**UNDERSTANDING SEVERE ACUTE MALNUTRITION IN CHILDREN GLOBALLY:**

**A SYSTEMATIC REVIEW**

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**Abstract**

Severe acute malnutrition (SAM) affects 13 million children under the age of 5 worldwide, and contributes to 1-2 million preventable deaths each year. Malnutrition is a significant factor in approximately one third of the nearly 8 million deaths in children who are under 5 years of age worldwide (1). There have been many revolutions in treatment of SAM over time; however, the exact etiology of this preventable condition is not well understood.  This review serves to identify the most common risk factors for the development of SAM in children and to identify the most effective treatment for the disease.  There are many factors that contribute to developing and surviving SAM as a child, and this systematic review serves to highlight the most common variables that lead to this cause of mortality.  An exhaustive review of PubMed was conducted to complete this review. The literature review demonstrates that the most common risk factor for the development of SAM is **low maternal literacy.**

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**Introduction**

Acute malnutrition is a condition resulting from a nutritional deficit over a relatively short duration of time, and Severe Acute Malnutrition is an exacerbation of symptoms. Severe Acute Malnutrition (SAM) is defined as a weight-for-height measurement of 70% or more below the median, or three SD or more below the mean National Centre for Health Statistics reference values, which is called "wasted"; the presence of bilateral pitting edema of nutritional origin, which is called "edematous malnutrition", or a mid-upper-arm circumference of less than 110 mm in children age 1–5 years (1,2,3). Malnutrition in all forms is a serious public health problem in both developing and developed countries worldwide, and is an underlying factor in 10-11 million deaths of children under 5 years old who die from preventable causes (1,6,8). The most concentrated prevalence of acute malnutrition in children under 5 years old throughout the world can be found in Sub-Saharan Africa and South Asia with 9% and 15% of children population respectively (1). There are classically two forms of protein energy malnutrition: Kwashiorkor and Marasmus. Both forms are deficient in protein; however, their etiologies and clinical presentations are different. Marasmus, stemming from the Greek terminology meaning "withering" is classified as severe wasting. In contrast to Marasmus, which is previously described as a chronic malnutrition of total calorie deprivation where the body is able to adapt the under nutrition for a prolonged period of time, Kwashiorkor is specifically a deprivation of protein in the child's diet and clinically presents in a much different way. This type of malnutrition is often an acute process as a result of a rapidly decreasing nutrients. Children have severe diffuse edema, dry skin lesions as well as lethargy and liver malfunction. Commonly, children globally will have a mixture of both forms of protein energy malnutrition and will present with Marasmus Kwashiorkor. This presentation is a combination of abdominal edema and extremity wasting. Severe acute malnutrition is a major area of importance globally causing millions of preventable deaths. In order to address this epidemic, identifying the risk factors that lead to the development of this illness provide a foundation to remedy the issue. Many studies have evaluated numerous risk factors associated with SAM. This review will assess the current literature regarding the risk factors that lead to this preventable cause of mortality.

**Materials and Methods**

Exhaustive literature searches were conducted throughout the NCBI Pub-med data base to complete this systematic review by one person. The search terms included keywords "Severe Acute Malnutrition" "Children" "Risk Factors". The types of studies that were included in the review included randomized control trials, case controls, cross-sectional studies, and case reports that investigated risk factors associated with the development of severe acute malnutrition. The included studies investigated children under the age of 18 with severe acute malnutrition determined by the World Health Organization criteria of weight for height <3 SD from WHO growth standards. Systematic reviews were excluded from this review. Additional exclusion criteria include any study that chose specific risk factors to evaluate prior to the study to decrease likelihood of any confirmation bias.

**Results**

A total of 243 articles populated with the above search terms, and a total of 15 articles complied with the inclusion and exclusion criteria listed above. Table One is a comprehensive table of the articles within this review demonstrating the country of study, the population studied, type of study, the list of risk factors and the description of the measures used to diagnose severe acute malnutrition. Throughout the review of the 15 articles listed above, there were 27 different risk factors uncovered that were significantly associated with the development of severe acute malnutrition in children. Figure 1 demonstrates the frequency of each risk factor throughout the literature. The most common risk factors associated with the development of severe acute malnutrition include low maternal education, concurrent infections at the time of diagnosis with SAM and a child within a family dwelling whose earnings are below the poverty line of the respective community. Figure 2 demonstrates the percentage of children with SAM and a mother with low education status per publication. However, due to the use of different of statistical analysis methods, Jeyaseelan L et al. is not included in the graph. Figure 3 and 4 similarly demonstrate the percentage of children with SAM that were found to have concurrent infections or living below the poverty line respectively.

Table 1.

| Article (Title, Author) | Population | Country | Study Design | Risk Factors | Primary outcome (criteria for determining severe acute malnutrition) |
|---|---|---|---|---|---|
| Risk factors for severe acute malnutrition in under-five children: a case-control study in a rural part of India<br><br>Ambadekar, et al. | 737 children under the age of 5 years old | India | Case control | • Below the poverty line (66%)<br>• Have a kuccha (cow pie/mud) house (59%)<br>• > 3 children (80%)<br>• Working mother (63%)<br>• Low maternal education up to primary level (28%)<br>• Unemployed father (17%)<br>• No water purification measure (15%)<br>• No handwashing before or after defecation (39%)<br>• Father with addictive behavior (31%)<br>• Maternal height < 145cm (10%)<br>• Maternal weight < 45kg (69%)<br>• Prelacteal feeds (28%)<br>• More than 5 infections in one year (54%) | 2006 WHO criteria for SAM<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months based on weight for height Z score (WHZ) of <–3 SD as per WHOs growth standards of 2006 |
| Risk factors for child malnutrition in Bangladesh: a multilevel analysis of a nationwide population-based survey<br><br>Chowdhury MR et al. | 568 children less than 5 years of age | Bangladesh | Cross-sectional Study | • Female sex (15,2%)<br>• Low paternal education status (no education 17%; primary school education 17%)<br>• Muslim religion (15.8%)<br>• Food insecurity (15.5%) | Child was considered stunted, wasted, and underweight, respectively, if the height-for-age, weight-for-height, and weight-for-age indices were less than 2 SDs below the respective median of the WHO reference population |
| Epidemiological and clinical profile of hospitalized children with moderate and severe acute malnutrition in South India<br><br>Devi, R.U., Krishnamurthy, S., Bhat, B.V. et al. | 252 Children 1-60 months of age | India | Prospective Case Control Study | • Not exclusively breastfed (67%)<br>• Associated infections (19%)<br>• Prelacteal feeds (7%)<br>• Low maternal education; only primary/middle school (31%)<br>• Illiterate mother (18%) | 2006 WHO criteria for SAM:<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months based |

