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Pediatric Malnutrition: A Global Health Threat

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Abstract

Pediatric malnutrition is a major cause of morbidity and mortality in developing nations. In Ghana, one-third of childhood deaths are attributable to it. The most common forms of severe acute malnutrition include kwashiorkor (protein deficiency), marasmus (overall energy deficiency), and various micronutrient deficiencies (iodine, vitamin A, zinc, iron). Thirteen percent of Ghanaian children are moderately or severely underweight, 23% are stunted, and 6 % are wasted due to malnutrition. Princess Marie Louise Children's Hospital (PML) is the largest facility in the greater Accra region for managing cases of pediatric severe acute malnutrition (SAM). Current public health guidelines to reduce disability and mortality from pediatric malnutrition in developing nations stem from the World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) protocols for managing childhood malnutrition. Public health programs designed to combat pediatric malnutrition specific to Ghana include the Under Fives Child Health Policy (UFCHP) and Strengthening Health Outcomes Through the Private Sector (SHOPS) programs. Pediatric SAM is a complex issue that is unlikely to be eliminated in the foreseeable future. Therefore, public health efforts to prevent and treat pediatric SAM must be continuously optimized to reduce the societal and individual burden associated with malnutrition.

Keywords: kwashiorkor, marasmus, severe acute malnutrition, pediatric malnutrition, Ghana, MUAC, WHZ, stunting, wasting, underweight

Introduction

Pediatric Malnutrition as a Global Health Problem

The first United Nations (UN) 2015 Millennium Development Goal is to eradicate extreme poverty and hunger (Frempong & Annim, 2017; Grantham-McGregor et al., 2007). The public health and general global community must continue to work towards making this goal a reality. Severe acute malnutrition (SAM) affects almost 20 million preschool-aged children on a global scale, and is a major cause of childhood morbidity and mortality, particularly in developing nations (Tette, Sifa, & Nartey 2015; WHO, 2013). Unfortunately, six million of these children die each year from preventable malnutrition and concurrent infections associated with it (Grantham-McGregor et al., 2007). Malnutrition is considered to be one of the greatest risk factors for disease and mortality globally, and it is one of the primary factors associated with 52.5% of all deaths in young children (Caulfield et al., 2006; Tette et al., 2015). Case fatality rates from malnutrition are especially high in infants (Tickell & Denno, 2016). The risk of death is nine times higher in malnourished children relative to well-nourished children, with or without complications (Mogre, Yakubu, Fuseini, Amalba, & Aguree, 2017).

Children suffering from malnutrition have a reduced ability to properly fight infection, and are therefore more susceptible to disease, infection, and death from diarrhea, pneumonia, malaria, measles, and general respiratory infections (Caulfield et al., 2006; Caulfield, de Onis, Blössner, & Black, 2004; Grantham-McGregor et al., 2007; Tette et al., 2015; WHO, 2015). An estimated 44-60% of childhood deaths from measles, malaria, pneumonia, and diarrheal diseases can be attributed to comorbid malnutrition (Caulfield et al., 2006). However, the susceptibility to contracting or developing a comorbid condition due to malnutrition depends largely on the

condition itself (Caulfield et al., 2006). For example, contracting illnesses that have available vaccines and are highly contagious, such as measles, are less likely to be impacted by malnutrition when compared to other infections, such as pneumonia or malaria (Caulfield et al., 2006).

Specifically, micronutrient deficiencies such as vitamin A, iron, iodine, and zinc increase the risk of morbidity and mortality in children (Caulfield et al., 2006; Mogre et al., 2017). Vitamin A deficiency is a substantial and preventable cause of blindness (Caulfield et al., 2006). If a child develops blindness from vitamin A deficiency, they only have a 50% chance of survival over the next year (Caulfield et al., 2006). On a global scale, iodine deficiency is the most common cause of brain damage (UNICEF, 2019). Adequate dietary intake of iodine is necessary for regulating the thyroid and maintaining normal thyroid hormone function (Caulfield et al., 2006). Thyroid hormones regulate growth, development, and overall metabolism (Caulfield et al., 2006). Zinc is shown to be essential for cell growth, differentiation, protein synthesis, immune function, and overall human growth and development (Caulfield et al., 2006). Proper zinc supplementation is shown to help combat the effects of diarrhea associated with malnutrition (Dr. Esinam, personal communication, June 2018; WHO, 2015;). Shellfish are a dietary source rich in zinc, but high fiber diets high-phytates foods, such as grains, nuts, and legumes, inhibit the absorption of zinc (Caulfield et al., 2006). A barrier in assessing zinc deficiency can be attributed to a lack of scientific consensus on how to objectively measure zinc deficiency in humans (Caulfield et al., 2006).

Global prevalence & trends.

In 2011, over two million children were admitted to the hospital for SAM globally, and greater than 80% of these admissions were in sub-Saharan Africa (Mogre et al., 2017). Luckily, there has been recent global progress in combating childhood malnutrition. There has been an observed global decline in underweight children from 25% to 15%; however, Africa has undergone the smallest relative decline in prevalence of underweight children when compared to other nations. Specifically, Africa has reduced its prevalence of underweight children from 23% in 1990 to 17% in 2013 (Tette et al., 2015).

In the mid-2000s, the annual estimated number of under-five child deaths per thousand in Sub-Saharan Africa attributable to various nutrient deficiencies are as follows: 383 for vitamin A deficiency, 21 for iron deficiency and anemia, and 400 for zinc deficiency. By comparison, South Asia observed 157 deaths due to vitamin A deficiency, 66 due to iron deficiency anemia, and 252 attributable to zinc deficiency. The Middle East and North Africa observed 70 due to vitamin A deficiency, 10 due to iron deficiency anemia, and 94 due to zinc deficiency. Latin America and the Caribbean observed 6 due to vitamin A deficiency, 10 due to iron deficiency anemia, and 15 due to zinc deficiency. Eastern Europe and Central Asia documented 0 fatalities attributable to vitamin A deficiency, 3 attributable to iron deficiency anemia, and 4 due to zinc deficiency. East Asia and the Pacific observed 11 due to vitamin A deficiency, 18 due to iron deficiency anemia, and 15 due to zinc deficiency. In high-income countries, only 6 fatalities were linked to iron deficiency anemia, whereas 0 deaths could be attributed to either vitamin A or zinc deficiency (Caulfield et al., 2006). This is especially relevant because it indicates that African regions have the most substantial need for improvement when it comes to reducing prevalence of malnutrition-related death in children when compared to other regions in more

industrialized nations. Figure one below elucidates these trends.

Region	Vitamin A Deficiency	Iron Deficiency Anemia	Zinc Deficiency
Sub-Saharan Africa	383	21	400
South Asia	157	66	252
Middle East & North Africa	70	10	94
Latin America & the Caribbean	6	10	15
Eastern Europe & Central Asia	0	3	4
East Asia & the Pacific	11	18	15
High-income Countries	0	6	0

Figure 1: Prevalence of nutritional deficiency death in children younger than five by region (per 1,000). Adapted from "Stunting, Wasting, & Micronutrient Deficiency Disorders" by Caulfield et al., 2006, *Disease Control in Developing Countries.* Copyright 2006 by Oxford University Press.

Importance of Adequate Pediatric Nutrition

Malnutrition is not only strongly associated with mortality, but chronic comorbid or recurrent disease and infection, delayed cognitive and motor skill development, and poor emotional, and social development, as well as many social, educational, and economic disadvantages during adulthood, making a public health effort focused on combating malnutrition in developing nations one of the top priorities for improving infant and child health globally (Caulfield et al., 2006; Frempong & Annim, 2017; Grantham-McGregor et al., 2007; Mogre et al., 2017; Tette et al., 2015). The first few years of a child's life are of crucial developmental importance (Grantham-McGregor et al., 2007). Each year, 200 million children younger than five years old do not reach their full cognitive developmental potential due to

malnutrition in early childhood (Grantham-McGregor et al., 2007). Of these 200 million children, six million die from preventable severe malnutrition (Grantham-McGregor et al., 2007). Early brain development is modified substantially by nutritional quality and environment (Grantham-McGregor et al., 2007). Animal studies suggest that undernutrition, iron-deficiency, and environmental toxins can affect brain structure and have a lasting negative impact on cognitive functional and emotional effects (Grantham-McGregor et al., 2007).

However, the brain is particularly vulnerable during the early stages of development, and proper interventions during the earliest stages can help correct the issues associated with early malnutrition. The earlier an intervention is implemented, the greater the chance for recovery and probability of correcting these issues (Grantham-McGregor et al., 2007). Therefore, preventing malnutrition during the early developmental stages of childhood remains a crucial public health goal to improve future health outcomes and longevity of society as a whole.

Social Determinants Associated with Pediatric Malnutrition

It is proposed that the etiology and causes of SAM in children are heterogeneous, encompassing many different social determinants, including parental socioeconomic status and family poverty (Tette et al., 2015). According to UNICEF, the main causes of childhood malnutrition can be categorized into one of the three following factors: household food insecurity, inadequate care and unhealthy household environment, and lack of access to healthcare services (Tette et al., 2015). These three factors are most strongly associated with social determinants of health, including socioeconomic and political factors (Tette et al., 2015).

Poverty is considered to be the greatest factor contributing to childhood malnutrition and the social determinants associated with it (Grantham-McGregor et al., 2007). There is substantial

evidence to suggest that malnutrition and poverty are often intergenerational, and therefore likely to be passed down with each subsequent generation due to a predisposition for disadvantage (Caulfield et al., 2006). While managing pediatric malnutrition and the preventable deaths related to it are of extreme importance, the public health implications attributable to survivors of pediatric SAM can have negative, long-term societal consequences. Malnourished children living with socioeconomic disadvantages are less likely to perform well academically than their well-nourished and more privileged counterparts (Caulfield et al., 2006; Grantham-McGregor et al., 2007). This is due to malnutrition contributing largely to adverse or stunted cognitive development in children. Children suffering from delayed or stunted cognitive and social-emotional development as a result of poor nutrition are prone to perpetuating the cycle of intergenerational poverty because they tend to do poorly in school, have high fertility, and relatively low income potential, thus, often providing less than adequate care for their children (Caulfield et al., 2006; Grantham-McGregor et al., 2007). In order to prevent the long-term public health consequences of childhood stunting, public health efforts targeting pediatric SAM must also reach moderately malnourished children in order to improve future health outcomes.

