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Efficacy of a reduced dose of multiple micronutrient powder supplementation among children aged 6-59 months in Arusha district, Tanzania

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EFFICACY OF A REDUCED DOSE OF MULTIPLE MICRONUTRIENT POWDER SUPPLEMENTATION AMONG CHILDREN AGED 6-59 MONTHS IN ARUSHA DISTRICT, TANZANIA

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A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Life Science and Engineering of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Iron deficiency anaemia is the most prevalent nutritional problem affecting children under-five years old in the developing countries. The deficiency is a result of inadequate intake and insufficient absorption of iron-rich foods that may be caused by diseases or dietary factors prevalent in rural areas. The most appropriate approach for solving the problem in rural settings is the use of Multiple Micronutrient Powder supplements (MNP). The recommended supplementary dose is one (1) sachet per day. However, in areas where resources are limited, the recommended weekly dose of seven sachets is considered expensive. The aim of this study was to assess the efficacy of a lower weekly dose, say three sachets of a MNP for dietary supplementation of complementary foods in Arusha district. A community-based longitudinal study with the intent to assess this efficacy was adopted for this study. Subjects were randomized into four intervention groups and given a Multiple Micronutrient Powder in different doses for six months. Anthropometric measurement, dietary assessment and haemoglobin levels were collected during the intervention involving 436 children under five years old in Arusha district of Tanzania. At baseline, 84.6% of the children were anaemic. Low birth weight and dietary factors (non-consumption of iron rich foods like meat, vegetable, and fruits) were predictors of anaemia. At the end of the intervention, haemoglobin levels were significantly higher in the groups which received three to five sachets of micronutrient powder per week than in children who received one or two sachets per week. Prevalence of infectious diseases was reduced significantly ($p < 0.05$) from 65% to 30.5% and anaemia, from 100% to 43.0% in all the groups. Two-thirds of mothers expressed willingness to pay for the micronutrient powder at the selling price of 150 TZS per sachet. However, the willingness to pay was associated with socio-demographic and economic characteristics of the participants. This study provides evidence that three to five sachets of MNP per week is an efficacious treatment for anaemia among children under-five years old in Arusha district. Families in low-income communities should be advised to use at least the lower weekly dose of 3 sachets to achieve the desired outcomes.

Keywords: Multiple Micronutrient Powder (MNP), supplementations, Anaemia, Children under five years old, Micronutrient Deficiency.

DECLARATION

I, Dyness Dickson Kejo do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

…………………………………….. **……………………….**

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance for the dissertation entitled "Efficacy of multiple micronutrient powder supplementations (MNP) in children under-five years in Arusha district". In fulfilment of the Award of Doctor of Philosophy in Food Science and Nutrition at The Nelson Mandela African Institution of Science and Technology.

Approval of dissertation

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DEDICATION

I dedicate this work to my family. I am so blessed to have Ryan and his dad Barnabas in my life. I thank them for tolerating my absence and busy schedule.

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LIST OF ABBREVIATIONS

AOR	Adjusted Odds Ratio
COR	Crude Odds Ratio
NBS	National Bureau of Statistics
NIMR	National Institute for Medical Research
OR	Odds Ratio
RNI	Recommended Nutrient Intake
TDHS	Tanzania Demographic and Health Survey
MNP	Multiple Micronutrient Powder
WTP	Willingness to Pay
UNICEF	United Nations Children's Fund
WHO	World Health Organization
HF-TAG	Home Fortification- Technical Advisory Group
TFNC	Tanzania Food and Nutrition Centre
RCH	Reproductive and Child Health Services
TZS	Tanzanian Shillings
IYCF	Infant and Young Child Feeding
NNS	National Nutrition Strategy
USD	United State Dollars

CHAPTER ONE

1.1 Introduction

This dissertation examined efficacy of multiple micronutrient powder (MNP) supplementation in reduction of anaemia among children under-five years of age in Arusha district. It sought to find out the prevalence and risk factors of anaemia in children under-five years of age. After identifying the causes of anaemia, a nutritional intervention was set to alleviate the problem. The intervention involved home fortification of complementary foods with MNP. Research shows that food fortification is the best strategy to alleviate micronutrient deficiencies (De-Regil *et al.*, 2013); however, if done industrially, not all communities can access such products, especially people living in rural areas who produce their own food for consumption. Home based fortification works better in rural settings where micronutrients are added to ready to eat foods. Since not all families are capable of purchasing micronutrients to be added to their meals daily, it was important to do trials to understand the minimum number of MNP sachets needed per child to maintain a healthy micronutrient status while preventing anaemia and other nutrition-related conditions. Therefore, this study was a community randomized trial with intent to treat anaemia among children under-five years old for six months. This was a paper-based dissertation with four original and one review paper of which two were published and the other three sent for publication in different scientific journals.

1.2 Background

Childhood under-nutrition is recognised as a major public health concern among children in developing countries. The leading causes of death among children under five in 2017 were preterm birth complications, acute respiratory infections, intrapartum-related complications, congenital abnormalities and diarrhea (WHO, 2017). The problem is frequently part of a vicious cycle that includes poverty and disease (UNICEF, 2013). Under-nutrition includes stunting (low-height-for-age), wasting (low-weight-for-height), underweight (low-weight-for-age) and micronutrient deficiencies (Black *et al.*, 2013) and has been used as an indicator to measure the development of a nation (Black *et al.*, 2013; Badake *et al.*, 2014) as it reflects how the most vulnerable are treated. Different goals and strategies have been set at different times with the purpose of improving the status of child nutrition (WHO, 2013).World Health Organization (WHO), established targets on reducing the number of stunted children under-five years old by 40% by 2025 (UNICEF, 2013). However, there is insufficient progress to reach the target set for 2025 and the Sustainable Development Goals (SDG) set for 2030 (UNICEF, 2017).

Monitoring trends in nutrition status indicators, such as wasting, underweight, and stunting have been topics of discussions regarding progress in developing countries. Globally, the current status of under-nutrition (wasting, and stunting) is estimated that 8% of children under-five years old are wasted and 16% are underweight (UNICEF, 2017). Stunting accounts for 23% of the global prevalence. The majority, 90%, of children affected with stunting live in Africa and Asia (UNICEF, 2017). Interventions to prevent and significantly reduce the prevalence of under-nutrition among children in developing countries have traditionally focused on children who are under 5 years of age. There is a growing consensus that the greatest nutritional threat to children occurs in the period from 6 to 24 months of age (Dewey, 2013).

Child under-nutrition is a serious problem in Tanzania, more than 32% of children die due to under-nutrition (NBS and MACRO, 2010). Knowing that under-nutrition is not the immediate cause of death, many are not aware of the role that nutrition plays in the unacceptably high death rate in children under the age of five years (DPG, 2010). Furthermore, Tanzania has made significant strides in reducing child under-nutrition, between 1999 and 2015, child underweight fell from 29% to 14%, child stunting fell from 44% to 34%, and child wasting fell to 5% (NBS and MACRO, 2015). Nevertheless, Tanzania continues to suffer from one or more forms of under-nutrition, including stunting, underweight, wasting, and micronutrient deficiencies like vitamin A deficiency, iodine deficiency disorders, and anaemia (NBS and MACRO, 2010). Micronutrient deficiencies not only cause needless human suffering, they reduce physical work, capacity, and productivity, learning capacity, innovation, and cost. Tanzania loses about 450 million USD each year due to lost productivity (DPG, 2010; Tulchinsky, 2010). Infant diets in developing country settings are more often deficient in multiple micronutrients rather than in single nutrients and/or energy (Allen *et al.*, 2009). The diets of young children are mainly cereal-based. This generally provides insufficient amounts of key micronutrients particularly iron to meet the nutrient requirements. In order to combat micronutrient deficiencies in developing countries, we need food fortification. This will provide better nutrition for young children who are accessible and affordable by the majority.

Cost-effective approaches for reducing micronutrient deficiencies in low-income countries are common goals of international health agencies and country governments (Harrison, 2010; Bhutta *et al.*, 2013). Exclusive breastfeeding, diversified diet, which includes foods with highly absorbable vitamin and minerals, such as meat and meat products, food fortification of staples and complementary foods are considered the optimal approach for minimizing micronutrient deficiencies (Allen *et al.*, 2006; Bhutta *et al.*, 2008). Establishing proper supplementation programs would certainly improve the nutritional status of children. The Multiple Micronutrient Powder (MNP) is a single dose sachet containing dry powder with vitamins and minerals that can be mixed into semi-solid and solid foods that are ready for consumption. The aim is to ensure that the diet, i.e. complementary foods, meets the nutrient need of young children (HF-TAG, 2012). MNP was initially developed to offer the recommended daily nutrient intake of iron and other nutrients such as Vitamin A, C, vitamin B complex and zinc. These are required for treating nutritional anaemia in the target population (HF-TAG, 2012). Home fortification with MNPs was proposed for complementary feeding due to its importance. These different vitamins and minerals should be added to the formulation. Low production cost, affordable transport, low cost of storage and distribution lowers the cost of the dose (sachet) (Zlotkin *et al.*, 2005). Fortification of staple foods with MNP would provide a major improvement in key micronutrients in developing countries including Tanzania (Allen *et al.*, 2006; Adu-Afarwuah *et al.*, 2007). The use of MNP is a novel and effective strategy to combat anaemia which is mainly due to iron and other micronutrient deficiencies for children under-five years (Rah *et al.*, 2012; De-Regil *et al.*, 2013). The efficacy trials of MNP are well established in a control trial settings (Jefferds *et al.*, 2015).

The National Nutrition Strategy (NNS), World Bank, and the Food and Nutrition Policy of 2013 address food fortification as a national priority intervention to prevent micronutrient deficiencies. Achieving wide spread utilization of fortified foods will be difficult because the majority of the population live in rural areas which depend on subsistence agriculture for their livelihood and cannot afford the fortified products (Lundeen *et al.*, 2010). Most foods consumed by this section of society are produced at home and fortification of staple foods is a major challenge. The Government of Tanzania in collaboration with development partners like the *Tuboreshe Chakula* project dealing with supply of MNP has put effort into alleviating micronutrient deficiencies in the country through home-fortification. Therefore this study aims to assess the efficacy of MNP supplementation in reducing anaemia among under-nourished children below five years of age in Arusha region.

1.3 Research problem and justification of study

Tanzania is one of the developing countries which have high prevalence of anemia at a reported 58% among children under-five years (NBS and MACRO, 2015). NBS and Macro (2005, 2015) shows that the prevalence of IDA is increasing from 52% to 58% due to inadequate intake of iron rich foods, fruits, and vegetables, with Arusha reporting a high (57%) prevalence of iron deficiency anaemia (NBS and MACRO, 2015).

Home fortification with MNP is a new strategy used to combat micronutrient deficiencies. Previous studies showed that daily use of MNP for 60 days helped to build up nutrient stores which are necessary for haemoglobin (Hb) synthesis (Mosha *et al.*, 2014). However, the use of daily MNP supplementation is expensive for rural people who have very limited income. Families with more than one child cannot afford to buy one sachet at 150 Tanzanian shillings (USD 0.068) per child for daily consumption. Once the body has enough of these key nutrients, daily consumption of micronutrients may not be necessary as long as the diet provides the micronutrients needed for Hb synthesis. Therefore this study aims to reveal how a recommended dose of MNP can be made affordable to resource poor areas for use.

1.4 General objective

To investigate the efficacy of introducing a lower weekly dose of MNP supplementation that will be affordable while reducing anaemia among children under-five years.

1.5 Specific objectives

(i) To assess the nutrition status and prevalence of anaemia in children aged 6-59 months.

(ii) To determine the causes of anaemia and growth impairment in children aged 6-59 months.

(iii) To assess socio-economic and demographic factors influencing the use of MNP

(iv) To assess the efficacy of MNP supplementation at different doses on improving haemoglobin levels of children.

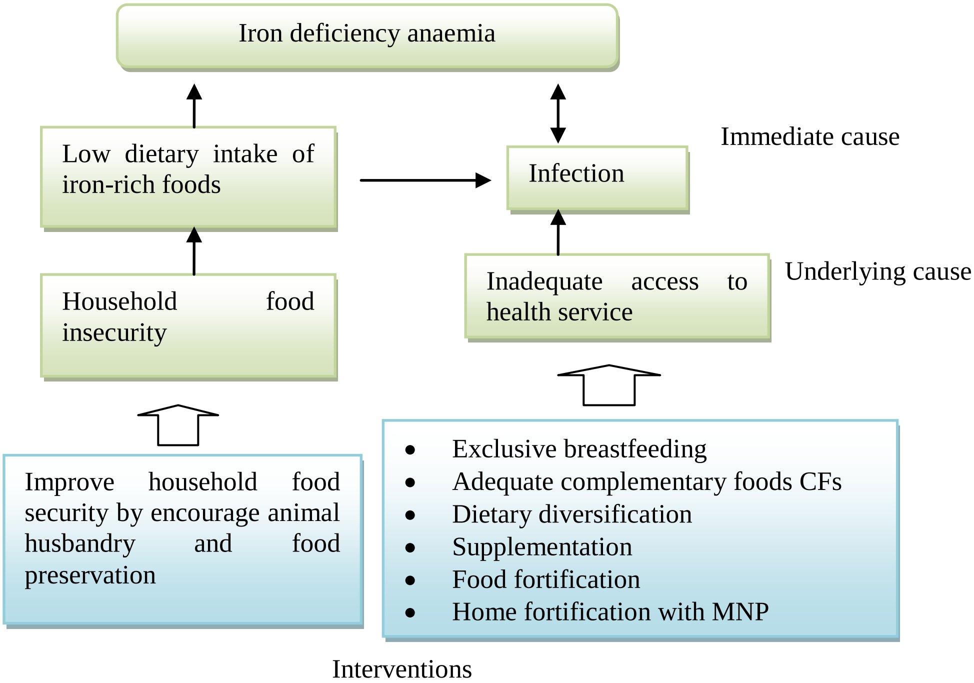
1.6 Hypothesis

There is no significant difference in haemoglobin levels between children supplemented with different lower weekly doses of MNP.

1.7 Significance of the research

This study is of importance to the community and globally because it investigate the efficacy of an affordable and optimal MNP dose in reducing anaemia. It provides information helpful in recommending micronutrients supplement intake and social marketing of the MNP especially in low-income areas where families cannot afford to buy sachets on a daily basis.

1.8 Conceptual frame work



Source: Modified from UNICEF, 1990 malnutrition conceptual frame work

Figure 1: Conceptual frame work of the study

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CHAPTER TWO

Nutritional status and interventions to reduce stunting and anaemia among under-five children in Tanzania

Abstract

Available evidence shows that childhood under-nutrition is a major public health problem among children in developing countries. The problem is expressed in different forms including stunting, underweight, wasting and micronutrient deficiencies (hidden hunger). Stunting and anaemia are the most prevalent nutritional problems among children below the age of five in Tanzania. Anaemia is a result of inadequate intake of iron rich foods and insufficient absorption of iron that may be caused by disease, parasitic infection, or dietary factors such as phytate and tannins. This review reveals that in Tanzania, under-nutrition in children is associated with poor breastfeeding practices, poor dietary intake, diseases, inadequate maternal nutrition knowledge, and household food insecurity. A number of nutritional interventions have been introduced to supplement or increase the micronutrients availability to children. These interventions include dietary diversification, fortification and supplementation of complementary foods. However, due to lack of availability, the use of fortified complementary foods for children in rural communities is not fully implemented. To address this deficit, home fortification with micronutrient powder introduced into the children's diets holds promise to alleviate the incidence of anaemia.

Keywords: Anaemia, under-nutrition, multiple micronutrient powder, home fortification.

2.1 Introduction

Under-nutrition is a major health problem among children under-five years in developing countries. The problem is estimated to cause about one third of deaths within this age group (United Nations International Children's Emergency Fund (UNICEF, 2013). Children suffer from different forms of under-nutrition including underweight, stunting, wasting, and micronutrient deficiencies (Black *et al.*, 2008; Victora *et al.*, 2010). These forms of under-nutrition are measured by anthropometric indices and these forms are important in evaluating nutritional status (Jones *et al.*, 2014). Efforts to mitigate under-nutrition have been implemented including promotion of optimal nutrition practices, encouraging micronutrient supplementation, as well as programs to prevent and treat severe acute under-nutrition (UNICEF, 2013). Poor nutritional status during childhood has implications for future adult economic achievement and health (El Kishawi *et al.*, 2015) with long-term consequences, including short adult height, reduced intellectual development and economic productivity, and low birth weight (Victora *et al.*, 2010; Black *et al.*, 2013).

Globally, in 2011 an estimated 165 million (26%) of children under-five years were stunted as a result of a chronic under-nutrition; 101 million (16%) were underweight; and 52 million (8%) were wasted (UNICEF, 2013). The prevalence of stunting, underweight and wasting varies by region and sub-region throughout low-income countries. South Asia and sub-Saharan Africa were reported as the most affected regions. South Asia (33%), followed by sub-Saharan Africa (21%), had the highest prevalence of underweight. In South Asia, the prevalence of stunting and wasting were 39% and 16% respectively while, in sub-Saharan Africa, the respective prevalence at 40% and 9% (UNICEF, 2013). More than one-third of all under-five child deaths were attributable to under-nutrition, with the majority of these occurring in low and middle-income countries (WHO, 2013). Under-nutrition resulting from micronutrient deficiency is one of the most prevalent problems in the world, specifically in sub-Saharan countries (Bhutta *et al.*, 2013). The global estimate indicates that anaemia prevalence of children under-five years was 43%, with nearly two-thirds (64.6%) of affected children living in Africa (McLean *et al.*, 2009; Stevens *et al.*, 2013).

In Tanzania, poor feeding practices and insufficient dietary intake accelerated by household food insecurity are the immediate cause of under-nutrition. (Kulwa *et al.*, 2015; Safari *et al.*, 2015). The Tanzania ministry responssible for health in partnership with other organizations have implemented several interventions, such as education, on the importance of optimal breastfeeding, dietary diversity for complementary foods (CFs), vitamin A supplementation, deworming, provision of mosquito nets, and health education, with limited impact. Despite all these efforts, millions of children in Tanzania still manifest with different forms of under-nutrition including low birth weight, stunting, underweight, wasting and micronutrient deficiencies (Makani *et al.*, 2011). This review reveals the nutritional status among under-fives, determinants of under-nutrition and nutrition interventions including education on the importance of optimal breastfeeding, CFs, and food fortification with multiple micronutrient powders (MNPs) and its impact on child health in Tanzania.