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| | | | | | on weight for height Z score (WHZ) of <−3 SD as per WHOs growth standards of 2006 |
| Protein-energy malnutrition in children less than five years old in a rural zone in Senegal (Khombole)<br><br>Diouf S et al. | 400 children less than 5 years old | Senegal | Cross-sectional study | • Geophagy<br>• Anemia<br>• Intestinal parasite | N/A |
| Maternal profiles and social determinants of malnutrition and the MDGs: What have we learnt?<br><br>Edem M. A. Tette et al. | 371 mothers of both well-nourished children and severely malnourished children | Ghana | unmatched case-control study | • Single mothers (17.6%)<br>• Low maternal education (Basic education 62.6%)<br>• Illiterate mothers (25%)<br>• Low family income less than 500 Gh (76.9%) | 2006 WHO criteria for SAM:<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months based on weight for height Z score (WHZ) of <−3 SD as per WHOs growth standards of 2006 |
| An investigation on factors associated with malnutrition among under-five children in Nakaseke and Nakasongola districts, Uganda<br><br>Habaasa G et al. | 104 children under 5 years old | Uganda | Cross-sectional secondary data study | • Age of the child <1 year old (73.1%)<br>• Mother's occupation (peasant farmers 50%) | 2006 WHO criteria for SAM:<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months based on weight for height Z score (WHZ) of <−3 SD as per WHOs growth standards of 2006 |
| Prevalence and risk factors for under nutrition among children under five at Haramaya district, Eastern Ethiopia<br><br>Hiwot Yisak et al. | 791 children under the age of 5 years | Ethiopia | Cross-sectional Study | • Children from a rural area<br>• Birth order of 6 or above<br>• Households with 2 or more children<br>• Presence of diarrhea<br>• Mothers with low BMI <18.5<br>• Male sex | 2006 WHO criteria for SAM:<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months based on weight for |

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| | | | | | height Z score (WHZ) of <−3 SD as per WHOs growth standards of 2006 |
| Risk factors for malnutrition in south Indian children<br><br>Jeyaseelan L et al. | 2496 children aged 5-7 years old | India | Cross-sectional study | • Male sex<br>• Older age (6-7 years old)<br>• Decreased maternal education (significant for education only up to middle school)<br>• Decreased family income (<2000 Rupees)<br>• Children living under thatched houses<br>• Children defecating in the premises of the house<br>• Use of dung or firewood compared to petroleum for fire fuel | Less than 60% of body weight based on the age- and sex-specific reference value determined through the US National Center for Health Statistics reference values of age- and sex-specific body weights |
| Determinants of stunting and severe stunting among under-fives in Tanzania: evidence from the 2010 cross-sectional household survey<br><br>Lulu Chirande et al. | 7324 children aged 0-59 months | Tanzania | Cross-sectional Study | • Mothers with no schooling (25.8%)<br>• Mothers with only primary school education (68.0%)<br>• Male sex (49.8%)<br>• Small for gestational age at birth (7.9%)<br>• Unsafe drinking water (57.8%) | Level of stunting and severe stunting in children 0-59 months, stunted (>-2SD) or not severely stunted (>-3SD) and category 1 (stunted (>-2SD) or severely stunted (>-3SD) |
| Risk factors for severe acute malnutrition in children below 5 y of age in India: a case-control study.<br><br>Mishra, K., Kumar, P., Basu, S. et al. | 191 children aged 6 months to 5 years old | India | Case Control | • Maternal illiteracy (60.5%)<br>• Daily family income < 200 rupees (72.3%)<br>• No breast feeding for first 6 months of life (44.7%)<br>• Prelacteal feeds given (64.5%)<br>• Bottle feeding (47.4%)<br>• Deprivation of colostrum (39.4%)<br>• Incomplete immunization (42.1%) | 2006 WHO criteria for SAM:<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months, based on weight for height Z score (WHZ) of <−3 SD as per WHOs growth standards of 2006 |

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| Prevalence and assessment of malnutrition risk among hospitalized children in Romania<br><br>Oana Mărginean et al. | 271 children aged 1-17 years old | Romania | Prospective single-center study | • Cleft lip and/or palate (1.4%)<br>• Premature birth (2.9%)<br>• Bleeding disorders (6.6%)<br>• Chronic gastrointestinal disorders (11%)<br>• Neurodevelopmental disorders (7%)<br>• Respiratory conditions (8.1%)<br>• Cardiac malformations (4.8%)<br>Endocrine disorders (2.5%) | WHO classification of malnutrition- Acute malnutrition or wasting was considered severe if WFH z-score was below −3 and moderate if between −2 and −3 SD |
| Severe acute malnutrition in a population of hospitalized under-five nigerian children<br><br>Ogunlesi TA et al. | 208 children less than 5 years old | Nigeria | Cross Sectional study | • Low maternal education (84.2%)<br>• Non-exclusive breastfeeding (84.2%)<br>• Cessation of breastfeeding before 12 months (45.5%)<br>• Presence of concurrent infections (84.2%) | 2006 WHO criteria for SAM:<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months based on weight for height Z score (WHZ) of <−3 SD as per WHOs growth standards of 2006 |
| What's new? Investigating risk factors for severe childhood malnutrition in a high HIV prevalence South African setting<br><br>Saloojee H et al. | 300 children less than 5 years old | South Africa | Case Control Study | • Suspicion of HIV in child or parent (OR 217.7)<br>• Male sex (OR 2.72)<br>• Birth order > 3rd (OR 2.28)<br>• Child support grant (OR 0.44)<br>• Weaning practices (OR 3.04)<br>• Food diversity (OR 0.53)<br>• Parental death (OR 38.01)<br>• Father smokes marijuana (OR 3.91)<br>• TB in family (OR 3.21) | The diagnosis of severe malnutrition was based on the Wellcome classification of malnutrition, i.e. weight-for-age less than 80% of median with oedema (kwashiorkor); or weight for age less than 60% of median, with (marasmic kwashiorkor) or without oedema (marasmus) |
| The social, family and medical backgrounds of children with kwashiorkor presenting at a teaching hospital<br><br>Sive AA et al. | 159 children | South Africa | Case Control Study | • Illiterate mothers (43%)<br>• Unmarried mothers (75%)<br>• Received no financial support from the father (64%) | Less than 60% of body weight based on the age- and sex-specific reference value |