Defining, Measuring, & Treating Pediatric Malnutrition

Kwashiorkor, Edema, & Marasmus

Kwashiorkor is a subtype of malnutrition caused by protein or amino acid deficiency (Coulthard, 2015). Marasmus is a subtype of malnutrition caused by overall energy deficiency and most often results in severe wasting (Coulthard, 2015). One of the most distinguishing factors associated with kwashiorkor is edema, or severe swelling caused by fluid retention (Coulthard, 2015). Many patients presenting with kwashiorkoric edema suffer from septic shock

as a result. Case fatality rates associated with septic shock as a symptom of kwashiorkor are extremely high; 50% of these patients die (Coulthard, 2015; Mogre et al., 2017).

In the 1950s, it was established that edema from kwashiorkor is associated with extremely low plasma serum concentrations of albumin, whereas marasmus alone does not present itself with hypoalbuminemia. Following this observation, it was established in the 1970s that lower levels of serum albumin were associated with greater severity of edema in patients presenting with kwashiorkor-related edema (Coulthard, 2015). Currently, correcting hypoalbuminemia is associated with relatively quick recovery from edema, with an average recovery time between six and 12 days (Coulthard, 2015). Overall, the case fatality rates in resource-constrained environments (predominantly sub-Saharan Africa) for marasmus are 20%-30% and 50%-60% for kwashiorkor (Mogre et al., 2017).

Mid Upper Arm Circumference & Weight-for-height

Nutritional rehabilitation centers in resource-constrained nations typically use a standardized method to determine malnutrition status in children, referred to as the measurement of the Mid Upper Arm Circumference (MUAC); additionally, a weight-for-height z-score (WHZ) can also be used to diagnose SAM (Tette et al., 2015; Roberfroid et al., 2013). The MUAC method is predetermined by the WHO and is used for children aged six to 59 months suspected of suffering from malnutrition (WHO, 2018). Children measuring with a MUAC < 115 mm, a WHZ of at least < -3 SD, or with any physical signs of bilateral pitting edema are considered to be suffering from SAM; these patients should be admitted to a program designated to treating and managing SAM (Das et al., 2018; Roberfroid et al., 2013; WHO, 2018). Moderate malnutrition is defined as a WHZ ≥ -3SD to < -2SD (Tette et al., 2015).

Stunting, wasting, & underweight.

Stunting, wasting, underweight, and other types of undernutrition are all major causes of permanent or long-term disability to survivors (Caulfield et al., 2006; Mogre et al., 2017). Stunting is defined as a low length or height relative to age (Caulfield et al., 2006; Mogre et al., 2017). Chronic undernutrition is the cause of stunting, and therefore stunts overall linear growth (Caulfield et al., 2006). Wasting is defined as rapid weight loss as a result of malnutrition. Acute malnutrition over a shorter period of time is the cause of wasting. Underweight is defined as combined stunting and wasting.

The objective measurement to consider a child stunted is when their relative height-for-age z-score (HAZ) is below -2 SD. With a HAZ below -2 SD, the chances of being a normal height are less than 3% (Caulfield et al., 2006). According to the UN, 26% (165 million) children under the age of five suffered from malnutrition-related stunting in 2011 on a global scale; greater than 75% of these children resided in sub-Saharan African and Asian regions (Mogre et al., 2017). The objective measurement that constitutes wasting is when a child's WHZ is below -2 SD (Caulfield et al., 2006). The objective measurement for underweight is defined as a weight-for-age z-score (WAZ) is below -2 SD (Caulfield et al., 2006). More than 130 million children younger than age five are underweight (Caulfield et al., 2006).

Although the above mentioned standard deviations are objective measurements to define and diagnose stunting, wasting, and underweight, it is relevant to note that children who have a WAZ below -1 SD are still at a high risk for malnutrition-related death and developing comorbid infections (Caulfield et al., 2006). Differentiating between childhood stunting, wasting, and underweight is particularly important because the prevalence of all three is decreasing on an

international level, but the prevalence of stunting has been steadily increasing in Africa in recent years (Frempong & Annim, 2017; Caulfield et al., 2006).

In the mid-2000s, 32% of children younger than five in Sub-Saharan Africa had a WAZ below -2 SD, while 38% had a WAZ between -2 SD and -1 SD. In South Asia, 46% had a WAZ below -2 SD, while 44% scored between -2 SD and -1 SD. In the Middle East and North Africa, 21% had a WAZ below -2 SD, and 35% scored between -2 SD and -1 SD. In Latin America and the Caribbean, 6% had a WAZ below -2 SD, while 23% scored between -2 SD and -1SD. Eastern Europe and Central Asia observed 6% and 21% for the same scores, and East Asia and the Pacific documented 18% and 29%, respectively (Caulfield et al., 2006). Figure two below elucidates these trends.

Region	WAZ<-2 SD	WAZ>-2 SD & <-1 SD
Sub-Saharan Africa	32	38
South Asia	46	44
Middle East & North Africa	21	35
Latin America & the Caribbean	6	23
Eastern Europe & Central Asia	6	21
East Asia & the Pacific	18	29
High-Income Countries	2	14

Figure 2: Prevalence of underweight in children younger than five by region (%). Adapted from “Stunting, Wasting, & Micronutrient Deficiency Disorders” by Caulfield et al., 2006, *Disease Control in Developing Countries.* Copyright 2006 by Oxford University Press.

Identifying infants younger than six months.

Infants who are younger than six months old should be admitted to clinical care for SAM management if any of the following symptoms occur: recent weight loss or failure to gain expected amounts of weight, any serious medical complication that may cause malnutrition, persistent observed ineffective feeding for at least 15-20 minutes (defined as ineffective attachment, positioning, or suckling while breastfeeding), any type of pitting edema, or any social or medical issue requiring intensive support (such as a physical or mental disability) (WHO, 2013). Once admitted, feeding approaches focused on exclusive breastfeeding practices should be the primary focus during recovery (WHO, 2013).

Protocols & Recommendations for Treating & Preventing Pediatric Malnutrition

Current protocols and guidelines for treating and preventing pediatric malnutrition are issued by the World Health Organization (WHO) and supporting statements from the United Nations International Children's Emergency Fund (UNICEF) (Mogre et al., 2017). The WHO and UNICEF standards have been in place since the 1980s and were implemented as a response to combat the high rates of case fatalities associated with inpatient hospital treatment of childhood severe acute kwashiorkor and marasmus (Mogre et al., 2017). The WHO's first protocol guidelines for managing pediatric SAM focused specifically on protein-energy malnutrition and were initially published in 1981, but were replaced in 1999 to target multiple aspects of SAM (Tickell & Denno, 2016). Protocol revisions were also made in 2003 and 2013, but the interventions still focus on managing all aspects of SAM (Tickell & Denno, 2016). Relevant joint statements from WHO, UNICEF, and other public health agencies were issued in 2007 and 2009 (Tickell & Denno, 2016). Currently, there is some evidence-base to support the use of these protocols, as evidence shows that the WHO protocols and UNICEF relevant

statements have resulted in a decrease in SAM-related fatalities from a previously estimated 30%-50% fatality to about only 5%-15% fatality with the proper adherence to these protocols (Mogre et al., 2017). Additionally, recommendations regarding antenatal, postnatal, and delivery care are included in the guidelines in order to prevent malnutrition and promote positive long-term health outcomes for mothers and their infants (Dickson, Darteh, & Kumi-Kyereme, 2017).

Maternal & infant preventative care.

The fourth 2015 UN Millennium Development Goal is to reduce under-five child mortality to 40/1000 live births, and the fifth 2015 UN Millennium Development Goal is to improve maternal health (UN, 2015). Lack of antenatal care can negatively impact the accuracy of health information that expectant mothers have access to, and lack of accurate health information can contribute to overall poor maternal health, leading to poorer health outcomes for expectant mothers and their infants (Dickson et al., 2017). One of the most common adverse health outcomes for expectant mothers with inadequate antenatal care is delivering premature babies or low birth weight infants. In addition to poor antenatal care, low birth weight infants are most frequently associated with young mothers, maternal malnutrition, low gestational weight gain, maternal weight loss induced by illness, and adverse conditions during pregnancy (including malaria, smoking, and excessive alcohol consumption) (Caulfield et al., 2006; Tette et al., 2015). It is also relevant to note that infants born with a low birth weight suffer from intrauterine growth retardation and are more likely to develop non-communicable diseases in adulthood, such as hypertension and type II diabetes; therefore, preventing malnutrition is crucial even in antenatal stages of development (Caulfield et al., 2006; Tette et al., 2015).Thus, in order

to improve overall health outcomes for mothers and infants, it is recommended that pregnant women make at least four antenatal care visits (Dickson et al., 2017). In 2014, only 60% of pregnant women made at least four antenatal care visits globally, and these visits were most often made later than recommended (Dickson et al., 2017).

Another recommendation is that all infant births are delivered by a skilled birth attendant, such as a midwife (WHO, 2015). The importance of having a skilled birth attendant to deliver a baby is related to their training for managing deliveries properly and the period after delivery more effectively when compared to untrained birthing attendants (WHO, 2015). Postnatal care visits are recommended as soon as possible after infant birth, generally within one or two days after delivery (WHO, 2015). These recommendations are made in order to diagnose and treat newborns who are ill, manage and treat adverse health conditions, and prevent newborn deaths (WHO, 2015).

An additional area of concern for maternal and infant nutrition is related to a high prevalence of anemia, both in children and women of childbearing age (WHO, 2015). Iron deficiency is the most common cause of anemia, although vitamin A deficiency, blood loss, folate deficiency, malaria, and HIV can also be causal factors for developing anemia (Caulfield et al., 2006). Iron deficiency can cause irreversible neurological damage in children (Caulfield et al., 2006). In 2003, an estimated three-quarters of all children were anemic, while 45% of women of reproductive age also suffered from anemia (WHO, 2015). This data indicates a need to combat both childhood and maternal malnutrition through interventions targeting not only general malnutrition, but also interventions that specifically target increased dietary consumption of iron and its bioavailability, along with other micronutrients. Iron is found primarily in

hemoglobin, and although all plant-sources of food contain a certain amount of iron, dietary sources of animal-based foods contain greater amounts of iron and iron bioavailability when compared to plant-based foods (Caulfield et al., 2006). Currently, there is no strong evidence-base to suggest that iron deficiency and anemia are causes of stunting, although its deficiency can cause or be exacerbated by other adverse, and often fatal, health outcomes mentioned above (Caulfield et al., 2006).

Determining appropriate treatment: inpatient vs. outpatient care.