2.2 Nutritional status among under-five children in Tanzania

Improving child nutrition has a significant economic and social benefit as it reduces morbidity and mortality and improves the learning capacity of communities (Victora *et al.*, 2010; Makani *et al.*, 2011). In Tanzania, under-nutrition is the most serious health problems affecting children aged 0 - 59 months (Kulwa *et al.*, 2015), more than 43 000 children die every year and more than 600 000 children under-five years have died in the past decade due to inadequate nutrition (Twaweza, 2010). Since under-nutrition is not the immediate cause of death, many are not aware of the role that nutrition plays in the unacceptably high death rates in children under the age of five years. According to the Tanzania Demographic and Health Survey (TDHS) reports, significant progress in improving the nutritional status of under-five children was made between 1992 - 2015. Stunting decreased from 50% to 34%; underweight from 24% to14%; and wasting from 7% to 5% (NBS and MACRO, 2015).

Studies done in Tanzania showed high levels of under-nutrition among children under-five years. (Mamiro *et al.*, 2005; Muhimbula and Issa-Zacharia, 2010; Chirande *et al.*, 2015). A study in Kilosa found 34.5% of infants at 6 months of age were stunted and 76% were iron deficient (Mamiro *et al.*, 2005). In Nzega, the prevalence of stunting, wasting, and underweight among under-fives were 26.1%, 6.5%, and 11.7%, respectively, (Safari *et al.*, 2015) with a 77.2% prevalence of anaemia often associated with malaria and unemployment of the parents (Simbauranga *et al.*, 2015). Whereas, within Arusha Region, prevalence for stunting were 36%, underweight 20%, wasting 6.5%, and anaemia 57% (NBS and MACRO, 2015). According to WHO (2013), if the prevalence of stunting, underweight, wasting, and anaemia is higher than 20%, 10%, 5% and 40%, respectively, as is the case in this region, the problems are considered to be of public health significance.

Micronutrient deficiencies affect maternal, newborn, and child health resulting in birth defects, intrauterine growth restriction, impaired cognition, and increased morbidity (Black *et al.*, 2008; Arsenault *et al.*, 2012; Balarajan *et al.*, 2012). The micronutrient deficiencies, including deficiencies of vitamin A, iron, zinc and iodine, are common among children in low-income countries (Black *et al.*, 2013). The deficiencies are an important cause of hidden hunger (Bhutta, 2008) contributing to the global burden of disease, impaired child development, and stunting (Black *et al.*, 2013). Poor quality diets due to lack of dietary diversification account for most micronutrient deficiencies among under-fives (Ferguson *et al.*, 2015). Thus the control of vitamin and mineral deficiencies is an essential part of the overall effort to fight hunger and under-nutrition (WHO, 2013).

2.2.1 Anaemia and iron deficiency anaemia

Anaemia is a global public health problem which affects human health and economic development both in developing and developed countries (WHO, 2008; Black, 2014). Anaemia is a blood condition that impairs the oxygen carrying capacity due to a reduced number and size of red blood cells and is frequently reported as a lower than normal range haemoglobin concentration (WHO, 2014). The haemoglobin cut-off values range based on age and/or gender from 11 g /dL for pregnant women and children 6 months to 5 years, 12 g /dL for non-pregnant women, and 13 g /dL for men (WHO, 2017). Severe anaemia (Hb less than 7.0 g /dL), a condition which is possible at any life stage but is frequently see in pregnant women and young children (WHO, 2008). Iron deficiency is the most common cause of anaemia globally but there are other causes which include deficiencies in folic acid, vitamin B12, vitamin A, parasitic infections (such as malaria, hookworms), inherited disorders, and human immunodeficiency virus and acquired immunodeficiency syndrome (WHO, 2013).

According to the TDHS Report, 58% of children 0 - 59 months were anaemic (NBS and MACRO, 2015). Studies indicated that anaemia in children 6 - 59 months is likely due to a combination of physiological requirements for increased iron requirements for rapid growth, early introduction of CFs, low availability of foods rich in iron (meat, fish, and poultry) and lack of dietary diversification (Amsalu and Tigabu, 2008; Santos *et al.*, 2011; Balarajan *et al.*, 2012; Al-Qaoud *et al.*, 2015; Kulwa *et al.*, 2015).

Besides that, other factors contributing to anaemia are: socio-demographic characteristics including geographic location, gender, age, income, education and poor child feeding practices, such as the early or late introduction of CFs with low iron (Yang *et al.*, 2012; Leite *et al.*, 2013; Al-Qaoud *et al.*, 2015; El Kishawi *et al.*, 2015; Simbauranga *et al.*, 2015; Zuffo *et al.*, 2016). Plant components such as polyphenols and phytate in vegetables, tea and coffee limits iron absorption as they tend to bind the iron receptors (Zijp *et al.*, 2000). Studies found that drinking tea with meals is significantly associated with anaemia (Nelson and Poulter, 2004; Zaida *et al.*, 2006; El Kishawi *et al.*, 2015; Fan, 2016). For vulnerable groups, advice should be given to avoid drinking tea with meals or they should wait and drink tea an hour after the meal (Nelson and Poulter, 2004; Bhutta, 2008). Vitamin C enhances iron absorption and mitigates the effect of tannins in tea and phytic acid in cereals and legumes (Rah *et al.*, 2012). Therefore meals high in vitamin C rich foods are recommended.

In addition to plant-based foods, cow's milk is often used as complentary foods (CFs) in developing countries like Tanzania (Nyaruhucha *et al.*, 2006; NBS and MACRO, 2010; TFNC, 2014). Consumption of cow's milk is related to high risk of anaemia in the first year of life as cow's milk is a poor source of iron (e Carlos and Monteirob, 2004; Janus and Moerschel, 2010).

There is low coverage of essential nutrition interventions for the prevention and control of anaemia in Tanzania. Deworming, provision of mosquito nets, treatment of malaria during pregnancy, vitamin A, and iron-folic supplementation have been implemented with minimal impacts on addressing anaemia prevalence. In order to reduce anaemia, programs should emphasize proper feeding practices like improved food recipes and use of multiple micronutrient powders through home fortification.

2.3 Determinants of poor nutritional status in Tanzania

The UNICEF conceptual framework of malnutrition explains the determinants of child under-nutrition. This framework also shows that optimal nutritional status results when children have access to affordable, diverse, nutrient-rich foods, appropriate maternal and child-care practices, adequate health services, and a healthy environment including safe water, sanitation, and good hygiene practices (UNICEF, 2013).

In Tanzania, poor breastfeeding practices, inadequate dietary intake from CFs, high rates and repeated episodes of diseases, inadequate maternal nutritional knowledge, and household food insecurity are associated with poor nutrition status (Mamiro *et al.*, 2005; Kulwa *et al.*, 2006). Studies show that under-nutrition has impact across the life cycle and may begin in the womb during pregnancy with intra-uterine growth retardation, caused by disease (e.g., malaria) and poor maternal nutrition which lead to low birth weight (Mamiro *et al.*, 2005; TFNC, 2012). Therefore, nutritional status during pregnancy influences maternal and child outcomes (UNICEF, 2013). Interventions, such as micronutrient supplementations with iron-folate or MNPs among pregnant women, will help to reduce the risk of low birth weight.

The first 1000 days of life is a critical window; it is a period of rapid growth, where optimal breastfeeding and complementary feeding need to be practiced to avoid inadequate intake, which increases susceptibility to diseases (Tanzania Food and Nutrition Center (TFNC, 2012). TFNC's landscape analysis showed a linkage between under-nutrition, inadequate dietary intake, and repeated episode of infectious diseases forming a vicious cycle. Studies have shown that repeated episodes of infectious disease like Acute Respiratory Infections (ARI), diarrhoea and worms increases the odds of child under-nutrition (Saha *et al.*, 2008; Mgongo *et al.*, 2013; Fekadu *et al.*, 2015). These diseases have effect on dietary intake, absorption and nutrient utilization hence affect nutrition status (Dewey and Mayers, 2011). During an infection, the immune system needs more nutrients to fight against the invading organisms and therefore early treatment of infections is important to avoid under-nutrition (Dewey and Mayers, 2011).

Nyaruhucha *et al.* (2006) found that food insecurity, mothers with no formal education, large household size, and early complementary feeding were among the determinants of child under-nutrition in Simanjiro, Tanzania (Nyaruhucha *et al.*, 2006). Socio-demographic characteristics (child sex, age, education level), access to safe water, disease, and inadequate health services were the reported risk factors of under-nutrition among children in Nzega (Safari *et al.*, 2015).

Tanzania's National Nutrition Strategy (2011-16) indicated that there is relationship between poverty and child under-nutrition due to lack of resources to produce or purchase sufficient foods. Poor economic status may limit the household's access to food and health services. The TDHS report showed children from lower economic status are more likely to be undernourished than those of higher economic status (NBS and MACRO, 2010). Different sectors, such as health, agriculture, community development and education, are required to complement and address both the immediate and underlying causes of under-nutrition. Ultimately, the Tanzania Ministry of Health and Social Welfare (MOHSW) are responsible for implementing policies and strategies which directly or indirectly affect nutrition outcomes.

2.3.1 Feeding practices

Appropriate child feeding practices include the use of appropriate (in terms of both quality and quantity) foods at the right frequency in alignment with the child's stage of growth and development (UNICEF, 2013).

2.3.2 Exclusive breastfeeding

Exclusive breastfeeding (EBF) is practiced when infants receive only breast milk from the mother or expressed breast milk for the first six months of life without any additional drinks, not even water with exception of oral rehydration solution, or drops/syrup of vitamins or minerals and medicine (WHO, 2008). Breast milk contributes significantly to nutrition and health of infants and young children (Milman, 2011). Exclusive breastfeeding is recommended for the first six months of life and with evidence of its provision of optimal nutrition and health benefits to the child (WHO, 2008). Exclusive breastfeeding is a simple and cost-effective intervention in reducing child mortality and morbidity in low-income countries (Lutter *et al.*, 2011).

Globally, about 39% of infants less than 6 months were EBF; and in sub-Saharan Africa, 37% are exclusively breastfed (UNICEF, 2013; Victora *et al.*, 2016). In Tanzania, almost all children (98%) were breastfed, though the prevalence of EBF is 59% (NBS and MACRO, 2015). Tanzania has guidelines on Infant and Young Child Feeding (IYCF) practices which stipulate that children should receive optimal breastfeeding (breastfedwithin one hour of delivery and exclusively for the first six months) and thereafter, receive nutritianally adequate and safe CFs with continued breastfeeding up to two years (Makani *et al.*, 2011). However, they do not practce what is recommended (Mgongo *et al.*, 2013). Although mothers were aware of the importance of EBF, socioeconomic conditions curtailed many mothers from complying due to pressures to return to income generating activities and employment leading to early introduction of foods other than breast milk (Mgongo *et al.*, 2013; Moshy *et al.*, 2013; Safari *et al.*, 2015). Many Tanzanian women give their infants water, cow's milk, and / or thin porridge, in addition to breast milk, during the first six months of life (Nyaruhucha *et al.*, 2006; Kimiywe and Chege, 2015; Dewey, 2016).

For the child to thrive, the first breast milk is important because it contains colostrums which is rich in nutrients, antibodies, hormones, and antioxidants (Black *et al.*, 2008; UNICEF, 2013). Children should be optimally fed based on their age to ensure proper growth, and development.

2.3.3 Complementary feeding

After six months of age breast milk alone can no longer supply the required nutrients making it important to introduce other foods in addition to breast milk (Milman, 2011). Foods or non-milk fluids that are provided in parallel with breast milk are referred to as CFs (WHO, 2008; Agho *et al.*, 2009). Past six months of life, children have an increased demand for energy and nutrient requirements for their growth and development (Vitolo *et al.*, 2008; Dewey, 2013). Intake of a variety of available foods has been recommended to achieve adequate nutrient intake foods available in the household, but often the opposite is true in low-income countries where children are typically fed nutrient-poor diets (watery cereal gruels) (Dewey, 2013). In resource-constrained populations, diets consist mainly of cereal-based staple foods and access to nutrient-rich foods, such as animal products, fruits, and vegetables, is limited (Ruel *et al.*, 2004; Dewey, 2016).

Growth faltering is most evident particularly during complementary feeding (6-24 months) when food of low nutritional quality begins to replace breast milk and rate of infectious diseases like diarrhoea is at its highest (Vitolo *et al.*, 2008). As a result, CFs given to children need to be of high nutritional quality. Studies in Tanzania have shown that the main CF given to children is maize porridge which is low in nutrient content, contributing to under-nutrition (Mamiro *et al.*, 2005; Nyaruhucha *et al.*, 2006; NBS and MACRO, 2010; Shirima *et al.*, 2015).

In most developing countries CFs are of low nutrient content especially in terms of micronutrients and therefore, home fortification with multiple micronutrients (MNP) is recommended to ensure that the CFs provide required nutrients. During this period, continued breastfeeding up to 24 months of age is crucial for child growth and well-being.

2.5 Intervention to improve nutritional status

Nutrition specific interventions are actions that have a direct impact on the prevention and treatment of under-nutrition and meeting of micronutrient requirements (UNICEF, 2013). For long-term impacts, interventions should focus on maternal nutrition and optimal IYCF (Black *et al.*, 2013; UNICEF, 2013; WHO, 2013). The first 1000 days is a crucial period for preventing under-nutrition and its long-term effects (Dewey, 2013). Between 6-24 months of age, there is often a high incidence of infection, which also increases nutritional needs (Dewey, 2013). Strategies for preventing micronutrient deficiencies include dietary diversification, supplementation with mega dosages of vitamins/minerals to specific vulnerable groups, home fortification of CFs, and fortification of staple foods (Allen *et al.*, 2006; Salam *et al.*, 2013). Modification of CFs by fortification of traditional foods is a cost-effective strategy to improve child nutrition (Allen *et al.*, 2006; Kupka, 2015). According to Allen *et al.* (2006), food fortification refers to the addition of micronutrients to processed foods. Fortification increases the micronutrient value of traditional foods which fail to provide adequate levels of nutrients in the diet, potentiating a sustainable impact. The World Bank has been instrumental in advancing food fortification initiatives in Tanzania (Makani *et al.*, 2011). However, achieving widespread utilization of fortified foods is difficult because the majority of the population live in rural areas and depend on subsistence agriculture for their livelihood (Lundeen *et al.*, 2010). Most foods consumed in this society are produced at home or in their village making fortification of staples a major challenge.

A number of intervention studies have been conducted according to a prospective randomized design, whereby micronutrient powder was used in solving a nutritional challenge (Adu-Afarwuah *et al.*, 2008; Kounnavong *et al.*, 2011; Suchdev *et al.*, 2012; Mosha *et al.*, 2014; Irena *et al.*, 2015). The results indicated that there was increase in haemoglobin concentration and reduction of anaemia prevalence. MNPs are aimed at tackling the wide spread challenges of micronutrient deficiencies including anaemia. They are formulated to provide the recommended daily nutrient intake of 2 or more vitamins and minerals to children under-five years. Table 1 shows the summary of studies on efficacy trials of micronutrient supplementation conducted in developing countries.

In Tanzania, one efficacy trial for MNPs was conducted in a geographic area with high prevalence of malaria to evaluate the efficacy of micronutrient powder supplementation (Mosha *et al.*, 2014). Results indicated that there was an increase in haemoglobin concentration and a reduction of anaemia and malaria incidence among children below the age of five years. Currently, there are no data to provide evidence-based recommendations for micronutrients consumption especially in resource-poor areas. Initiative on national food fortification is underway to fortify industrial processed foods with MNP but elsewhere in the country there is inadequate access. Therefore a community-based point-of-use food fortification is needed to be explored in Tanzania. A study on efficacy of MNPs at different dosage is of importance and will be useful for recommending micronutrients supplementation and also in social marketing of micronutrients powders.

Table 1: Summary of studies on the efficacy of micronutrient supplementation in developing countries

Author	Type of study	Site	Nature of intervention	Indicator
(Adu-Afarwuah *et al.*, 2007)	Efficacy	Ghana	Children received added micronutrients through fortification for 6 months	Growth, motor development, morbidity and iron status
(Kuusipalo *et al.*, 2006)	Efficacy	Malawi	Malnourished children received fortified food with micronutrients in the form of milk or soy-based spread for 3 months	Growth and iron status
(Giovannini *et al.*, 2006)	Efficacy	Cambodia	Children received added micronutrients through home fortification with sprinkles™ for 12 months	Growth and iron status
(Bilukha *et al.*, 2011)	Efficacy	Nepal	Bhutanese refugee children received micronutrient powder through home fortification for 13 months	Anaemia and growth
(Jack *et al.*, 2012)	Efficacy	Cambodia	Daily micronutrient Sprinkles™ alongside infant and young child feeding (IYCF) education for 6 months	Anaemia, vitamin A, zinc and growth
(Kounnavong *et al.*, 2011)	Efficacy	Lao people's Democratic Republic	Children received daily or two sachets per week of MNP through home fortification for 2 months	Anaemia
(Mahfuz *et al.*, 2016)	Efficacy	Dhaka Bangladesh	Children received MNP for 4 months	Anaemia and Morbidity
(Serdula *et al.*, 2013)	Efficacy	Kyrgyz Republic	Children received home fortification with MNP for 2 months	Anaemia and vitamin A
(Rah *et al.*, 2012)	Program experience	Kenya, Nepal, and Bangladesh	Subjects consume MNP either daily or every other day over an extended period of time	Anaemia and stunting
(Mosha *et al.*, 2014)	Efficacy	Tanzania	Children received MNP for two months	Anaemia and morbidity
(Suchdev *et al.*, 2012)	Efficacy	Kenya	Children receives Sprinkles™ MNP at home through community market vendors for 12 months	Anaemia and vitamin A
(Lundeen *et al.*, 2010)	Efficacy	Kyrgyz Republic	Children receive 60 sachets of MNP for 2 months	Haemoglobin

2.5.1 Home fortification

Home fortification refers to point-of-use fortification. It includes several products in powder or paste form that are mixed into foods soon before consumption and can be used with any vulnerable population, starting with children at six months when complementary feeding begins (Jefferds *et al.*, 2015). Home fortification with MNP is sachets of vitamins and minerals that can be mixed with semi-solid foods right before eating (Salam *et al.*, 2013). It is recommended to ensure CFs provide required nutrients to meet nutritional needs of children during the critical window for growth and development between 6 - 24 months (HF-TAG, 2012). Nutritional education to mothers should be designed to promote healthy feeding practices and increasing energy density of complementary foods through home fortification with MNPs.