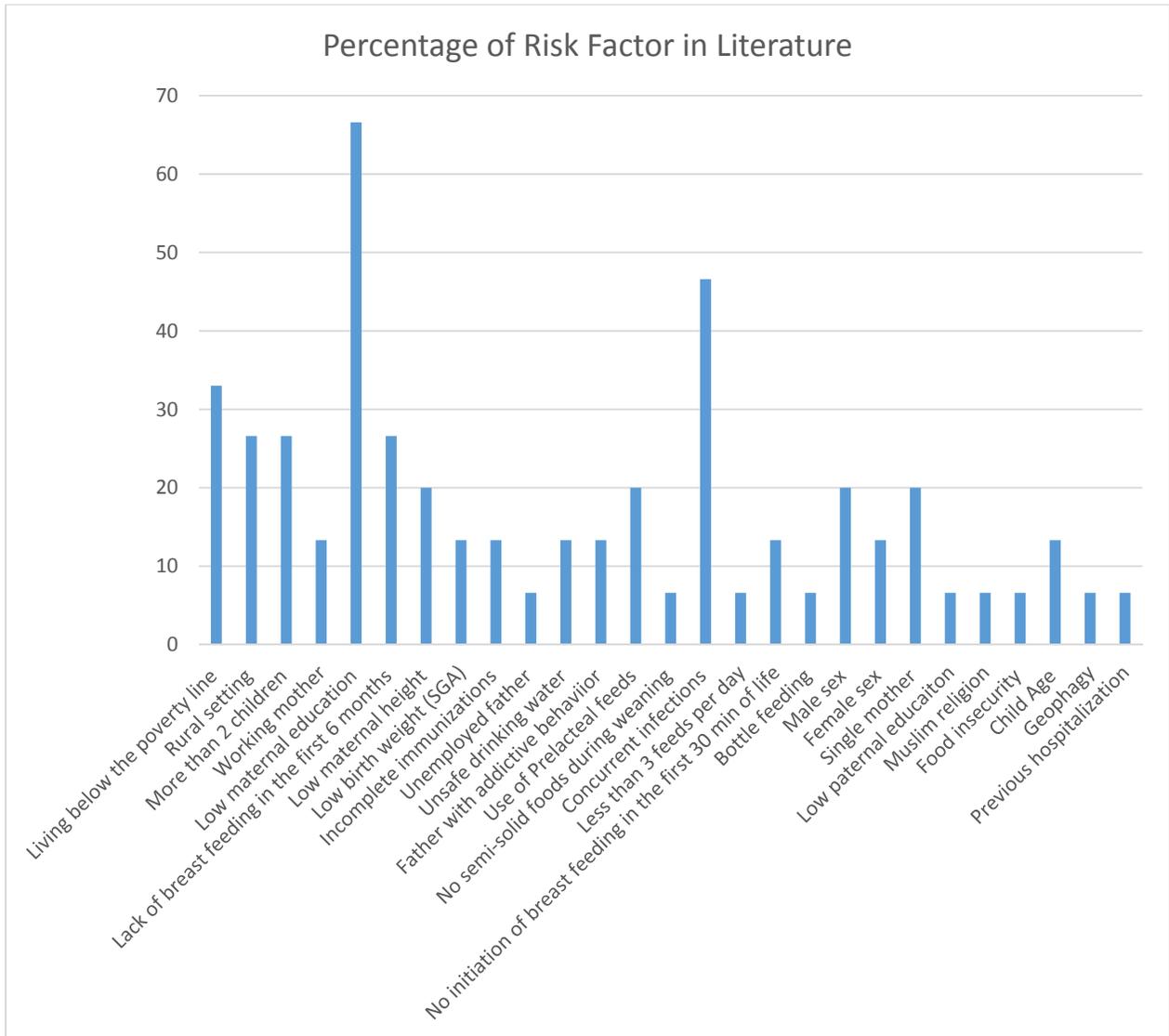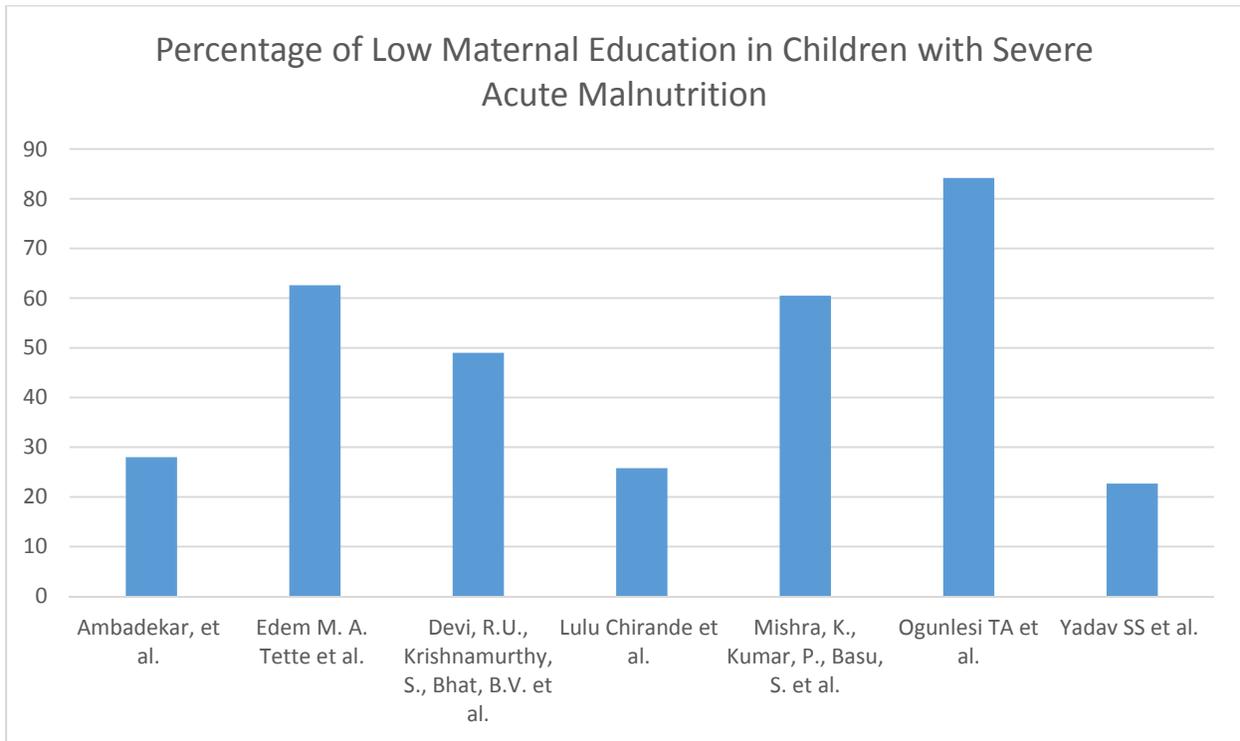| | | | | | |
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| | | | | • Previous hospitalization for diarrhea illness (60%) | determined through the US National Center for Health Statistics reference values of age- and sex-specific body weights |
| An epidemiological study of malnutrition among under five children of rural and urban Haryana<br><br>Yadav SS et al. | 750 children age range from 3 months – 60 months | India | Cross-sectional Study | • Female sex (10.9%)<br>• Low maternal education Primary school completion (12.8%)<br>• Illiterate mother (9.9%)<br>• Low socioeconomic status (class VI or V; 65.5%) | 2006 WHO criteria for SAM:<br><br>For the study, cases were defined as severe acute malnourished (SAM) children in the age group of 6–60 months based on weight for height Z score (WHZ) of <−3 SD as per WHOs growth standards of 2006 |