Children presenting with uncomplicated SAM are not required to be admitted to inpatient care (WHO, 2013). While SAM can be effectively managed and treated through outpatient care when it presents itself in isolation without additional medical complications, there are many instances in which SAM presents itself with other infections, metabolic dysfunction, or anorexia; such cases warrant inpatient management to treat both the SAM and the additional health complications associated with it (Tickell & Donno, 2016). After the child is diagnosed with SAM, the child must be assessed for whether inpatient or outpatient treatment is the most appropriate for managing their individual case.

Children presenting with SAM must undergo a comprehensive medical exam that assesses whether the child has other medical complications aside from malnutrition, as well as whether they have an appetite or not. Children who pass the appetite test, meaning that they do have appetite, and who are additionally clinically well, should be treated as outpatients. Children who do not pass the appetite test, have medical complications, severe edema, or at least one Integrated Management of Childhood Illness (IMCI) danger sign should be treated as inpatients (WHO, 2018).

Edema is clinically considered severe when it is generalized to the feet, arms, face, and legs. Mild edema consists of edema in both feet, while edema is considered to be moderate if it is present in both feet and the lower legs, hands, or lower arms (WHO, 2013). The IMCI danger signs include the following: a child's inability to drink or breastfeed, consistent vomiting after food intake, at least one (or more) convulsions typically lasting less than fifteen minutes, and lethargy or unconsciousness (WHO, 2018). Children presenting with SAM who are being managed in outpatient care should be given a course of oral antibiotics, such as amoxicillin (WHO, 2013). Children who are undernourished but do not meet the criteria for SAM should not be given antibiotics, unless they also show signs of an infection in addition to their malnutrition (WHO, 2013).

Therapeutic foods, F-75, & F-100.

Formula 75 solution (F-75) is a low-protein milk formula used as a starter formula used in the early phases of treating complicated SAM (University of Oxford, 2016). It is given to children in the early phases of treating malnutrition because it is shown to help improve metabolic homeostasis in order to help the child achieve catch-up growth and appropriate weight gain in the later phases of treatment (University of Oxford, 2016). F-75 contains a high proportion of calories from carbohydrates, as well as added sucrose, lactose, and maltodextrin (University of Oxford, 2016). The formula contains 75 kcal and 0.9 grams of protein per 100 mL (UNICEF, 2017). Children being managed in outpatient care should be given F-75 as an initial treatment (WHO, 2013). Subsequently, the rehabilitation phase follows the initial F-75 feeding phase (WHO, 2013). When transitioning children from F-75 to therapeutic foods during the

rehabilitation phase, it is recommended that they are given approximately 100-135 kcal per kilogram body weight per day (WHO, 2013).

Formula 100 solution (F-100) is a formula solution given to children during the rehabilitation phase of treating SAM (UNICEF, 2017). It contains a greater number of calories from carbohydrate and protein relative to F-75 and helps rebuild wasted tissue in children suffering from SAM (UNICEF, 2017). F-100 formula contains 100 kcal and 2.9 grams of protein per 100 mL (UNICEF, 2017). Children admitted to inpatient care should be provided with F-100 solution for weight gain, followed by therapeutic foods for recovery (WHO, 2013)

Ready-to-use therapeutic foods (RUTF) are used during the rehabilitation phase of treating SAM, similar to the use of F-100 (WHO, 2013). RUTF is an energy-dense paste enhanced with nutrients and vitamins (UNICEF, 2017). Some of the primary ingredients of RUTF are peanuts, oil, sugar, milk powder, and nutritional supplements (UNICEF, 2017). RUTF is shown to help children gain appropriate amounts of weight during the rehabilitation phase of SAM-recovery (UNICEF, 2017).

Vitamin A supplementation.

Vitamin A deficiency is a substantial and preventable cause of blindness (Caulfield et al., 2006). If a child develops blindness from vitamin A deficiency, they only have a 50% chance of survival over the next year (Caulfield et al., 2006). Children presenting with SAM should be given vitamin A supplements daily. However, children receiving daily F-75, F-100, or RUTF in compliance with WHO guidelines do not need daily high-dose vitamin A supplementation, as foods in compliance with WHO standards are already appropriately supplemented with vitamin A (WHO, 2013). If children are diagnosed with SAM and are not receiving fortified foods or

other daily vitamin A supplements, they should be given high-dose vitamin A with an age-dependent dose, such as 50 000 IU, 100 000 IU, or 200 000 IU (WHO, 2013). The benefits of supplementing adequate vitamin A for managing SAM are that it can help minimize the effects of diarrhea and measles, while also having positive effects on immune system function (Caulfield et al., 2006).

Nutritional methods for preventing vitamin A deficiency include increasing dietary consumption of foods high in preformed vitamin A, carotenoids, and dietary fats. Carotenoids are precursors to vitamin A, although carotenoid-rich foods are typically less bioavailable than preformed vitamin A sources of food (Caulfield et al., 2006). When eaten, the body converts carotenoids into vitamin A, and dietary fat increases the absorption of vitamin A (Caulfield et al., 2006). Animal sources of food are typically rich in preformed vitamin A, whereas plant sources are high in carotenoids (Caulfield at al., 2006). Foods high in either preformed vitamin A of carotenoids include the following: liver, milk, egg yolks, cruciferous vegetables (i.e. spinach), and orange or yellow fruits and vegetables (excluding citrus fruits), such as mangoes, pumpkin, and squash (Caulfield et al., 2006).

Managing fluid intake & rehydration.

Children presenting with severe dehydration should only be given IV fluids if they have septic shock (WHO, 2013). Typically, IV fluids have too high of sodium and potassium concentrations that would unnecessarily strain the already weakened heart of a child suffering from SAM, and therefore could cause heart and organ failure, resulting in death (Dr. Esinam, personal communication, June 2018). Therefore, it is recommended that full-strength low-osmolarity not be used on children with SAM presenting without shock; instead,

half-strength solution with added potassium, glucose, and 20 mg zinc supplements should be used in cases of children presenting with SAM who are not in shock (El-Khoury, Banke, & Sloane, 2016; WHO, 2013).

Children should be rehydrated slowly through either by consuming fluids orally or through a nasogastric tube. The recommended amount of fluid intake is approximately 5-10 mL per kg depending on height. (WHO, 2013). However, children presenting with cholera should be given solution that is not diluted, as higher strength solution helps with severe diarrhea (WHO, 2013). Children with septic shock should be rehydrated either through IV or nasogastric tube with either half-strength Darrow's solution, plus 5% added dextrose, or Ringer's lactate solution with 5% added dextrose; if neither is available, 0.45% saline with added 5% dextrose is sufficient (WHO, 2013).

Managing HIV-infected children.

Children presenting with SAM who are also HIV-infected should be treated with the same antiretroviral drug treatment regimens as children who are HIV-infected without SAM (WHO, 2013). However, HIV-infected children with SAM need to be monitored closely for the initial six-to-eight weeks of antiretroviral therapy for potential metabolic complications and other infections associated with comorbid SAM and HIV (WHO, 2013). The same therapeutic food approaches should be used for HIV-infected children with SAM as for children with SAM who are not infected with HIV (WHO, 2013). HIV-infected children should be administered high-dose vitamin A supplementation dependent on age (50-200,000 IU), and zinc for management of diarrhea (WHO, 2013). If persistent diarrhea of HIV-infected children does not resolve with this type of standardized management, they need to be examined for carbohydrate

intolerance and other infections that may need to be treated in order to resolve the persistent diarrhea and SAM (WHO, 2013).

Assessing recovery.

Children who are admitted to inpatient care for the management of SAM can eventually be transferred to outpatient care once their symptoms, such as poor appetite and edema, improve and they are considered otherwise clinically well. However, specific anthropomorphic measurements, such as MUAC and WHZ, should not be the sole determinants taken into consideration when deciding to transfer children to outpatient care (WHO, 2018). In order to transfer a malnourished child from inpatient to outpatient care, the actual symptoms of nutrient deficiency should show significant signs of improvement, rather than simply an increased weight or MUAC measurement.

After a child is moved from an inpatient to an outpatient program for managing malnutrition, certain criteria must be met prior to releasing the child from the treatment program. Children should only be discharged from treatment for severe acute malnutrition when their WHZ is ≥ -2 SD, they have had no edema for at least two weeks prior to discharge, or if their MUAC is ≥ 125 mm (WHO, 2018). The anthropometric measurement used to diagnose malnutrition should also be the same one used to assess the child's recovery. For example, if a child's MUAC was the primary anthropometric measure used to diagnose malnutrition, it should also be used to assess the child's improvements in health and recovery. Percentage weight gain should not be used as a criteria to discharge a patient (WHO, 2018). In addition, children presenting with SAM who are discharged should be monitored periodically through follow-up exams in order to prevent any relapse (WHO, 2013).

Ghana As A Case Study

General Background Information

Ghana is a coastal country in the West-African region, with a population greater than 21 million (WHO, 2015). Close to 60% of Ghanaians live in rural areas, whereas only 40% of the population resides in urban areas (WHO, 2015). Over 500,000 babies are born in Ghana each year (Vidal, 2011). The fertility rate in rural Ghana is an estimated 5.6 live births per woman, and the fertility rate in urban areas is 3.1; the total fertility rate (TFR) for the country as a whole is 4.4 (WHO, 2015). It is relevant to note that the vast majority of Ghana's population today is relatively young (most Ghanaians are under 30 years old), making public health efforts to promote positive long-term health outcomes is a major priority for the country on a community level. Over 40% of the total population consists of children younger than 15, with an estimated 15% of the population consisting of preschool-aged children younger than five (Vidal, 2011; WHO, 2015). The elderly make up very little of the total Ghanaian population, with approximately only 3% of total residents consisting of residents older than 60 years (Vidal, 2011).

Recent economic progress & childhood mortality.

In 1999, the overall level of poverty among Ghanaians was 40%, with 27% of the entire population living in extreme poverty (WHO, 2017). There has been some positive social and economic progress in Ghana over the past two decades. In the last 20 years, the country has managed to achieve a sustained per capita income growth, and as a result, this has been associated with a reduction in overall poverty among Ghanaian families (Frempong & Ammin, 2017; WHO, 2015;). The reduction in poverty has been concentrated in the Greater Accra

Region, which is the capital. However, even with these economic advancements, childhood mortality rates for children younger than five are still very prevalent due to poverty-related malnutrition, malaria, tuberculosis, HIV, and diarrheal diseases.

