A Chi-Square test result (p = .001) indicated that there was a statistical difference across the years for those identified as having IDA. However a general trend of decrease then increase was seen over the five year period. In 2009 the lowest rate was seen (24.1%) and in 2012 the highest prevalence (34.1%) was found (see Table 2 above).

There was no statistical difference over all the 5 years combined for the occurrence of IDA in males or females. This was indicated by a Chi Square test (p = .269). Of those classified as having IDA 46.9% were females and 53.0% were males. However between years there was a difference in males and females having IDA (see Figure 1 below).

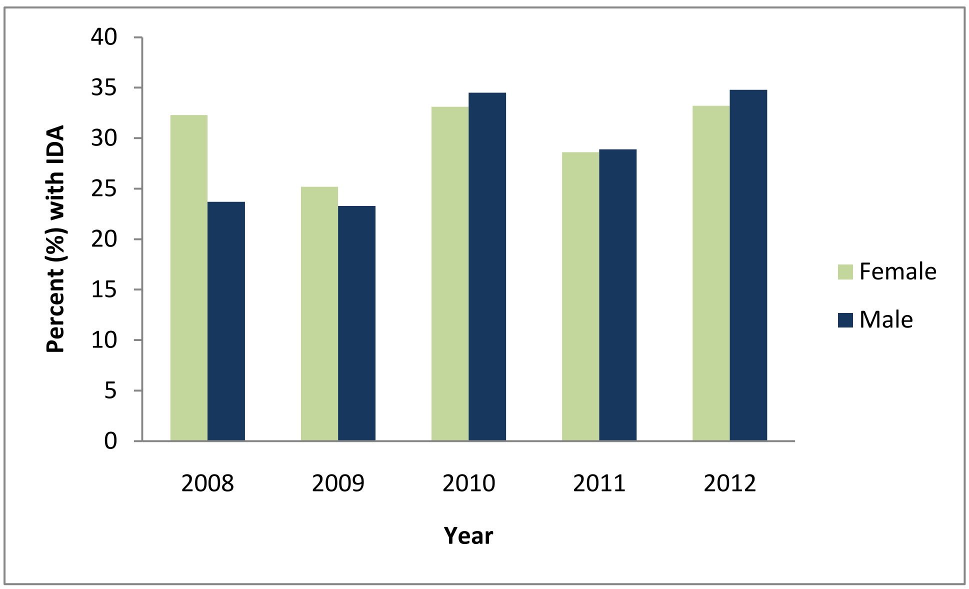

Figure 1. Percentage of females vs. males who are classified as having IDA for each year 2008-2012 within gender groups.

Note. Two indeterminate genders were reported for 2010 and were not included in the analysis for gender.

The percentage of males compared to females was not much different for each year, however, they seem to rise and fall from year to year in sync with the exception of 2008 where females seem to have a higher rate of IDA than males. Males and females had the highest prevalence of IDA in 2012, 34.8% and 33.2% respectively while both showed the lowest prevalence in 2009, 23.3% and 25.2% respectively. These were calculated within gender groups based on all the males and all the females within a given year that had a hemoglobin test done.

When compared to all those who had a hemoglobin test within a given year males showed a slight difference from 2009 to 2012 with generally higher prevalence than females (Figure 2 below). The year 2008 is an exception where females almost had twice the rate of IDA than males. A Chi Square analysis result ($p = .02$ and $p = .001$) indicated a statistical difference within females and male gender groups respectively between years.

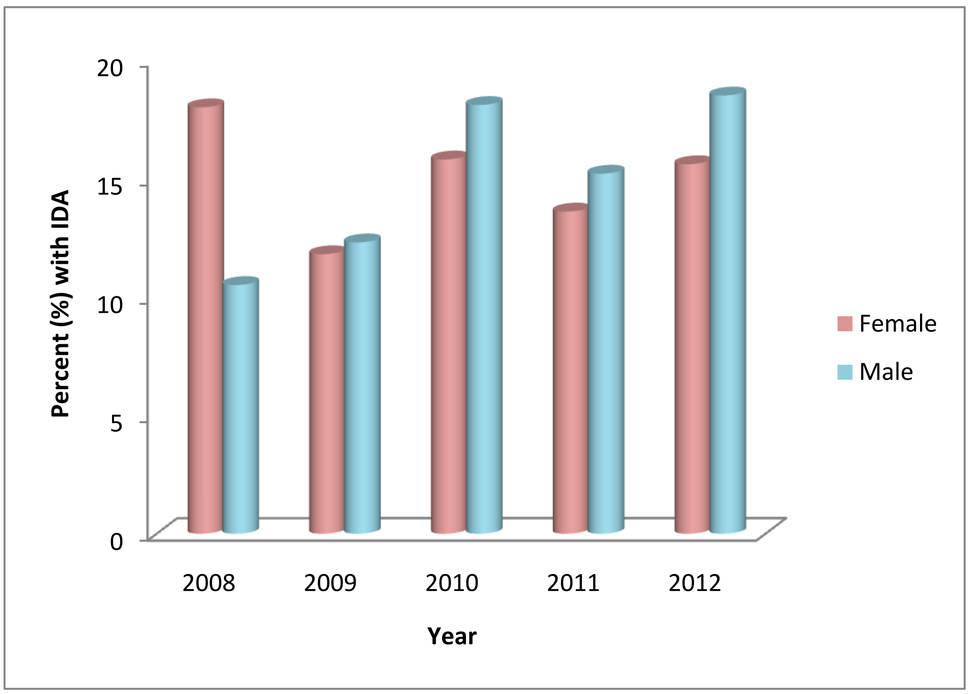

Figure 2. Percentage rate of IDA for females and males out of all hemoglobin tests performed from 2008-2012.

There was also a statistical difference found within age groups; 5, 6, 7 and 11 year old had a Chi Square value of .00, .014, .005 and .038 respectively. All other age groups had no difference within age group across years. Generally 5 year olds had the highest prevalence of IDA within age group with the exception of 2009 (28%) and 2010 (41%) (Figure 3 below). In those two years 6 year olds had the highest prevalence of IDA (33% and 42%, respectively). Twelve year olds did not fit the general trend of decreasing IDA prevalence as age increases across years as seen for the other age groups. More cases were included in this age group since it had a higher normal value of 12 g/dL while all others were cut off at 11.5 g/dL. The highest rate of IDA in 12 year olds was seen in 2010 with a prevalence of 35.2% within this age group for that year. Forty nine percent (49%) of 5 year olds were classified as IDA in 2012, a sharp increase from the previous 2 years at 40.7% in 2010 and 40.3% in 2011.

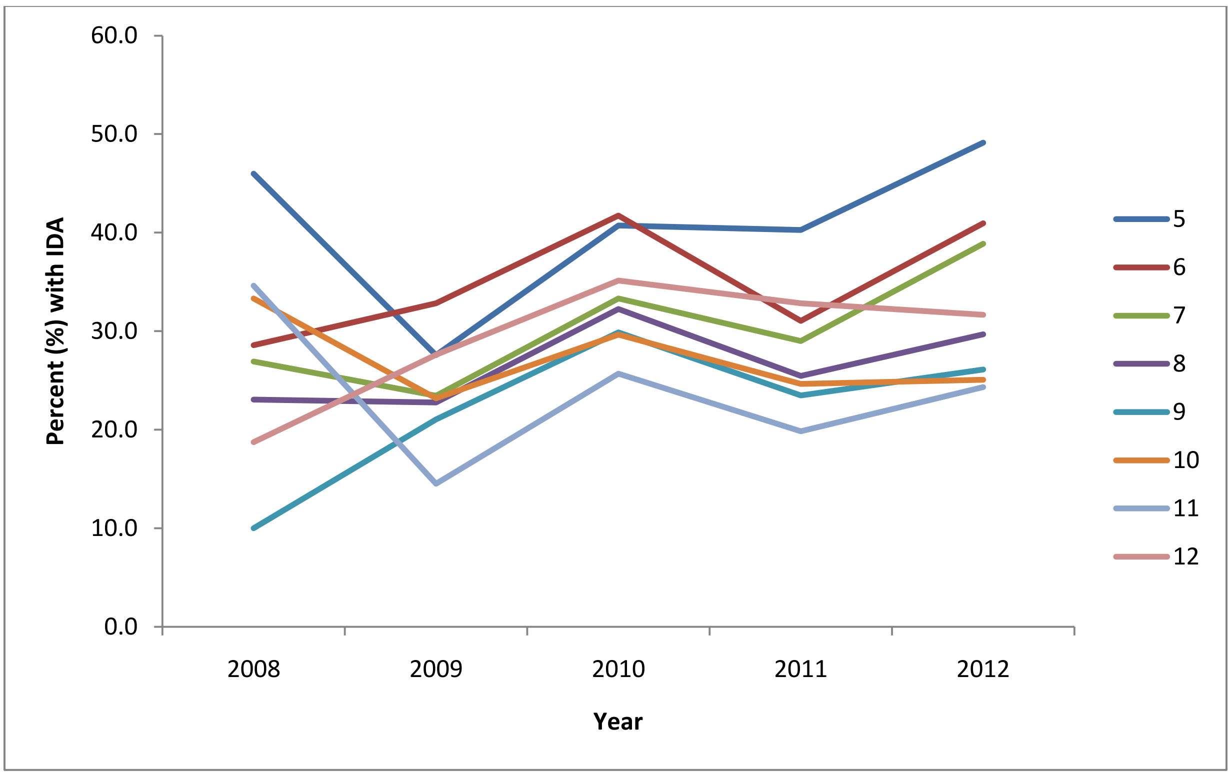

Figure 3. Prevalence of IDA within age groups from 2008-2012.

Eleven year olds have the lowest prevalence of IDA from 2009 (14.5%) to 2012 (24.3%). With the exception of 12 year olds, all age groups show a similar pattern across years with a decrease from 2008 to 2009, an increase in 2010 followed by a decrease in 2011 and an increase again in 2012. Six year olds also had a deviation in that they increased approximately 4% in IDA prevalence from 2008 to 2009 and continued their upward trend in 2010. However they followed the remaining pattern as the other age groups in 2011 and 2012. Ten year olds also deviated a little from the general trend in 2008 and 2009 where it had a slightly higher prevalence than 9 year olds in these 2 years. The lowest prevalence of IDA within age groups was seen in 9 year olds in 2008 (10%) while the highest was in 5 year olds in 2012 (49%). Seven year olds and 8 year olds followed the general trend and had IDA prevalence ranges between 23% and 39% from 2008 to 2012. See appendix E for percentages of each age group across years.

The differences noted across age groups and between years were found to be statistically significant by means of a Chi Square test ($p < .001$). As stated above, the general trend across years was decrease in IDA prevalence with increase in age with the exception of 12 year olds. This can be clearly seen with the contribution of each age group to the overall prevalence of IDA cases across all five years combined (see Table 3 below).

Table 3

Percentage of Total IDA Cases for Each Age Group

Age	5	6	7	8	9	10	11	12
Percent of IDA Cases	20%	16%	13%	11%	10%	10%	8%	11%

By geographical location, the Cayo district had the highest frequency of IDA cases followed by the Belize District from 2009 to 2012. The Stann Creek district had the third highest frequency for each year followed by the Toledo district, with the exception of 2008. The Corozal and Orange Walk Districts had the lowest number of IDA every year (Figure 4 below). The greatest proportion of prevalence of IDA was found in the Cayo District from 2009 to 2012 with 24.3%, 40.1%, 39.6% and 46.6 % respectively. The Belize District followed with 28.6%, 19.8%, 24.1%, 19.5% and 26.2% IDA prevalence within the district from 2008 to 2012 respectively (Figure 5). A Chi Square analysis revealed that there was a significant difference across districts between years. There was also a difference within the Belize, Cayo, Toledo and Corozal Districts between years (See Table 4 below).