Home fortification has emerged as an important component of interventions in developing countries to prevent anaemia and micronutrient deficiencies, as part of IYCF efforts (UNICEF, 2013; Mangani *et al.*, 2015). Government agencies and their partners have increasingly advanced home fortification interventions in the past 10 years worldwide, focusing primarily on MNP (Rah *et al.*, 2012; Jefferds *et al.*, 2013). Subsequently, MNP was initiated and preliminary field tested aimed at treating multiple micronutrient deficiencies (Gross *et al.*, 2005). MNPs offer an average daily recommended dietary intake, and its delivery is more convenient, novel, and intrinsically sustainable approach to public health (Gross *et al.*, 2005). It contains vitamins A, D, E, C, B1, B2, niacin, B6, B12, folate, iron, zinc, copper, and iodine, and are flavored to mask the taste of the iron which is not encapsulated (Smuts *et al.*, 2005; WHO, 2011).

There are different types of multiple micronutrient supplement, assuring adequate micronutrient status of infants, like Sprinkles®, Plumpy Nut® and Nutributter® (peanut-based spread) which are the point of use to improve micronutrient contents in CFs (Rivera *et al.*, 2003; Serdula *et al.*, 2013). Home fortification with MNPs aims to ensure that the diet (CFs) meet the micronutrient needs of young children and is recommended where CFs do not provide adequate nutrients (HF-TAG, 2012; Rah *et al.*, 2012). Home fortification with MNP improves micronutrient status and child health, reduces morbidity and mortality, and increases child's appetite (Jefferds *et al.*, 2010; Tripp *et al.*, 2011).

Based on a global assessment carried out in 2011, 22 developing countries were implementing MNP interventions to improve the quality of CFs (UNICEF, 2013). MNPs interventions were found highly effective in preventing anaemia (Giovannini *et al.*, 2006; Kounnavong *et al.*, 2011; Jack *et al.*, 2012; Suchdev *et al.*, 2012; De-Regil *et al.*, 2013; Mosha *et al.*, 2014; Jefferds *et al.*, 2015; Mahfuz *et al.*, 2016). A systematic review of randomized controlled trials found that multiple micronutrient powders were associated with reduced anaemia as well as improved iron and vitamin A status in children aged 6 months to 11 years (Salam *et al.*, 2013).

Multiple micronutrient powders are affordable in many countries and highly acceptable. In Tanzania, the retail cost of a sachet of MNP is 150 TZS (US$0.068). One sachet provides the recommended daily intake but, due to cost, it might be unaffordable to low income families. The implementation of home fortification with MNP is a fairly complex process, requiring government policy and processes ranging from programs to delivery, plus rigorous monitoring and impact evaluation (Rah *et al.*, 2012). Such an introduction involves the decision of which group(s) to target, with how many sachets, over what period, addressing what micronutrient needs, and how much will it cost. Therefore, given the magnitude of the problem, greater efforts are needed to develop and implement programs that are affordable, both to prevent and to control anaemia through dietary modification, and to improve provision of iron-fortified foods through home fortification to reduce the problem.

2.6 Conclusion and recommendations

Chronic under-nutrition and anaemia have persisted in Tanzania. Since the burden of under-nutrition continues to affect child health, it is important that efficacy of different interventions is assessed to see whether they are effective, whereas other strategies should be put in place to reduce the problem. The consumption of a balance diet will normally help in alleviating under-nutrition; however, most households or communities in developing countries, Tanzania inclusive, cannot afford this. Food fortification has been seen to be a cost effective approach in reducing micronutrient deficiency. The government alone cannot support fortification; public- private- partnership is important to enable industrial food fortification. For urban population, there is increasing consumption of industrially processed foods of which many are good vehicles of fortification. In rural areas, most households consume what they have produced therefore they have no access to fortified foods. In such settings, community-based point-of-use food fortification initiatives may need to be explored further. This circumstance holds promise to reducing anaemia prevalence and other micronutrient deficiencies. Through cost sharing the private sectors can partner with the government in donation and commercialization of MNPs to communities in need. This will assure sustainability in MNP delivery.

CHAPTER THREE

Prevalence and predictors of under-nutrition among children under-five in Arusha District, Tanzania[1]

Abstract

Childhood under-nutrition is a global health challenge impacting child growth and survival rates. This deficit in nutritional status contributes to the increasing chronic disease prevalence and economic burden in individuals and throughout developing contexts. A community based cross-sectional study was conducted in Arusha District of Tanzania to determine the prevalence and predictors of under-nutrition in 436 children. A structured questionnaire was used to collect data on demographic and socio-economic factors as well as feeding practices and prevalence of preventable childhood diseases. Anthropometric data were collected through measurement of length/height and weight of all children. Prevalence of under-nutrition was estimated based on Z-scores indices below -2SD of the reference population for weight-for-age (underweight), height-for-age (stunting), and weight-for-height (wasting). Fifty percent, 28%, and 16.5% of the children were stunted, underweight, and wasted, respectively. Age above 2 years and being a male were associated with stunting. Age above 2 years, non-exclusive breastfeeding children, and living at Seliani and Oturumeti were associated with being underweight. Similarly, morbidity, none exclusively breastfed children, living at Oturumeti, and being born to a mother 35 years and above were associated with wasting. In this study, we found the prevalence of child under-nutrition in Arusha District is high in comparison with national and regional trends and appears to be associated with being a male. It is recommended that nutritionists and health planners should focus on these key predictors when planning nutrition interventions to address the problem of under-nutrition among under-five children in Arusha District

Keywords: Predictors, underweight, stunting, wasting, Tanzania

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3.1 Introduction

Childhood under-nutrition is a global health challenge impacting child growth and survival rates, contributing to future increased chronic disease prevalence, and reducing individual and national economic productivity (Chang *et al.*, 2002; Srivastava *et al.*, 2012; Black *et al.*, 2013). Childhood under-nutrition is embedded within the complexities of inter-sectoral and multi-level interfaces related to food security and equities in health. Inadequate access to the 'basics' cause childhood under-nutrition and is realized in the forms of inadequate nutrition due to improper child feeding and infectious diseases (i.e., diarrhoea, acute respiratory infection, malaria); lack of sanitation and clean water; and limited access to necessary and appropriate health care (De Onis *et al.*, 2012; Dangour *et al.*, 2013) underpin this state. Childhood under-nutrition has frequently been cited as an indicator to measure the development of a nation (Black *et al.*, 2013; Badake *et al.*, 2014) as it reflects how the most vulnerable are treated and is used as an indicator to measure progress towards the millennium development goals (MDG1) which aimed to halve the percentage of people who suffer from hunger by 2015.

Global efforts to positively address childhood under-nutrition have been made but deficits and challenges persist. Monitoring indicator trend, such as wasting, underweight, and stunting, have dominated discussions regarding progress in developing countries. Wasting, which is linked to acute under-nutrition and manifests as a 10% or greater unwanted weight loss, is often associated with droughts and seasonal periods of food insecurity (UNICEF, 2013). In 2014, the global prevalence of wasting was reported to be 7.5% (UNICEF, 2015). The prevalence of underweight declined from 25% to 16% (UNICEF, 2013). Stunting, which is linked to chronic under-nutrition and manifests as short in stature for age cohort, is a widespread problem in many parts of the world (UNICEF, 2013). According to UNICEF (2013), height at two years has been reported as the strongest predictor of future human capital. Although global stunting rates have decreased from 39.6% in 1990 to 23% in 2016, the issue remains prevalent especially with males (Chirande *et al.*, 2015; UNICEF, 2017) and is nearing endemic rates in African regions.

Nutritional interventions have been developed and implemented in Tanzania by the Ministry of Health (MOH) to reduce child under-nutrition. These are infant and young child feeding (IYCF) protocols, sanitation, deworming, vitamin A supplementation, and health education (MOH, 2008). Despite these interventions, child under-nutrition still remains a developmental challenge. According to the Tanzania Demographic Health Survey (TDHS) report, the national profile shows wasting prevalence of 5%, underweight at 14%, and stunting of 34% (NBS and MACRO, 2015). The prevalence of under-nutrition in Tanzania is relatively well documented at the regional levels, but not specific at the district levels. Compared to other regions, Arusha Region reported a higher prevalence of wasting (6.5%), underweight (20%), stunting (36%), and anaemia (57%) than the national rates (NBS and MACRO, 2015). This local trend was attributed to poor feeding practices and minimal consumption of fruits and vegetables (NBS and MACRO, 2010). In Arusha Region, reports on child nutritional status at district level are lacking. The only available reports are of studies focusing on the Maasai communities (Nyaruhucha *et al.*, 2006; Agho *et al.*, 2009). This paper highlights prevalence and predictors of under-nutrition among under-fives in Arusha District, a multi-ethnic locale within Arusha Region.

3.2 Materials and methods

3.2.1 Study area

The study was conducted in 3 wards of Arusha District, namely: Oldonyosambu, Oturumeti, and Seliani. Children in rural areas are more likely to be more undernourished than their urban counterparts (NBS and MACRO, 2015); therefore, Arusha District, which is predominantly rural, was selected. Geographically, this District surrounds the Arusha Municipal and is economically rooted in agriculture and livestock production (United Republic of Tanzania (URT, 2014). Arusha District has 56 196 children under five years of age (28 397 females; 27 799 males) (NBS and MACRO, 2015). The district has 2 hospital, 4 health centres and 23 dispensaries (URT, 2014).

3.2.2 Study design

A quantitative cross-sectional community-based survey was used in this study.

3.2.3 Subject inclusion criteria

Inclusion criteria used for subjects' selection included families resident within the study villages, child (ren) between 6 and 59 months, child consuming some solid foods (no longer exclusively breastfeeding). Exclusion criteria included child below 6 months (regardless of solid food intake), child aged above 60 months, or the family rejected to participate in the study.

3.2.4 Sampling procedure

Multistage sampling was used to select one district from seven districts in Arusha region, whereby Arusha District (one of the districts in Arusha Region) were selected purposively. Arusha District has 20 wards which constituted the sampling frame. The sampling interval was calculated by dividing with the number of required clusters which was 3. Random numbers were generated using the computer method in order to obtain the required clusters with the first number produced by the computer yielding the first cluster with the subsequent cluster obtained by adding the cluster with sampling interval. In the selected wards, the research team with the help of village health workers visited all households with children aged 6 - 59 months. The purpose and nature of the study activities explained to parents/caregivers and those who agreed to participate gave consent and were invited to come to the nearby Reproductive and Child Health (RCH) care centre.

3.2.5 Sample size

A sample size was determined using the statistical power analysis formula $n = z^2p(1\text{-}p)/d^2$ (Burger and Pierre-Louis, 2002), whereby a prevalence rate of stunting (p) 44% was used as a proxy indicator at 95% confidence interval and 5% estimation error. A total of 436 mother-child pairs were selected to participate in the study.

3.2.6 Construction of questionnaire, pre-testing, and administration

A questionnaire was administered (appendix 1) through face to face interview administered by a trained research assistant with the mothers / guardians. The data collection tool was pre-tested on a group of non-participating subjects, reflected upon, and validated accordingly. Standard techniques and equipment were used for collecting anthropometric measurements (De Onis, 2006) that reflected the variables of height, weight, sex, and age.

3.2.7 Measurements and tools

Anthropometric indicators used in this study aligned with international standards for underweight, stunting, and wasting. Under-nutrition was determined if the child is either stunted, underweight, wasted, or a combination of two or more. A Seca™ electronic scale was used for weight measurement. The device was placed on a flat floor and standardized to zero at the start of each day. To measure a child who could not stand alone, the mother was asked to step on the scale, without the child, for the mother’s weight to be displayed, and the scale was then tared (zero-out) when the child was passed to the mother, thereby displaying the child's weight. In cases where the child was able to stand alone, the child was weighed directly. In all cases, the scale was read to the nearest 0.1kg with minimal clothing and no shoes.

Recumbent length was measured for children under the age of 2 years. In these cases, the child was placed horizontally on a wooden measuring board (Perspective Enterprises™, Portage, MI, USA). The subject was placed facing upward with the head towards the fixed end and the body parallel to the long axis of the board. The subject's knees were pressed onto the board so that the legs were straight and the toes pointing directly upwards, then the movable footboard was brought to rest firmly against the heels and measured to the nearest 0.1 cm (Gibson, 1990). Standing height for a child above 24 months was measured vertically using a wooden measuring board (Perspective Enterprises™, Portage, MI, USA) measured to the nearest 0.1 cm (Badake *et al.*, 2014). All the anthropometric measurements were taken by two nutritionists.

3.2.8 Data analysis

The data collected was entered, cleaned, coded, and analyzed using SPSS™ Version 20 Nutritional data were entered and analyzed using SMART™ software provided by the WHO. Chi-squared tests were used to compare group differences for categorical variables. The dependent variables included were underweight, stunting and wasting while the independent variables were child's demographic information (i.e., sex, age, morbidity information, feeding practices) and parental socio-demographic information (i.e., education level, age, marital status etc). Bivariate logistic regression was performed to control for confounders for three outcome variables: underweight, stunting and wasting separately. The independent variables found significant ($p \leq 0.05$) during bivariate analysis were selected for multivariable analysis. Multivariable binary logistic regressions were fitted using the backward elimination technique to identify determinants of underweight, stunting, and wasting separately. Association between dependent and independent variables was assessed using odds ratio (OR), adjusted odds ratio (AOR) and 95% confidence interval (CI). Statistical association was declared significant if $p \leq 0.05$.

3.2.9 Ethical consideration

Ethical clearance was obtained from the Ethics Committee of the National Institute for Medical Research (NIMR) Tanzania. Permission to undertake the study in Arusha district was obtained from the regional and district health departments. All study participants gave a written informed consent (Appendix 2).

3.3 Results

A total of 436 children aged 6 - 59 months participated in the study. Table 2 summarizes the socio-demographic characteristics.

Table 2: Socio-demographic characteristics of participants by gender

Variable	N	Female (%)	Male (%)	P-value
Residence				
Oldonyosambu	159	41.8	32.2	0.06
Seliani	150	34.0	37.7	
Oturumeti	127	24.2	33.1	
Mother's age (years)				
15-24	213	53.6	45.0	0.4
25-34	197	43.3	46.7	
35-49	26	3.1	8.3	
Mother's education				
No formal education	67	12.4	17.8	0.2
Primary education	291	67.0	66.5	
Secondary and above	78	20.6	15.7	
Father's education				
None or primary incomplete	36	7.7	8.7	0.8
Primary complete	347	80.9	78.5	
Secondary and above	53	11.3	12.8	
Marital status				
Single	44	9.8	10.3	0.8
Married	392	90.2	89.7	
Child's age (months)				
6-24	291	63.4	69.4	0.2
Above 24	145	36.6	30.6	
Morbidity				
No	142	34.5	31.0	0.4
Yes	294	65.5	69.0	
Types of diseases				
Diarrhoea	66	23.4	22.0	0.7
Fever	51	17.7	17.3	
Cough	25	6.5	10.1	
Multiple diseases	150	52.4	50.6	
Income level (Tshs)				
>2500	59	15.5	12.0	0.3
<2500	377	84.5	88.0	

3.3.1 Child feeding practices

Table 3 offers a comparison of feeding practices. There was an apparent gender bias in the practice of exclusive breastfeeding with females being more likely to experience this practice.

Table 3: Feeding practices of children under the age of five years by sex

Variable	N	Female (%)	Male (%)	P -value
Exclusive breastfeeding				
Yes	70	29.4	5.6	0.00
No	366	70.6	94.6	
Age child started other foods/fluids				
1-3 months	181	39.2	43.4	0.00
4-5 months	185	31.4	51.2	
At six months (exclusively breastfed)	70	29.4	5.4	
Types of food/fluid child started				
Water	84	17.0	21.1	0.5
Cow's milk	167	41.8	35.5	
Plain thin porridge	150	33.0	35.5	
Kideri[a]	35	8.2	7.9	
Daily food frequency				
Two times	41	41.5	58.5	0.3
Three times	166	47.0	53.0	
Four times	191	45.5	54.5	
Five times	38	31.6	68.4	

[a] *banana mixed with sour milk (local food)*

3.3.2 Prevalence of diseases

The prevalence of morbidity was 67.4% (n = 294), with the most commonly reported diseases being diarrhea, fever, and cough. About 67% (n = 194) of children aged 12 - 24 months were reported to be ill. Diarrhoea and multiple symptoms (diarrhoea, fever, and/or cough) were prevalent among children aged 6 - 24 months, reported as 29% (n = 56) and 50.8% (n = 98) respectively ($p < 0.001$).

3.3.3 Nutritional status

Table 4 shows the distribution of underweight, stunting and wasting among the children under the age of five years by sex.

Table 4: Prevalence and distribution of child under-nutrition by sex

Variable	N	Female (%)	Male (%)	P -value
Underweight	123	23.2	32.2	0.04
Stunted	218	43.8	55.0	0.00
Wasted	72	12.9	19.4	0.06

3.3.4 Factors associated with underweight, stunting, and wasting

Table 5 shows the determinants of underweight among children aged 6 - 59 months. In univariate logistic regression, four determinants were significantly associated with being underweight. These were being a male (OR: 1.4, 95% CI: 1.0 - 2.3), age above 2 years (OR: 1.7, 95% CI: 1.1 - 2.7), being ill within the two weeks prior to data collection (OR: 4.5, 95% CI: 2.5 - 8.0), and living in Oturumeti ward (OR: 1.5, 95% CI: 2.6 - 7.8) or Seliani ward (OR: 1.5, 95% CI: 0.8 - 2.6). In multivariate logistic regression, only three risk determinants were significantly associated with being underweight, namely child age above 2 years (AOR: 1.7, 95% CI: 1.02 - 2.7), recent illness (AOR: 4.2, 95% CI: 2.3 - 7.6) and living in Oturumeti (AOR: 4.6, 95% CI: 2.6 - 8.2) or Seliani (AOR: 1.9, 95% CI: 1.1 - 3.5).