Nutrition Research: Significance of Princess Marie Louise Children's Hospital

Princess Marie Louise Children's Hospital (PML) was established in the Greater Accra Region of Ghana in the year 1926 with the function of providing speciality services for maternal and child healthcare delivery. In 1933, Dr. Cicely Williams was the first scientist to classify kwashiorkor, including its progression, at PML hospital (Heikens & Manary, 2009). High mortality rates from severe acute kwashiorkor in children have remained fairly constant since the condition was first described in 1933. Half of children suffering from septic shock associated with severe acute kwashiorkor die (Coulthard, 2015; Mogre et al., 2017).

While malnutrition caused by overall energy deficiency resulting severe wasting is referred to as marasmus, kwashiorkor (protein deficiency) is accompanied by severe swelling due to fluid retention, also known as edema (Coulthard, 2015). Pediatric kwashiorkor and marasmus are both common in Ghana. One of the most distinguishing features of kwashiorkor is edema, usually followed quickly by death (Heikens & Manary, 2009; Waterlow, 1984). Dr. Williams observed that edema and kwashiorkor in Ghanaian children was most frequently associated with a maize diet (Heikens & Manary, 2009). Dr. Cicely Williams' observation of the association between kwashiorkor and a predominantly maize diet lead her to believe that amino acid or protein deficiency could potentially be one of the primary causes of the condition (Heikens & Manary, 2009). Since this discovery, PML hospital is currently the largest hospital facility in the Greater Accra Region of Ghana dedicated to treating and managing pediatric cases

of kwashiorkor and complicated or uncomplicated SAM. The hospital currently has 74 inpatient beds and several outpatient programs, as well as primary care and specialized pediatric care services (Tette et al., 2015).

Prevalence & Trends

Childhood mortality & malnutrition status.

From 2001-2006, under-five childhood mortality was exceptionally high, with a prevalence of 111/1000 live births (WHO, 2015). Newborn deaths, however, still constitute the greatest number of under-five childhood deaths and the prevalence of such is 43/1000 live births, accounting for over 40% of all childhood mortality cases in Ghana (WHO, 2015). For purposes of clarity, newborn deaths are defined as infant deaths occurring within the first 28 days of life (WHO, 2015). As a response, the fourth global 2015 UN Millennium Development Goal is to reduce under-five child mortality to 40/1000 live births (UN, 2015). A positive decrease in measles-related childhood deaths over the last five years in Ghana can be attributed to higher rates of measles vaccination coverage (WHO, 2015). In 2006, childhood immunization rates for measles were an estimated 78% (WHO, 2015). In addition, an estimated 64% of children between the ages of one and two during the same time period were also fully up-to-date on their immunizations, making Ghana an African country with relatively high childhood immunization rates (WHO, 2015).

One-third of all childhood deaths in Ghana can be attributed to malnutrition (UNICEF, 2017). Fifty-seven percent of children under the age of five in Ghana suffer from anemia (UNICEF, 2019). One in seven children under age five are moderately or severely underweight, 23% are moderately or severely stunted, and 6% are moderately or severely wasted (Frempong

& Annim, 2017; Mogre et al., 2017; WHO, 2015). In the northern region of Ghana, which has a greater proportion of rural-dwellers relative to other regions, an estimated 37% of children are stunted (UNICEF, 2019). The prevalence of underweight and stunting has been decreasing in Ghana, but the prevalence of child wasting increased by 1% between 2003-2008 (Frempoing & Annim, 2017). Expanding on this, although the overall prevalence of underweight and stunting have declined in Ghana since 2003, the prevalence is still above the global average of 25% (Frempong & Annim, 2017). Figure three elucidates on recent prevalence and trends in pediatric stunting, wasting, and underweight in Ghana (Frempong & Annim, 2017).

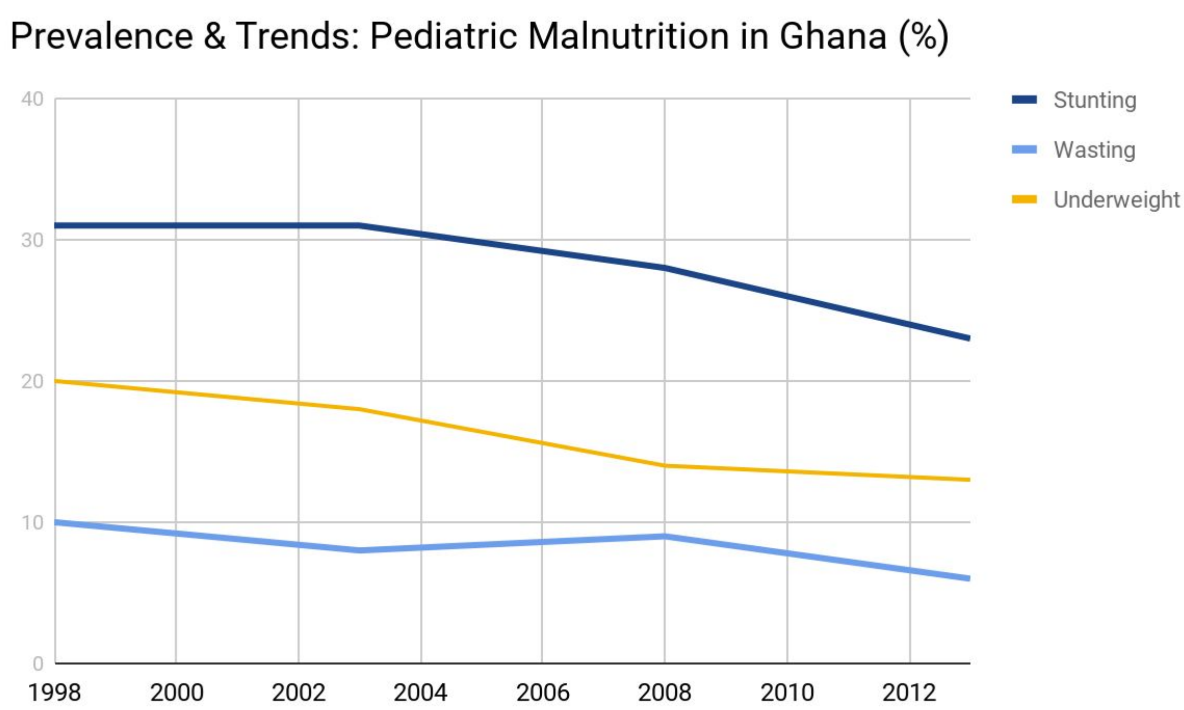

Figure 3: Prevalence and trends of childhood stunting, wasting, and underweight in Ghana (%). Adapted from "Dietary diversity and child malnutrition in Ghana" by Frempong & Annim, 2017, *Heliyon*, *3*(5). Copyright 2017 by Elsevier Ltd.

Antenatal, delivery, & postnatal care participation.

In 2014, Ghana ranked above the international average for antenatal care participation, with an estimated 87% of pregnant women making a minimum of four antenatal care visits (Dickson et al., 2017). In 2003, only 59% of pregnant women in Ghana made at least four or more antenatal care visits; the substantial rise in accessing antenatal care from 2003-2014 will likely result in more positive future health outcomes for Ghanaian women and their infants in the future (WHO, 2015). However, antenatal care visits in Ghana are still most often made later in pregnancy than is recommended. In addition to late accessing antenatal care late, only 50% of pregnant women received all of their doses of tetanus toxoid vaccine (WHO, 2015). In 2006, only 50% of all infant births and deliveries in Ghana were made by a skilled and properly trained birth attendant, such as a midwife (WHO, 2015). In 2006, 54% of newborns received some type of postnatal care and postnatal visits. Generally, postnatal visits are desirable as soon as possible after birth (within the first two days) in order to identify and diagnose newborns who are ill, manage and treat adverse health conditions, and prevent newborn deaths (WHO, 2015). However, this recommendation is rarely met in Ghana. In 2003, 34% of newborns received some type of postnatal visit within the first week after birth (WHO, 2015). Therefore, there is still a need for improvement in improving maternal and infant health care practices.

Fortunately, the increasing prevalence of formal education among Ghanaian women is shown to be positively associated with increased rates of accessing antenatal, delivery, and postnatal care (Vidal, 2011). In the early and mid-1900s, antenatal care was relatively uncommon for pregnant women in Ghana, but as the population becomes more educated, seeking out some form of antenatal care has risen to a prevalence of about 95%, even if pregnant

women do not make at least four antenatal care visits (Vidal, 2011). Although the percentage of Ghanaian women accessing antenatal care services has been steadily improving, the prevalence needs to continue to increase and the quality of care needs to continuously be improved for better future health outcomes of mothers and infants (WHO, 2015).

Demographic differences in accessing antenatal care.

It is relevant to note that the data indicates demographic differences in antenatal care participation among Ghanaian women. Higher education, urban-dwelling, and higher socioeconomic status were positively associated with utilizing antenatal care, whereas lack of education, rural-dwelling, and lower socioeconomic status were negatively associated with antenatal care participation (Dickson et al., 2017). Additional factors documented as negatively influencing antenatal care participation were younger maternal age, lack of access to transportation, and greater number of children mothers already had (Dickson et al., 2017).

However, regardless of socioeconomic and other demographic factors, evidence suggests that women enrolled in the National Health Insurance Scheme (NHIS) are more likely to use antenatal care services than women who are not enrolled in NHIS (Dickson et al., 2017). This evidence may indicate that policies and programs aimed to enroll pregnant women in NHIS may be the most beneficial intervention for increasing antenatal care participation among pregnant Ghanaian women. This type of intervention may also lead to more positive long-term infant and maternal health outcomes, per the 2015 UN Millennium Development Goals four and five, because a greater proportion of women and their infants will have access to preventative health care services if they are enrolled in health insurance.

Factors Contributing to Pediatric Malnutrition in Ghana

Resource-constraints accompanying overpopulation.

Some of the most common adverse health issues complicating SAM in Ghana are malaria, tuberculosis, edema, and HIV. Although the rate of live births per woman in Ghana have been steadily declining in recent years due to the country's recent socioeconomic advancements mentioned above, the survival rates of mothers and infants have also increased due to the positive advancements in medical care and increased public health resources associated with these socioeconomic advancements. This has ultimately led to a population explosion, even with the reduction of live births (Vidal, 2011). In addition, there is substantial cultural pressure for Ghanaians to have children, further contributing to a rise in population (Vidal, 2011).