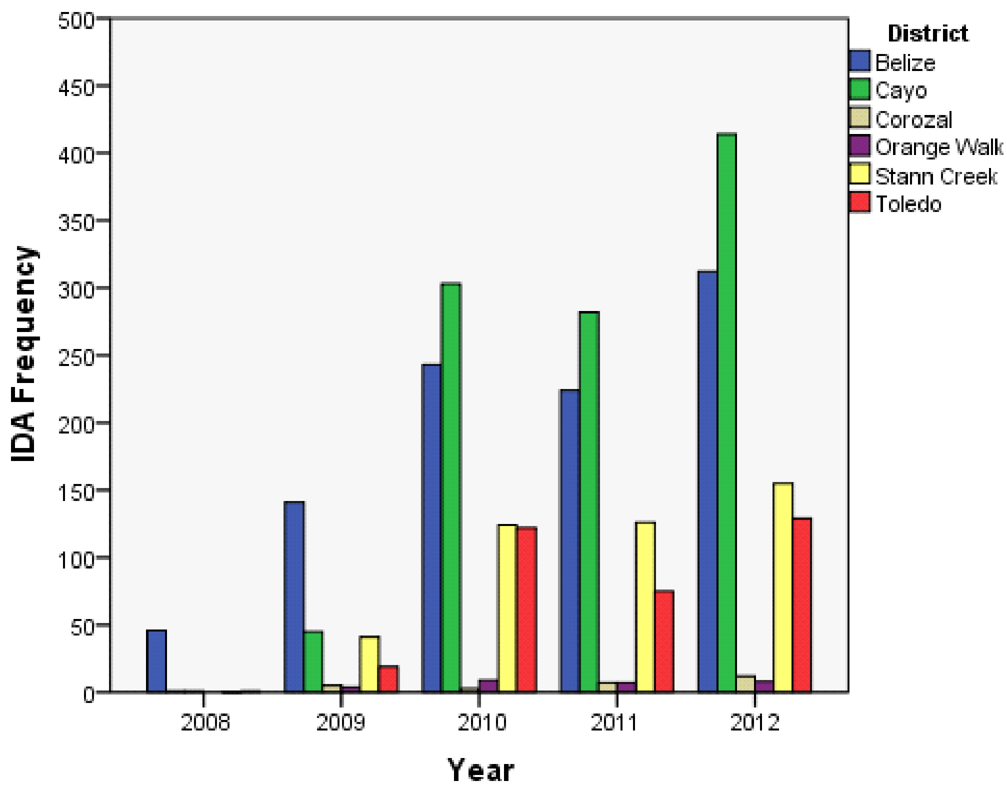

Figure 4. Frequency of IDA in each district from 2008 to 2012.

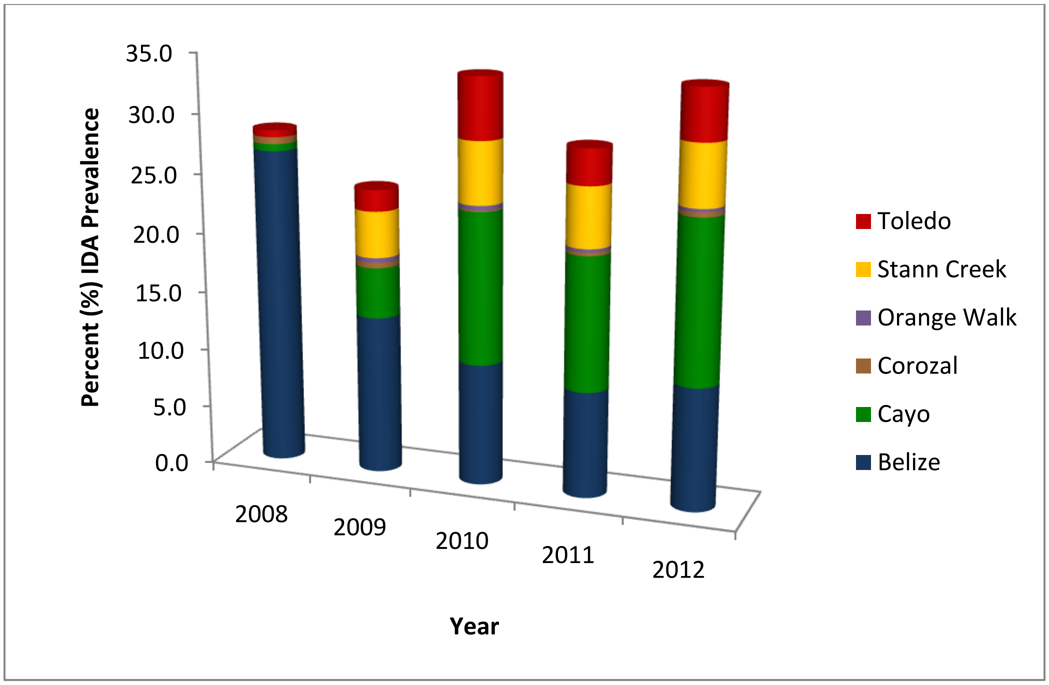

Figure 5. Relative percentage of IDA prevalence in each district from 2008 to 2012.

Table 4

Result of Pearson Chi-Square test within Each District between years from 2008 to 2012

District	N of Valid Cases	Value	df	[a]Asymp. Sig. (2-sided)
Belize	4224	22.591	4	.000
Cayo	2545	33.876	4	.000
Corozal	204	18.777	4	.001
Orange Walk	100	1.699	3	.637
Stann Creek	934	6.731	4	.151
Toledo	1121	16.615	4	.002
Total	9130	51.345	4	.000

Note. One unknown district was reported in 2010 and 2012 and were not used in the analysis by district.

df = degrees of freedom

[a]Asymp. Sig. (2-sided) <.05 as considered as a statistical significant difference

The total number of hemoglobin tests done in the Corozal and Orange Walk districts were significantly lower than those done in other districts for each year (refer to appendix B). The Belize district consistently performed the highest number of test for each year followed by the Cayo district. The Toledo district reported more test than the Stann Creek district from 2010 to 2012. All district had significantly lower number of tests reported for 2008 and they showed a gradual increase in 2009. The districts had different trends across the five year period (Figure 6). In 2008 both the Toledo (100%) and Stann Creek (0%) districts prevalence were skewed due to insufficient test results.

However, after deselecting districts with less than 50 results the Stann Creek district showed the highest prevalence of IDA,(52.6%, 51.0%, 44.4% and 47.7%) from 2009 to 2012, respectively. There was no difference in these rates from year to year (Table 5). Generally the Corozal and Belize districts had the lowest prevalence of IDA overall years combined (13.7% and 22.9%, respectively). However the changes between years were significant in these districts ($p = .001$ and $p < .001$, respectively). The Cayo district had the second highest prevalence (41.1%) overall and also in 2010 to 2012 with 40.1%, 39.6% and 46.6%, respectively. The differences in prevalence for the Cayo district were significant ($p < .001$). There was also significance in the prevalence rates between years in the Toledo district ($p = .002$), which had the third highest overall prevalence (30.9%). The Orange Walk district had an overall prevalence of 28.0% which was not significant.

The Toledo district consistently decreased while the Cayo district consistently increased in IDA prevalence. Belize, Corozal and Orange Walk districts showed a wave pattern of decrease then increase over the five years. The Stann Creek district had a unique pattern of a sharp increase then decrease over 2009 and 2010 followed by a slight increase in 2012. It is important to note that the Belize district showed the lowest prevalence of IDA even though it had the highest number of tests each year. Also Cayo district, despite having the highest number of IDA cases consistently across years, it was second to the Stann Creek district which had the highest prevalence of IDA within districts.

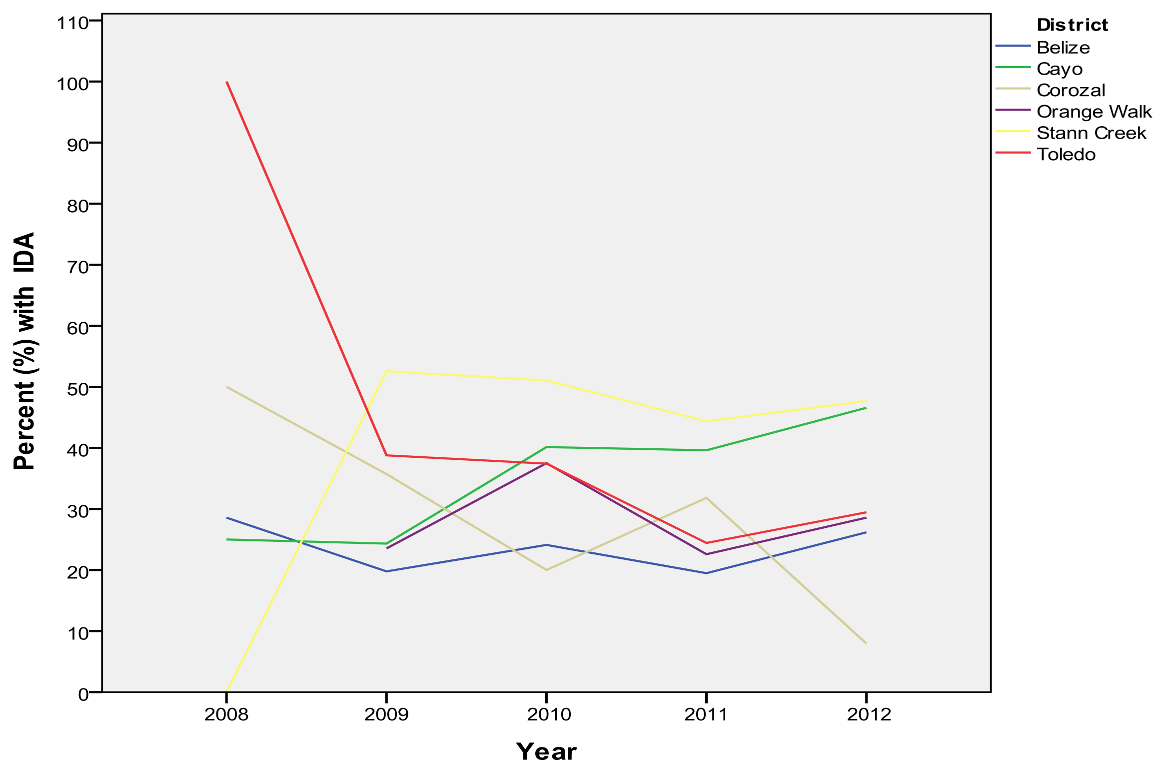

Figure 6. Trend of IDA prevalence between 2008 to 2012 for each district.

Those cases identified as IDA were further categorized into severe IDA, moderate IDA and mild IDA. See appendix I for cutoff values for each category. These were analyzed by year, gender, age and district. The prevalence of severe cases was under 5%

for each year except 2009 where it jumped to 7.1% (see Table 5 below). Moderate level IDA was most frequent in 2008 and 2012. In 2009, 2010 and 2011 mild IDA was seen in majority of cases, 48.6%, 49.9% and 50.6%, respectively. When compared to all hemoglobin tests (N=9130), the prevalence of each category would be reduced for each year since table 5 below only analyzes severity within children classified as having IDA.

Table 5

Percentage of Severe, Moderate and Mild IDA Within the Year for Each Year from 2008 to 2012

IDA Level	2008	2009	2010	2011	2012
Severe (*n* =117)	2.0%	7.1%	4.4%	3.6%	3.6%
Moderate (*n* =1353)	61.2%	44.3%	45.8%	45.8%	49.7%
Mild (*n* = 1389)	36.7%	48.6%	49.9%	50.6%	46.7%
Total (N = 2859)					

There was a similar distribution of severity levels of IDA among males and females between the years and over all the years combined. There was no difference between severity levels between males and females. The proportion of severe, moderate and mild IDA within the year was similar across all age groups (Figure 7). In 2008 eight year olds had the highest percentage of severe cases at 16.7%. Eleven year olds had a 27.8% prevalence within age group of severe IDA in 2009, the highest seen in any year and any age group. Eleven year olds also had the highest rate of severe IDA in 2011 and 2012 with 7.3% and 9.9% respectively. In 2010 the highest severity was seen in 10 year olds with a rate of 8.40% within the age group. There was no significant difference in moderate and mild cases between age groups and across years.