Figure 1.



Percentage of Risk Factor in Literature

Categories (left to right): Living below the poverty line, Rural setting, More than 2 children, Working mother, Low maternal education, Lack of breast feeding in the first 6 months, Low maternal height, Low birth weight (SGA), Incomplete immunizations, Unemployed father, Unsafe drinking water, Father with addictive behavior, Use of Prelacteal feeds, No semi-solid foods during weaning, Concurrent infections, Less than 3 feeds per day, No initiation of breast feeding in the first 30 min of life, Bottle feeding, Male sex, Female sex, Single mother, Low paternal educaiton, Muslim religion, Food insecurity, Child Age, Geophagy, Previous hospitalization

Figure 2.



Percentage of Low Maternal Education in Children with Severe Acute Malnutrition

Figure 3.



Percentage of Children with Concurrent Infections

Figure 4.

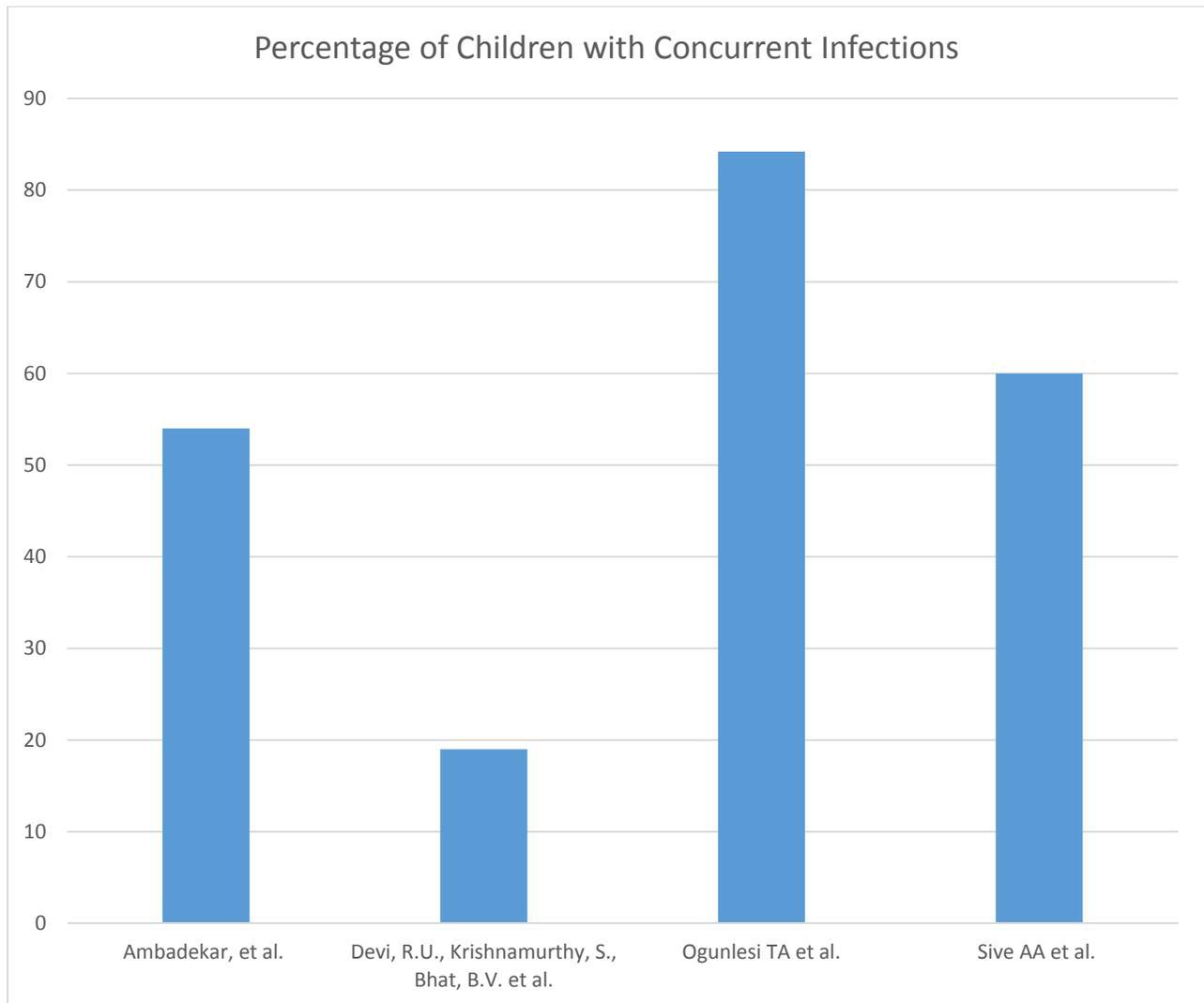

Percentage of Children with SAM Living Below the Poverty Line
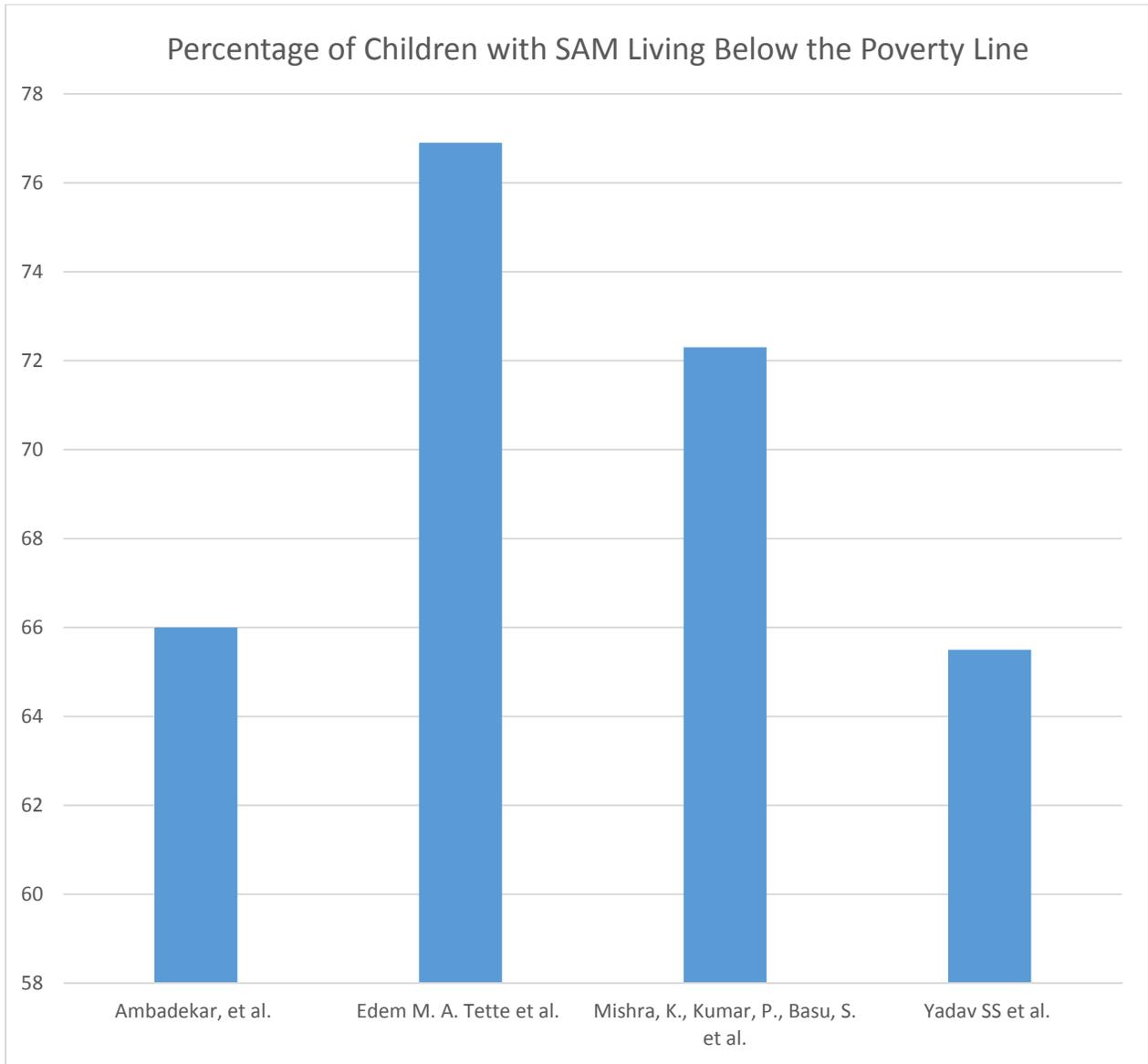
**Discussion**

The data above demonstrate that the risk factors associated with the development of severe acute malnutrition are multifactorial with connections to various aspects of life. As children are dependent upon their mothers and fathers for nutrition in the early part of their lives; especially the immediate infancy of their lives; it is clear that feeding practices are very well connected to the nutritional status of children. The review of the literature highlighted many different variations of breastfeeding or lack thereof and its relationship to SAM. However, the most common risk factor throughout the literature was not the feeding practices of children, but the educational status of the mother. This review suggests that maternal education is the most common and subsequently the most important risk factor linked to the development of SAM. There were some studies that evaluated paternal education status and the link to malnutrition in their offspring but this was not uniformly evaluated or found to be a  definitive risk factor. However, it is clear that maternal education is very important in regards to nutritional status of children. This link is likely associated with the dependent nature of children on their mothers for nutrition, and how the physical dependence for breast feeding is intimately linked to the mother's education and awareness of the demands of children. The exact reason for decreased maternal education in areas with high prevalence of SAM is unknown, but can be inferred that it is due to lack of access to educational resources and potentially decreased cultural and social emphases for women to become educated. Additionally, the next most common risk factors, concurrent infections and living below the poverty line, demonstrate the intimate relationship of a child's surroundings and their nutritional well-being. If financial resources are low, then access to food will be scarce. Subsequently, infection increases the nutritional demand of children; and if that demand is not met with adequate resources, acute malnutrition ensues.