Table 5: Determinants of underweight among children under the age of five years

Variable	N	(%)	COR (95% CI)	P-value	AOR (95% CI)	P -value
Child's sex						
Female	194	23.2	1		1	
Male	242	32.2	1.6 (1.0- 2.3)	0.04	1.2 (0.7-1.9)	0.5
Child's age (months)						
6-24	291	24.4	1		1	
Above '24	145	35.9	1.7 (1.1-2.7)	0.01	1.7 (1.02-2.7)	0.04
Illness weak preceding survey						
No	142	11.3	1		1	
Yes	294	36.4	4.5 (2.5-8.0)	0.00	4.2 (2.3-7.6)	<0.01
Exclusive breastfeeding						
Yes	70	15.7	1		1	
No	366	30.6	2.4 (1.2-4.7)	0.01	2.8 (1.3-5.8)	<0.01
Residential area						
Oldonyosambu	159	17.0	1		1	
Seliani	150	23.3	1.5 (0.8-2.6)	0.2	1.9 (1.1-3.5)	0.03
Oturumeti	127	48.0	4.5 (2.6-7.8)	0.00	4.6 (2.6-8.2)	<0.01

Determinants of stunting are summarized in Table 6. Many factors were associated with stunting whereby three risk factors were significantly linked with stunting. These were: being a male (OR: 1.6, 95% CI: 1.1 - 2.3), child age above 2 years (OR: 1.6, 95% CI: 1.1 - 2.4); and being ill in the past two weeks prior to the survey (OR: 1.5, 95% CI: 0.9 - 2.2), having a father with primary education (OR: 0.4, 95% CI: 0.2 - 0.8) and living in Oturumeti village (OR: 1.7, 95% CI: 1.1 - 2.7). Multivariate logistic regression indicated that two determinants were significantly linked with stunting namely being a male (AOR: 1.5, 95% CI: 1.1 - 2.4) and age above 2 years (AOR: 1.7, 95% CI: 1.1 - 2.5).

Table 6: Determinants of stunting among children under the age of five years

Variable	N	(%)	COR (95%CI)	P -value	AOR (95% CI)	P -value
Child's gender						
Female	194	43.8	1		1	
Male	242	55.0	1.6 (1.12.3)	0.02	1.6 (1.1-2.4)	0.01
Child's age(months)						
6-24	291	46.0	1		1	
Above 24	145	57.9	1.6 (1.1-2.4)	0.02	1.7 (1.1-2.5)	0.01
Illness weak preceding survey						
No	142	43.7	1			
Yes	294	53.1	1.5 (0.9-2.2)	0.06		
Exclusive breastfeeding						
Yes	70	44.3	1			
No	366	85.8	1.3 (0.8-2.2)	0.3		
Father's education						
None or primary incomplete	36	69.4	1			
Primary complete	247	47.8	0.4 (0.2-0.8)	0.02		
Secondary and above	53	50.9	0.4 (0.2-1.0)	0.08		
Residential area						
Oldonyosambu	159	45.9	1		1	
Seliani	150	46.7	1.0 (0.7-1.6)	0.8	1.1 (0.7-1.7)	0.7
Oturumeti	127	59.1	1.7 (1.1-2.7)	0.02	1.6 (0.9-2.6)	0.06

Determinants of wasting are summarized in Table 7. In univariate logistic regression, factors which were significantly associated with wasting were being ill a week before survey (OR 3.5, 95% CI: 1.8 - 7.0), not exclusively breastfed (OR 2.3, 95% CI: 0.9 - 5.6), having mother aged 35 years and above (OR 2.6, 95% CI: 1.1 - 6.3) and living in Oturumeti (OR 5.2: 95% CI: 2.6 - 10.2). In multivariate logistic regression, factors that remained significantly associated with wasting were: being ill in the two weeks prior the survey (AOR 3.1, 95% CI: 1.5 - 6.4), children not exclusively breastfed (AOR 2.5, 95% CI: 1.0 - 6.3), children born to mothers above 35 years (AOR: 3.9, 95% CI: 1.5 - 10.6) and living in Oturumeti (AOR: 5.9, 95% CI: 2.9 - 12.2).

Table 7: Determinants of wasting among children under the age of five years

Variable	N	(%)	COR (95% CI)	P -value	AOR (95%CI)	P -value
Child's gender						
Female	194	12.9	1		1	
Male	242	19.4	1.6 (0.97-2.7)	0.06	1.1 (0.6-2.0)	0.7
Child's age(months)						
6-24	291	15.1	1			
Above 24	145	19.3	1.3 (0.8-2.3)	0.2		
Illness weak preceding survey						
No	142	7.0	1		1	
Yes	294	21.1	3.5 (1.8-7.0)	<0.01	3.1 (1.5-6.4)	<0.01
Exclusive breastfeeding						
Yes	70	8.6	1		1	
No	366	18.0	2.3 (0.9-5.6)	0.05	2.5 (1.0-6.3)	0.05
Mother's age						
15-24	213	16.1	1		1	
25-34	197	13.7	0.8 (0.5-1.3)	0.4	0.9 (0.5-1.6)	0.6
35-49	26	34.6	2.6 (1.1-6.3)	0.03	3.9 (1.5-10.6)	<0.01
Residential area						
Oldonyosambu	159	8.2	1		1	
Seliani	150	12.7	1.6 (0.7-3.4)	0.2	1.9 (0.9-4.0)	0.1
Oturumeti	127	31.5	5.2 (2.6-10.2)	<0.01	5.9 (2.9-12.2)	<0.01

3.4 Discussion

The study indicates that almost half of under-five children in the study population were undernourished and that this group was disproportionately represented by males. This study showed a prevalence of stunting (50%), underweight (28.2%), and wasting (16.5%). Child age above 2 years, being a male, morbidity, non-exclusive breastfeeding, maternal age above 35 years, and living at Oturumeti or Seliani were predictors of children being undernourished.

Research shows stunting is a significant health problem among infants and young children in Tanzania (Safari *et al.*, 2013; Kulwa *et al.*, 2015). Stunting affected 55% of male children which is twice as high as the reported regional prevalence of stunting (27%) reported by Tanzania National Nutrition Survey (TFNC, 2014), and slightly higher than the 36% prevalence reported in the TDHS (NBS and MACRO, 2015). Likewise, underweight and wasting remain at unacceptably high levels, with study findings exceeding those of the regional reports (TFNC, 2014; NBS and MACRO, 2015). Rural areas account for the largest number of stunted children in the current study, which mirrors previous reports (Mamiro *et al.*, 2005; NBS and MACRO, 2010, 2015; Shirima *et al.*, 2015). UNICEF, WHO, and World

Bank (2015) regard stunting as “very high” if it exceeds 40% in a population. This threshold was exceeded in our study population, which highlights the need for more urgent efforts to tackle the problem. Other studies reported stunting causative factors include poor maternal nutrition which may contribute to intrauterine growth retardation, preterm and low birth weight babies, inadequate CFs, and frequent infections (Black *et al.*, 2008; Prendergast *et al.*, 2014).

As previously stated, male children were more likely to be stunted than their female counterparts, which mirrors findings described previously (Wamani *et al.*, 2007; Vitolo *et al.*, 2008; Agho *et al.*, 2009; Hien and Hoa, 2009; Asfaw *et al.*, 2015; Chirande *et al.*, 2015). Compared with their female cohort, the likelihood of underweight was higher amongst males when not adjusted, but non-significant when adjusted for other factors. The higher odds of stunting in male children may be attributed to the early introduction of complementary feeds, with most (95%) males versus many (70%) of females introduced to complementary feeding before the WHO’s (2018) recommended age. Early introduction of complementary feeding also may expose children to infections including acute respiratory infections, diarrhea, and worm manifestation (Arifeen *et al.*, 2001; Kalanda *et al.*, 2006). Future studies are needed to consider gender specific and gender neutral approaches to address this issue of complementary feeding patterns.

The increased paternal educational level was shown to reduce the risk of child stunting. This finding is consistent with other studies conducted in Africa which suggested paternal education to be a protective factor against childhood stunting (Wamani *et al.*, 2004; Amsalu and Tigabu, 2008; Agho *et al.*, 2009). The rationale attributed to this linkage appears to align with the increased economic power to provide quality food and services for the family (Islam *et al.*, 2013), as in most developing contexts the presence of a father contributes to the economic power of the family.

Findings suggested that the risk of under-nutrition increases with age; specifically, children above 2 years were found to be at greater risk of being underweight and stunted. Similar findings were reported by other researchers (Ergin *et al.*, 2007; Vitolo *et al.*, 2008; Olack *et al.*, 2011). This finding may be attributed to poor child care and feeding practices where parents leave the child to be more independent. Also, at this age, some mothers might be pregnant or have another baby necessitating attending to the needs of the newborn, and potentially neglecting the older one (Buitrón *et al.*, 2004). Beyond two years, stunting is irreversible, so significant efforts must be focused on the first 1000 days of life.

Childhood illness over the previous 14 days was associated with underweight and wasting (Basit *et al.*, 2012; Manyike *et al.*, 2014). Infections impair the immune competence to fight against diseases. Illness causes failure to gain weight or loss of weight due to increase in energy expenditure, demand for nutrients and depressed appetite (Asfaw *et al.*, 2015). In this study diarrhea and multiple infections were more prevalent among children aged 6 - 23 months. These patterns seem to align with the introduction of complementary foods, which may be contaminated due to the preparation and hygienic issues.

Maternal age above 35 years was identified as a risk factor for wasting among children. This finding is contrary to other studies which showed that wasting was more prevalent among children born to young mothers (< 20 years) (Chirande *et al.*, 2015). This variance may lead to an interesting consideration of the two age extremes and what each grouping might bring to the child's nutritional status.

Living at Oturumeti or Seliani were risk factors for underweight and/or wasted status, which may be related to cultural behaviors and climatic conditions which may contribute to the differential pattern from children in Oldonyosambu. One element may relate to gender-based roles such as child care and household chores as primarily a woman's responsibility, whereas resources are controlled by men which may lead to conflicting priorities leading to child under-nutrition. This type of variance is also asserted by other studies (Ergin *et al.*, 2007; Hien and Hoa, 2009).

3.4.1 Conclusion

In conclusion, high prevalence rates of under-nutrition among children below the age of five years were observed in selected communities within Arusha District. Male children were found to be at greater risk of being malnourished than female counterparts, which was evidenced by the presence of stunting in nearly half of all male children. Through factor analysis, factors associated with child under-nutrition in this study were: being male, child age above 2 years, non-exclusive breastfed children, being born to a mother of 35 years and above, morbidity within the 2 weeks prior to the study, and area of residence (specifically, rural areas of Oturumeti and Seliani).

It is recommended from this study that nutritionists and health planners should focus on these key predictors when planning nutrition interventions to address the problem of under-nutrition among under-five children in Arusha District. Future studies are needed to consider gender specific and gender neutral approaches to address the issue of complementary feeding patterns.

In this chapter we determined the prevalence and predictors of child's nutritional status. The next chapter attempts to assess the prevalence and predictors of anaemia among children aged 6 - 59 months.

CHAPTER FOUR

Prevalence and predictors of anaemia among under-five in Arusha District, Tanzania[2]

Abstract

Anaemia is a global health problem affecting most developing countries, which merited the examination of prevalence of anaemia and its predictors among under-five children in Arusha District, Tanzania. Random sampling technique was used to identify 436 children aged 6-59 months. Anaemia status was assessed by measuring haemoglobin concentration in finger-prick blood using HemoCue (HemoCue® Hb 201+) photometer. Demographic information and dietary intake data were collected using a standardized questionnaire. Anaemia cut off points were defined according to World Health Organization standards for children aged 6-59 months. Logistic regression using backward procedure was used to estimate odds ratios (ORs) at 95% confidence intervals (CIs). The prevalence rate of anaemia among under-five was found to be 84.6%. Multivariable logistic regression identified the following predictors of anaemia; low birth weight (LBW) (adjusted odds ratio (AOR) 2.1, 95% CI: 1.1 - 3.8), not consuming - meat (AOR: 6.4, 95% CI: 3.2 - 12.9), not consuming vegetables (AOR: 2.1, 95% CI: 1.1 - 4.1), drinking milk (AOR: 2.5, 95% CI: 1.1 - 5.2), and drinking tea (AOR: 4.5, 95% CI: 1.5 - 13.7). It was concluded from the study that low birth weight and dietary factors (non-consumption of iron-rich foods like meat, vegetable, and fruits) were predictors for anaemia among children under-five years living in a rural setting. Community education on exclusive breastfeeding and introduction of complementary foods should be improved. Mothers/caretakers should be educated about the use of micronutrient powder to improve the nutritional quality of complementary foods.

Keywords: Anaemia, low birth weight, dietary intake, predictors, under-fives

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4.1 Introduction

Childhood anaemia is a condition where a child has an insufficient haemoglobin (Hb) level to provide adequate oxygen to the body tissues. For children between 6 and 59 months (generally referred to as under-fives the threshold Hb level for being non-anaemic is 11.0 grams per decilitre (g /dL) (WHO, 2011). Anaemia has numerous potential aetiologies. Apart from acute blood loss and heredity or acquired diseases, the most common cause of anaemia in young children is low consumption and absorption of iron-rich foods (meat and meat products) (Cardoso *et al.*, 2012; Yang *et al.*, 2012; Bhutta *et al.*, 2013; Black *et al.*, 2013). These conditions most often lead to iron deficiency anaemia (IDA), which accounts for approximately half of all anaemia cases globally, with under-five children and women being the most affected (Benoist *et al.*, 2008; Schrier, 2016). Although relevant across the lifespan, anaemia in under-five children is a special case given its significance to underpinning a range of morbidities and mortality within this population sub-set (Allen *et al.*, 2006). Not only are these patterns concerning due to their highly preventable and treatable nature, but they project potential long-term individual and social consequences of this condition. At the individual level, childhood anaemia contributes to poor motor and cognitive development, poor school performance, as well as increased morbidity and mortality (DPG, 2010; Kounnavong *et al.*, 2011). At the societal level, there are strong indicators that anaemia impacts on the socio-economic well-being and productivity of a country (Tulchinsky, 2010). Globally, data indicate that 43% of under-five children were anaemic in 2011, with the prevalence in developing world, specifically South Asia and East Africa, increased to 58% and 55%, respectively (Stevens *et al.*, 2013). Generally, there is high variability in the reported prevalence of anaemia across the continent of Africa. A number of reports (Heckman *et al.*, 2010; Magesa and Magesa, 2012; Foote *et al.*, 2013) suggested rates ranging between 71 and 79% in Kenya, South Africa, and Tanzania. According to the Tanzania Demographic and Health Survey 2015 (TDHS), 58% of children under the age of five years in Tanzania were anaemic. A recent study in Mwanza Tanzania reported a prevalence rate of anaemia at 77.2 % (with mild, moderate and severe anaemia being 16.5, 33, and 27.7 %, respectively) (Simbauranga *et al.*, 2015).

Pregnant and lactating women and under-five children are the most vulnerable social groups to micronutrient deficiencies due to their accentuated needs for vitamins and minerals (Arimond *et al.*, 2010). Along with this greater need comes a higher consequence due to lesser reserves. The literature is replete with a litany of nutrition interventions (Allen *et al.*, 2006; WHO, 2013), which clearly reveals the 'one-off, cross-sectional nature of most interventions. Stoltzfus (2001) indicated that effectiveness of such interventions has been inconsistently demonstrated, leading to difficulties in scaling up (Stoltzfus, 2001). Given the significantly high levels of anaemic under-five children in Tanzania, there is a strong need for action. In order to design and deliver effective interventions, it is important to know the strong risk factors for predicting anaemia among under-five children. The intent of this study was to first affirm the baseline prevalence rates of anaemia in selected wards of the predominantly peri-urban or rural Arusha District prior to implementation of an intervention to control anaemia among the under-five children. Consideration of factors contributing to anaemia among under-five children in the specific locations would be essential to ensure the effectiveness of the proposed intervention.

4.2 Material and Methods

4.2.1 Study area

This community-based cross-sectional study was conducted in Arusha Rural District, Tanzania. This District is primarily rural, shares similar socio-economic patterns with most of the rural districts in Tanzania, demonstrates cultural diversity, and reports childhood anaemia prevalence similar or above national levels (NBS and MACRO, 2015). Within the district, there are 20 wards each having at least one reproductive and child health (RCH) clinic for mothers and children. Of these, three wards; Oldonyosambu, Oturumeti and Seliani were randomly selected for the study.

4.2.2 Subject inclusion criteria

Inclusion criteria used for subjects' selection included family residence within the study villages, children between 6 and 59 months attending a designated outpatient RCH clinic, children consuming some solid foods (i.e., no longer exclusively breastfeeding). Exclusion criteria were children aged above 60 months, having sickle-cell anaemia or currently consuming multi-vitamin and /or mineral supplements on a regular basis or the family rejected to participate in the study.

4.2.3 Sampling procedure

The sampling frame was established and 20 wards with heath facilities offering RCH clinic services were identified and coded from 01 to 20. Three wards out of 20 wards were randomly selected by using a table of random numbers. In the selected wards, parents

/guardians with children aged 6 - 59 months were invited to the selected health facilities for free anaemia screening and nutritional status assessment. Children who met the inclusion criteria were selected for the study. A total of 127, 159, and 150 children from Oturumeti, Oldonyosambu and Seliani, respectively were sampled for the study.

4.2.4 Sample size

A sample size was determined using the statistical power analysis formula $n = z^2p(1-p)/d^2$ (Burger and Pierre-Louis, 2002), where; n = sample size, P = prevalence of anaemia (60%) (NBS and MACRO, 2010), z = value at 95% confidence (1.96), d = level of significance (5%) with an anticipated attrition of 18% to follow up yielded a total of 436 mother-child pairs were needed to participate in the study.

4.2.5 Anaemia screening

At each RCH clinic, children were screened for anaemia using HemoCue (HemoCue® Hb 201+) photometer. Safety lancets were used to obtain the finger prick blood which was collected by the micro-cuvettes. Blood sample in the micro-cuvette was loaded in the calibrated HemoCue photometer and Hb concentration read to the nearest 0.1 g/dL. Alcohol swabs were used to clean the fingers before pricking. The first drop of blood was wiped out by cotton wool, while the second drop was collected by micro-cuvette. Children with Hb level <11 g/dL were considered anaemic with, mild (10 - 10.9 g/dL), moderate (7 - 9.9 g/dL) and severe (<7 g/dL) anaemia (WHO, 2011).

Data on a range of socio-economic, demographic, and childhood-related illnesses were captured using a structured pretested, questionnaire at baseline during face-to-face interviews with the parents / guardians. Key elements were: i) child-information such as gender, age, birth weight, feeding practices, and illness two weeks prior survey; and ii) family specific information such as socio-economic and demographic characteristics of parents / family, including education level, marital status, occupation, and ownership of animals and land. This information was critical for determining risk factors for anaemia among children and which would be essential in planning implementation, and evaluation of intervention programs for controlling childhood anaemia.