By district level within each year severe cases of IDA was low, i.e. less than 5.0% for most districts for most years (Figure 8). In 2008 the Belize district was the only district to report severe IDA results with a 2.2% within the district for that year. The Stann Creek district had a rate of 24.4% of severe IDA in 2009. Orange Walk took the lead in 2010, 2011 and 2012 with 11.1%, 14.3% and 12.5% respectively. A Chi Square test resulted in $p<.001$ which showed that there was a statistical difference among districts and between years for the different levels of severity of IDA (Figure 9, 10 and 11).

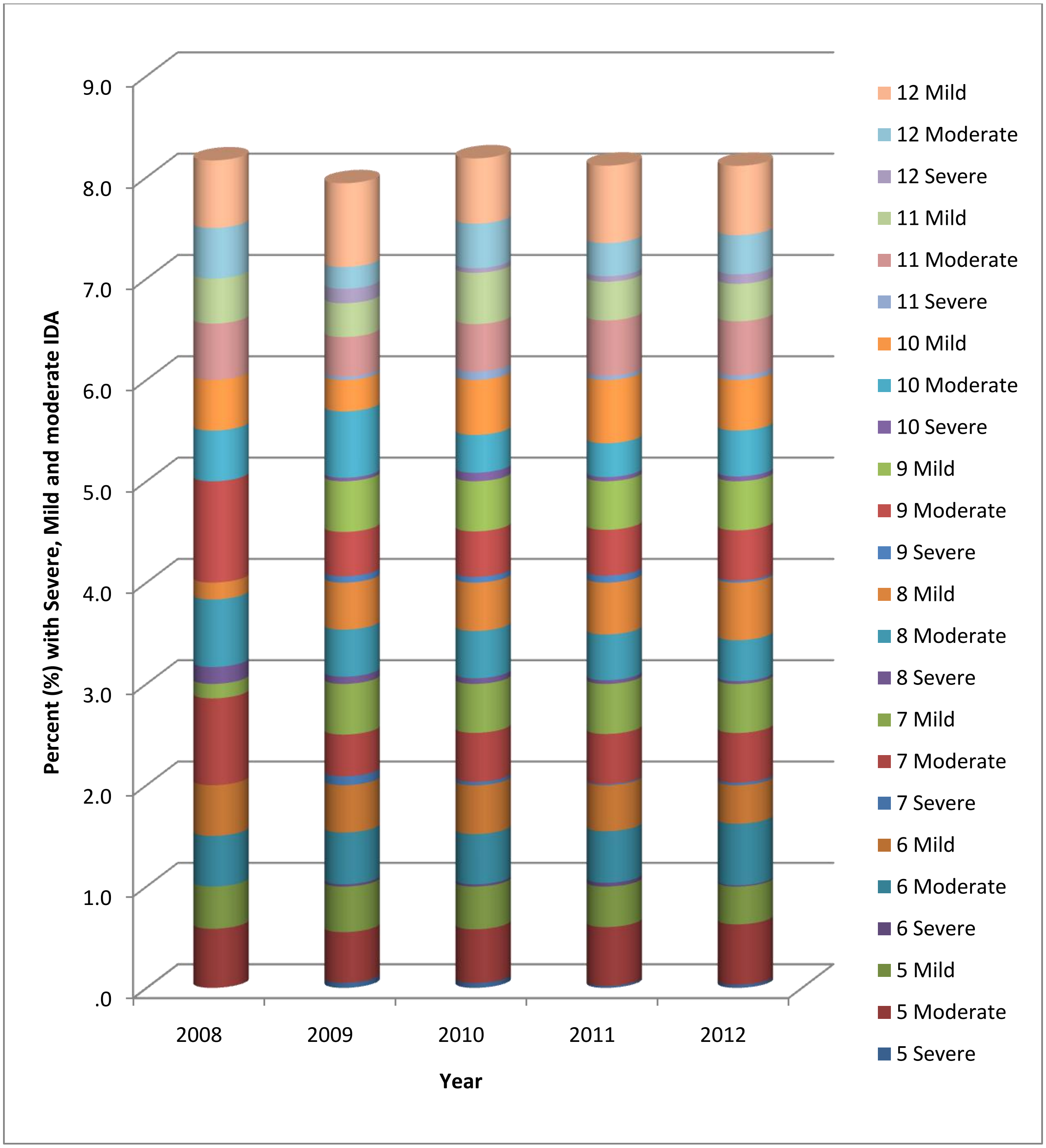

Figure 7. Relative proportion of severity of IDA by age within each year from 2008 to 2012.

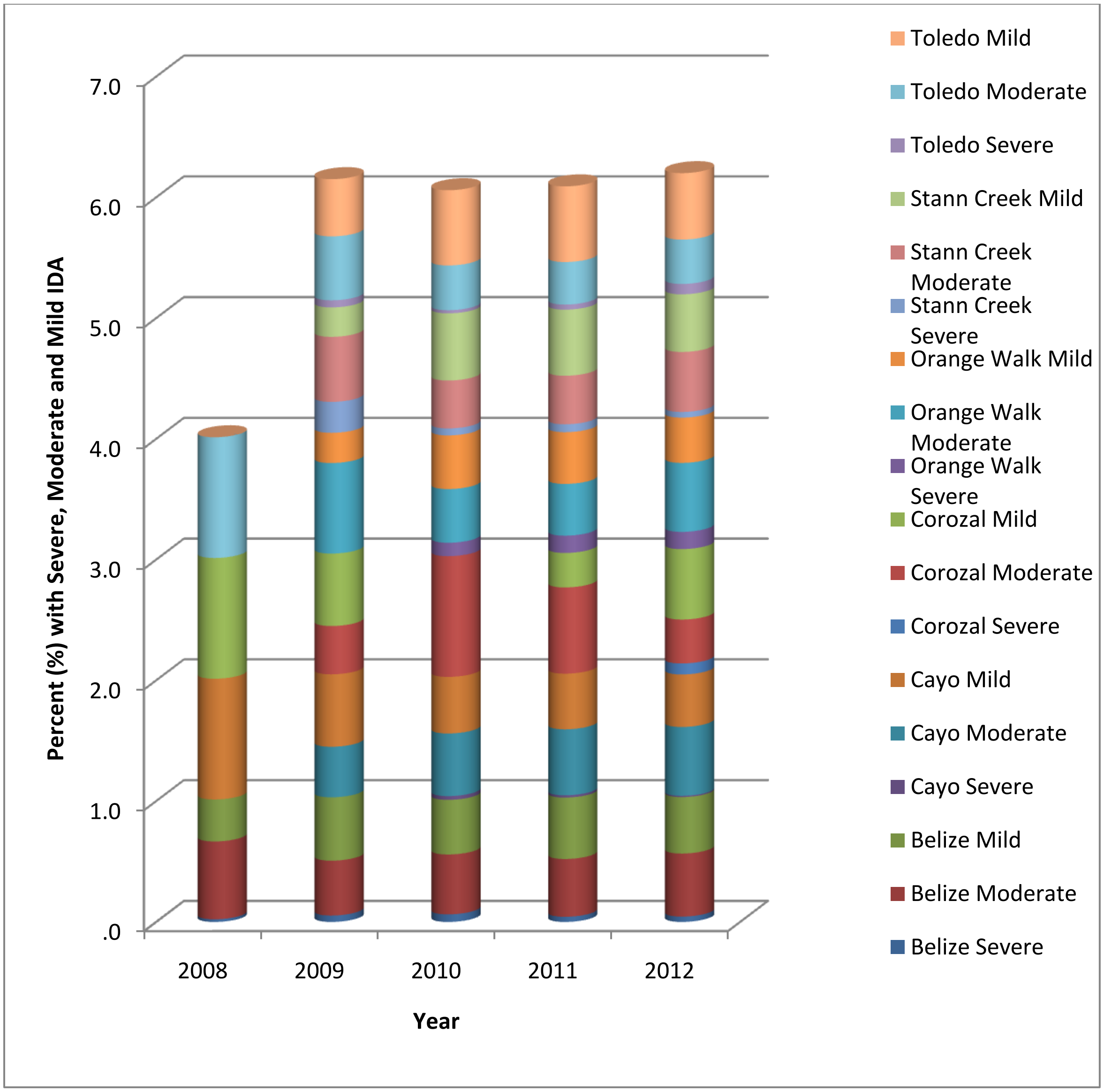

Figure 8. Relative proportion of severity of IDA cases in each district for each year from 2008 to 2012.

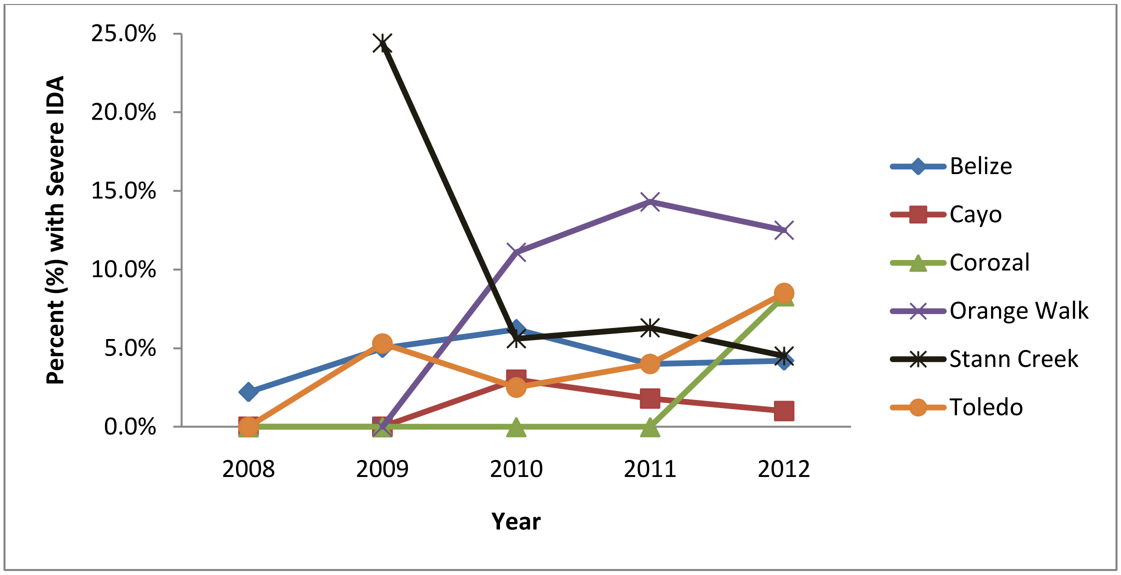

Figure 9. Percentage of severe IDA cases in each district for each year from 2008 to 2012.

Note. Severe IDA is defined as hemoglobin concentration less than 8.0g/dL in children 5-14 years old.