All of the articles within this review demonstrate factors that lead to the development of SAM without any preexisting knowledge or hypothesis of risk factors to study. However, there is a potential problem with this approach; as many of the cross-sectional studies utilized the survey method and this method could narrow the amount of risk factors evaluated based on the

specific details of the survey. Additionally, the majority of these studies were conducted in medical centers evaluating the children presenting with SAM and while these studies had adequate control subjects, the population of children without access to medical care who develop SAM are left out of the study. Therefore, there are theoretically many more children with various risk factors that are unknown that have developed SAM. Additionally, these study designs eliminate the ability to study access to medical care as a potential risk factor because the children evaluated are already seeking medical attention.

**Conclusion**

Severe acute malnutrition is a devastating illness that disproportionately affects children worldwide and has become the devastating cause of millions of preventable deaths annually. In order to begin to solve this major global problem, it is imperative that the factors that lead to the development of SAM are acknowledged and then addressed. This review demonstrates that the development of SAM is multifactorial, including socioeconomic factors, cultural factors, and maternal characteristics. This study demonstrates that the most common risk factor associated with SAM is low maternal education status leading to the conclusion that this is the most important factor to be addressed in steps towards eliminating this problem. Promoting women health and education is the most important avenue to decrease deaths from severe acute malnutrition worldwide.

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**Comprehensive Review**

**Introduction**

Acute malnutrition is an unstable condition resulting from a nutritional deficit over a relatively short duration of time, and Severe Acute Malnutrition is an exacerbation of these symptoms. Severe Acute Malnutrition (SAM) is defined as a weight-for-height measurement of 70% or more below the median, or three SD or more below the mean National Centre for Health Statistics reference values, which is called "wasted"; the presence of bilateral pitting edema of nutritional origin, which is called "edematous malnutrition", or a mid-upper-arm circumference of less than 110 mm in children age 1–5 years (1). Severe acute malnutrition (SAM) affects 13 million children under the age of 5 worldwide, and contributes to 1-2 million preventable deaths each year. Malnutrition is a significant factor in approximately one third of the nearly 8 million deaths in children who are under 5 years of age worldwide (1). There have been many revolutions in treatment of SAM over time and this review serves to identify the most common risk factors for the development of SAM in children and to extract the most effective treatment for the disease. There are many factors that contribute to developing and surviving SAM as a child, and this review serves to highlight the variables and determine the most efficacious and holistic approach to treating SAM.

**Pathophysiology**

Assessment of growth is an essential aspect to the pediatric physical exam, and the most important step in determining the nutritional status of a child. The measurement of a child's growth is a reflection of both their physical and mental environment. For normal children, there is a characteristic pattern of growth after birth with the highest postnatal growth to be immediately after birth. There are two periods of time in a child's life where growth spurts occur; between ages 1.5-3 years old and a mid-childhood growth spurt from ages 4-8 years old. (2). It is throughout these vital periods of growth makes children more vulnerable to malnutrition and plays a role in the global problem of childhood malnutrition.

Malnutrition is a general term that encompasses any disorder of nutritional status including excess nutrients and deficiency of nutrient intake.  In developing countries, deficiency in nutrients is the most common cause of malnutrition leading to under nutrition (4). Malnutrition, or more specifically, under nutrition can be subdivided into two major categories: primary and secondary causes. Primary malnutrition results from inadequate food intake where as secondary malnutrition is a consequences of a disease process that alters food intake, nutrient requirements or absorption (3).  Primary malnutrition is most common throughout the world in developing countries, and secondary malnutrition is found more commonly within developed nations (3,4).  The major constituents of primary malnutrition are protein-energy malnutrition and micronutrient deficiency, and together they are a major health risk to the population. Children are extremely susceptible to under nutrition due to their increased energy demands through their growth spurts. The focus of this review will be protein-energy malnutrition and the progression to Severe Acute Malnutrition.

There are classically two forms of protein energy malnutrition: Kwashiorkor and Marasmus. Both forms are deficient in protein; however, their etiologies and clinical presentations are different. Marasmus, stemming from the Greek terminology meaning "withering" is classified as severe wasting. This is the result of a total calorie depletion that causes the subcutaneous fat and muscles to be broken down for energy. The breakdown of the subcutaneous fat provides glucose available for the body, but especially the brain, to use as fuel for energy. The breakdown of the proteins via muscle breakdown provides essential amino acids to be used to hepatically synthesize glucose via gluconeogenesis. By providing amino acids and glucose through protein and fat catabolism, the body is allowed to maintain homeostasis. Classic marasmus is a result of chronic total calorie and nutrient deficiency, and the body's ability to maintain homeostasis is reflected in the clinical presentation. The children with marasmus are severely wasted with little to no subcutaneous fat and wasted muscles and present with extremely thin bodies and you can often see their ribs and the bones in their extremities. However, since they are able to maintain homeostasis for a long period of time, they are able to

maintain a serum albumin level within normal ranges and do not present with obvious metabolic abnormalities.