The recent and drastic increase in population has put a strain on healthcare services and resources in the country (Vidal, 2011). A result of this overpopulation is the limitation of available resources to address one of Ghana's major public health challenges, the prevention and treatment of childhood malnutrition. Almost half of all hospital resources and funding in Ghana are spent on childbirth, and the remaining amounts are typically most often used to treat malaria and health complications related to it, leaving few remaining resources available to combat pediatric malnutrition (Vidal, 2011).

Lack of adherence to current protocols for managing child health.

Elucidating on this, evidence suggests a need for substantial improvement in following current protocols and guidelines for managing malnutrition and concurrent infections. In 2006, only 37% of children in Ghana suffering from dehydration due to infection appropriately received Oral Rehydration Solution (ORS) (also known as oral rehydration salts or oral

rehydration therapy), only 34% of children with pneumonia received the appropriate care from a properly trained healthcare provider (while only 33% received the appropriate antibiotics to treat pneumonia), only 60% of children in Ghana had received appropriate vitamin A supplementation within the previous six months, and only 61% of children who presented with a clinical fever received the correct treatment against malaria (WHO, 2015). Methods to ensure all children presenting with various childhood illnesses complicated by malnutrition must be improved to reach a greater number of children.

Female, maternal, & child disadvantages.

Ghanaian women and their children are more susceptible to poverty and other factors associated with social and economic disadvantage when compared to their male counterparts (Caulfield et al., 2006; Frempong & Annim, 2017; WHO, 2015). Agricultural cultivators and farmers constitute 60% of the impoverished Ghanaian population, and food crop farmers are predominantly female (WHO, 2015). Not only are 34% of households in Ghana headed by women, but women also have higher rates of illiteracy and lower rates of formal education relative to their Ghanaian male counterparts; 28% of women have no formal education, whereas only 18% of men have no formal education by comparison (WHO, 2015). Expanding on this, only 12% of women have some type of formal secondary education, whereas 23% of men have completed some kind of formal secondary education (WHO, 2015).

Forty percent of all total childhood deaths in Ghana can be attributed to newborn infant deaths (WHO, 2015). Forty percent of neonatal deaths in Ghana occur within the first day of life, the remaining majority of neonatal deaths occur within the first week of life (WHO, 2015). There are major maternal demographic differences associated with higher instances of newborn deaths,

including younger age of the mother, lower socioeconomic status and overall household income, rural-dwelling, and little to no level of higher maternal education (WHO, 2015). Households with the most deprived mothers across all variables have been found to be at greatest risk for newborn death (Frempong & Annim, 2017; WHO, 2015). Additional variables positively correlated with increased prevalence of newborn deaths include shorter duration of labor, deaths related to infections, asphyxia, premature birth, and low birth weight (WHO, 2015). Most childhood deaths that happen after the newborn period can be attributed to several other factors, including the following: poverty, malaria, pneumonia, diarrhea, general malnutrition, and vitamin A deficiency (WHO, 2015).

Public Health & Medical Responses to Treating Pediatric Malnutrition

Overview of child health programs in Ghana.

One of the major public health challenges in Ghana is overall child health (WHO, 2015). As a response to the resource-constraints and challenges the nation faces associated with improving overall child health, various public health and medical interventions have been implemented with the goal of improving future, long-term child health outcomes. To date, Ghana has several policies and public health programs aimed to prevent and treat cases of childhood malnutrition. The current public health programs and clinical protocols for managing inpatient and outpatient cases of pediatric malnutrition have been issued by the WHO, along with supporting joint statements and guidelines issued by UNICEF, among other public health organizations (Mogre et al., 2017; Tette et al., 2015; Tickell & Denno, 2016; WHO, 2013). Local programs include the Strengthening Health Outcomes Through the Private Sector (SHOPS) program and the Under Fives Child Health Policy (UFCHP), discussed in further detail.

SHOPS program.

Diarrhea is the fourth leading cause of childhood death in Ghana (El-Khoury et al., 2016). Fatalities attributable to diarrheal diseases can be prevented through low-cost interventions that incorporate oral rehydration salts, including zinc, into treatment of severe diarrhea (El-Khoury et al., 2016). In 2006, only 37% of children in Ghana suffering from dehydration due to infection appropriately received ORS, indicating a need for improvement in following protocols to manage proper rehydration (El-Khoury et al., 2016). As a response to these poor protocol adherences, the SHOPS program was implemented in 2011 in collaboration with the Ghanaian Ministry of Health, among other public health agencies, with the purpose of managing pediatric diarrhea through interventions that incorporate zinc and other rehydration salts into diarrheal treatment (El-Khoury et al., 2016). It is estimated that an increase in the appropriate use of zinc could reduce diarrhea-related mortality by 23% (El-Khoury et al., 2016). Since the SHOPS program has been implemented, proper protocols for managing cases of diarrhea through rehydration salt interventions have reached almost 30% of children presenting with severe diarrhea, whereas these interventions previously only reached less than 1% of children who needed them (El-Khoury et al., 2016).

An additional secondary aim of the SHOPS program is to reduce inappropriate use of antibiotics for management of pediatric diarrhea (El-Khoury et al., 2016). Since the SHOPS program has been implemented, there has been a significant reduction in the percentage of children presenting with severe diarrhea inappropriately receiving antibiotics to manage it. Prior to the program, over 65% of cases were managed incorrectly with antibiotics, and now only about 38% of cases are incorrectly managed with antibiotics (El-Khoury et al., 2016). However,

the 2014 demographic health survey (DHS) documented that the prevalence of diarrhea over the last two weeks in Ghanaian children younger than age five was still 12% (El-Khoury et al., 2016). This indicates that the health system in Ghana must continue to strengthen the program and public health efforts to prevent and effectively treat and prevent childhood cases of diarrhea.

UFCHP.

The UFCHP is managed through different agencies that collectively belong to the Ghanaian Ministry of Health with the goal of improving maternal and infant health and preventing mortality (WHO, 2015). Agencies working with the UFCHP have gathered statistical data through the 2008 Ghanaian Demographic Health Survey (DHS), indicating a 30% decrease in under-five child deaths from previous years (WHO, 2015). These results show positive future prospects for continuing to reach the goal of steadily decreasing childhood deaths, particularly because the prior DHS had indicated no previous decline in childhood deaths, producing stagnant rates for the last two decades prior (WHO, 2015). The 2015 UN Millennium Development Goal four was to reduce the under-five childhood mortality rate to 40/1000 live births (WHO, 2015). Even though immense strides have been made in achieving this goal, there have also been several barriers that require further addressing, such as managing HIV, tuberculosis, malaria, micronutrient deficiencies, and dehydration. Unfortunately, newborn infant deaths still account for 40% of all childhood deaths (WHO, 2015).

The UFCHP incorporates reproductive health interventions, including antenatal and postnatal care, into its policies to promote adequate infant and maternal nutrition and positive health outcomes. Some postnatal policies include the following: promotion of breastfeeding, complementary feeding practices, growth monitoring, immunization programs, regular

deworming of children, information on strategies for feeding children with special nutritional requirements (i.e. feeding practices for infants of mother's with HIV/AIDS), information on preventing and treating childhood illness (i.e. diarrheal disease), and infant vitamin A supplementation (Tette et al., 2015; WHO, 2015).

It is documented that in 2006, only 54% of infants in Ghana six months or younger were exclusively breastfed, only 58% of babies who were between six and nine months old received proper complementary feeding, and only 60% of children had received the proper vitamin A supplementation within the last six months (WHO, 2015). These statistics indicate a lack of adherence to the current protocols and suggest a need for promoting better protocol compliance and public understanding of interventions in order to prevent pediatric malnutrition and poor infant and child health outcomes in Ghana.

PML Clinical Malnutrition Study

In 2012, there were 157 admissions at PML hospital for pediatric malnutrition, with an 11.7% mortality rate (Tette et al., 2015). One unmatched case-control study conducted by a medical team at PML hospital examined socioeconomic factors, health outcomes, and the compliance of mothers for various interventions to prevent SAM in both malnourished and well-nourished children admitted to the hospital (Tette et al., 2015). Essentially, the study examined various social determinants and other factors contributing to malnutrition status in Ghanaian children. Malnourished children with either SAM or moderate malnutrition were recruited to participate in the study to be compared to well-nourished children, with WHZ anthropometric measurements used to classify nutritional status. Recruiting controls took longer

than anticipated, because at the time of the initial screening, many children did not meet the standard criteria used for being defined as “well-nourished” (Tette et al., 2015).

Moderate malnutrition was defined as a WHZ $\geq$ -3SD to $<$ -2SD, and SAM was defined as a WHZ $<$ -3SD and MUAC $<$ 115 mm, with or without the presence of edema. This classification is consistent with the WHO definitions of moderate malnutrition and SAM. The control group consisted of children younger than five, with a WHZ measuring above -2 SDs (Tette et al., 2015). The total sample size consisted of 371 participants, divided into groups of 182 malnourished and 189 well-nourished children. Children with chronic diseases influencing nutritional status, such as sickle cell, liver disease, congenital heart disease, and renal failure, as well as children who met MUAC criteria but did not meet the WHZ criteria, were excluded from the study due to the potential for confounding factors (Tette et al., 2015).

The study results found that, among socioeconomic and demographic factors, a monthly family income less than 200 Ghana Cedis ($35.93 USD) was most strongly associated with malnutrition ($p<0.001$), and children who were 24 months old or less had a significantly greater chance of being malnourished relative to children aged 25-59 months ($p=0.003$). Gender, mother’s educational level, and mother’s occupation were not associated with malnutrition ($p>0.05$) (Tette et al., 2015). This evidence conflicts with other current evidence that suggests a mother’s educational level are associated with their children’s malnutrition status. Among health outcomes, low birth weight ($p=0.032$), diarrhea ($p=0.002$), and developmental delays ($p=0.001$) were most strongly associated with malnutrition status (Tette et al., 2015). Among health status and delayed preventative interventions, insufficient antenatal visits were moderately associated with malnutrition status ($p=0.049$), delayed and stunted growth were highly significantly

correlated with malnutrition ($p<0.001$), and not deworming children was significantly associated with continued malnutrition status, with an 8.47 greater likelihood of children being malnourished relative to their dewormed counterparts ($p=0.004$). Conversely, immunizations, number of postnatal care visits, and vitamin A supplementation were not associated with malnutrition status (Tette et al., 2015).