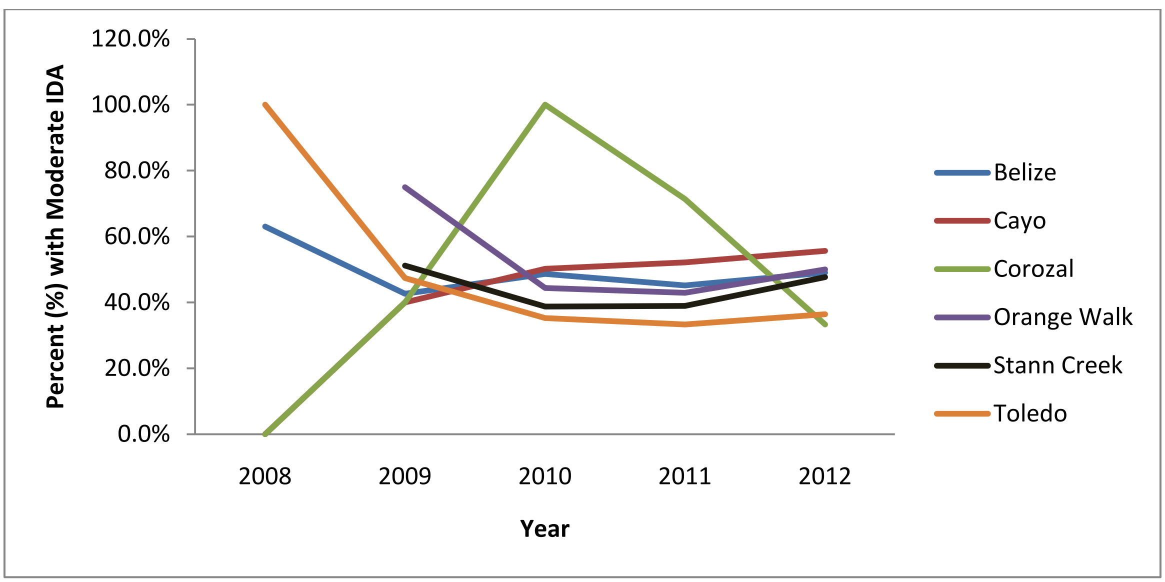

Figure 10. Percent within districts that are classified as having moderate IDA from 2008 to 2012. *Note*. Moderate IDA is defined as a hemoglobin concentration between 8 and 10.9 g/dL for children between ages 5 and 14 years.

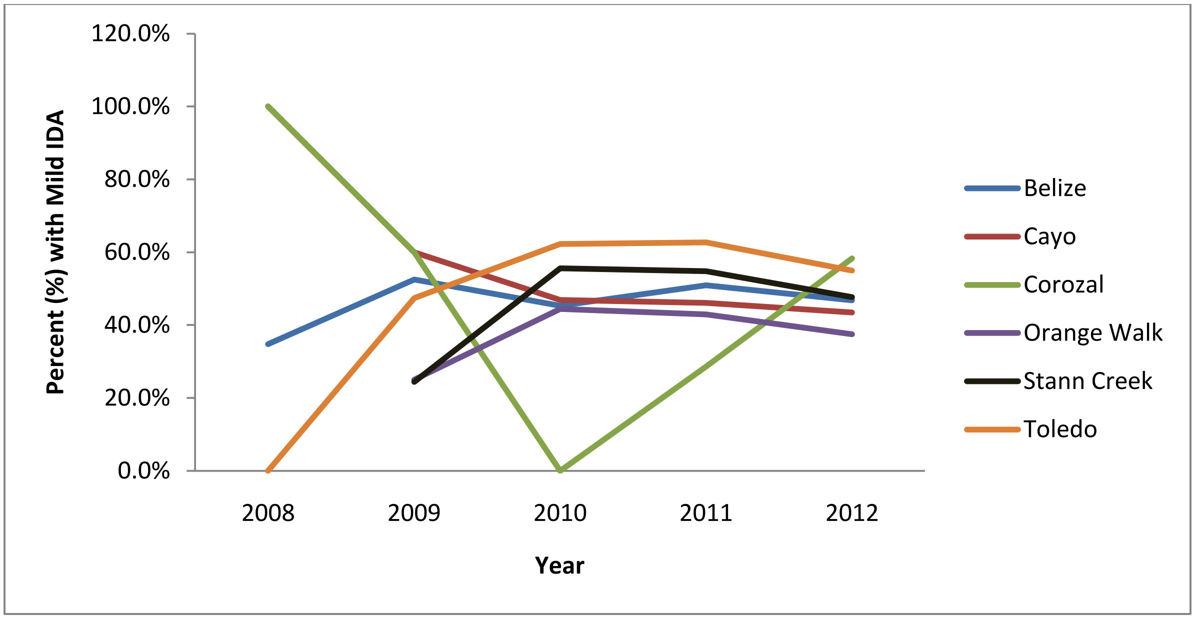

Figure 11. Percent classified as having mild IDA within districts from 2008 to 2012.

Note. Mild IDA is defined as a hemoglobin concentration between 10.9 and 11.4 g/dL for 5-11 year olds and between 10.9 and 11.4 g/dL for 12-14 year olds.

Hemoglobin was the primary test used to determine IDA status of the target group of children in this study. However, as supplemental data, the hematocrit was also analyzed for those who had both hemoglobin and hematocrit tests done. Out of the 9130 patients who had a hemoglobin test done over the 5 years, 9068 (99%) also had a hematocrit test reported. The data showed that approximately 24.3% of the cases were classified as IDA by having both low hemoglobin and hematocrit results combined over the five years. Approximately 30% was found to be IDA by hematocrit alone which is similar to the 31.3% IDA prevalence found by hemoglobin alone. Thirty six point one (36.1%) prevalence of IDA was found when all low hemoglobin and low hematocrit results were tabulated for all patients who had both tests done across the five years. The results of hemoglobin and hematocrit tests were similar and reflected the same clinical picture for the patients (Figure 12). Since the results for both hemoglobin and hematocrit were similar it is deduced that similar findings between genders, age and district across years existed for hematocrit as was found for hemoglobin. Therefore no difference was detected in IDA prevalence between the two tests.

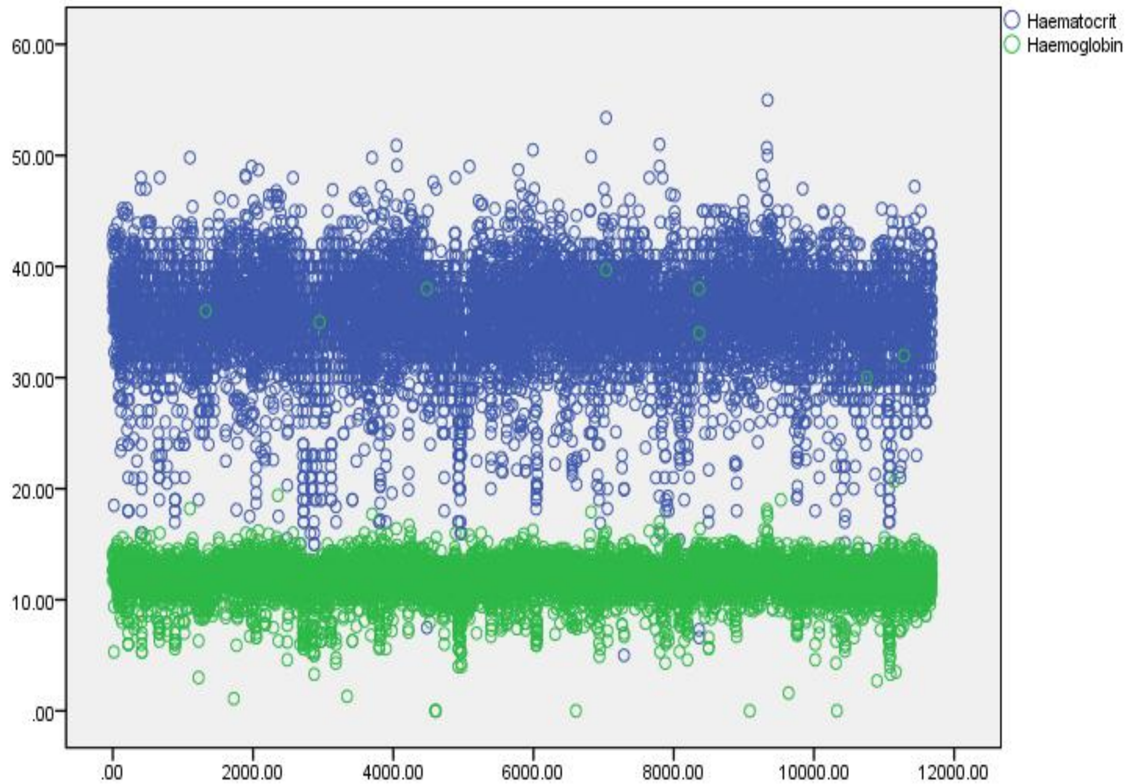

Figure 12. Hematocrit and hemoglobin test results (all) for each patient over five years from 2008 to 2012 showing similar pattern (direction) of results between tests.

Other tests retrieved for analysis included MCV, CRP, serum iron and ferritin. The number of tests for serum iron and ferritin were extremely low (see Table 1). The two ferritin tests done were normal as they were above the cutoff value of 10-12ug/L recommended for IDA classification by WHO (2011). The serum iron results, except one, were above the reference range of 32-175uL/dL defined by the CDC for children ages 3-17 years old. The abnormal serum iron result was 15.7uL/dL by a 9 year old female from Belize district in 2012. The MCV was used to see the correlation of microcytic cells, i.e. cells that have a size <80fL to IDA results. The results showed a difference between years for the rate of MCV results that were <80fL (Table 6). A Chi Square test confirmed that this difference was statistically significant with a result of p=.031.

Table 6

Rate of MCV results that were <80fL for each year from 2008 to 2012

	Year				
MCV Tests	2008	2009	2010	2011	2012
Total N = 107	21	34	23	5	24
N% below 80fL	47.6%	67.6%	56.5%	20.0%	29.2%

Further analysis by gender, age and district revealed that there was no statistical difference between males and females across the years for low MCV as well as no difference between age groups. There was a statistical difference for the Cayo district as well as the difference between districts over all the years was significant by Chi Square analysis (.004 and .031, respectively).

The CRP test was different from the MCV test in that it had a steep fall in positive rates from 2008 to 2009 where it was reduced by 44%. It then rose in 2010 and 2011 and then fall again in 2012 drastically. Females consistently had positive results more than males across the years (Table 7). The positive CRP results do not show the same pattern as the IDA pattern across years.

Table 7

CRP test results from 2008 to 2012

CRP Tests	2008	2009	2010	2011	2012
N	8	25	44	56	53
% Positive	50	28	40.9	42.8	26.4
% Female	100	57.1	66.6	58.3	64.3
% Male	0	42.9	33.4	41.7	35.7

The IDA results for 2008 to 2012 were 28.5%, 24.1%, 33.9%, 28.8% and 34.1% for each consecutive year (Table 2). An overall prevalence of 31.1% was found across all five years combined by hemoglobin results. The population of 5-12 year olds in Belize for each year ranges from approximately 70,000 in 2009 to 66,000 in 2012 (Table 8). Over the last 3 years this age group made up approximately 19% of the total population of Belize.

Table 8

Mid-year Population of 5-12 year old in Belize from 2009 to 2012

	Year			
Population	2009	2010	2011	2012
N	70,127	62,377	64,013	65,693
%N	21.0	19.3	19.3	19.3

Source: Statistical Institute of Belize.

CHAPTER 5

DISCUSSION

The results of the study revealed that there was an overall 31.1% prevalence of IDA among those children who had access to hemoglobin testing in their district for all five years combined. The average prevalence over the 5 year period was approximately 30% of IDA in children 5-12 years old. This is higher than the 19% prevalence in 2-8 year olds found by Makdani, et. al., (1996) as reported by the FAO (2003). Therefore the data showed that Belize has a moderate public health problem for IDA since its prevalence exceeds the 5% threshold set by the WHO and it falls between 20% and 40%. This supports the prediction that the prevalence of IDA exceeded 5% in the target population of school-aged children.

The WHO in 2008 reported that 25.4% of school aged children globally had anemia. Therefore, Belize is above the global prevalence. Belize also has a higher prevalence than the rest of the Americas which was found to have approximately 23% prevalence of anemia in children 0-5 years old. Fortunately when compared to other developing countries, Belize is significantly lower than the 53% anemia rate that is seen in 5 to 14 year olds in these countries (Semba, R.D.; Piot, P. and Bloem, M.W., 2008).