4.2.6 Data analysis

Analysis of data was done using the Statistical Package for Social Sciences™ (Version 20.0). Frequency means and standard deviations were used to describe the characteristics of the study population, and to estimate the prevalence of anaemia. Chi-square tests were used to compare group differences for categorical variables. Univariate logistic regression was performed and all variables having a $p \leq 0.05$ were included in the multivariate logistic regression model. Using a backward elimination method a stepwise regression was done to progressively exclude independent variables which had no effect when put together. Association between dependent and independent variables was assessed using Odds Ratios (OR) at 95% Confidence Interval.

4.2.7 Ethical consideration

Ethical clearance was obtained from the National Institute for Medical Research, Tanzania (NIMR). Permission was also obtained from the regional and district health offices in Arusha to conduct the study in the RCH clinics. The purpose of the study was explained to all mothers/guardians of the children and those who agreed to participate signed an informed consent to affirm their willingness to participate. After screening for anaemia, results were shared and discussed with parent(s) / guardian(s). Children found to be severely anaemic (Hb < 7.0 g/dL) were referred to the medical doctor for treatment because severe anaemia usually needs immediate medical attention to treat the underlying causes and restore the normal levels of red blood cells; hence, they were excluded from the intervention aspects of this study.

4.3 Results

A total of 436 children aged 6 - 59 months participated in the study. The mean age of participating children was 20.3 ± 10.8 months. About 85% (n = 369) had anaemia (Hb < 11g /dL) with no significant difference by gender (i.e., 81.4% females; 87.2% males). Younger children (under 2 years) were more likely to be anaemic compared to their older peers (Table 8).

Table 8: Child's characteristics in relation to anaemia status

Variables	N	(%) with anaemia	P -value
Gender			
Female	194	81.4	0.09
Male	242	87.2	
Age (months)			
6-11	116	86.2	0.9
12-23	163	85.3	
24-35	108	83.3	
36-59	49	81.6	
Morbidity			
Not ill	142	82.4	0.3
With illness	294	85.7	
Type of disease			
Diarrhoea	66	84.8	0.07
Fever	51	74.5	
Cough	25	92	
[a]Multiple diseases	150	88.7	
[b]EBF			
Exclusive breastfed	70	80.0	0.2
Non-exclusive breastfed	366	85.5	
Birth weight			
Normal weight (>2.5kg)	224	79.0	0.00*
Low birth weight (< 2.5kg)	212	90.6	
Occupation of the head of household			
Employed	50	96	0.02*
Farmer	247	81.4	
Pastoralist	76	90.8	
Self-employed	63	81	
Marital status of mother			
Single	44	90.9	0.2
Married	392	83.9	
Mother's age (yrs)			
15-24	213	86.9	0.4
25-34	197	82.2	
above 34	26	84.6	
Residence			
Oldonyosambu	159	76.1	<0.001*
Seliani	150	86.7	
Oturumeti	127	92.9	

[a]*multiple response if the child had two or more disease (diarrhoea, fever or a cough)* [b] *Exclusive breastfeeding*

4.3.1 Association of anaemia and feeding practice

Table 9 shows the feeding habits that were associated with anaemia. Only 12.6% (n = 55), of the children consumed meat and 1.8% (n = 8), consumed fruits. Most complementary foods were plant-based. The main foods given to the children were thin plain maize porridge and composite flour porridge. The composite flour was obtained from a mixture of finger millet, rice, peanuts, and sardines.

Table 9: Association of anaemia and feeding habits

Variable	N	% with anaemia	P -value
Meat			
Consumed	55	50.9	0.00*
Not consumed	381	89.5	
Beans			
Consumed	380	83.6	0.2
Not consumed	56	90.5	
Milk			
Consumed	377	86.4	0.09
Not consumed	56	73.3	
Vegetable			
Consumed	261	80.5	0.00*
Not consumed	175	90.9	
Fruits			
Consumed	8	37.5	0.00*
Not consumed	428	88.5	
Loshoro[a]			
Consumed	346	84.4	0.7
Not consumed	90	85.6	
Kideri[b]			
Consumed	365	84.9	0.8
Not consumed	71	83.0	
Composite porridge			
Consumed	284	84.2	0.7
Not consumed	152	85.5	
Tea with sugar			
Do not drink	21	52.4	0.00*
Drink	415	86.3	

[a]*Local foods cooked from maize and mixed withsour milk,* [b] *mashed banana mixed with sour milk**$P \leq 0.05$

4.3.2 Anaemia and associated risk factors

Table 10 summarizes factors associated with anaemia. Five factors were significantly associated with anaemia among the under-five children. These factors were: low birth weight, non-consumption of meat, vegetables, fruits and drinking tea. In multivariate analysis, the following factors remained as independent risk factors associated with anaemia: having low birth weight (AOR) 2.1, 95% CI: 1.1 - 3.8 non-consumption of meat (AOR: 6.4, 95% CI: 3.2 - 12.9), non-consumption of vegetable (AOR: 2.1, 95% CI: 1.1 - 4.1), drinking milk (AOR: 2.5, 95% CI: 1.1 - 5.2) and drinking tea (AOR: 4.5, 95% CI: 1.5 - 13.7).

Table 10: Determinants of child anaemia

Variable	N	Anaemia (%)	COR (95%CI)	P-value	AOR (95%CI)	P -value
Birth weight						
Normal weight (>2.5kg)	224	79.0	1		1	
LBW(< 2.5kg)	212	90.6	2.5 (1.5-4.5)	0.01*	2.1 (1.1-3.8)	0.02 *
Child age						
Less than 2years	291	84.5	1		1	
Above 2years	145	84.8	1.0 (0.6-1.8)	0.9	1.4 (0.7-2.9)	0.4
Meat						
Consumed	55	50.9	1		1	
Not consumed	381	89.5	8.2 (4-15)	<0.01*	6.4 (3.2-12.9)	<0.01*
Beans						
Consumed	380	83.6	1			
Not consumed	56	90.5	1.9 (0.8-4.5)	0.2		
Milk						
Not consumed	56	73.3	1		1	
Consumed	377	86.4	2.3 (1.2-4.4)	0.01*	2.5 (1.1-5.2)	0.02*
Vegetable						
Consumed	261	80.5	1		1	
Not consumed	175	90.9	2.4 (1.3-4.4)	<0.01*	2.1 (1.1-4.1)	0.03*
Fruits						
Consumed	8	37.5	1		1	
Not consumed	428	85.5	9.8 (2.3-42.2)	<0.01	2.8 (0.5-14.0)	0.2
Tea with sugar						
Do not drink	21	52.4	1		1	
Drink	415	86.3	5.7 (2.3-14.0)	<0.01*	4.5 (1.5-13.7)	<0.01*
Residence						
Oldonyosambu	159	76.1	1		1	
Seliani	150	86.7	2.0 (1.1-3.7)	0.02	1.6 (0.8-3.3)	0.2
Oturumeti	127	92.3	4.1 (1.9-8.9)	<0.01*	2.2 (0.9-5.2)	0.06

*Variables in the model were controlled for sex and age of the children, *Significant P≤ 0.05.*

4.4 Discussion

This community-based cross-sectional study documented the prevalence and determinants of anaemia in three wards of Arusha District, Tanzania. It was revealed that the prevalence rate of anaemia was 84.6%, which was higher than the regional (57%) and Tanzanian (58%) prevalence rates (NBS and MACRO, 2015). The current findings were similar to a previous study in Mwanza which showed a 77.2% prevalence rate of anaemia (Simbauranga *et al.*, 2015). The observed high prevalence could be due to a deficiency in iron intake among under-five children associated with poor food availability, cultural behaviours (which are not necessarily evidence-informed and may contribute to nutritional deficits), and maternal factors such as employment (Simbauranga *et al.*, 2015). Mothers used thin gruel prepared from cereal (maize, rice, millet or sorghum) as a major complementary food for their children. This finding mirror results from other studies in Tanzania (Mamiro *et al.*, 2005; Kulwa *et al.*, 2006; Nyaruhucha *et al.*, 2006; Kimanya *et al.*, 2009). Mothers used thin maize porridge due to the early introduction of complementary foods. Most mothers also did not follow internationally recommended practices, which require exclusive breast-feeding up to 6 months (Kulwa *et al.*, 2006; Kimiywe and Chege, 2015) possibly due to lack of nutritional education and other socio-demographic conditions (Simbauranga *et al.*, 2015).

Our study revealed that children below two years were more likely to be anaemic compared to the older children. This concurred with prior findings showing that at the younger age, there is high demand for nutrients to support the rapid body growth of children (Adu-Afarwuah *et al.*, 2008) which further increases their need for iron. Complementary foods begin when the children reach 6 months if nutritionally poor complementary foods were introduced children were more likely to be anaemic (Tatala *et al.*, 1998). Children above two years are able to eat more variety of foods which put them at less risk of being anaemic (El Kishawi *et al.*, 2015). In our study, about 84% of children were not exclusively breastfed. This practice led to the early introduction of complementary foods, which are often of low quality and insufficient quantity. Frequently reported complementary foods included thin plain maize porridge and cow's milk, which are poor sources of iron. Consumption of cow's milk has a negative influence on iron status, as it reduces the bioavailability of iron provided by other foods and has been shown to have a negative effect on non-haem and haem iron absorption (Wilson *et al.*, 1999; e Carlos and Monteirob, 2004). In the current study, consumption of cow's milk was found to be a risk factor for childhood anaemia (Hallberg *et al.*, 1992; Persson *et al.*, 2001; Silva *et al.*, 2007; Adu-Afarwuah *et al.*, 2008; Hurrell and Egli, 2010; Vanderhoof and Kleinman, 2015).

Drinking tea was found to increase the risk of childhood anaemia in this study. According to El Kishawi *et al.* (2015) tea contains polyphenols which bind iron to form an insoluble complex which cannot be absorbed. Polyphenol in tea binds to iron and form non hydrolysable complexes which are then excreted in the faeces (Ma *et al.*, 2011). Tea given with meals should be discouraged as this reduced the bioavailability of iron in food. Other authors have reported a significant association of anaemia with intake of tea and other meals (Merhav *et al.*, 1985; Wilson *et al.*, 1999; Nelson and Poulter, 2004; Zaida *et al.*, 2006). The WHO (1999) reported that it is impossible to supply enough iron from unmodified plant-based complementary foods to meet the recommended daily intake (RDI) of iron for under-five without including animal products such as liver, fish, beef, and eggs (Dop *et al.*, 1999). Apart from other causes of anaemia like blood loss, diseases, vitamin A and folate deficiency (Olivares *et al.*, 1999), multivariate analysis revealed that, in our population, poor feeding practices especially non-consumption of iron-rich foods (i.e., meat, vegetables and fruits) was significantly associated with the presence of childhood anaemia. Meat and/or meat containing infant foods were rarely (12.6%) consumed by the study subjects. This finding reflected the previously reported challenge in Tanzania, which many households could not afford animal products (i.e. high iron content foods). Consumption plant-based products (low iron content foods) were the only alternatives (Mamiro *et al.*, 2005; Kulwa *et al.*, 2006; Nyaruhucha *et al.*, 2006). The quality of complementary foods was significantly associated with anaemia in the present study. For example, consumption of vegetables and fruits was associated with reduced rates of anaemia. Further, almost 98% (n = 428) of study children did not eat fruits which may have contributed to the higher prevalence rate of anaemia. Vitamin C which originates from fruits potentiates absorption of non-haem iron that is found in legumes and other plant-based meals (Amsalu and Tigabu, 2008). According to WHO (2011) guidelines, MNP which is a single dose packets of powder containing iron, vitamin A, zinc and other vitamins and minerals that can be sprinkled onto any semi-solid food at home or at any other point of use to increase the content of essential nutrients in the infant's diet during this period. This is done without changing the usual baby diet.

We observed low birth weight as a significant risk factor for anaemia in children, in line with previous findings (Mamiro *et al.*, 2005; Kalanda *et al.*, 2006). Although it is known that, low birth weight is strongly associated with maternal anaemia, which negatively impacts the iron store of the child at birth, we did not explore this factor in our study (Kidanto *et al.*, 2009; Haggaz *et al.*, 2010). The overall high prevalence rate of anaemia among the under-five children was associated with early introduction of nutritionally poor complementary foods and lack of exclusive breastfeeding for the first six months of life. Introduction of nutritious complementary foods, such as iron-fortified cereals and meat / meat products, could have highly reduced the prevalence rate of anaemia among the children.

One of the study limitations of this study that may have affected the results is the cross-sectional nature of the study which precludes identifying seasonal patterns. At the time of the study, it was the dry season which may have contributed to higher levels of childhood anaemia and lower levels of consumption patterns of unavailable/expensive foods. Another limitation of note may relate to the 'illness status' of the children. Although the children were outpatient visits to the RCHs for regular anthropometric measurements, many reported an illness in the 14 days prior to their visit. It is recognized that illnesses or treatments of such illnesses may in fact, cause a mild anaemia. Hence, a future study may control for such confounding factors.

4.5 Conclusion

In conclusion, the findings of this study affirmed high prevalence rate of anaemia among under-five children in Arusha District which was higher than the previous rate reported by NBS and Macro (2015). It was found that best predictors of anaemia among under-five children living in a rural setting were low birth weight and dietary factors (non-consumption of iron-rich foods like meat, vegetables, and fruits). It was recommended based on this study that community nutrition education, especially on exclusive breastfeeding and introduction of complementary foods, should be improved. The use of MNP to improve the quality of CFs and control of anaema among the under-five through home fortification strategy is highly recommended. Hence, the next chapter attempts to assess the factors influencing willingness to pay for MNPs supplement for young children.

CHAPTER FIVE

Factors influencing willingness to pay for multiple micronutrient powder (*virutubishi*) supplements for young children in Arusha, Tanzania[3]

Abstract

Multiple micronutrient powders have shown a positive effect on anaemia prevention in children 6-59 months. For the purposes of uptake and sustainability, we explored ‘‘willingness to pay’’ for these health products at the household level for the potential of co-investment in multiple micronutrient powders. During the intervention (six months), household surveys were conducted once with mothers of children 6 - 59 months in the Arusha District regarding willingness to pay for the multiple micronutrient powders. Results from the survey showed that about 66% of the target mothers are willing to pay for multiple micronutrient powders required for the feeding of children at 0.068$ per sachet. Willingness to pay was associated with higher paternal education, higher maternal age, and families which do not keep animals. The results findings help to know the market situation of nutritional products. This information is useful for health policy planners in assessing economic viability and sustainability of the distribution of multiple micronutrient powders to consumers to avert micronutrient deficiencies and their effects on young children.

Key words: Multiple micronutrient powder, willingness to pay, childhood anaemia, Tanzania

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[3] *Submitted to Plos One*

5.1 Introduction

The most common cause of anaemia worldwide is iron deficiency, resulting from prolonged negative iron balance caused by inadequate dietary iron intake or absorption (WHO, 2011). According to the WHO (2001), the relative proportion of anaemia due to iron deficiency increases as the prevalence of anaemia increases and iron deficiency will be 2.5 times that of anaemia(WHO, 2001). In any population if prevalence rate exceeds 40%, the condition is considered a severe public health risk (Bondi and Lieuw, 2009). Anaemia is a major global public health problem affecting about 50% of children under-five years (U5s) (Bondi and Lieuw, 2009). In Tanzania, anaemia is prevalent among all age groups but children between 6 - 59 months are highly (58%) affected (NBS and MACRO, 2015). This trend is attributed to consumption of lower than the recommended daily iron requirement from complementary foods (CFs), as most of the consumed iron is plant based which as compared to animal source iron is not as readily absorbed in the body. Further, there is limited access to food in most households, a condition that leadsto most children experiencing iron deficiency (Bhutta *et al.*, 2013). The alarmingly high prevalence of anaemia among U5s, coupled and associated with adverse health, development, and economic consequences highlights the need for intensified actions to address this ongoing public health problem.

Home fortification with MNP is a cost-effective intervention, which was developed to tackle the problem of childhood anaemia by delivering iron and a blend of other essential vitamins and minerals that can easily be mixed into available CFs before serving (Salam *et al.*, 2013). The Home Fortification Technical Advisory Group (HF-TAG) and WHO made a recommendation on MNP availability to target groups including the frequency and duration of supplementation (HF-TAG, 2012). They recommend when; dietary diversity is low, poor bio-availability of micronutrient in plant-based foods (due to inhibitors in the diet) and low nutrient content of complementary foods. Several trials suggest that iron-containing MNP administered daily (Ahmed *et al.*, 2005; Christofides *et al.*, 2006; Adu-Afarwuah *et al.*, 2008; De-Regil *et al.*, 2013), weekly (Hyder *et al.*, 2007) or according to flexible regimens (Ip *et al.*, 2009) is effective to reduce anaemia and increase haemoglobin level for children.

For sustainability of nutritional supplementation such as MNP, the government has introduced a private market approach to sell the MNPs to target populations at a controlled cost of about 0.068 US$ per sachet. Given the diversity of families in terms of education level, maternal age and food security it remains unclear whether parents will be willing or able to pay for the micronutrients. The objective of this study was to determine the socio-economic factors affecting willingness to pay (WTP) for the MNPs and amount of money families are willing to pay for the service.

5.2 Material and methods

5.2.1 Study area

The study was conducted in Arusha District, which surrounds the Arusha City in Tanzania. The District is primarily rural with socio-economic patterns that are similar to those of most districts in Tanzania. The districts is characterized with cultural diversity and reports childhood anaemia prevalence similar or above national levels (NBS and MACRO, 2015)

5.2.2 Sample size and sampling technique

Within the Arusha District, there are twenty wards each having at least one reproductive child health (RCH) clinic for mothers and children. Of these, three ward; Oldonyosambu, Oturumeti and Seliani were randomly selected for the study. At each site, the researcher, with the help of village health workers identified households with children between 6 - 59 months of age. In total 436 mothers-child pairs were identified and screened. About 369 children were eligible to participate in the stud and those who agreed gave written consent. However, 58 mothers did not gave consent to participate in the study. Thus 310 mothers–child pairs were recruited and participated in the study.

5.2.3 Data collection

A structured pre-tested questionnaire was used as part of a face to face data collection. During the baseline survey socioeconomic and demographic data, such as education level, age, land ownership, household size and income were collected. During the intervention (six months) the MNP sachets were provided for free to the participants. Therefore, the parents were once asked if they would be willing to pay the sachets at a price of 150 TZS.