In contrast to marasmus, which is previously described as a chronic malnutrition of total calorie deprivation where the body is able to adapt the under nutrition for a prolonged period of time, Kwashiorkor is specifically a deprivation of protein in the child's diet and presents in a much different way. This type of malnutrition is often an acute process that occurs when the child is weaned off of breast milk. Breast milk provides high amounts of protein, but when the child is weaned, their diets change to a high carbohydrate and low protein diet. With the carbohydrates present the body can break them down to provide glucose for the brain metabolism, and the need to break down muscles for hepatic synthesis of glucose via gluconeogenesis is not necessary. However, due to the deficient proteins, there is a deficient amount of amino acids to use for essential synthetic purposes (3,6). This deficiency leads to a deficiency in serum albumin, which decreases the oncotic pressure in the blood, forcing fluid to the extremities. The children with kwashiorkor present with pitting edema in the extremities, enlarged liver, and electrolyte imbalance. Due to the impaired synthetic protein capacity of these children, they often present with skin and hair abnormalities such as increased amount of skin infections, poor wound healing or easy hair pluckability (3,4,5).

Both marasmus and kwashiorkor, even with different etiologies and clinical presentation, can lead to the development of severe acute malnutrition (SAM). SAM is an emergent state of the child where the malnutrition is so severe that vital organ function is beginning to be compromised and can lead to death. Most often patients will present with a mixed form of marasmus-kwashiorkor where they are severely wasted and also have the presence of edema. This exact etiology of this mixed process is unknown (3,4,5). These patients have major disturbances in fluid and electrolyte balance, and the protein deficiency leads to immune deficiency and the children cannot appropriately respond to immunologic stressors such as infection. The immune system becomes so depressed that they cannot develop an

inflammatory response or a fever. In short, the patients are hypothermic, dehydrated and hypoglycemic which will lead to cardiac and liver malfunction (3,4,5).

**Epidemiology**

Malnutrition in all forms is a serious public health problem in both developing and developed countries worldwide, and is an underlying factor in 10-11 million deaths of children under 5 years old who die from preventable causes (1,4,6). The most concentrated prevalence of acute malnutrition in children under 5 years old throughout the world can be found in Sub-Saharan Africa and South Asia with 9% and 15% of children population respectively. There are 6 countries that account for 50% of the worldwide deaths in children under the age of 5 years old, and 42 countries that account for 90% (5,6). In some of the poorest countries around the world, like Malawi where HIV is extremely prevalent in young children, malnutrition is the most common cause of pediatric hospitalizations.  In India alone, there are 5 million children that are severely wasted (4,5). The other four countries are:

The child mortality rates around the world are declining; however, there is a discrepancy between the decline in the child mortality rate in the areas where severe malnutrition is the most prevalent such as Sub-Saharan Africa and South Asia where the decline in the death rate has decelerated (5) There is extreme variability in the differences that is continuing to increase between the causes of malnutrition in various areas of the world. A large gap exists between the declining death rates of child mortality throughout industrialized countries compared to the developing countries, and the gap is widening as the industrialized countries continue to improve on decreasing child mortality at a faster rate than the developing countries (5). Thus, the countries throughout Sub-Saharan Africa and South Asia where child malnutrition is extremely prevalent will continue to remain elevated as their declining rates in child mortality are decelerating despite the improvement of treatment for acute malnutrition. The reasoning for this continued disparity of child malnutrition throughout the world is a multifactorial issue that can be linked to varying political and socioeconomic structures that impact the access and quality of healthcare provided to the communities. (5).

The political unrest that is common throughout the developing countries leads to economic instability, which predisposes the countries to malnutrition and complications such as infection and disease that will be discussed later in this review. For example, in 1991 there was a Kurdish refugee crisis where thousands of refugees were displaced to Iraq as a consequence of rebellions of the public against the Iraqi government as a result of the Persian Gulf War. There were prompt relief efforts supplied to the refugees; however, despite the efforts, there were high rates of malnutrition and mortality of children living in the refugee camps (3).  This high mortality of children during this time amidst the relief efforts reflects the multifactorial nature of the malnutrition problem. Therefore, etiologies or SAM stem from political and socioeconomic unrest that give rise to a multitude of factors. In addition to political and social instability aggravating malnutrition in developing countries, natural disasters play a role as well. In the 20th century, the frequency and severity of natural disasters in increasing and plays a role in perpetuating malnutrition and leading to the development of SAM (5, 7). The natural disasters impede food resources, shelter and often create unsanitary quarters. These factors predispose children to infection and disease, which complicate SAM. A very common complication of natural disaster is diarrhea, which further complicates pre-existing malnutrition or can create severe malnutrition throughout a previous healthy child population. In summary, many different factors contribute to the development of SAM including political unrest, low socioeconomic status as well as natural disasters.

**Co-Morbidities**

There is no one size fits all model when describing malnutrition, but many different factors can lead to the development of severe acute malnutrition. Sometimes the patients will present with additional disease processes, or co-morbidity, in addition to their severe malnourishment, and these patients are described as "complicated SAM". The list is endless of the co-morbidities that can be associated with a malnourished child; however, there are some diseases that are more commonly associated with the presentation of SAM throughout the literature. Of the many possible complications, HIV, malaria, diarrhea and respiratory infections are the additional disease processes that are most common.

When an infection occurs in the human body, the immune system executes both an innate and then adaptive immune responses upon continuous infection. Throughout the activation of the immune system, each process, innate or adaptive, require DNA/RNA replication and protein synthesis to occur in rapid and increased amounts than under normal circumstances. The activation of the immune system requires immense anabolic energy (8). This excess energy requirement is analogous to increased nutritional demand. When a person is infected with HIV, their immune system is compromised over time and makes them susceptible to infections. When a child is simultaneously malnourished, this has an additive effect of the HIV and increases the susceptibility to life threatening infections to children (8). In Sub-Saharan Africa, there is the highest prevalence of HIV infection throughout the world, and this contributes to the increase in the prevalence of severe malnutrition in children. The increased metabolic requirements of infection are compounded in the presence of malnutrition and have a synergistic effect on the child and can be incredibly lethal (8).

In addition to HIV infection, malaria is also prevalent in Sub-Saharan Africa and South Asia and exacerbates malnutrition. This parasitic infection also increases the energy demand on the human body similar to HIV; however, instead of destroying the immune cells as is the case in HIV, malaria destroys red blood cells and further exacerbates the energy demand by causing

severe anemia and can lead to respiratory distress. Unlike HIV, malaria is a treatable and curable disease. However, the destruction of the red blood cells in addition to activation of the immune system, a malaria infection can make a child more susceptible to malnutrition and cause severe complications that can be lethal (8,12). Thus, malaria can exacerbate preexisting malnutrition and complicate the presentation and treatment of SAM.