. According to a report, *Nutrition, Gender and Poverty in the Caribbean Subregions* (2006), Jamaica reported a 24% prevalence of anemia while Guyana and Grenada reported values over 50% and St. Vincent and the Grenadines reported 19%. Therefore with an average prevalence of 30%, Belize is not extraordinary in its IDA rate compared to the Caribbean neighbors. In fact a report by the Caribbean Food and Nutrition Institute, *Nutrition Challenges in the Caribbean*, stated that under nutrition remains a public health problem for most Caribbean countries. In this article Belize reported had 8 deaths per 100,000 people due to deficiency diseases. When compared to some countries in Asia which has the overall highest anemia prevalence rate of 58.4% globally, such as Vietnam and Indonesia where the prevalence is 12% and 28% respectively, Belize is higher in IDA prevalence. However, nationally, it is lower than the prevalence rate found in Africa which has a 49.8% (PCD, 2002).

The highest prevalence was seen in the year 2012 with 34.1% followed by 2010 with 33.9%. Being that this is the most recent and most complete data set available from the inception of BHIS in 2008 it is probably the most representative of the true IDA prevalence in school age children in Belize. However, there is consistency in a rise and fall pattern of IDA levels over the five years (28.5%, 24.1%, 33.9%, 28.8% and 34.1% from 2008 to 2012 respectively). This is not expected as the World Bank increased the classification of Belize from a low-middle income to an upper middle income country in 2013. If the country is improving economically then the rate of micronutrient deficiencies should decrease since there is a connection between socioeconomic status and micronutrient deficiencies as established in previous studies. This was not supported in this study since as the economy was improving, IDA was increasing.

Interestingly, according to the World Bank reports, the GDP of Belize showed a pattern from year to year that does not support the pattern of IDA prevalence from 2008 to 2012. There was a decrease in 2009 (1.34 USD bn) from 2008 (1.36 USD bn), an increase in 2010 (1.39 USD bn), another increase in 2011 (1.44USD bn) and 2012 increase (1.55 USD bn). Ideally, if socioeconomic status influences nutrition, then the IDA prevalence should show the opposite trend of the GDP. Hence when GDP falls, IDA should increase and visa-versa. However, the GDP of the country had no effect on the IDA prevalence from year to year since even though the GDP increased from 2010 to 2012, there was an increase in IDA in 2010 and 2012 from previous years. IDA prevalence had a consistent pattern in all districts which showed 2012 being the highest reported prevalence year in each. This could also be due to more availability of and access to testing facilities and increased utilization of BHIS to report results. Hence cases that were not represented in previous years were now represented in 2012 causing there to be an increase in the rate of IDA.

Just as there seemed to be no effect of income level on IDA prevalence in the country, similarly gender did not show any difference ($p = .269$) in prevalence of IDA over the five years combined. Overall children were just as likely to have IDA or not have IDA whether they were male or female. This is similar to the 2006 report by the MOH which showed very little difference by gender for wasting and stunting in children under 5 years old. Despite this overall picture, however, when a year to year analysis was done a clear trend which showed boys having a slightly higher prevalence of IDA than girls was seen from 2009 to 2012, however not significant ($p = .348$). This is somewhat similar to the findings of the national height census which found that boys (18.2%) were more likely to be stunted than girls (12.5%). Also, this finding does not reflect results of studies done in other countries where girls are usually found to have higher anemia prevalence than boys and usually in older children approaching puberty (PCH, 2002; Odeh 2006)). In fact, the only difference in IDA prevalence for gender was the changes between years within the gender groups themselves. Therefore indicating that the changes seen in IDA prevalence from year to year for both males ($p < .001$) and females (p = .002) were statistically significant.

Although the findings suggest that the difference between males and females is not significant the fact that both groups showed significant increases and decreases in sync across the years requires further scrutiny. A study on the nutrition status of children in Toledo (1997) found that 34.7% of the children had an acute respiratory infection (ARI) of which 18.9% had complicated symptoms. Although the study did not differentiate between gender and ARIs, this could account for why both sexes are affected in similar fashion over the years. In the same study males were found to be slightly more undernourished (16.8%) than girls (15.5%). This could account for the slight increase of IDA that is seen in males over females from 2009 to 2012. This is because microorganisms such as viruses and parasites, cause IDA due to the sequestering or iron by macrophages during an infection causing less iron availability for erythropoeisis. This is a part of the body’s mechanism to fight the infection since some organism need iron to carry out their metabolic processes. More information on prevalence of viral and parasitic infections in children would be beneficial to explain the trends seen in this study. A recent study was done in the Toledo district to find out the prevalence of hookworm infection. However the results were not ready at the time of this study. It would be critical to see if the hookworm infection shows a similar pattern between males and females as is the IDA prevalence.

While the hemoglobin results indicated that both genders were just as likely to have IDA the CRP results did not agree since girls consistently had more positive results than males for this test. This is indicating that girls had a higher rate of C-reactive protein, which is a non-specific protein released during infection or injury. Having a higher rate of infection should result in higher rate of IDA due to the effect of iron leeching by the macrophages and also some parasites. However, there was no difference seen in females when compared to males for IDA prevalence overall and furthermore, within years males had a slightly higher prevalence which was contrary to the CRP results. This inconsistency could be due to the low number of CRP tests done and the lack of specificity of the test and its subjective analysis. The major limitation of the CRP test is that it is non-specific and cannot aid in a specific diagnosis.

Males and females of all age groups were affected by IDA at prevalence rates exceeding 20% with the exception of 9 year olds in 2008 (10%) and 11 year olds in 2009 (14.5%). The highest IDA prevalence was seen in 5 year olds (49%) in 2012 followed by 6 year olds (41%). Both age groups showed a significant difference in IDA prevalence in all years combined with $p < .001$ for 5 year olds and $p = .014$ for 6 year olds. These two age groups were the only ones to hit the 40% IDA prevalence mark, which is classified as a severe public health problem, for two or more years. This does support the general view that younger children are more susceptible to IDA. However the fact that all age groups had high prevalence of IDA proves that they are also susceptible and are suffering from the hematological disorder as well in Belize. Subsequently, 7 year olds and 11 year olds also showed a significant difference in developing IDA over the five years combined ($p = .005$ and $p = .038$, respectively). This high rate of IDA in these school aged children requires attention and action by the appropriate authorities. The general trend showed that as the age increased, the prevalence of IDA decreased. However, 12 year olds showed an increase in prevalence over 11 year olds from 2009 to 2012.

Furthermore when looking at the district level, the highest prevalence of IDA was found in the Stann Creek district (50%) and in children who were 5 years old (46%) which is similar to the rates found in countries in Africa and Asia. The second highest prevalence of IDA was likely to be seen in children who were from Cayo (40%, 40% and 47% from 2010 to 2012) and who were 6 years old. These findings are not in agreement with previous studies that showed that the Toledo district has the highest rate of malnutrition (43.7%) and stunting (39%) among school children. Malnutrition leads to micronutrient deficiency which causes IDA over time. With such a high rate of child malnutrition (43.7%) in Toledo it was expected that this district would have the highest IDA prevalence. The data did not prove this. The highest rate was found in Stann Creek district with 53%, 51%, 44% and 48% from 2009 to 2012. These rates are comparable to the African region and also Haiti where poverty is high. This suggests that there is something other than nutrition that is causing the high rate of IDA in this district. On the other hand the results mirror the results of the IDA study in pregnant women in Belize, 1996 where the same two districts, Stann Creek and Cayo were found to have the highest rates of anemia among pregnant women. Belize and Corozal districts had the lowest prevalence of IDA among school children in this study while Corozal and Orange Walk had the lowest prevalence among pregnant women in the 1996 study.

The finding of high IDA in both pregnant women and school age children in Stann Creek warrants a closer look at the diet of the people in the district since, both socioeconomic status and nutrition were not found to have an effect in IDA prevalence. According to WHO (2001) foods such as meat and organs from cattle, fowl, fish, and poultry; and non-animal foods such as legumes and green leafy vegetables are iron rich foods. While foods that support the absorption or use of iron include fruits, vegetables, and tubers, particularly those that contain vitamin C and vitamin A. Foods that contain phytates- cereal bran, cereal grains, high-extraction flour, legumes, nuts, and seeds; iron binding phenols-tea, coffee, cocoa, herbal infusions in general, certain spices such as oregano, and some vegetables; and calcium, from milk (dairy) sources are all inhibitors of iron absorption and utilization. The WHO recommended eating iron rich foods alternately with iron inhibiting foods.

Hence, the diet of the people could be the main contributing factor to IDA than unavailability of food, socioeconomic status or infection. Corn, particularly corn tortillas, is a main staple in the Mestizo and Mayan diet and in the typical Belizean kitchen. However, meat such as fish and chicken are also a part of the diet and are eaten together with these iron inhibiting foods. Coffee, tea or milk is also often taken with the morning meal. Vegetables are included in the diet but probably not in enough quantities to overcome the quantity of inhibitors consumed at each meal. Particularly for the Garifuna ethnic group in the Stann Creek district, coconut milk is a major part of the meals. The milk from the coconut is rich in calcium which is an inhibitor of iron absorption and thus could be one explanation for the high IDA found in this district. The Cayo district is mostly Mestizo (67.5%) and therefore, the corn based diet could be one reason for the high IDA seen in this district. Although, the Orange Walk and Corozal districts have similar populations of Mestizo, 79.7% and 79.3% respectively, as the Cayo district they did not show the high prevalence of IDA as the Cayo district (SIB, 2013). This is could be attributed to the low numbers of test results from these two districts.

There was approximately equal prevalence of mild IDA compared to moderate and severe cases combined except in 2008 where moderate to severe cases was the majority. Severe cases were less than 5% for four out of the five years. The Orange Walk district showed the highest prevalence of severe cases followed by the Stann Creek district where the highest IDA rate was found. However, the data may be skewed for Orange Walk in this regard since it had very low number of results reported for each year. This low testing was seen in Corozal as well and as a result the data for this district was also skewed and deviated from the pattern seen in the other districts. Corozal showed a high prevalence of moderate cases and a low prevalence of mild and severe cases. The reason for the low testing which was reflected by low numbers of hemoglobin results, could be that patients from these two districts utilize private health services that do not utilize BHIS or they go across the border to Mexican health facilities. Therefore, the real severity may also very well be in the Stann Creek district which had the highest prevalence of IDA. The highest prevalence of mild cased was seen in the Toledo district. While the Cayo and Belize district had a similar occurrence of moderate IDA cases. Again Toledo is not showing the malnutrition nor socioeconomic effects on micronutrient deficiency. The percentage of moderate cases in all years is very high (62.5%, 47.1%, 47.2%, 48.0% and 51.2% from 2008 to 2012 respectively) and warrants immediate attention to prevent these cases from increasing in severity. The highest prevalence of moderate cases was seen in 5 year old (56.8%) and the lowest prevalence was in 12 year olds (37.7%). All districts showed a similar pattern of increase in 2012 of moderate cases with the exception of Corozal.

Females had higher prevalence of severe cases (9.6%, 5.1%, 4.1% and 3.8%) than males (4.6%, 3.7%, 3.2% and 3.4%) for 2009 to 2012 respectively. The CRP result that showed girls having a higher rate of positive tests than boys could explain the higher severity in girls. Also Leenstra (2004) found that parasitic infections had an effect on IDA in girls age 12 to 13 years old, therefore this could be one reason for the high prevalence of severe cases in females over males. The older age groups generally had a higher rate of severe cases over all 5 years combined. Eleven year olds had the highest rate of severity with 8% within this age group having severe IDA followed by 5.5% in 10 year olds overall. Therefore, within 11 and 10 year old age groups the severity of IDA is greater than the 5% cutoff established by WHO. This could be attributed to the changes that the females in the age groups face with the onset of menstruation at puberty. However, within the 12 year age group only 4.6% showed severe low levels of hemoglobin concentration as opposed to their younger peers. Both males and females have increased iron requirements as they grow and mature but there is another factor that is causing the severity seen in females since the 12 year old do not fit the pattern seen in the other age groups. Generally, the prevalence of severe cases decreased as age decreased with the exception of 5 year old who had a higher prevalence (3.3%) than 6 year olds (2.2%).