Overall, the study concluded that family poverty status is one of the key underlying social determinants affecting a child's malnutrition status in Ghanaian children admitted to PML hospital. This is consistent with the UNICEF causes of malnutrition and can be attributed to poverty influencing all three of these causes of malnutrition (Tette et al., 2015). Interventions targeting the upstream determinants of health influencing a family's socioeconomic status are therefore likely to be the most effective in improving a family's household food security and socioeconomic status (Tette et al., 2015). Figure four elucidates the significant associations that the study found for pediatric malnutrition admissions.

Characteristic	P-Value
Low birth weight	0.032
Infants ≤ 24 months	0.003
Income ≤ 200 GC ($35.93)	<0.001
Diarrhea	0.002
Developmental delays	0.001
Not deworming	0.004
Insufficient antenatal care	0.049

Figure 4: Pediatric malnutrition admissions and significant associations at PML in 2012. Adapted from "Factors affecting malnutrition in children and the uptake of interventions to prevent the condition" by Tette et al., 2015, *BMC Pediatrics 15*(189). Copyright 2015.

Proposed Future Interventions Aimed at Preventing SAM

While Ghana has made promising efforts and progress toward their specific and measurable UN Millennium Development Goal four of reducing their under-five mortality rate to 40/1000 live births by 2015, an inordinate amount of public health progress in reducing childhood mortality rates in Ghana remains (WHO, 2015). One of the major barriers in reaching this goal is the lack of collective synergy through various health and non-profit organizations to combat childhood malnutrition (WHO, 2015). A proposed future intervention for preventing an even greater number of under-five childhood deaths related to malnutrition would be to implement a program that allows all involved agencies to collectively work together toward a shared and common vision. This type of future action would eliminate the current constraints associated with lack of collective planning to reach of specific, shared goal.

Expanding on this concept, programs to promote better infrastructure changes and efforts for improved sanitation could have a positive impact on overall childhood health and susceptibility to malnutrition. There has been an observed correlation between clean drinking water and decreased incidence and prevalence of malnutrition (Frempong & Annim, 2017). In Ghana, the prevalence of underweight among children who don't have clean water access at home is an estimated 17%, whereas their counterparts who do have access to clean drinking water at home have an 11% prevalence of underweight (Frempong & Annim, 2017). Household sanitation factors in Ghana have a significant impact on stunting and wasting. For example, one

cross-sectional study found that 30% of children who use a bucket or a bush at home as a toilet are also stunted; conversely, only 10% of their counterparts who had flush toilets at home were stunted (Frempong & Annim, 2017). Proper sanitation helps improve overall childhood health by reducing the likelihood of transmission of water-borne infections, as well as by reducing malnutrition (Frempong & Annim, 2017). Thus, future public health interventions targeting improved water sanitation are suggested in order to combat pediatric malnutrition and improve general child health. In addition, implementing public nutrition education programs to promote food diversity in the diet have shown positive effects in reducing childhood malnutrition in Ghana (Frempong & Annim, 2017). Therefore, it is suggested that programs educating the public on the nutritional benefits of consuming a nutritiously diverse range of foods is also an area for future improvement.

There is also a strong evidence-base to support the use of antenatal care services to improve overall maternal and infant health outcomes (Dickson et al., 2017; Vidal, 2011; WHO, 2015). Demographic data suggests that the strongest factor associated with expectant mothers in Ghana seeking out antenatal care is enrollment in NHIS (Dickson et al., 2017). This variable alone was shown to be the most effective independent from other social determinants, such as socioeconomic status, transportation, living circumstances, and education level of the mother (Dickson et al., 2017). Therefore, a proposed intervention to increase maternal access to antenatal care to improve future health outcomes of infants and mothers would be a policy to enroll as many women of reproductive age in NHIS as possible. Overall, greater efforts must be made by public health agencies to increase antenatal care, delivery, and postnatal care for greater positive health outcomes to prevent infant and maternal malnutrition in Ghana (WHO, 2015).

From 2011-2015, the SHOPS program has been effective in improving the management of childhood diarrhea in Ghana through implementing the use of ORS and zinc supplementation (El-Khoury et al., 2016). Due to the SHOPS program, these interventions now reach an estimated 29.2% of children younger than five presenting with severe diarrhea, which is a drastic increase from the previous proportion of 0.8% of children being treated appropriately for their diarrhea (El-Khoury et al., 2016). In addition, the SHOPS program has reduced the inappropriate use of antibiotics for treating non-bloody diarrhea from a previous 66.2% to an approximate 38.2% (El-Khoury et al., 2016). Since the program has been highly effective thus far, a proposed future intervention would be to continue to grow the SHOPS program in order to properly reach a greater proportion of children to prevent future fatalities associated with diarrheal diseases in Ghana.

Exclusive breastfeeding & complementary feeding.

Infants aged 24 months or younger are documented as being the most vulnerable to the negative effects of malnutrition (Tette et al, 2015). Therefore, promotion of breastfeeding, complementary feeding determined on a case by case basis, supplementation of vitamin A, and case management of malnutrition are thus far shown to be the most effective in preventing the effects of malnutrition in younger children (Tette et al., 2015; WHO, 2015). However, only 54% of infants younger than six months were exclusively breastfed in Ghana in 2006, indicating a gap in potential knowledge among new mothers regarding the health benefits of exclusive breastfeeding (WHO, 2015).

Currently, there are multiple approaches to encourage exclusive breastfeeding for infants, including public health education programs, professional support, lay support, and health sector

changes (Caulfield et al., 2006). The evidence from these interventions suggests that women who receive any type of support are 22% less likely to discontinue exclusive breastfeeding, whereas women receiving lay support were 34% less likely to discontinue exclusive breastfeeding (Caulfield et al., 2006). These statistics indicate that incorporating greater public health education programs to support and educate breastfeeding mothers may be positively associated with adequate infant nutrition in the future.

Supplementation & promotion of higher intakes of essential nutrients.

Programs that promote higher intakes of foods rich in either preformed vitamin A or carotenoids may be effective in reducing the effects of malnutrition related to vitamin A deficiency. In addition, the evidence-base suggesting that recovery from edema is possible relatively quickly by correcting low levels of serum albumin may indicate that incorporating foods rich in albumin could be effective in helping children recover quickly and successfully from edema related to kwashiorkor (Coulthard, 2015). Future interventions targeting the management of severe acute kwashiorkor and edema may also require revised protocols. In 12 different clinical studies comparing plasma serum albumin concentrations of children with kwashiorkor and edema to children with marasmus who did not have edema, all studies produced significant p-values <0.05, and a paired t-test of combined means produced a highly significant p-value of <0.0001 (Coulthard, 2015). Most studies also reported an approximate recovery from edema between six and 12 days when hypoalbuminemia was corrected through feeding (Coulthard, 2015). Albumin-rich foods are typically derived from animal products. Some of these foods include the following: beef, milk, eggs, Greek yogurt, cottage cheese, and fish (Villines, 2018). This evidence may be highly useful for implementing future protocols that

include treating kwashiorkor and edema through feeding methods that correct low levels of serum albumin.

Barriers in Reducing SAM Mortality & Protocol Effectiveness

There are various areas of medical care that need to undergo improvements in not only quality of the care itself, but also delivery thereof (WHO, 2015). Some current barriers in the effectiveness of preventing pediatric mortality related to malnutrition include relatively low quality antenatal care, neonatal resuscitation, and poor management of newborns who are ill (WHO, 2015). The effectiveness of the WHO and UNICEF protocols to prevent death in severely malnourished children are entirely dependent on the willingness of medical staff to comply, as well as the motivation and skill to learn the proper protocol for managing SAM (Mogre et al., 2017). Therefore, not all resource-constrained medical environments or developing nations adhere to the WHO and UNICEF standards, and this is a major obstacle in decreasing childhood mortality from malnutrition. Some of the reasons for not upholding the protocols for managing malnutrition cases include lack of knowledge and resources (Mogre et al., 2017). The WHO states that by following their standard protocols for managing cases of pediatric malnutrition, less than 10% of children admitted with complicated SAM should die; however, in Sub-Saharan African regions, health centers still frequently report case mortality rates as high as 40% among severely malnourished patients (Tickell & Denno, 2016).

However, it is important to note that, although resource-constrained health centers with poor adherence to the WHO protocols contribute most largely to the preventable fatalities associated with SAM, SAM is a serious enough condition that it is a major cause of death even in resource-equipped environments that report full adherence and implementation of the WHO

protocols (Tickell & Denmo, 2016). Therefore, a barrier in achieving reduced mortality rates from pediatric SAM may be partially due to the protocols themselves not being ideal due to a relatively low-quality evidence base; this indicates a large need to continue making protocol revisions in order to implement the most effective intervention for managing SAM through evidence-based research (WHO, 2018).

Complicated Malnutrition Cases.

HIV-complicated malnutrition.

An additional barrier related to decreasing the rates of malnutrition-related childhood mortality specific to Sub-Saharan Africa is malnutrition complicated by HIV, malaria, and tuberculosis (Tickell & Denno, 2016; WHO, 2015). HIV is considered to be a major contributing factor to childhood deaths associated with malnutrition. Evidence from a recently conducted meta-analysis indicates an approximate overall case fatality rate of 15% in pediatric patients admitted for SAM without an HIV infection (Tickell & Denno, 2016). This may indicate that African health centers are generally following the WHO standard protocol for managing pediatric cases of SAM, but underlying health complications from HIV could be a major barrier in successful recovery. Interventions aimed to reduce HIV transmission and manage the condition over a chronic period may be necessary in order to reduce future fatalities associated with HIV-complicated SAM in Sub-Saharan Africa (Tickell & Denno, 2016).

Malaria-complicated malnutrition.

Additionally, malaria is another major adverse health issue in developing nations that greatly impacts the survival rate of malnourished children. Malaria and malnutrition have a complex reciprocal relationship, and understanding how one complicates the other is crucial in

developing more effective public health strategies to minimize the effects of both individually, as well as synergistically (Das et al., 2018). The evidence-base also suggests that protocols to manage and treat malaria in Ghanaian children and expectant mothers must be improved to reach a higher percentage of the affected population. In 2006, only 22% of children and 40% of expectant mothers reported having slept under an appropriate mosquito net at night (WHO, 2015). This is a positive improvement over the previous five years, but less than 50% of the total population reports the use of a proper mosquito net at night to prevent malaria transmission (WHO, 2015).

In a database review of PubMed, Global Health, and Cochrane libraries, 33 articles were selected to assess the relationship between malaria and malnutrition (Das et al., 2018). Although no consistent correlation between contracting malaria as a higher risk for developing SAM were established, chronic malnutrition was fairly consistently correlated with severity of malaria. The results found that the longer and more malnourished an individual was, the more severe their malaria also was if they developed it (Das et al., 2018).