5.2.4 Assessment of willingness to pay micronutrient powder

The MNP for which the WTP was explored to mothers-children pairs involved in the intervention was manufactured by Manisha Pharmo Plast Pvt. Ltd (Umbergaon-396171.Gujarat India). The components and composition of the multi-micronutrient formula are based on the recommendations by UNICEF/WHO/WFP. The MNP contains 15 vitamins and minerals based on the Recommended Nutrient Intake (RNI) for children (HF-TAG, 2012). The nutrient content for 1 g of MMP includes vitamin A (RE 400 μg), vitamin D3 (5 μg), vitamin E (5mg), vitamin B1, B2, B6 each (0.5 mg), folic acid (15 mg), niacin (6 mg), vitamin B 12 (0.9 μg), vitamin C (30 mg), iron (10 mg), zinc (4.1 mg), selenium (17 μg), copper (0.56 mg), and iodine (90 μg). The MNP has to be supplied in a single-dose sachet (1 dose = 1 sachet) and one pack contained 30 × 1 g sachets.

5.2.5 Data analysis

Data analysis was done using SPSS version 21 and Chi-square test for a categorical variable. A logistic regression model was performed to estimate the determinant of being willing to pay for the multiple micronutrient powders (MNP) at the price of USD 0.068 based on socioeconomic and demographic characteristics.

5.3 Results

The summary of respondent's demographic characteristics with respect to WTP for MNP is reported in Table 11. There is a significant ($p < 0.01$) association of willing to pay for MNP and mother's age.

Table 11: Socio-economic and demographic characteristics on consumer willingness to pay for micronutrient powders

Variable	N	n (%)	P -value
Child's gender			
Female	130	89 (43.8)	0.48
Male	180	114 (56.2)	
Age (months)			
6-11	86	52 (25.6)	0.56
12-23	114	77 (37.9)	
24-35	70	44 (21.7)	
36-59	40	30 (14.8)	
Mother's age(yrs)			
15-24	143	92 (45.3)	
25-34	146	105 (51.7)	<0.01
35-49	21	6 (3.0)	
Father's education			
No formal education	33	25 (12.3)	0.24
Primary	241	152 (74.9)	
Secondary	36	26 (12.8)	
Mother's education			
No formal education	54	33 (16.3)	0.09
Primary	195	124 (61.1)	
Secondary	61	46 (22.7)	
Livestock keeping			
Yes	207	122 (60.1)	<0.01
No	103	81 (39.9)	
Source of food			
Own production	85	52 (25.6)	0.18
Buying	225	151 (74.4)	
Occupation			
Employed	31	22 (10.8)	0.4
Farmers	175	118 (58.1)	
Pastoralist	52	26 (12.8)	
Casual labour	43	31 (15.3)	
Business	9	6 (3.0)	
Income (USD)			
> 1.25	45	35 (17.2)	0.17
<1.25	265	168 (82.8)	

5.3.1 Determinant of willing to pay for MNPs

Table 12 presents an estimated coefficient of logistic regression that examines the effect of WTP for micronutrients. In univariate analysis, mother's age, a family who do not keep animals and parents with low income (< 1.14$) were found to be a determinant of WTP. These results were confirmed by multivariate analysis modal. Mothers aged above 35 years (OR: 4.9, 95% CI: 1.7 - 14.2) were likely to pay for MNP compared to younger mothers. Fathers with primary education (OR: 3.1, 95% CI 1.2 - 7.9) and parents who do not keep animals (OR: 2.5, 95% CI: 1.4 - 4.5) were more likely willing to pay for MNP.

Table 12: Determinants of willingness to pay for multiple micronutrient powders

Variable	N	COR (95% CI)	P-value	AOR (95% CI)	P -value
Mother's age(yrs)					
15-24	143	1		1	
25-34	146	0.7 (0.4-1.2)	0.2	0.6 (0.4-1.1)	0.1
35-49	21	4.5 (1.6-12.3)	0.03	4.9 (1.7-14.2)	0.004
Father's education					
No formal education	33	1		1	
Primary	241	1.8 (0.8-4.2	0.2	3.1 (1.2-7.9)	0.02
Secondary	36	1.2 (0.4-3.5)	0.7	2.1 (0.6-6.9)	0.2
Mother education					
No formal education	54	1			
Primary	195	0.9 (0.5-1.6)	0.7		
Secondary	61	0.5 (0.2-1.2)	0.1		
Livestock keeping					
Yes	207	1		1	
No	103	2.6 (1.5-4.4)	0.00	2.5 (1.4-4.5)	0.00
Source of food					
Own production	85	1			
Buying	225	0.7 (0.5-1.3)	0.3		
Occupation					
Employed	31	1			
Farmers	175	1.2 (0.5-2.7)	0.6		
Pastoralist	52	2.4 (0.9-6.3)	0.9		
Casual labour	43	0.9 (0.3-2.6)	0.8		
Business	9	1.2 (0.25-5.9)	0.5		
Income ($)					
> 1.14	45	1		1	
<1.14	265	2.0 (1.0-4.3)	0.05	2.0 (0.9-4.5)	0.08

5.4 Discussion

Little is known about willing to pay (WTP) for nutritional supplements like multiple micronutrient powders in Tanzania and East Africa. Willingness to pay is the maximum amount an individual is willing to spend to procure a product or service (Munene, 2006) and the price of the transaction will be at a point somewhere between a buyer's willingness to pay and a seller's willingness to accept. Studies in Tanzania report on WTP for safety inspected tomatoes, organic products and health services (Aizuddin *et al.*, 2012; Alphonce and Alfnes, 2012).

The results from this study provide insight for society to use their financial assets for nutritional products like MNP as part of their strategies for addressing their children's health. These results also indicate that micronutrient supplementation is highly valued by parents. Results show that more than half of the mothers (65.5%) involved in the intervention were willing to pay for micronutrient powder at the given price of TZS150 (USD 0.068) after observing the effectiveness in improving children's health. These findings align with other studies in developing countries (Adams *et al.*, 2011; Chowdhury *et al.*, 2011), where women are the main/primary caretakers of their households. They plan what should be eaten, a position that allows them to significantly influence household expenditures on food and health (Trost *et al.*, 2006). Women have a higher preference than men to spend a larger share of the household budget on food and health which potentiates positive nutrition and health outcomes for household members, particularly their children (Trost *et al.*, 2006). In the current study, the mother's willingness to pay reflects the perceived health benefit which their children attained during the supplementation period.

In this study results indicate that demographic and socioeconomic characteristics have a positive influence on parent's willingness to pay for MNPs. Older mothers above 35 years and fathers with primary education demonstrate significant interest in purchasing MNP sachets for their children's health. These results are similar with other studies (Chowdhury *et al.*, 2011; Aizuddin *et al.*, 2012; Nguyen *et al.*, 2015). Parents with high education can understand the importance of nutrition counselling as the results they are easy to make a decision on purchasing MNPs and allocate money for nutritious products like micronutrient powder. Results from this study mirror with previous findings that mothers age was a determinant factor of willing to pay for products (Xia and Zeng, 2008; Aizuddin *et al.*, 2012). In this study, it was found that not keeping animals was positively associated with WTP. It appears that non-animal rearing families believe that their children diet will lack the nutrients accessed from animal products (egg, milk and meat) hence increasing their willingness to pay for MMPs. This was similar to study in Iran where socioeconomic factors positively influenced WTP on an organic micronutrient product (Haghjou *et al.*, 2013).

Child's age may influence mothers WTP, with 63.5% of mothers with children below 2 years showing willing to pay for MNPs although statistically there is no significant different from those who did not show WTP. Mothers with young children in the transition period from exclusive breastfeeding to complementary feeding potentially have more demand to use nutritional products for child's health. However, the study did not show a significant association between child age and WTP.A study done in Ethiopia found that parents with children below 2 years were willing to pay for lipid-based nutrient supplement than parents with older children (Segrè *et al.*, 2015). Family income was positively associated with willingness to pay for micronutrient in univariate analysis but when combined with other factors in multivariate analysis, shows a week association. Willingness to pay for nutritional products is beyond the financial ability of the parents, it can be influenced by many other factors. Tanzania national health policystates that "children under-five should receive health services free but this does not apply when it comes to the provision of MNPs. Non-governmental organization are dealing with distributing micronutrients through the dealers who sell them, as the services may be less than optimal in government hospitals where capacities focus on meeting basic health services for the majority of Tanzanian children. The limitation of this study is that, the assessment of WTP was performed once. The results can be further validated by assessing seasonally, twice per year as the purchasing power varies.

5.5 Conclusion

The socio-economic and demographic factors were found to contribute to willing to pay for MNPs. The findings help to understand market implications of nutritional products by investigating potential consumer factors on WTP for MNPs for the sustainable marketing and distribution considerations. The factors found to have significant associations with WTP were age, education, non-livestock keeper and income. Information on WTP can be useful for designers and planners in assessing the economic viability of projects, setting consumers cost parameters, evaluating policy alternatives, assessing financial sustainability, and designing socially equitable subsidies. It also provides useful information for developing marketing strategies for MNPs and assisting in the formulation of policies and education programs to ensure that families make the best possible choices for the health of their children. Based on the findings it is possible to inform the national health policy to include nutritional supplementation considerations, such as the provision of MNPs to children as a vector to enhancing future health and catalysing social capital for the national. For those children that are diagnosed with anaemia should be prescribed to MNP as part of the treatment therapy and the cost thereafter subsidized for them, especially those that are economically challenged. Hence, the next chapter attempts to assess the efficacy of MNPs to reduce anaemia among children in the area.

CHAPTER SIX

Efficacy of multiple micronutrient powders on haemoglobin concentration in children aged 6-59 months in Arusha District[4]

Abstract

In Tanzania's Arusha District, anaemia is a significant public health problem. Recently, home-fortification with multiple micronutrient powder was recommended and daily use of one sachet has shown to be effective. However, it is a challenge for deprived families with low income to afford the daily sachet. The aim of this study was to compare efficacy of different administration frequencies of micronutrient power in reducing anaemia in children aged 6 to 59 months. This research used a community-based, randomized longitudinal trial design with the intent to treat anaemia. Children aged 6 to 59 months (n = 369) were randomly assigned to one of four intervention groups which received, on a weekly basis, either five sachets (n = 60), three sachets (n = 80), two sachets (n = 105) or one sachet (n = 124) for a six month; 310 children completed the study. Using HemoCue technique, a finger prick blood was taken at baseline, middle, and end points of the intervention to determine haemoglobin levels. The effect of treatment on haemoglobin was assessed with analysis of covariates with Bonferroni posthoc to test group difference ($p > 0.05$) from each other. At the end haemoglobin levels were significantly higher in participants who received three or five sachets of micronutrient powder per week compared to those who received one or two micronutrient powder sachets per week ($p < 0.05$). The prevalence of illnesses was reduced from 65% to 30.5% in all groups. This finding indicates that economically challenged families may opt for three times per week sachet administration rather than more costly daily administration.

Trial registration: PACTR201607001693286 registered on 12 July 2016

Keywords: Anaemia, multiple micronutrient powder, home fortification, supplementation.

[4]Published Journal of Scientifica Hindawi

6.1 Introduction

Low haemoglobin concentrations is measure of anaemia, is a significant global challenge not only at the individual level (i.e., development, illnesses) but also at the societal level (economic and social capital) (Stevens *et al.*, 2013). Anaemia, as one indicator of micronutrient deficiencies, is mainly attributed to iron deficiency, but also may be associated with vitamin A, folic acid, and vitamin B12 deficiencies and other non-nutritional causes like infection, loss of blood and genetic disorder (Milman, 2011). Infants and children are most vulnerable to micronutrient deficiency, given the high vitamin and mineral intake needed to support their rapid growth and adequate development. About 273 million children under the age of five years are affected by anaemia with the majority being located within developing countries (Bhutta *et al.*, 2013; Stevens *et al.*, 2013). In Tanzania, more than half (57%) of children under-five years of age are anaemic (NBS and MACRO, 2015).

Beyond the ‘anaemia level’, iron deficiency anaemia, is the most common cause of anaemia in most parts of the world (Stoltzfus, 2001). Generally, high-quality and fortified foods are unavailable and /or unaffordable for low-income families. A diversified diet and food fortification of staple foods are considered as the optimal approaches for minimizing micronutrient deficiencies, especially iron deficiency anaemia. Historically, achieving dietary diversity and widespread utilization of fortified food is a relatively slow process for example, utilization of iodized salt has shown extremely slow uptake in Tanzania (Mosha *et al.*, 2014). Use of fortified complementary foods (CFs) for young children is also a limited option in rural communities as fortified foods are simply not available but also eaten in such small quantities that are not sufficient to assume micronutrient intake from commercially fortified foods among children aged 6 - 59 months.

Home fortification with multiple micronutrient powder (MNP) is considered an opportunity when the CFs does not provide enough essential nutrients (WHO, 2011). Micronutrient intervention with MNP is recognized as a cost-effective approach for reducing micronutrient deficiencies in low-income countries (Bhutta *et al.*, 2013). Micronutrient powder comes in a sachets containing dry powder with micronutrients that can be added to any semi-solid or solid food that is ready for consumption (HF-TAG, 2012). In most developing countries, such as Tanzania, cereal gruels are commonly used for complementary feeding. These are normally rich in phytate and tannins while concomitantly being deficient in protein and micronutrients, thus predisposing children to iron deficiency anaemia (Smuts *et al.*, 2005; Nyaruhucha *et al.*, 2006; NBS and MACRO, 2010; Bhutta *et al.*, 2013).

Initially, MNP was developed to provide iron and other nutrients required for treating nutritional anaemia (HF-TAG, 2012). Many efficacy trials of MNP interventions to improve micronutrients status, especially iron status and anaemia, have been well established and ongoing (Rah *et al.*, 2012; De-Regil *et al.*, 2013; Serdula *et al.*, 2013; Jefferds *et al.*, 2015). The Government of Tanzania, in collaboration with development partners, has been accelerating efforts to alleviate micronutrient deficiencies in the country. Mothers are required to buy the MNP sachets daily from selected agents or a health facility. Research has shown that daily MNP supplementation produced the best result in terms of anaemia reduction (Kounnavong *et al.*, 2011; Mosha *et al.*, 2014); however, for poor families (most have more than one child under-five years of age), it is expensive to buy one sachet at Tanzania shillings 150 (approximately $0.08) on a daily basis. Therefore, this study assesses the efficacy of home fortification with MNP at a different dosage in relation to their affordability among affected children below five years in Arusha District.

6.2 Material and methods

6.2.1 Study area

This study was done in Arusha District, Northern Tanzania. The District is primarily rural with a similar socio-economic pattern to most rural districts in Tanzania, demonstrates cultural diversity, and reports a childhood anaemia higher (84%) than previously reported District average prevalence (58%) (Kejo *et al.*, 2018). Arusha District has twenty wards with at least one reproductive child health clinic for mothers and children in each ward. Three wards Oldonyosambu, Oturumeti, and Seliani which serve 170, 182 and 200 children under five years respectively were randomly selected for inclusion in this study.

6.2.2 Study design, sample size and randomization

The study was a community-based, randomized longitudinal trial with intent to treat anaemia. The intervention study was designed to last for six months with data collection at baseline, midline and end line of the intervention. The sample size was determined using the statistical power analysis formula $n = z^2p(1\text{-}p)/d^2$ (Burger and Pierre-Louis, 2002) for anaemia assessment, where n = sample size p = prevalence of anaemia (60%) (NBS and MACRO, 2010), z = value at 95% confidence (1.96), d = level of significance (5%), with an anticipated attrition of 18% to follow-up yielded a total of 436 mother–child pairs. The purpose of the study and the benefits of consuming the multiple micronutrient supplements that contained iron (10 mg) were explained to the child mothers. Eligibility criteria were: the family had to reside to the selected ward; the child must 6 - 59 months of age, haemoglobin (Hb) levels from 7.0 – 9.9 g/dL and children who started complementary foods. Exclusion criteria were Hb concentrations ≤ 6.99 g/dL or ≥ 10.0 g/dL), child who does not consume solid foods, chronic conditions such as type 1 diabetes mellitus, some inborn errors of metabolism, HIV infection or known hemoglobinopathies.

After the baseline assessment, eligible (n = 369) children were randomly allocated (using a computer-generated list) to one of four intervention groups. Group one (n = 60) was given MNP five per week (5/wk); Group two (n = 80) was given MNP three times per week (3/wk); Group three (n = 105) was given MNP twice per week (2/wk); and Group 4 (n = 124) was given MNP once per week (1/wk). For this efficacy trial, the primary outcome was anaemia status. To control for confounders, all children aged 24 months and older were given a single dose of albendazole™ for de-worming during the baseline assessment. Six to 11 months old children were not treated for helmenths.

6.2.3 Sampling frame

The sampling frame was established and 20 wards with health facilities offering Reproductive and Child Health (RCH) clinic services were identified and coded from 01 to 20. Three wards out of 20 wards were randomly selected using a table of random numbers (due to lack of funds few wards were selected). From these wards all households with infants aged 6 - 59 months were identified and selected randomly with the help of village health workers with those who agreed to participate being invited to the RCH (as a meeting point) for baseline assessment. The study objectives were explained by the researcher to mothers/caregivers and a written informed consent was obtained.

6.2.4 Intervention and compliance monitoring

Mothers/caregivers were instructed to mix the content of a full sachet of MNP with the child's prepared (cooked) complementary food by sprinkling contents as per sachet instructions. They were encouraged to mix the MNP when the food is warm and to ensure the child consumes all the food after addition of MNP. The MNP contained 15 vitamins and minerals. The nutrient content of 1 g of MMP was vitamin A (RE 400 µg), vitamin D (5 µg), vitamin E (5 mg), vitamin B1 , B2, B6 each (0.5 mg), folic acid (0.15 mg), niacin (6 mg), vitamin B12 (0.9 µg), vitamin C (30mg), iron (10 mg), zinc (4.1 mg), selenium (17 µg), copper (0.56 mg), and iodine (90 µg). The MMP was supplied in a single-dose sachet (1 dose = 1 sachet) and one pack contained 30 × 1 g sachets based on the Recommended Nutrient Intake (RNI) for children (HF-TAG, 2012).

In this study, community health workers were involved in the follow up of study participants. They visit homes of participant children on a weekly basis to record supplement use and collected empty sachets weakly to monitor compliance. Their visits ensured the supplement was given to the targeted child and encouraged continued use of the supplement.