Fortunately, the rate of severe cases overall is not high (<5%). However, with a prevalence of 30% IDA, Belize is classified as having a moderate public health problem according to WHO definition. Belize also fits this category for anemia in pre-school children and non-pregnant women of child bearing age (WHO, 2008). This finding is in agreement with the *LSMS* (2002) which established that at least 39% of children nationally were poor. Thus on a national level, the poverty rate is similar to the rate of IDA in children. According to Government of Belize (1992) in *Belize Food, Nutrition and Health Assessment*, in their evaluation of micronutrient deficiencies, concluded that

IDA was not a problem for children between three and eight years old. However, the results of this study revealed the highest prevalence was in children 5 and 6 years old contrary to what was reported in 1992. Government of Belize (2006) indicated that the Ministry of Health (MOH) was providing iron syrup supplement for infants as prophylaxis treatment of anemia, it is unknown whether this program is still operating and if school aged children have access to these supplements.

An IDA prevalence between 5 and 20% suggests appropriate interventions based on dietary modifications, provision of iron-fortified foods, targeted iron supplementation, and control of infections (WHO 2001). However, if the iron supplementation is still ongoing, according to WHO standards, it is not effective since Belize has an IDA prevalence greater than 20%. *Strategies of the Pan American Health Organization/World Health Organization for the Control of Iron Deficiency in Latin America* (1997) recommended food fortification and supplementation for children in developing countries as a strategy to address micronutrient deficiencies. Other countries such as India and South Africa have implemented cost effective programs in the form of multi-nutrient fortified biscuits. This could be one strategy to help children all over Belize who cannot afford nutritious foods to supply their growth and development needs.

As highlighted before, all the studies done so far have been nutrition based studies. However, IDA is not only caused by insufficient availability through food as was seen in Alaimo, et. al., (2001). IDA may be caused due to malabsorption of iron in the intestines, chronic inflammatory disorders and or blood loss which could be due to various clinical conditions especially parasitic infections in this age group. As mentioned above the Stann Creek district had the highest prevalence of IDA, however the diet of the people of this district is very rich in ground foods and fish. This is strong evidence that the IDA that exists is due to another factor and not nutrition. The *LSMS* (2002) showed that poverty rate in the Stann Creek district was 34.8% and only 5% of the poor population was indigent-very poor compared to the Toledo district which had a 79% poverty rate of which 56% were indigent. The fact that Toledo district has the highest malnutrition but not the highest IDA also points to another cause of the IDA prevalence and not due to food insufficiency due to poverty. The Cayo district also had a higher rate than Toledo and it is similar to the study done on pregnant women which is also indicating another source that is causing IDA, probably diet. Socioeconomic status is a factor that influences food availability and hence nutrition of children but this study failed to prove this.

As with all tests in the medical laboratory, preanalytical, analytical and post analytical factors could have affected the quality of results; thus causing a degree of error in the resulting prevalence rate for IDA. Preanalytical variables such as altitude and ethnicity, which could have possible effects on the hemoglobin level of the children, were not factored into the analysis. The children in the highest areas of Belize should show the highest hemoglobin levels and thus the lowest rate of IDA. This could be one reason why Toledo’s children do not reflect IDA based on the WHO cutoff values that were used since this district has some of the highest terrain in Belize. The Cayo district also has some high mountains but also a high rate of IDA so this too does not account for the differences seen in IDA prevalence across the districts.

Another test that was used as support for the study was the mean corpuscular volume which determines the average size of the red blood cells. Microcytic red cells are characteristic of iron deficiency anemia. However, the results of the MCV did not agree with the IDA prevalence. Approximately 50% or more of the MCV tests showed a microcytic result from 2008 to 2010 and only 20% to 29% in 2011 and 2012 respectively, had MCV values below 80fL. The 2012 result is close to the IDA rate for this year, however the trend is different from that seen with the hemoglobin tests. Therefore the results of the Hemoglobin and hematocrit are similar but the supporting tests, MCV and CRP, are showing different outcomes and are not in agreement with the findings of the hemoglobin test. This could be due to the underreporting of these test in this age group or under utilization of the CRP test for children. Similarly the under utilization of ferritin and serum iron tests for children, probably due to factors such as cost, also creates a gap in the analysis of iron status of these children resulting in inconsistent patterns and inconclusiveness.

Hence, there remain many questions that need to be addressed by future research. What exactly is causing the high rates of IDA seen in the Stann Creek and Cayo districts. What is the efficacy of food fortification and supplementation on IDA treatment? Is IDA a factor in the low performance of students on the PSE exams? How much of the sick claims are due to IDA and what is the financial impact of IDA on Belize's economy and productivity? There also have to be some administration efforts to ensure the quality of the data in BHIS for proper and efficient utilization of the data to help inform public health policy and programs.

Conclusion

Among children who visited the public health facilities between 2008 and 2012 and who had a hemoglobin test result reported, an average prevalence of 30% IDA was found. The prevalence from year to year was highest in the Stann Creek district, males and 5 year olds. The second most affected with IDA were children from the Cayo district and who were 6 years old. This study did not prove any relationship between socioeconomic status or poverty and malnutrition with the prevalence of IDA at the district level. However at the national level the average prevalence of IDA is 10% lower than the poverty rate. It is thus speculated that it may be diet, food consumption practices, that may be contributing to the high IDA prevalence at the district level. Infection with parasites could also be a contributing factor, however this requires further research. Nationally, the classification as a lower-middle income country is on par with the 30% average IDA prevalence. As a developing country, Belize is moderately affected and falls in between the spectrum of IDA prevalence in the Caribbean countries. In comparison to the Americas, the rate of IDA is high. The government could address this high rate of IDA by: considering expansion of the iron syrup supplement program to include school aged children, implementing school-based iron supplement programs, monitoring and evaluating flour fortification program, improving access to lab test, especially in rural areas and by strengthening education programs that inform the population of healthy eating habits when it comes to iron nutrition.

IDA seems to be increasing and males who are 5 years old are affected more than females. Twelve year olds also need to be studies more in depth to find out exactly why they have a higher prevalence of IDA than their younger peers. The Stann Creek and Cayo districts must be studied extensively to find out what is causing the high rate of IDA seen in these two districts. The government could implement more affordable and attractive lab services to residents in the Corozal and Orange Walk districts. This would provide increased availability of reliable data that could help to improve community health programs in these districts.

Of all the areas that need further research, the one that needs urgent attention is to determine the effect of IDA on PSE performance by students who have completed their primary school education. This is the next step for the investigator in this study.

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APPENDICES

Table A – Number and percent of IDA vs. non-IDA hemoglobin results from 2008 to 2012.

Classification of IDA		Year					
		2008	2009	2010	2011	2012	Total
Not Deficient	n	123	801	1568	1786	1996	6274
	n%	71.5	75.9	66.1	71.3	66.0	68.7
Deficient	**n**	**49**	**255**	**804**	**721**	**1030**	**2859**
	n%	**28.5**	**24.1**	**33.9**	**28.7**	**34.0**	**31.3**
Total	N	172	1056	2372	2506	3024	9130

Table B - Total number of hemoglobin test for each district from 2008 to 2012.

	Year					
District	2008	2009	2010	2011	2012	Total
Belize	161	713	1008	1150	1192	4224
Cayo	4	185	755	712	889	2545
Corozal	2	14	15	22	151	204
Orange Walk	0	17	24	31	28	100
Stann Creek	4	78	243	284	325	934
Toledo	1	49	326	307	438	1121
Total	172	1056	2372	2506	3024	9130

Table C - Total number of males and females and their percentage for each year that had a hemoglobin test reported from 2008 to 2012.

Gender		Year					
		2008	2009	2010	2011	2012	Total
Female	n	96	497	1129	1192	1419	4333
	n%	55.8	47.1	47.6	47.6	46.9	47.5
Male	n	76	559	1242	1314	1605	4796
	n%	44.2	52.9	52.4	52.4	53.1	52.5
Total	N	172	1056	2372	2506	3024	9130

Table D – Males and Females with IDA for each year from 2008 to 2012.

Gender	n-n%	2008	2009	2010	2011	2012
Females	n	31	125	374	341	471
	n%	32.3	25.2	33.1	28.6	33.2
Males	n	18	130	429	380	559
	n%	23.7	23.3	34.5	28.9	34.8
Total	N	49	255	804	721	1030

Note. One indeterminate gender was reported for 2010 and was not included in the analysis for gender.

Table E – IDA cases in age groups from 2008 to 2012

		Year					
Age	n-n%	2008	2009	2010	2011	2012	Total
5	n	12	40	147	155	225	579
	n%	46	28	41	40	49	42
6	n	4	45	139	108	163	459
	n%	29	33	42	31	41	37
7	n	7	34	91	87	159	378
	n%	27	23	33	29	39	33
8	n	6	28	90	82	109	315
	n%	23	23	32	25	30	28
9	n	2	32	89	73	95	291
	n%	10	21	30	23	26	25
10	n	6	29	83	72	84	274
	n%	33	23	30	25	25	26
11	n	9	18	75	55	81	238
	n%	35	15	26	20	24	23
12	n	3	29	90	89	114	325
	n%	19	28	35	33	32	32

Table F – Chi Square test results within age groups between 2008 to 2012.

Age	Chi Square Test	Value	df	Asymp. Sig. (2-sided)
5	Pearson Chi-Square	22.798	4	.000
n = 1375	Likelihood Ratio	23.317	4	.000
	Linear-by-Linear Association	15.035	1	.000
6	Pearson Chi-Square	12.539	4	.014
n = 1230	Likelihood Ratio	12.668	4	.013
	Linear-by-Linear Association	.774	1	.379
7	Pearson Chi-Square	15.014	4	.005
n = 1153	Likelihood Ratio	15.226	4	.004
	Linear-by-Linear Association	9.484	1	.002
8	Pearson Chi-Square	5.998	4	.199
n = 1117	Likelihood Ratio	6.052	4	.195
	Linear-by-Linear Association	.498	1	.480
9	Pearson Chi-Square	7.856	4	.097
n = 1145	Likelihood Ratio	8.347	4	.080
	Linear-by-Linear Association	.529	1	.467
10	Pearson Chi-Square	3.353	4	.501
n = 1050	Likelihood Ratio	3.298	4	.509
	Linear-by-Linear Association	.427	1	.513
11	Pearson Chi-Square	10.118	4	.038
n = 1052	Likelihood Ratio	10.388	4	.034
	Linear-by-Linear Association	.250	1	.617
12	Pearson Chi-Square	3.455	4	.485
n = 1008	Likelihood Ratio	3.604	4	.462
	Linear-by-Linear Association	.175	1	.676
Total	Pearson Chi-Square	51.345	4	.000
N = 9130	Likelihood Ratio	52.446	4	.000
	Linear-by-Linear Association	15.261	1	.000

Table G - IDA cases by district from 2008 to 2012

		Year					
District	n	2008	2009	2010	2011	2012	Total
Belize	n	46	141	243	224	312	966
	n%	28.6	19.8	24.1	19.5	26.2	22.9
Cayo	n	1	45	303	282	414	1045
	n%	25.0	24.3	40.1	39.6	46.6	41.1
Corozal	n	1	5	3	7	12	28
	n%	50	36	20	32	8	14
Orange Walk	n		4	9	7	8	28
	n%		23.5	37.5	22.6	28.6	28.0
Stann Creek	n	0	41	124	126	155	446
	n%	0.0	52.6	51.0	44.4	47.7	47.8
Toledo	n	1	19	122	75	129	346
	n%	100.0	38.8	37.4	24.4	29.5	30.9

Note. There was one unknown district reported in 2010 and one in 2012 which were not used in analysis for district.

Table H - Chi-Square test results for IDA cases for each district between 2008 to 2012.