Another infection that is extremely prominent in developing countries is tuberculosis, and this infection can also augment the morbidity of malnutrition. Malnutrition is generally accepted as a major risk factor for active tuberculosis and can lead to a worse prognosis of the disease (8). As previously mentioned, malnutrition affects both the innate and the adaptive immune response because activation of both sides of the immune system are present in infection, and increase the metabolic demands on the human body (8,13). In a tuberculosis infection, the adaptive or cell-mediated immune response is the principal defense to fight off the infection. Malnutrition profoundly decreases the ability of the adaptive immune response through the depletion of energy reserves to assist in the increased anabolic demand and ultimately is a lethal co-morbidity in the child population.

Another prevalent infection in developing countries, diarrhea, can occur from a multitude of reasons. In addition to having a similar effect on the immune system as the aforementioned disease by activating the immune responses and increasing the energy demand, diarrhea has an additional additive component that increases the morbidity of children who are malnourished. Diarrhea not only has increased energy demands, but it accelerates the depletion of fluid and micronutrients of the child much more rapidly than the previously mentioned diseases. Malnutrition can be a cause of diarrhea, especially in developing countries. However, diarrhea can rapidly lead the development of malnutrition in pre-existing healthy children or it can provoke a malnourished child to rapidly develop severe malnourishment and lead to death.

In summary, disease and infection are prevalent throughout the developing world and have a similar distribution to the areas where malnutrition is extremely prevalent. This is due to the

synergistic relationship that infection and disease have on malnutrition. Immune activation leads to an increase in energy demands on any individual, and can lead to the development of malnutrition. On the other hand, malnutrition weakens the immune system and can predispose individuals to infection. The vicious cycle with illness and malnutrition is an important aspect to consider as infection increases the child's vulnerability to SAM and increases the risk of mortality (13-16).

**Treatment**

The World Health Organization (WHO) updated their international guidelines for the treatment of Severe Acute Malnutrition in 2013 (20). SAM will typically present to medical attention when a health crisis such as infection occurs and the body adaptation to malnutrition and an infection is no longer adequate (17-18). Once a child meets the WHO criteria for SAM (mentioned above), the first decision that needs to be made in the care of the child is where the child's care will be taking place. Worldwide, there typically are both community- based therapeutic centers as well as hospitals with inpatient facilities and resources. In short, patients who present with "uncomplicated SAM" should be cared for in a community setting and the "complicated SAM" patients should be transferred to a facility that has the resources to treat critically ill patients. The major difference in determining uncomplicated versus complicated SAM is the presence of one of more co-morbidity in addition to the nutritional deficit. As mentioned above, the major co-morbidities that accompany and complicate SAM are HIV, tuberculosis, malaria and diarrhea. In addition to the presence or absence of co-morbidities, if there is 3+ pitting edema present in any child presenting with malnutrition, they need to be treated in an inpatient facility whether or not a co-morbidity is also present (19).

According to the WHO guidelines, the treatment for SAM is divided into three phases that total up to 6 weeks of treatment. The phases are: initial stabilization, rehabilitation and follow up (19,20). In the initial phase of stabilization, the life threatening medical issues are addressed including hypoglycemia, hypothermia, infection and dehydration. These conditions are

addressed with early and repeated feeding, warming, and broad-spectrum antibiotics. Feedings are begun in this phase and should be small and frequent feeds (19-21) to maximize absorption and decrease the chance of complications (18,19).  An important clinical decision needs to be made with dehydration and the process for rehydrating the patient.  Due to the risk of heart failure by overloading a malnourished child's heart that has a decreased cardiac output with fluid, IV fluid resuscitation should only occur if the child presents in shock (18-20). If the child is not in shock, then rehydration is completed with the use of ReSoMal, which is an oral rehydration salt with many micronutrients that can be reconstituted in clean water (19). Another important note for the initial stabilization phase is the absence of iron supplementation. The malnourished child has decreased transferrin levels circulating throughout the body, and in order to prevent iron overload, iron is not supplemented until the rehabilitation phase (18).

Once the initial stabilization phase, which can last up to two weeks, is completed, the next phase of treatment is the rehabilitation phase. Throughout this phase, the major issues of the initial stabilization phase are still monitored; however, the patient is now also receiving supplemental iron. This phase begins once the child's appetite improves. The feedings transition from F-75, which is formula with 75 kcal/100mL supplementation to F-100 in order to provide the necessary nutrients for growth catch up. The child is fed numerous times a day while mixing in a diet that does not solely consist of formula until the child can be fed without any formula at all and they are eating a similar diet to what they would receive at home (18,19).

The final stage of treatment is the follow up stage where the patient is discharged to their home and can resume their daily activities. Throughout this phase, there is an education component to the mother and if possible, to the child  about recognizing malnutrition early and seeking treatment. In addition to education, this phase of treatment also addresses the physical, mental and emotional development of the child with continuous follow up care (18, 23).

**Summary & Conclusion**

Severe Acute Malnutrition (SAM) is a major problem in developing countries throughout the world. Malnutrition places the child in a health crisis situation and has a high morbidity and mortality worldwide (18). Approximately 9% of children worldwide suffer from SAM and this precipitates the death of nearly a third of 8 million deaths of children that occur each year worldwide (20). Simply put, there are millions of preventable deaths that occur each year where malnutrition is a key factor in the cause of death. The WHO has recognized Severe Acute Malnutrition a problem in children under 5 years old with the highest morbidity and mortality (20). Overall, the developing world is the most vulnerable to this multifaceted problem due to increased risk of infection, political and social unrest, and lack of resources. Furthermore, recognition and knowledge of SAM worldwide should be instituted to decrease its morbidity and mortality. There are current treatments available to malnourished children, and the WHO recently updated the guidelines in 2013 (21,22). Successfully decreasing or eradicating the morbidity and mortality of SAM will undoubtedly improve not only the developing world through increased productivity.

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