Unfortunately, there is only very limited evidence available on malnutrition status and whether it impacts the efficacy of an antimalarial treatment or not (Das et al., 2018). Since the exact relationship between malaria, malnutrition, and recovery remains complex and unclearly understood, there is a need to further establish how the two conditions relate and what clinical interventions can be made to combat both collectively (Das et al., 2018). Until then, malaria and malnutrition must both be managed independently at the same when presented with symptoms of both health indicators.

Tuberculosis-complicated malnutrition.

The gold-standard diagnostic tuberculosis test is obtaining a sample culture of Mycobacterium tuberculosis (MTB), which is the slow-growing bacillus that causes tuberculosis (Jones & Berkley, 2014). However, it is frequently difficult to obtain a sample culture of MTB from children because children with pulmonary tuberculosis often are unable to produce a substantial enough sample due to concurrent infections leading to a low number of bacilli (Jones & Berkley, 2014). Therefore, false negatives for tuberculosis-infected children are common (Jones & Berkley, 2014). In addition, resource-constrained environments may not have the appropriate resources to conduct the proper diagnostic tuberculosis tests on children suffering with SAM, further complicating a clinical diagnosis of tuberculosis.

The WHO guidelines state that children with SAM should be diagnosed with tuberculosis based on tests that examine a child's immune memory response to MTB (Jones & Berkley, 2014). Some of these tests include the Tuberculin Skin Test (TST), Interferon-gamma Release Assays (IGRAs), Quantiferon, and T-Spot TB (Jones & Berkley, 2014).

Due to the high frequency of false negative tuberculosis results among children suffering from SAM, diagnosing tuberculosis-infected children in developing nations is often made based on clinical features of the condition, even prior to obtaining a positive culture or other diagnostic test (Jones & Berkley, 2014). Many children also present with clinical features that are non-specific to tuberculosis, including weight loss and persistent fever (Jones & Berkley, 2014). This can make a tuberculosis diagnosis difficult in children presenting with SAM due to these features being applicable to a variety of different infections or SAM in isolation. However, tuberculosis should be considered if a child with SAM fails to gain weight, even with the

appropriate interventions and therapeutic foods, or if a child is given antibiotics and continues to have a persistent fever (Jones & Berkley, 2014).

Additional complications related to nutrient absorption.

Additionally, treating pediatric SAM can be challenging because malnutrition is often associated with malabsorption of various kinds of carbohydrates and lactose (University of Oxford, 2016). Malabsorption of lactose can lead to osmotic diarrhea, and diarrheal diseases are already common among children suffering from SAM. A further barrier in intervention efficacy related to this is that children switching from an energy-deprived, starved state to a high-energy diet can lead to severe electrolyte abnormalities and thus, multiple organ dysfunction. This type of dysfunction is referred to as “re-feeding syndrome” (University of Oxford, 2016).

Limitations of Evidence-Base

Incomplete descriptive data

Data regarding specific differences in prevalence of stunting and wasting among children is the most accurate when assessing the magnitude of the global health issue of pediatric malnutrition; however, data regarding the combination of both factors (underweight) is the most accessible and documented (Caulfield et al., 2006). It has been observed that there is a higher correlation between the prevalence of stunting and underweight relative to wasting (Caulfield et al., 2006). This information indicates that descriptive statistics regarding underweight children may be mostly relevant to establishing the magnitude of stunted growth due to chronic malnutrition, rather than encompassing the magnitude of wasting from undernutrition over a shorter time period (Caulfield et al., 2006). Lack of specific differential data between stunting and wasting may be a limitation in assessing the overall effects, importance, and magnitude of

pediatric malnutrition, particularly because stunting is increasing in prevalence in Africa, while wasting and underweight have been declining (Caulfield et al., 2006). Globally, there must be a greater effort to gather data specifically differentiating between the prevalence of wasting, stunting, and underweight in order to more accurately assess the prevalence of malnutrition in children.

Limitations of MUAC & WHZ measurements.

In the late 90s, the WHO standardized the use of a WHZ <-3 SD in infants and children between six and 59 months old as the sole admission criteria for nutritional rehabilitation programs (Roberfroid et al., 2013). However, in the early 2000s, the UN supported a MUAC measurement of <110 mm as an independent diagnostic method for SAM, along with either edema or a WHZ measuring <-3 SD (Roberfroid et al., 2013). Only recently has the MUAC cut-off been changed to <115 mm because it is considered to better align with the 2006 WHO Child Growth Standards of a WHZ of <-3 SD. When diagnosing SAM, a MUAC method is increasingly becoming an isolated anthropometric measurement for the admission criterion to nutritional rehabilitation centers, whereas MUAC in conjunction with a WHZ have been previously used as a collective admission criterion (Roberfroid et al., 2013). These two variables are considered to correlate poorly when reviewing the evidence-base of different health outcomes of children treated for SAM on an isolated basis of either of MUAC or WHZ (Roberfroid et al., 2013; Roberfroid et al., 2015). Rarely does a child diagnosed with SAM fit both anthropometric criteria. An additional limitation of the MUAC method is that, while sensitive, this test lacks specificity (Roberfroid et al., 2015). This evidence further indicates that

improving diagnostic criteria to include tests that are both sensitive and specific may be necessary in order to accurately diagnose more children suffering from SAM.

Data was gathered from 16 cross-sectional studies carried out by Action Against Hunger International assessing WHZ and MUAC measurements of 14,409 children. Of this total sample, only 23.1% (3,328) of these children were diagnosed as suffering from SAM based on either a WHZ or MUAC measurement independently. However, when assessing these children for SAM with both anthropometric indicators, only 28.5% (949) of the 3,328 fell within both criteria (Roberfroid et al., 2015). Factors associated with being detected by MUAC, but not be WHZ, were being stunted, being female, and being younger than 24 months old, whereas factors associated with being detected by WHZ, but not by MUAC, were having longer than average legs (Roberfroid et al., 2015). While sensitivity of both indicators is relatively high, the sensitivity of detecting SAM though MUAC was found to be much lower when compared to WHZ sensitivity (31.% versus 70.6%, respectively) (Roberfroid et al., 2015).

One of the greatest variables found to affect sensitivity of MUAC was age; MUAC detected 57.4% of children suffering from SAM who were younger than 24 months, but only detected 18.1% of children who were older than 24 months (Roberfroid et al., 2015). In addition, MUAC, WHZ, WAZ, and HAZ measurements can assess stunting, wasting, and underweight, but these measurements do not take micronutrient deficiencies into account (Das et al., 2018). Children can suffer from micronutrient deficiencies even if they are getting enough energy and are within a healthy weight range; therefore, measures to assess micronutrient intakes to be incorporated into overall nutritional assessments may be beneficial in detecting all forms of malnutrition (Das et al., 2018).

Additional evidence suggests that, despite numerous collective efforts being made to combat childhood mortality related to malnutrition through various governmental agencies, development partners, and non-governmental agencies, these efforts lack collaborative synergy in planning and coordinating within the program, which currently is a major obstacle in reaching the 2015 UN Millennium Development Goal four of reducing under-five childhood deaths to 40/1000, along with other national goals (WHO, 2015).

Low-quality evidence for WHO protocols.

One meta-analysis analyzed the effectiveness of current WHO protocols for managing SAM in various health centers. Eight studies were used for the meta-analysis because they were the only documented sources that used 33 of the most current WHO recommendations. Sixteen of these recommendations (48.5%) are based on expert opinion, as opposed to evidence derived from a published scientific evidence-base, nine (27.3%) recommendations are based on either indirect or direct observational evidence, while only eight recommendations (24.2%) are supported by at least one randomized control trial (Tickell & Denno, 2016). Most of the WHO recommendations and protocol for managing SAM are based on relatively low-quality evidence to back their use (WHO, 2018).

Additionally, evidence produced conflicting results regarding the impact of malaria on malnutrition status and severity. One survey including 2,905 children in Ghana between the ages of six and 108 months produced results supporting that clinical malaria was significantly associated with wasting. However, another study produced no correlation. This indicates a limitation that needs to be studied further so that the public health community can eventually

better understand the complicated relationship between malaria and malnutrition and how to prevent and treat both conditions (Das et al., 2018).

Conclusion

There is no doubt that pediatric malnutrition is a major public health threat and causes a large proportion of childhood of fatality, disability, and comorbid disease. An estimated one-third of childhood deaths in Ghana are related to malnutrition (UNICEF, 2019). Although concurrent infections presenting with malnutrition contribute to ultimate fatality, the majority of these deaths could be prevented or treated through low-cost and simple interventions (WHO, 2015). Forty-five to 60% of global childhood deaths from measles, malaria, pneumonia, and diarrhea are associated with undernutrition (Caulfield et al., 2006). However, since pediatric SAM is a complex and multifactorial issue, it is unlikely that SAM and mortality related to it will be eliminated in the near future (Tickell & Denno, 2016). Interventions aimed to prevent the progression of malnutrition and its severity would first have to reach over 52 million children who are suffering from moderate malnutrition. An estimated 53% of childhood deaths could be prevented through efforts to eliminate global malnutrition (Caulfield et al., 2006; Tette et al., 2015). These statistics indicate that a major public health goal should be to continuously optimize the interventions in place that target the management of both uncomplicated and complicated malnutrition to prevent the progression of moderate malnutrition to SAM (Tickell & Denno, 2016).

The WHO has current methodology in place for the development of future guidelines for managing SAM (WHO, 2013). The main crucial components of guideline development include the following: identification of priority questions and outcomes, retrieval of the evidence,

assessment of the quality of evidence and synthesis of the findings, formulation of recommendations (including future research priorities), and planning for dissemination, implementation, impact evaluation, and updating the guideline (WHO, 2013). Currently, the WHO guidelines for diagnosing pediatric SAM state that either a WHZ measuring below -3 SDs the international reference population, or a MUAC measurement <115 mm can be used independently as a diagnostic criteria for SAM (Roberfroid et al., 2015). However, the most common indicators used on a global scale are a MUAC <125 mm or a WHZ <-2 SD, suggesting lack of universal uniformity when assessing children for malnutrition status (Roberfroid et al., 2015). When reviewing the evidence-base, these two indicators correlate poorly, and it has been observed that, overall, only 40% of children diagnosed with SAM by one indicator also fall within the criteria for the other indicator (Roberfroid et al., 2015).