District	Chi Square Test	Value	df	Asymp. Sig. (2-sided)
Belize	Pearson Chi-Square	22.591	4	.000
n = 4224	Likelihood Ratio	22.614	4	.000
	Linear-by-Linear Association	1.850	1	.174
Cayo	Pearson Chi-Square	33.876	4	.000
n = 2545	Likelihood Ratio	35.232	4	.000
	Linear-by-Linear Association	24.756	1	.000
Corozal	Pearson Chi-Square	18.777	4	.001
n = 204	Likelihood Ratio	15.827	4	.003
	Linear-by-Linear Association	14.406	1	.000
Orange Walk	Pearson Chi-Square	1.699	3	.637
n = 100	Likelihood Ratio	1.664	3	.645
	Linear-by-Linear Association	.016	1	.900
Stann Creek	Pearson Chi-Square	6.731	4	.151
n = 934	Likelihood Ratio	8.270	4	.082
	Linear-by-Linear Association	.435	1	.510
Toledo	Pearson Chi-Square	16.615	4	.002
n = 1121	Likelihood Ratio	16.715	4	.002
	Linear-by-Linear Association	6.758	1	.009
Total	Pearson Chi-Square	51.345	4	.000
N = 9130	Likelihood Ratio	52.446	4	.000
	Linear-by-Linear Association	15.261	1	.000

Table I - Classification of anemia (g/dL)

Age	Mild	Moderate	Severe
Children 6 - 59 months of age	10.0-10.9	7.0-9.9	lower than 7.0
Children 5 - 11 years of age	11.0-11.4	8.0-10.9	lower than 8.0
Children 12 - 14 years of age	11.0-11.9	8.0-10.9	lower than 8.0

Table J – Percent of severe, moderate and mild IDA from 2008 to 2012.

IDA Level		2008	2009	2010	2011	2012	Total
Severe	*n*	1	18	35	26	37	117
	n%	2.0	7.1	4.4	3.6	3.6	4.1
Moderate	*n*	30	113	368	330	512	1353
	n%	61.2	44.3	45.8	45.8	49.7	47.3
Mild	*n*	18	124	401	365	481	1389
	n%	36.7	48.6	49.9	50.6	46.7	48.6
Total	N	49	255	804	721	1030	2859

Table K – IDA levels by gender for each year from 2008 to 2012.

			Year					
Gender	IDA Level	n-n%	2008	2009	2010	2011	2012	Total
Female	Severe	n	0	12	19	14	18	63
		n%	0.0	9.6	5.1	4.1	3.8	4.7
	Moderate	n	19	50	166	157	238	630
		n%	61.3	40.0	44.4	46.0	50.5	46.9
	Mild	n	12	63	189	170	215	649
		n%	38.7	50.4	50.5	49.9	45.6	48.4
	Total	N	31	125	374	341	471	1342
Male	Severe	n	1	6	16	12	19	54
		n%	5.6	4.6	3.7	3.2	3.4	3.6
	Moderate	n	11	63	201	173	274	722
		n%	61.1	48.5	46.9	45.5	49.0	47.6
	Mild	n	6	61	212	195	266	740
		n%	33.3	46.9	49.4	51.3	47.6	48.8
	Total	N	18	130	429	380	559	1516

Table L – Prevalence (%) of each IDA level for each age group from 2008 to 2012.

		Year					
Age	IDA Level	2008	2009	2010	2011	2012	Total
5	Severe	0.0	5.0	4.8	1.9	3.1	3.3
	Moderate	58.3	50.0	53.1	58.1	59.6	56.8
	Mild	41.7	45.0	42.2	40.0	37.3	39.9
6	Severe	0.0	2.2	2.2	3.7	1.2	2.2
	Moderate	50.0	51.1	49.6	50.9	60.7	54.0
	Mild	50.0	46.7	48.2	45.4	38.0	43.8
7	Severe	0.0	8.8	3.3	1.1	2.5	2.9
	Moderate	85.7	41.2	48.4	49.4	49.1	48.9
	Mild	14.3	50.0	48.4	49.4	48.4	48.1
8	Severe	16.7	7.1	5.6	3.7	2.8	4.4
	Moderate	66.7	46.4	46.7	45.1	40.4	44.4
	Mild	16.7	46.4	47.8	51.2	56.9	51.1
9	Severe	0.0	6.3	5.6	6.8	2.1	4.8
	Moderate	100.0	43.8	44.9	45.2	49.5	46.7
	Mild	0.0	50.0	49.4	47.9	48.4	48.5
10	Severe	0.0	3.4	8.4	4.2	4.8	5.5
	Moderate	50.0	65.5	37.3	33.3	45.2	42.0
	Mild	50.0	31.0	54.2	62.5	50.0	52.6
11	Severe	0.0	27.8	2.7	7.3	9.9	8.0
	Moderate	55.6	38.9	46.7	54.5	53.1	50.4
	Mild	44.4	33.3	50.7	38.2	37.0	41.6
12	Severe	0.0	6.9	3.3	3.4	6.1	4.6
	Moderate	33.3	10.3	32.2	20.2	25.4	24.6
	Mild	66.7	82.8	64.4	76.4	68.4	70.8

Table M – Prevalence (%) of IDA levels in each district from 2008 to 2012.

		Year					
District	IDA Level	2008	2009	2010	2011	2012	Total
Belize	Severe	2.2%	5.0%	6.2%	4.0%	4.2%	4.7%
	Moderate	63.0%	42.6%	48.6%	45.1%	49.0%	47.7%
	Mild	34.8%	52.5%	45.3%	50.9%	46.8%	47.6%
	N	46	141	243	224	312	966
Cayo	Severe	0.0%	0.0%	3.0%	1.8%	1.0%	1.7%
	Moderate	0.0%	40.0%	50.2%	52.1%	55.6%	52.3%
	Mild	100.0%	60.0%	46.9%	46.1%	43.5%	45.9%
	N	1	45	303	282	414	1045
Corozal	Severe	0.0%	0.0%	0.0%	0.0%	8.3%	3.6%
	Moderate	0.0%	40.0%	100.0%	71.4%	33.3%	50.0%
	Mild	100.0%	60.0%	0.0%	28.6%	58.3%	46.4%
	N	1	5	3	7	12	28
Orange Walk	Severe		0.0%	11.1%	14.3%	12.5%	10.7%
	Moderate		75.0%	44.4%	42.9%	50.0%	50.0%
	Mild		25.0%	44.4%	42.9%	37.5%	39.3%
	N		4	9	7	8	28
Stann Creek	Severe		24.4%	5.6%	6.3%	4.5%	7.2%
	Moderate		51.2%	38.7%	38.9%	47.7%	43.0%
	Mild		24.4%	55.6%	54.8%	47.7%	49.8%
	N		41	124	126	155	446
Toledo	Severe	0.0%	5.3%	2.5%	4.0%	8.5%	5.2%
	Moderate	100.0%	47.4%	35.2%	33.3%	36.4%	36.1%
	Mild	0.0%	47.4%	62.3%	62.7%	55.0%	58.7%
	N	1	19	122	75	129	346

Table N – Prevalence of IDA using non random cases.

	Year				
District	2008	2009	2010	2011	2012
Belize	30.0	20.0	20.0	20.0	30.0
Cayo	30.0	20.0	40.0	40.0	50.0
Corozal	50.0	40.0	20.0	30.0	10.0
Orange Walk		20.0	40.0	20.0	30.0
Stann Creek	0.0	50.0	50.0	40.0	50.0
Toledo	100.0	40.0	40.0	20.0	30.0

Note. Highlighted cells indicate a sample (n) of less than 50.

Table O – Number of IDA cases in every 1000 case.

	Year				
District	2008	2009	2010	2011	2012
Belize	286	198	241	195	262
Cayo		243	401	396	466
Corozal					79
Orange Walk					
Stann Creek		526	510	444	477
Toledo			374	244	295

Table P – Prevalence (%) of IDA by age and gender for each district from 2008 to 2012 in non random samples.

		Gender				Gender	
District	Age	Female	Male	District	Age	Female	Male
Belize	5	30.0	30.0	Orange Walk	5		
	6	30.0	20.0		6		
	7	20.0	20.0		7		
	8	20.0	20.0		8		
	9	20.0	10.0		9		
	10	20.0	20.0		10		
	11	20.0	20.0		11		
	12	30.0	20.0		12		
Cayo	5			Stann Creek	5	30.0	30.0
	6				6	30.0	40.0
	7				7		30.0
	8				8	20.0	20.0
	9				9	30.0	20.0
	10				10	0.0	10.0
	11				11	60.0	
	12				12		30.0
Corozal	5			Toledo	5	40.0	40.0
	6				6	30.0	40.0
	7				7	30.0	40.0
	8				8	40.0	20.0
	9				9	40.0	20.0
	10				10	20.0	30.0
	11				11	20.0	20.0
	12				12	30.0	30.0

Figure A – Prevalence of IDA in males and females by district from 2008 to 2012 using non-random cases.

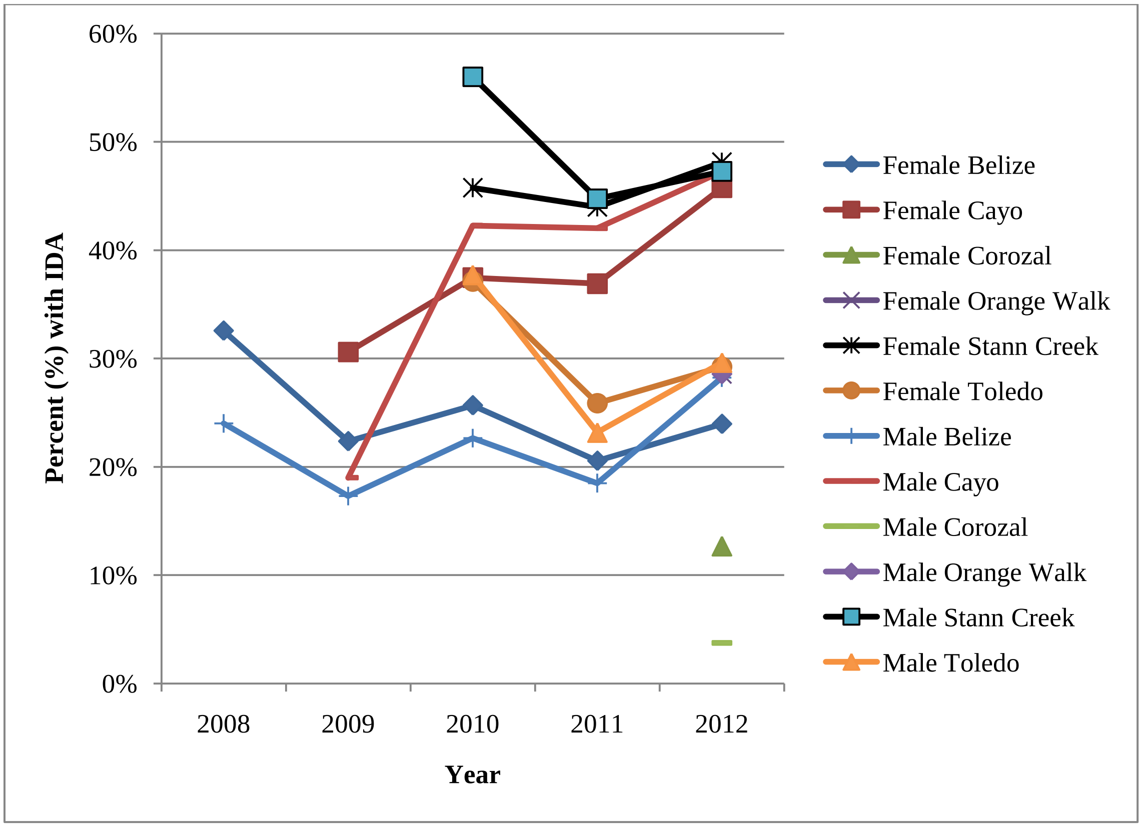


Figure B – Prevalence of IDA in males and females for each age group from 2008 to 2012 using non random samples.