6.2.5 Data collection

At baseline, the information on children and their families was collected through questionnaire guided interviews (face to face) with the child's mother or caregiver. Data on basic demographics, breastfeeding, CF practices, and recent illnesses in the preceding 14 days were collected. During the intervention community health workers recorded information about supplement acceptance, side effects and health information including diarrhea, fever, cough and other sickness also behaviour changes such as increase in appetite and increase in the level of physical activities.

6.2.6 Assessment of haemoglobin concentration

During the baseline study, midline and end line children were measured haemoglobin (Hb) concentration by HemoCue® Hb 201+ photometer (AB, Sweden) by qualified technician. Safety lancets were used to obtain the finger prick blood which was collected by the micro-cuvettes. Alcohol swabs were used to clean the fingers before pricking. The first drop of blood was wiped out by cotton wool, while the second drop was collected by micro-cuvette. Blood sample in the micro-cuvette was loaded in the calibrated HemoCue® photometer and Hb concentration read to the nearest 0.1 g/dL. Categorization of Hb levels was done based on WHO standard, where children with Hb level < 11 g/dL were considered anaemic, mild (10 -

10.9 g/dL), moderate (7 - 9.9 g/dL) and severe anaemia (<7 g/dL) (WHO, 2017). HemoCue machine were calibrated using available machine at RCH clinic.

6.2.7 Ethical considerations

The study received ethical clearance from Ethics Committee of the National Institute for Medical Research (NIMR) Tanzania. Written informed consent was obtained from the mothers / caregivers at time of enrolment in the study.

6.2.8 Data analysis

The data collected was entered, cleaned, coded, and analyzed using SPSS™ Version 20. Analysis was performed on the intension to treat basis. Descriptive statistics were calculated, reported as means and standard deviation. Analysis of variance (ANOVA) was done on continuous variables with normal distributions to test whether there were significant group differences (*F*-test). The effect of treatment on haemoglobin was assessed with analysis of covariates including treatment as a fixed factor, sex and age as covariate. Significance of Bonferroni posthoc test was used to specifically test whether each of the 4 supplementation groups differed significantly ($p > 0.05$) from each other. Differences in categorical variables were assessed using chi-square tests.

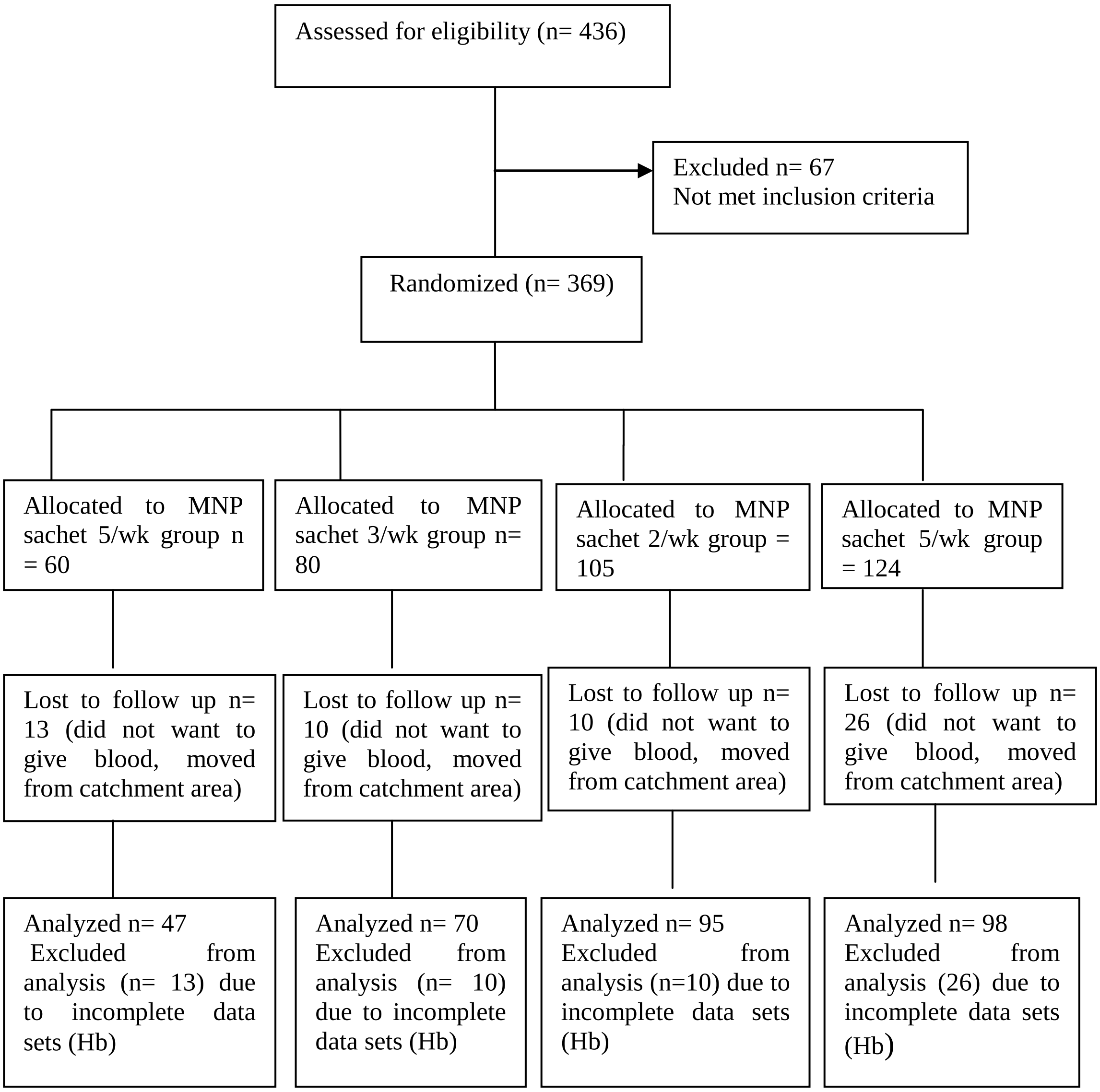

Figure 2: Flow diagram of subject's progress through the study

6.3 Results

After baseline assessment, 369 children met inclusion criteria and enrolled in the study, 16% (n= 59) loss to follow up and could not assessed at the end of intervention. Figure 1 shows the flow diagram according to CONSORT guideline. The compliance at the end of the intervention was 84%.

6.3.1 Baseline characteristics

Gender distribution among participating children was 58% (n = 180) males and 42% (n = 130) females. The randomized four intervention groups did not differ significantly in baseline characteristics, except for a significant age difference ($p < 0.001$) between-groups (Table 13).

Table 13: Baseline characteristics of the study population

Characteristics	Treatment group 5/wk (n=47)	3/wk (n=70)	2/wk (n=95)	1/wk (n=98)	P -value*
Child age (months)	17.7±7.9	18.5±6.9	20.1±10.1	14.4±7.9	0.00
Birth weight(kg)	3.1±0.5 (32)	3.4±0.5 (43)	4.2±11.5 (70)	2.9±0.5 (66)	0.6
Mother's age (yrs)	25.3±4.3	25.7±4.4	25.8±5.4	25.9±4.7	0.1
Sex, male (%)	44.7	64.3	64.2	54.1	0.08
EBF (%)	14.9	12.9	20.1	9.2	0.1
Stunting (%)	53.2	44.3	50.5	46.9	0.8
Underweight (%)	21.4	24.3	27.4	21.4	0.8
Wasting (%)	14.9	12.9	16.8	9.2	0.1
Marital status, married (%)	87.2	90.0	91.6	92.9	0.7

Values are means ± SD, * significant at the 0.05 level

Table 14 shows change in Hb concentration during intervention. There was an increased Hb concentration in all intervention groups (Table 2). The average Hb concentration increased from 9.0 ± 0.70 g/dL at baseline to 11.32 ± 0.52 g/dL at the end line of study in children consuming five sachets per week compared to others. Hb levels increased more in groups consuming three or five sachets per week compared to groups consuming one or two sachets per week. After six months of intervention, there was no significant ($p \geq 0.05$) difference in the increase in Hb concentration among those consuming MNP three or five times per week.

Table 14: Change in haemoglobin concentrations (mean ± SD) during intervention

Duration	Treatment groups 5/wk	3/wk	2/wk	1/wk	P -value*
Baseline	9.0±0.70	9.2±0.78	9.0±0.79	9.0±0.67	0.5
Midline	10.02±0.60	9.8±0.78	9.6±0.90	9.3±0.71	0.00
End line	11.32±0.52	11.10±0.8	10.80±1.02	9.60±0.70	0.00

*Significance difference between groups (Anova).

Table 15 shows the mean difference in increase of Hb concentration for the six months of intervention. At the end of intervention, groups consuming 5/wk, 3/wk and 2/wk Hb concentration were increased by 1.7 g/dL, 1.5 g/dL and 1.2 g/dL respectively. There were no significant difference ($p \geq 0.05$) was found between children consuming five and three sachets per week and children consuming two sachets per week versus three sachets per week.

Table 15: Mean difference of haemoglobin concentration between intervention groups

Duration	Comparison group [Dose (a)]	Comparison group [Dose (b)]	Mean difference (a-b) ± SE	P value [a]	95% CI
Midline	1/ wk	2/wk	-0.45 ±0.12*	0.001	¯ 076 - ¯0.15
		3/wk	-0.56±0.12*	0.00	¯0.89-¯0.24
		5/wk	-0.77±0.14*	0.00	¯1.14-¯0.41
	2/wk	1/ wk	0.45±0.12*	0.00	0.47-0.76
		3/wk	-0.11±0.12	1.00	-0.43-0.21
		5/wk	-0.21±0.14	0.01	-0.68-0.04
	3/wk	1/ wk	0.56±0.12*	0.00	0.24-0.88
		2/wk	0.11±0.12	1.00	-0.21-0.43
		5/wk	-0.21±0.15	0.88	-0.60-0.18
	5/wk	1/ wk	0.77±0.14*	0.00	0.41-1.14
		2/wk	0.320±0.14	1.00	-0.05-0.69
		3/wk	0.212±0.15	0.88	-0.18-6.00
End line	1/ wk	2/wk	-1.21±0.12*	0.00	¯1.54-¯0.88
		3/wk	-1.51±0.13*	0.00	¯1.85- ¯1.16
		5/wk	-1.69±0.15*	0.00	¯2.09- ¯1.31
	2/wk	1/ wk	1.21±0.12*	0.00	0.88-1.54
		3/wk	-0.29±0.13	0.13	¯0.64-0.05
		5/wk	-0.49±0.15*	0.006	¯0.88- ¯0.99
	3/wk	1/ wk	1.51±0.13*	0.00	1.16-1.85
		2/wk	0.29±0.13	0.13	-0.05-0.64
		5/wk	-0.19±0.15	1.00	-0.60-0.22
	5/wk	1/ wk	1.69±0.15*	0.00	1.31-2.09
		2/wk	0.49±0.15*	0.00	0.09-0.88
		3/wk	0.19±0.15	1.00	-0.22- 0.6

[*] Significant at 0.05 levels, [a]djusted for multiple comparisons Bonferroni

6.3.2 Prevalence of anaemia

At the end of the intervention, about 52%, 67% and 79% of the children in the groups received 2/wk, 3/wk and 5/wk sachets respectively had moved from being anaemic to having normal Hb levels > 11g/dl (Table 16). This suggests that these intervention groups were effective in decreasing prevalence of anaemia to 43%.

Table 16: The effect of micronutrient powders supplementation on prevalence of anaemia

	Treatment groups				
variable	**1/wk**	**2/wk**	**3/wk**	**5/wk**	**Total**
normal	0	51.6	67.1	78.7	42.9
Mild	38.8	28.4	24.3	19.1	29.4
Moderate	61.2	20.0	8.6	2.1	27.7

The effect of the intervention on disease occurrence among participating children at baseline 65.0% (n = 200) of children were having diarrhoea, fever, cough, and others having more than one type of diseases. It was observed that, after taking MNP for 6 months, children were significantly ($p \leq 0.05$) better. At the end of intervention, percentage of 65% children with symptoms of illness decreased to 30.6% (Table 17). Hence, the introduction of MNPs appears to have contributed to the reduction of the incidence of infectious diseases in supplement recipients.

Table 17: Impact of supplementation on morbidity

Morbidity	No of respondents	%
Illness at baseline	200	65.0
Illness after intervention	95	30.6

6.4 Discussion

In this study, more than half of the subjects were anaemic (displaying low Hb < 11 g/dL). The high (84%) prevalence of anaemia exceeded reported regional (58%) and national prevalence (57%); hence, the potential to introduce an intervention was deemed meritorious. According to the WHO (2011), in populations where the prevalence of anaemia in children under 5 years is 20% or higher, point-of-use fortification of CFs with iron-containing MNP among young children is recommended to improve iron status and reduce anaemia.

In the study communities, dietary factors, such as poor intake of iron rich foods was identified as a contributing cause of anaemia (Kejo *et al.*, 2018) as the most frequently consumed diets are predominantly plant-based with low iron content and have anti-nutritional factors (e.g. phytate) which hinder iron absorption. In settings, such as Arusha District, where iron-rich foods are lacking, iron supplementation is needed for vulnerable groups, including young children. Such efforts often include point-of-use fortification with MNP supplementation as part of an infant and young child feeding strategy to improve nutrient intake via CFs by children from six months of age and above (Bhutta *et al.*, 2013). In this study, MNP dosages of five sachets or three sachets per day were found to be effective in improving Hb concentrations as well as addressing mild and moderate anaemia. The significanteffect of MNP in raising plasma Hb concentration was evidenced in the five and three sachets intervention groups (1.7 g/dL and 1.5 g/dL respectively) when compared with the twice (1.2 g/dL) recipient groups. The three and five sachets weekly administration of MNP was significantly more effective than lesser frequencies.

Through this study, MNP supplementation was demonstrated to be effective in reducing the prevalence of anaemia to 43% (Table 16). Consequently, children receiving MNP supplementation of greater than two sachets per week were more likely to build up sufficient iron store to mitigate or avert anaemia recurrence for the next 6 months. This finding is in line with other studies on the effectiveness of home fortification (Menon *et al.*, 2007; Adu-Afarwuah *et al.*, 2008; Ip *et al.*, 2009; Lundeen *et al.*, 2010; Kounnavong *et al.*, 2011). Results from this study showed MNP was effective in reducing the prevalence of anaemia and improving Hb concentration in both groups, again mirroring the results of previous studies in several developing countries (Miller and Rodgers, 2009; Suchdev *et al.*, 2010; Serdula *et al.*, 2013; Mahfuz *et al.*, 2016). In this study, there is no significant increase in Hb concentration in either twice or three per week supplementation groups similar with 3/wk and 5/wk ($p \leq 0.05$). Children recovered from anaemia differently according to MNP dose given, indicating iron absorption was more effective in accordance with the dosages. Again, this finding aligns with previous micronutrient supplementation trials which suggest DMM as the optimal treatment to improve both anaemia and Hb concentration by more than 30% of the studied children (Smuts *et al.*, 2005; Kounnavong *et al.*, 2011; Mosha *et al.*, 2014).

The effectiveness of MNP in reducing the prevalence of anaemia in paediatric populations with high rates of mild and severe anaemia was confirmed in a Peruvian clinical trial evaluation (de Romaña *et al.*, 2005; De-Regil *et al.*, 2013). The current study went further to show similar effectiveness in anaemia reduction in 3/wk as 5/wk. Although reduction of anaemia was also observed in the twice per week supplementation group, the reduction was relatively smaller (52%) than in the five (79%) and three (67%) per week supplementation groups. At baseline all participating children were moderate anaemic Hb level below 10 g/dL, and during the end line assessment most had improved based on the dosage of MNP they received.

During the intervention period, mothers were prompted to recount any observed behaviour changes in their children post-supplementation. Some reported positive changes in physical activities (i.e., engaged more in play activities) and appetite. The positive health effect of MNP observed by all families included improved immunity as reflected in a reduction in the frequency of illness among the participating children. Reported morbidity among participating children was reduced significantly from baseline prevalence of 65% to terminal prevalence of 30.6%. Changes in stool colour were observed in children when consuming MNP, but the parents were assured that this alteration was not a concern or adverse effect. Point-of-use fortification improved the micronutrient status of recipient children, which has led to improved child health outcomes including reducing morbidity and improving appetite, which may, in the future, lead to improved future growth and social capacities.

6.5 Conclusion

This study, conducted on children with high anaemia prevalence at baseline, provides evidence that home fortification with MNP increases Hb concentration and reduces anaemia according to the frequency of administration. The administration of MNP supplementation three or five times per week produced optimal results in terms of anaemia reduction potentiating an improvement of micronutrient status, also can improve child health outcomes, including reduced morbidity, as well as increased appetite and other functional outcomes. Strategically, home fortification with MNP beginning at 6 months would give additional public health benefit by promoting the timely introduction of CFs and enhancing the likelihood of adequate micronutrient access. The study strongly suggests that low-income families can use a less expensive approach using three sachets rather than a daily administration while gleaning fairly similar results and benefits to their children. This evidence is both relevant and timely given the current Tanzania and global context in which ‘private-public partnerships’ are increasingly advancing primary health care initiatives such as home fortification with MNP by selling and creating awareness to mothers/caregiver to self-secure the MNP and assume co-responsibility for reduction of childhood anaemia. More studies are necessary to verify the optimal dose and economic feasibility of using MNP in a range of contexts and target sub-population.

CHAPTER SEVEN

7.1 General discussion

This dissertation is focused on investigating the efficacy of a lower weekly dose of home fortification with a multiple micronutrient powder among under-five children. The MNP supplementation intervention intended to come up with a reduced cost strategies which might be sustainable and affordable in reducing anaemia in Arusha district and similar settings.

Under-nutrition remains a serious challenge globally and mostly in developing countries where young children and pregnant women are mostly affected. Child's nutritional status can be used as an indicator to measure the evel of development in the community (Black *et al.*, 2008; Badake *et al.*, 2014). Anthropometric indicators such as weight-for-age (underweight), height-for-age (stunting) and weight-for-height (wasting) are used to evaluate nutritional status (WHO, 2006; UNICEF, 2015). Underweight is a composite measure of under-nutrition, and wasting is a measure of acute under-nutrition during the survey time (Black *et al.*, 2008; UNICEF, 2013).This situation is when the child does not receive sufficient food and face the immediate risk of death (UNICEF, 2015). Stunting is a measure of chronic under-nutrition during the most critical periods of growth and development in early life (Black *et al.*, 2008), and is a public health concern in developing countries including Tanzania. The primary causes of under-nutrition in developing countries among under-five children include inadequate access to food, poor child care practices and insufficient health services (Wamani *et al.*, 2007; Amsalu and Tigabu, 2008; Vitolo *et al.*, 2008; UNICEF, 2013; Safari *et al.*, 2015).