However, the fact remains that the vast majority of under-five deaths in Ghana are related to malnutrition and comorbid health complications associated with it. The majority of these deaths could be prevented or treated with simple and affordable interventions (WHO, 2015). Various public health agencies and other organizations must work collectively to come up with improved ways to continue to strive for fewer childhood malnutrition-related deaths, as well as greater evidence-based programs and policies that will allow for increased quality of life for survivors of pediatric malnutrition.

Personal Reflection

Any person, like myself, born with the privilege of growing up in a developed nation, has seen countless humanitarian effort ads of starving African children. These ads always seemed impersonal and detached from any grain of reality. They were just enough to give me fleeting

feelings of guilt before I returned to my life of privilege, forgetting all about them and taking no active course of action to help these suffering children on screen. However, my entire experience participating in a global health education program at Princess Marie Louise Children's Hospital (PML) in Accra, Ghana through the organization, Child Family Health International (CFHI), changed my entire perception of these ads that I had previously given little thought and attention. Some of the public health activities I had the opportunity to participate in included the following: observing and assisting clinicians and public health nurses in the family planning clinic, inpatient pediatric severe acute malnutrition ward, outpatient pediatric malnutrition ward nutrition counseling and follow-ups, community and home public health child immunization visits, child welfare and vaccination clinics, school health education visits, and the pediatric emergency room. This opportunity allowed me to experience first-hand the unfortunate reality of healthcare challenges attributable to resource-constraints, infrastructure-related issues, and social determinants leading to health inequities that many vulnerable populations in developing nations battle consistently.

On my first day at PML, upon entering the inpatient severe acute malnutrition ward, an emaciated toddler let out a nearly silent shriek, his gaunt body too weak and fragile to be noisy. Too dehydrated to produce even an isolated drop of bodily fluid, his profound weeping was absent of tears. His daunting gaze and muffled cries alone told a greater story of suffering than words ever could. He did not deserve this. No child deserved this. No *person* deserved this. I was unable to escape his agony as it enveloped my entire being, constricting me in a cocoon spun from his distress. He was the corporeal embodiment of childhood severe acute malnutrition. How could it be that I was so desensitized to virtual ads of starving African children, yet struck with

such a virulent pang of remorse when faced with a severely malnourished child in person? Was I a terrible person for being, essentially, so utterly indifferent all this time to images of severely wasted children tangoing intimately with death? What if I came across to my new Ghanaian acquaintances as yet another privileged person from an industrialized nation, coming into their country as a stranger under the pretenses of "humanitarian effort," while merely attempting to expand my resume for future career opportunities and personal gain, then abruptly leaving without ever returning to help their people again? All these inquiries and feelings of guilt required immense self-reflection on my part, but contemplating them still would not be the solution to severe childhood malnutrition in developing nations.

The child referenced in particular, Geoffrey (name changed to maintain patient confidentiality), had unintentionally ingested undiluted sodium hydroxide that was stored in a water bottle nine months prior. Sodium hydroxide, also known as caustic soda or lye, is a colorless, corrosive chemical with a strong alkaline base used to neutralize acids and make sodium salts; it is toxic by straight ingestion and can be lethal (NCBI, 2019). When heavily diluted, sodium hydroxide can be used for cooking purposes as a tenderizer or curing agent if used correctly, although health practitioners typically do not recommend it. Many Ghanaians use small amounts of sodium hydroxide when cooking stew and preparing other authentic Ghanaian dishes, which is why Geoffrey's mother kept a water bottle full of the undiluted substance easily accessible in the kitchen (Dr. Esinam, personal communication, June 2018). Due to the strong alkaline properties of sodium hydroxide, Geoffrey had chemically burned through the majority of his esophageal and stomach lining, along with permanently damaging the mucous membranes in his mouth (Dr. Solomon, personal communication, June 2018).

Geoffrey had been unable to eat properly now for almost a year, which caused him to suffer from rapid weight loss and become severely wasted. He was three years old, weighing 7.2 kg (15.87 lbs). A three year old male child should weigh at least 14 kg (31 lbs) (Dr. Esinam, personal communication, June 2018). Unable to chew and swallow, Geoffrey had already undergone one surgery for an enteral feeding tube, but the damage to his internal organs and tissues was so severe that this intervention was largely unsuccessful in adequately delivering nutrients to help him gain weight. He required another surgery for parenteral nutrition to bypass the usual bodily process of eating and digestion, but would not qualify unless he gained a certain amount of weight first. Geoffrey was simply too weak at his current state to survive another surgery. His organs were too weak to tolerate regular IV rehydration fluids, but he was unable to drink rehydration salts consistent with WHO protocols for managing severe dehydration. Eventually, he was given heavily diluted IV fluids with added dextrose that would be less likely to strain his organs (Dr. Esinam, personal communication, June 2018). During my month-long visit, Geoffrey only managed to briefly gain 0.2 kg, but quickly lost the weight again. He was still fighting to survive when I left on July 1st, 2018, but I do not know if he is still alive now. Geoffrey often still wanders my thoughts.

Although Geoffrey's case was one of the most extreme the hospital was treating at the time, children are frequently admitted to the ER at PML due to drinking non-water liquids that are being stored at home in water bottles (Dr. Esinam, personal communication, June 2018). Ghanaian children are taught since birth that faucet water is unsafe to drink, and therefore are typically aware of the fact that bagged and bottled water are the only safe drinking water options (Dr. Esinam, personal communication, June 2018). However, it is unfortunately common for

families to store non-edible liquids in empty water bottles because they have no alternate storage containers. This directly conflicts with the child's knowledge because the child recognizes the water bottle and has been taught that bottled water is safe--as a natural response to feeling thirsty, they drink the contents without realizing it is a potential poison (Dr. Esinam, personal communication, June 2018). As a result of these common storage methods that easily confuse small children, PML doctors treat an exceptionally high number of these cases. Some of the most common cases of accidental ingestion of a non-edible liquid treated at PML include the ingestion of kerosine, shampoo, hair products, and cosmetics (Dr. Solomon, personal communication, June 2018).

As a public health major, this specific child health issue resonated with me because cases of accidental non-edible liquid ingestion could be prevented entirely through so many measures, including prevention education, programs distributing storage containers for the explicit purpose of storing non-edibles, and implementing public recommended guidelines for parents who wish to store non-edible chemicals at home. In a country that faces so many resource-constraints already, preventing accidental childhood poisoning would not only benefit the individual children and families who are victims. It would also benefit the entire community because it would allow a greater number of medical resources to be allocated towards other health programs. The WHO and UNICEF issue protocols and supporting statements related to managing malnutrition cases and other health issues on a global scale, but lack global protocols for preventing accidental poisoning. Developed nations have guidelines, policies, and agencies in place to prevent accidental childhood poisoning through national organizations, and I would suggest that Ghanaian health agencies adopt a similar preventative strategy.

In addition, I believe that efforts to improve sanitation and infrastructure would greatly reduce accidental childhood poisonings, as well as prevent future cases of child malnutrition. Access to clean drinking water and flush toilets is associated with decreased malnutrition in Ghana. Evidence suggests that 17% of children who do not have access to clean drinking water are underweight, whereas only 11% of children with access to clean drinking water at home are underweight. Elucidating on this, 30% of children who use a bucket or a bush as a toilet are stunted, whereas only 10% of children who have a flush toilet at home are stunted (Frempong & Annim, 2017). This data indicates that future public health programs aimed to improve water quality in Ghana can potentially combat the effects of malnutrition and accidental poisonings.

A strength that I personally observed regarding the current WHO protocols for using a MUAC measurement to diagnose and determine severity of pediatric malnutrition is that this method is simple, low-cost, effective, and extremely easy to interpret for non-skilled workers. The MUAC method does not require extensive equipment, the tape measure used to diagnose malnutrition alone suffices. This is particularly relevant to developing nations that face many resource-constraints and a substantial portion of the population lacking formal medical education. Therefore, I fully support continuing the safe and effective MUAC method as a primary method of diagnosing pediatric malnutrition in developing nations.

Conclusion

My entire experience in Ghana reminded me why I chose to pursue a graduate education in public health nutrition. It reignited my desire to help the most vulnerable populations gain access to what I strongly believe are basic fundamental rights to healthcare, adequate nutrition, education, and resources that promote optimal wellbeing. The overall experience was difficult

for me, but it was so easy to fall in love with Ghanaian people and their culture. Something of great importance that I learned from most of my interactions with Ghanaians is to cultivate gratitude, be warm and welcoming to all, and to be more mindful of the daily gifts life has to offer. Although many Ghanaians do not have access to many of my assumed daily luxuries, such as clean water, electricity, advanced medical technology, education, and to be economically able to live what people of industrialized nations would refer to as, "comfortably," most Ghanaians I encountered radiated with joy and gratitude even when they had little, welcoming all people into their nation with open arms. Their warm Akwaaba (welcome) knew no cultural boundaries and was all-inclusive.

While most other students participated in the same global health education program in Accra to develop their professional skills in the health sciences, this intention was only secondary to me, although still an area of high importance. One of my primary intentions was to force myself to become more comfortable being uncomfortable, because I believe it is difficult to develop as an individual and professional from the comfort zone. As a future public health professional, I expect to encounter many uncomfortable situations in my career dedicated to improving long-term health outcomes of vulnerable populations. This experience brought to light many uncomfortable emotions, questions, and thoughts that allowed me to engage in a certain level of introspection for personal growth. Not only did participating in a global health education program allow me to gain first-hand professional public health experience in a developing nation, but it was essential to my personal journey of establishing an autonomous sense of self.

Although I still do not know exactly who I want to be, I have a better sense of it. Just as importantly, I know who I do not want to be. I want to be somebody who dedicates their

professional career to implementing community-based programs targteting impoverished demographics. I want to be somebody who is happy with less and happy with good health, regardless of my income or what material possessions I have. I do not want to be somebody who loses sight of professional and personal goals to earn more money. I always thought I was one person who was too insignificant to have any substantial positive impact on altering unfair social determinants resulting in health inequities for certain populations. While this may be true to an extent, one of the aims of public health is to promote collective organizational and individual effort to help the common good. This experience taught me that, although I may be a single person, I have the power to work collaboratively with other professionals, public citizens, and organizations to tackle multifaceted and intricate public health issues. Realistically, I know childhood severe acute malnutrition will not be entirely eliminated in the foreseeable future, but some of my future endeavors will be dedicated to minimizing its effects.

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