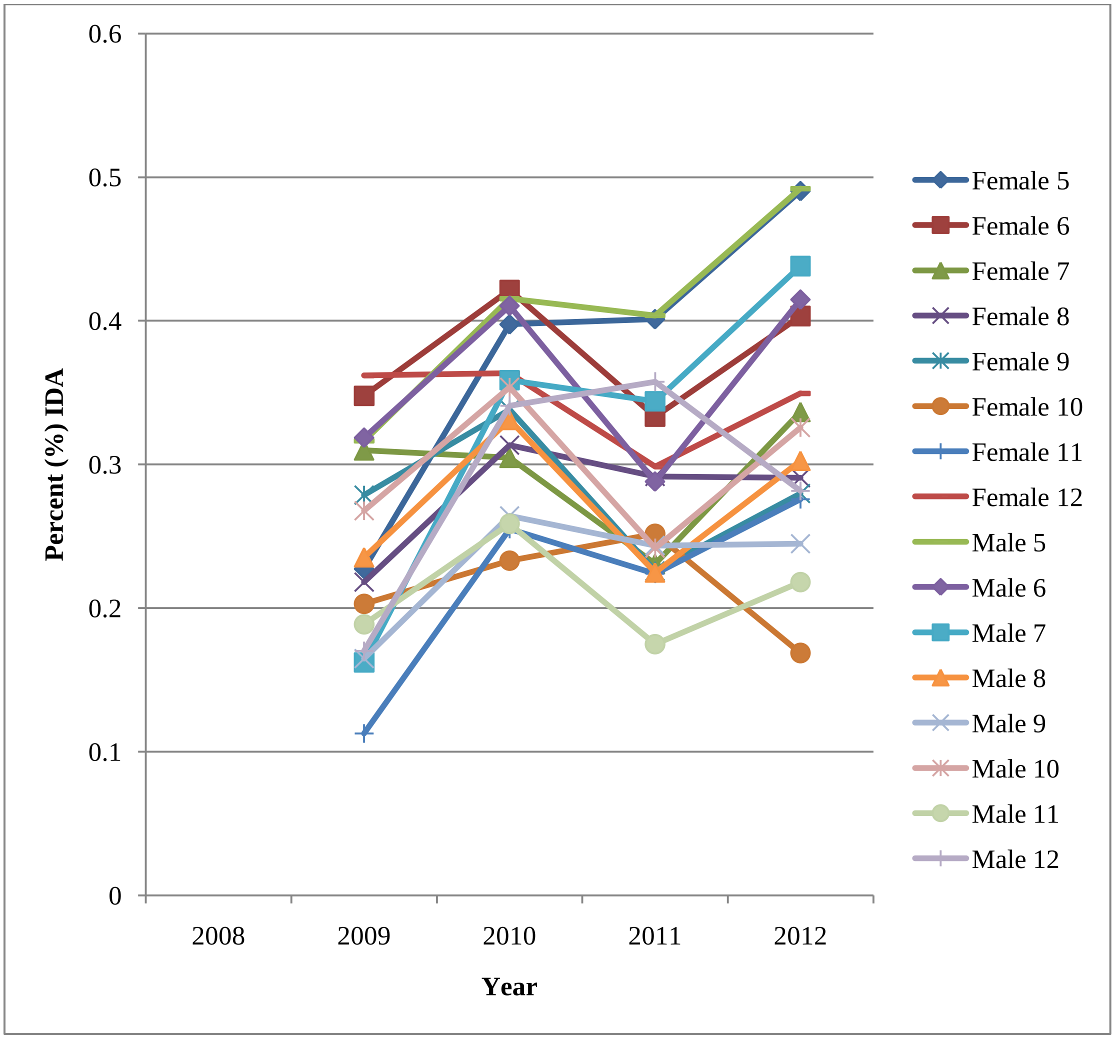
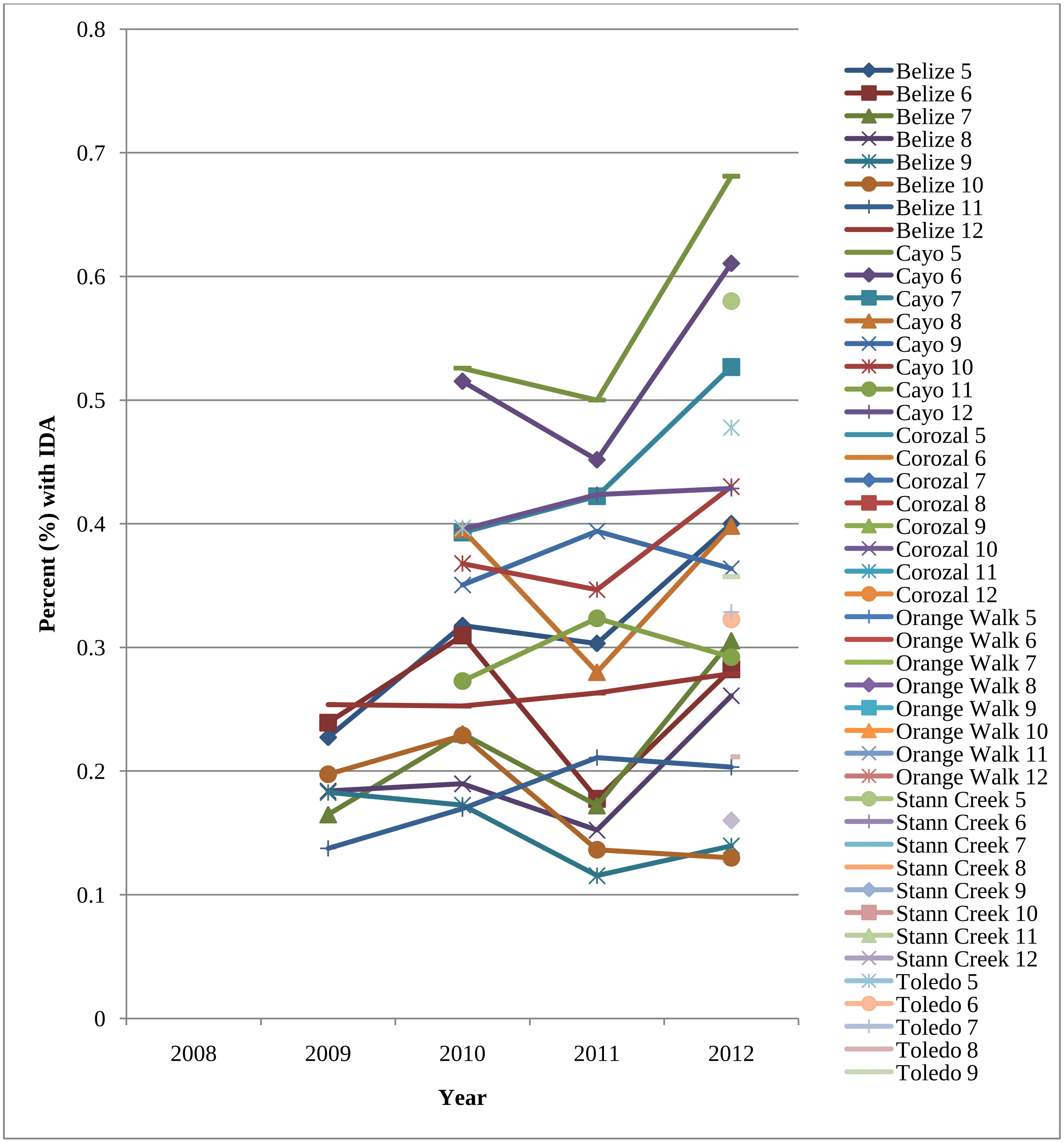


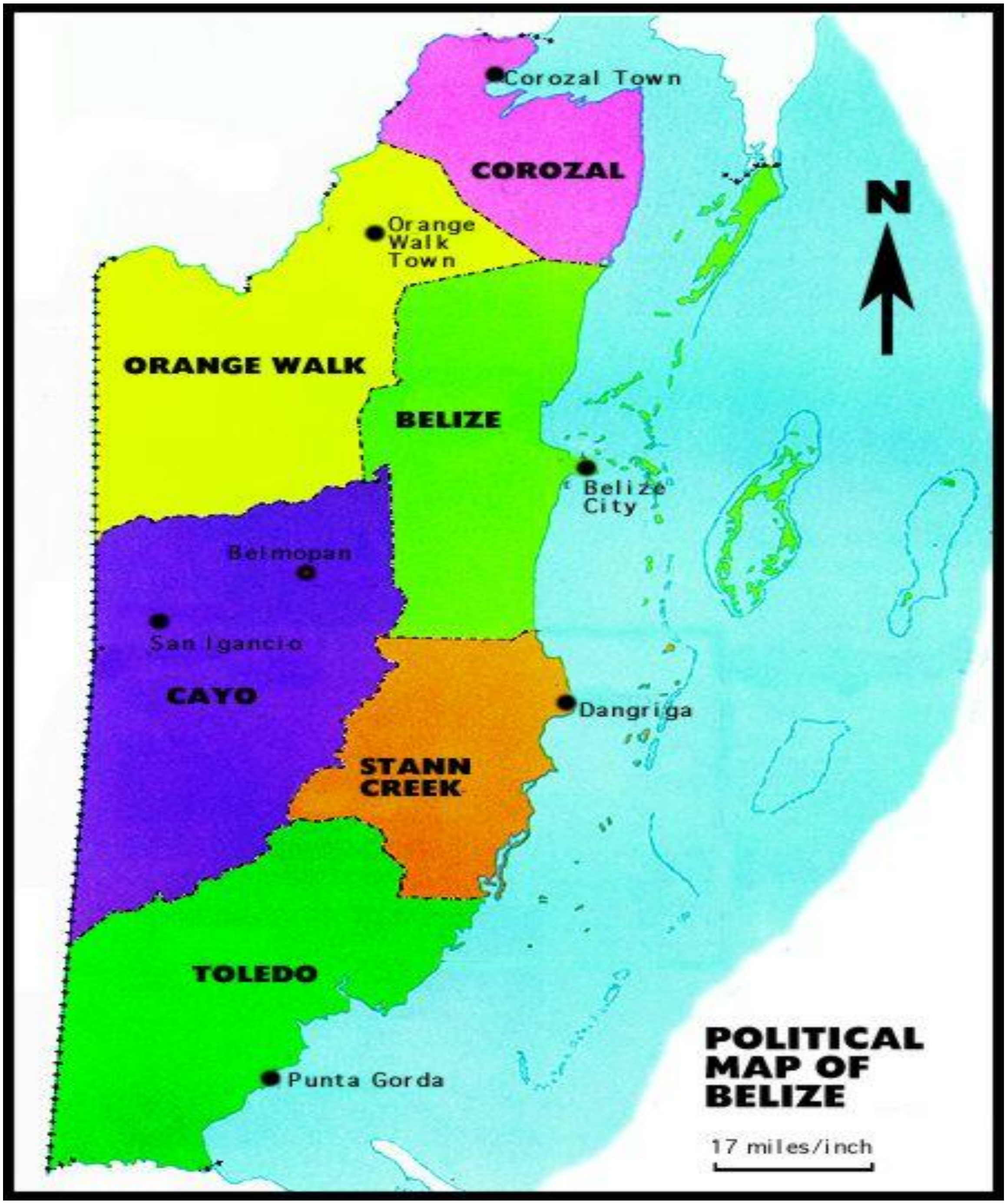
Figure C – Prevalence (%) of IDA for each age group by district for 2008 to 2012 using non random samples.



Box A – Map of the world

Source: http://www.worldatlas.com/webimage/countrys/namerica/camerica/bz.htm

Box B – Political Map of Belize



Source: http://www.belize.net/html/maps/politicalmap.shtml