Black (2014) observed that under-nutrition resulting from micronutrient deficiency is one of the most prominent nutritional problems in developing countries. Micronutrients that are of public health importance worldwide include; vitamin A, folate, Iron, Iodine and Zinc. These deficiencies are prevalent among young children and pregnant women in the developing countries and are linked to a wide range of poorhealth outcomes like; birth defects, growth restriction, and increased morbidity and mortality (Black *et al.*, 2013). The most difficult nutrient to attain the recommended levels is iron (Vitolo *et al.*, 2008) and affects mostly children and pregnant women.

WHO (2013) has developed strategies to overcome the problem of child under-nutrition. Most of the intervention to overcome child under-nutrition focuses on the first 1000 days.The first 1000 days is the period from pregnancy up to two years of life (Dewey, 2016). This period is essential for proper cognitive growth and physical development of a child. Not only that, but also is the right time to implement nutritional interventions to promote child survival and reverse negative health effects due to under-nutrition (Victora *et al.,* 2010). These nutritional interventions include, proper infant and young child feeding, supplementation, use of MNP and use of fortified foods (WHO, 2012). In developing countries, particularly, those section where household are in resource-poor environment there is a high burden of child under-nutrition due to limited access to clean and safe water, and inappropriate infant and child feeding practices.

In Tanzania, the rates of child under-nutrition are high. About 34% of children under- five years of age are stunted, which is an indicator of chronic under-nutrition, while the prevalence rate of anaemia is 58% (NBS and MACRO, 2015). Various studies demonstrate that inappropriate complementary feeding practices including the early or late introduction of foods other than breast milk, inadequate amounts of food, and nutritionally inadequacies are important determinants of under-nutrition among young children (Ergin *et al.*, 2007; Hien and Hoa, 2009; Dewey, 2016). In Tanzania, we have limited studies that have focused on interventions that aim to overcome child under-nutrition (Mamiro *et al.*, 2004; Mosha *et al.*, 2014).

Although micronutrients are required in relatively small quantities, they contribute to major physiological functions of the body (Ezzati *et al.*, 2002). However, meeting micronutrient needs from complementary foods, especially of plant origin, appear to be the greatest challenge in children under-five years in developing countries including Tanzania. It is not practically possible to supply enough micronutrients, especially iron from complementary foods to meet recommended daily intake (Bhutta *et al.*, 2013; UNICEF, 2013). Home-fortification of staple foods with MNPs is a novel strategy which potentially provides the recommended iron intake from complementary foods, as a result, reducing childhood anaemia and micronutrients deficiency. Randomized trials to address micronutrient deficiencies through supplementation of the specific vitamin to specific vulnerable groups, home fortifications of complementary food and staples for children aged 6 to 23 months have been implemented in the developing countries (Allen *et al.*, 2006; Jefferds *et al.*, 2015). The efficacy trials of MNP in the reduction of anaemia have shown positive results (Kounnavong *et al.*, 2011; Suchdev *et al.*, 2012; De-Regil *et al.*, 2013; Salam *et al.*, 2013) however limited in Tanzania (Mosha *et al.*, 2014). This situation underscores the need to develop optimal dose that would improve childhood anaemia in resource constrained families.

Chapter three of this study demonstrated the prevalence and predictors of under-nutrition among under-five children in the study area. It indicated that children aged above 2 years, being a male, child illness, non-exclusive breastfed, maternal age above 35 years, and living at Oturumeti or Seliani were predictors of under-nutrition among the participants. Results further showed that stunting affected 50% of under-five children in Arusha district, which is slightly higher than the regional prevalence of 36% (NBS and MACRO, 2015). Similarly, underweight (28%) and wasting (16.5%) remain at unacceptable levels when compared to the regional prevalence of 20% and 6.5% respectively (TFNC, 2014; NBS and MACRO, 2015). The current study has shown that rural areas account for the largest number of undernourished children and this is in line with what has been reported by others (Mamiro *et al.*, 2005; NBS and MACRO, 2010, 2015; Shirima *et al.*, 2015). Male children had higher risk of being stunted than their female counterparts. This could be due to common misconception that male children eat more and therefore they are introduced complementary foods earlier compared to their female counterparts.

Early introduction of complementary feeding may expose children to infections because in developing countries there is limited access to clean and safe water (UNICEF, 2013) which increases the risk of child under-nutrition. Study findings suggested also that the risk of under-nutrition increases with child's age. Children above 2 years were found to be more susceptible to underweight and stunting. This could be due to poor quality family foods like stiff porridge (*ugali*) and porridge, which are merely starch-based and there is lack of varieties. In developing countries, children receive a large quantity of food but of poor quality. Poor child caring practices such as early complementary feeding, lead to child under-nutrition. Recent child illness (before the survey 14 days) was also associated with underweight and wasting. Study in Ethiopia by Asfawi *et al*. (2015) found that infections impair the immune function to fight against diseases which causefailure to gain weight due to loss of appetite leading to low food intake. There is a need of studies to assess the association between child illness and under-nutrition due to reverse causality between the two.

In thefourth chapter, this study has shown a high (84.6%) prevalence of anaemia higher than the regional (57%) and national prevalence (58%) (Kejo *et al.*, 2018). The observed high prevalence could be contributed to dietary factors including deficiency of iron rich-foods among under-five children, associated with poor feeding practice and cultural behaviours. As reported previously from other studies, mothers used thin gruel prepared from cereals (maize, rice, millet or sorghum) as a major complementary food for their children (Kulwa *et al.*, 2006; Kimiywe and Chege, 2015). The predictors for anaemia among under-five children living in Arusha district were low birth weight and dietary factors which include non-consumption of iron-rich foods like meat, vegetable and fruits. The study observed also that, low birth weight was a significant risk factor for anaemia in children. Low birth weight could be a result of anaemia during pregnancy. This may indicate that low birth weight babies in this study were born from mothers that were anaemic. In Maasai community, pregnant women are restricted to eat nutritious food like meat, eggs and fish which are first class protein with more readily available and absorbable iron. Limiting the pregnant women from eating these foods predisposes them to anaemia and hence low birth weight babies. This is well documented by other studies which have reported that maternal anaemia during pregnancy is a risk to low birth weight babies (Kidanto *et al.*, 2009; Demelash *et al.*, 2015; Mitao *et al.*, 2016). There is a need for behavioural change intervention that will educate the Maasai community and other communities on the importance of proper diet during pregnancy to avoid low birth weight babies.

The study results showed that consumption of cow's milk and tea were found to be a risk factor for childhood anaemia. The effect of cow's milk could be due to high calcium levels which compete with iron uptake as previously reported by Pearson *et al* (2001) and Silva *et al* (2007). Tea contains polyphenols which bind iron and make it insoluble and form non-hydrolysable complexes which are then excreted in the faeces (Zaida *et al.*, 2006; El Kishawi *et al.*, 2015). Studies show that the main risk factors for iron deficiency anaemia (IDA) is the low intake of iron, poor absorption of iron and diets from high phenolic compounds (WHO, 2008; Kejo *et al.*, 2018). In this community tea and cows milk are common fluid given as a breakfast and its common drink with meals. Tea given with meals reduces the bioavailability of iron hence hinder absorption of iron in the body. There is a need to educate mothers on proper child feeding to reduce the chance of the child being anaemic.

WHO (2005) has developed strategies to overcome anaemia among children. The strategies involve proper maternal nutrition during pregnancy and food fortification. In the study, home fortification using MNP supplementation was effective to combat anaemia. At baseline, all the children were moderate anaemic after the intervention anaemia was reduced to 43% and the results were statistically significant. In this study children who were given two, three or five sachets of MNP per week had improved haemoglobin levels. The prevalence of infectious diseases was also reduced from 65% at baseline to 30.5% after using the MNPs. At baseline, there was more report of diarrhoea and upper respiratory infection. Literature shows that infection whether from bacterial or fungi destructs the red blood cells hence the child becomes anaemic (Viana, 2011). There is a need to treat infections early to overcome the problem of anaemia in children. Other similar studies reported similar findings although the efficacy of different doses has not been studied (Adu-Afarwuah *et al.*, 2008; De-Regil *et al.*, 2013).

In Tanzania, scale up nutrition strategies of 2013, whereby all foods were supposed to be fortified either at industrial or household level. The challenge is that the fortificant are not given free, one has to pay for them. In primary health care centres, the MNP were distributed but mothers had to pay 150 TZS to get them. This is still a challenge as in some communities families cannot afford this amount. This study evaluated the factors influencing willingness to pay for micronutrient powder and is discussed in chapter six. Results indicated that all (100%) of the mother involved in the intervention were willing to feed their children with the MNP sachets. More than half of the mothers (65.5%) were willing to pay for micronutrient powder at the given price of 150 TZS while the rest wanted the MNP sachets for free. Older mothers (above 35 years) and fathers with primary education were significantly ($p < 0.05$) willing to spend their money to buy sachets of micronutrient powder for child's health compared to their counterparts. Parents with high education could understand the importance of nutritional products as the results they could easily make a decision on purchasing MNPs and allocate money for nutritious products like micronutrient powder. These results align with others studies (Aizuddin *et al.*, 2012; Nguyen *et al.*, 2015).

Not keeping animals was also positively associated with willingness to pay for MNP. In this community, families who do not keep animals like cattle, goats, chickens believe that their children will not get nutrients from animal products like milk, eggs and meat hence their willingness to pay for MNPs, was highly positive compared to those with animals. Similar results were observed by Haghjou *et al.* (2013) where socioeconomic factors have positively influenced willingness to pay for organic micronutrient products. Child age influenced mothers to be willing to pay for about 64% of mothers with children below 2 years were willing to pay for MNPs. Mothers with young children on the transition period from exclusive breastfeeding to complementary feeding might have more demand to use nutritional products for child's health. However, the study did not show a significant association between child age and willingness to pay. A study done in Ethiopia by Segre *et al.* (2015) found that parents with children below 2 years were willing to pay for lipid-based nutrient supplement than parents with older children. There is a need for literacy education on child feeding and the importance of balanced meals for health and well being of children and other community members.

7.2 Conclusions

Micronutrients deficiency has persisted over the years and this, needs to be addressed. The sooner this is addressed the better so that Tanzania will have healthier communities for better productivity. This study showed that MNPs are effective in reducing anaemia and infections among children in this community. At baseline, there were high rates of anaemia andafter six months of intervention, anaemia prevalence was reduced. Result shows that the nutritional intervention contributes significantly positive effect to improve child nutrition and health in Tanzania. Factors that were associated with willingness to pay for MNPs were also studied. Parents with education were willing to pay for MNPs. In the studied community, parents with education had better income and indicated that they can afford to buy MNPs. Low calibre parents are not ready to purchase MNPs, this has a policy implication as MNP is not given for free indicating that the burden of anaemia may persist.

The results of this study indicate that MNP supplements given at 3 or 5 doses were effective in raising the haemoglobin concentration levels among children. However, despite the administration of 3 or 5 doses of MNP being effective in reducing anaemia, yet some children remained mildly anaemic by the end of the intervention. The study suggests that in addition to supplementation with MNP, there is a need forlong-term intervention to promote proper infant and young child feeding practices. MNP was also associated with reduction in infections among children. Though this is a positive finding, there is a need of studies to explore the association between anaemia and infections as there could be other confounding factors that led the infections to be reduced not due to the use of MNP.

7.3 Recommendations

Our children are our future therefore if we do nothing about this now our future is bleak. It is important to note that stunting is a vicious cycle, stunted women give birth to stunted children and the cycle goes on. We need to break this cycle to make justice to our people and our country. The following can be done;

(i) The Tanzania Ministry of Health should incorporate nutrition aspects such as the provision of MNPs for free to children as they go for growth monitoring as a vector to enhance future health and increase social capital for the national.

(ii) More community health literacy sessions on under-nutrition prevention among women of reproductive age to improve maternal and child nutrition during the first 1000 days.

(iii) Micronutrients deficiencies have been a problem and we need a universal strategy even across East African to tackle this problem. Advocacy on alternative feeding among communities will be of great value.

(iv) Data on micronutrient deficiencies in Tanzania is taken every five years through Tanzania Demographic and Health Survey (TDHS) this is a long time to wait because in five years children will have become stunted already. We need better monitoring for better results.

(v) There is a need of studies to investigate the association of childhood anaemia and infections as there could be other confounding factors that led the infections to be reduced not due to the use of MNP.

(vi) In addition to the use of MNP, there is a need forlong-term intervention to promote proper infant and young child feeding practices for optimal child growth and development. Example; starting community kitchens to teach women on food preparations using locally available food ingredients.

(vii) Based on the key findings of intervention a long-term MNP intervention with a wider coverage is recommended to verify the optimal dose and economic feasibility of using MNPs on a large scale.

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APPENDICES

Appendix 1: Study questionnaire

THE EFFICACY OF LOW DOSE MULTIPLE MICRONUTRIENT POWDER SUPPLEMENTATION IN CHILDREN UNDER-FIVE YEARS IN ARUSHA DISTRICT

District ----------------------- village ------------------- RCH …………………..

Ward------------------------- Date--------------------------

BASELINE QUESTIONNAIRE

NO	SECTION A: CHILD AND PARENTS' INFORMATION	CODE
	Child's name...	ID No.
	Name of the mother/care-giver...........	
1	Age of the mother:………(yrs)Age of the father………..(yrs)	
8	Total number of people in the household (Including your self)…………	
SECTION B: SOCIO-ECONOMIC and DEMOGRAPHIC CHARACTERISTICS		
2.	Type of the household? 1. Female headed……………. 2. Male headed………	
3.	Marital status? 1. Married 2. Single3. Divorced 4. Cohabit	
4.	Education level (number of years gone to school) Mother………..Father……	
5.	Occupation of the head of the household? 1. Farmer 2. Self employed 3. Paid employed 4. Casual labour 5.Others (Specify)………	
7	What is the major source of staple food for the household 1. Own farm 2. Buying from market	
	Family size............(including yourself)	
9	Total number of children under the age of 5 year……………..	
2		
3	What kind of toilet are you using 1.Pit latrine 2. Flashed toilet 3.No toilet 4. Other(specify)	
4	Main occupation 1. Subsistence farming 2. Pastoralist 3. Employment 4. Business 5. other (specify)	
5	**Who own the land?** 1. My Self2. Government3. landlord 4. village authority5. others (mention)	
6	How many meals does your household usually have per day 1. One 2. Two 3. Three 4. Four	
7	In the past week how many days your household eat 1.Meat---------------2. Fish---------------3.Fruits-----------------4. Vegetables------------------------------------	
Section C: CHILD'S INFORMATION		
1	Child's name	
2	Sex; 1. Male 2. Female	
3	Date of birth ……..… ……	
4	Birth weight (kg)	

5	How long after giving birth did you stay before putting your child to the breast? 1. Immediately 2. Less than 1hours. 3. Less than 24 hours 4.More than 24 hours	
5	Are you still breastfeeding your child. 1. Yes 2. No	
6	If yes, how many times do you usually breast feed your child during the day… .. Night…….	
	Section D: FEEDING PRACTICES	
1	What are you currently feeding your child? 1. Breast milk only 2. Breast milk and water, or juice 3. Breast milk and plain porridge 4. Other(specify)………………………………………	
2	At what age (months) didyou start to give your child fluids & foods other than breast milk?	
3	What type of foods/ fluids did you use to start complementing breast feeding your child? (Mention type of food and fluids & their ingredients) ………………………………………………………..	
4	Did you continue to breastfeed the child as you introduced other foods & fluids? 1. Yes 2. No	
5	How many times did your child eat yesterday including breastfeeding, meals & snacks. Breast feeding………. (times) Meals ………..(times). Snacks……….. (times)	
6	What do you think is the best number of times to feed young children per day apart from breast feeding?	
7	What types of foods are normally given to a child when the child is sick? 1. Breast milk only 2. Water 3. Porridge plain 4. Others (specify)……………………………………..	
8	Are there foods you don't give when child is sick? 1. Yes 2.No	
9	When your child falls sick how many times do you feed your child…………………	
	Section E: MORBIDITY INFORMATION	
1	Do you have a clinic card? 1. Yes 2. No	
2	Is the child regularly taken for MCH clinic.(Check on clinic card)	
3	Is your child full immunized according to the age? 1. Yes 2. No	
4	Has this child been ill in the past seven days? 1. Yes 2. No	
5	If yes, What is the illness? 1. Diarrhoea/vomitting Y/N 2. Fever ...Y/N 3. Pneumonia...Y/N 4. Malaria ...Y/N 5. Measles ....Y/N	

Section F: CHILD'S NUTRITIONAL STATUS

Child ID	Weight (kg)	Length/ht (cm)	Haemoglobin (g/dl)	Retinol	Ferritin

Section G: 24-h dietary intake

Type of food/drink	Ingredients	H/h measure	Cooking method	Amount consumed	Left over

FOLLOW-UP VISIT QUESTIONNAIRE

District --------------Month ---------------------------- Visit No-------------------

CHILD'S NUTRITIONAL STATUS					
Child Name	Weight (kg)	Length/ht (cm)	Haemoglobin (g/dl)	Retinol	Ferritin
24-h dietary intake					
Type of food/drink	Ingredients	H/h measure	Cooking method	Amount consumed	Left over

1. Has a child fall sick from the last visit?

1. Yes (If yes specify)------------------

2. No

Sensory attributes of the complementary food mixed with MNP

	Like Strongly	**Like Moderately**	**Like**	**Dislike Moderately**	**Dislike Strongly**
Smell					
Taste					
Colour					
Flavour					

1. Are you willing to buy virutubishi (MNP) if they available for sell
1. Yes
2. No ………………………..

2. If yes are you willing to pay for 150 Tsh?

1. Yes

2. No ………………………………………

Appendix 2: Statement of consent

I have read the above information or it has been read to me. I have had the opportunity to discuss this research study with researcher, and I have had my questions answered by her in a language I understand. I let my child to take part in this study of my own free will.

I agree to take part in this study:

------------------------------------ -------------------------------- ---------------

Subjects name Signature/ thumb print Date

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Investigator Name Signature Date