Distribution Agreement

Signature:

April 18th 2014

_____________________________ ______________

Banthida Komphasouk Date

Co-occurrence of anemia and low BMI in Vietnam

By

Banthida Komphasouk
Master of Public Health

Hubert Department of Global Health

____
Reynaldo Martorell, PhD
Committee Chair

____
O. Yaw Addo, PhD
Committee Member

Co-occurrence of anemia and low BMI in Vietnam

By

By Banthida Komphasouk

Bachelor of Social Science, Development and Health (Honors)
University of Queensland, Australia
2010

Thesis Committee Chair: Reynaldo Martorell, PhD

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Hubert Department of Global Health
2014

Abstract

Co-occurrence of anemia and low BMI in Vietnam
By Banthida Komphasouk

Objective: Anemia is a major public health problem worldwide. The causes of anemia are complex and often are shared with other nutritional issues. Anemia is most common among poorer regions of the world such as in Africa and Southeast Asia where low Body Mass Index (BMI) is also common. Yet, research on the co-occurrence of low BMI and anemia are lacking. The aim of this study is to investigate the association between low BMI and anemia in non-pregnant women of low socioeconomic status from rural Vietnam.

Methods: Data on non-pregnant women used in this study were obtained from a randomized controlled study known as PRECONCEPT. Baseline data on demographic, anthropometric measurements, hemoglobin concentration, social-economic status, household food insecurity and risk factors on 4972 women of reproductive age (15-44 years) were used. A descriptive analysis on anemia, low BMI and its co-existence as well as tests of mutual dependency to detect co-occurrence among anemia, low BMI and food insecurity were performed. Multiple logistic regressions were used to test associations of anemia, underweight and food insecurity with age, education, socio-economic status, hookworm and parity.

Results: Anemia (Hb < 12 g/dl) was present in 19.6 % of women, low BMI (<18.5 kg/m2) in around a third (31.5%) and 5.6% of the women had both anemia and low BMI. Mutual dependency tests (observed/expected) showed evidence for two co-occurrence combinations, anemia and low BMI (6.2% vs. 5.6%) and anemia and food insecurity (6.9% vs. 6.2%). After adjusting for potential confounders, BMI status, age, SES and education were significant predictors of anemia. Age was associated with low BMI while SES, education, age and parity were predictive of food insecurity.

Conclusion: Despite statistical evidence for co-occurrence, differences between expected and observed prevalence were small, suggesting that having one problem does not necessarily increase the probability of having the other. Effective nutrition intervention for this population should not only focus on food security but programs that empower women to reach their full potential through promoting education, increase skills and opportunities to increase household incomes and birth spacing.

Co-occurrence of anemia and low BMI in Vietnam

By

Banthida Komphasouk

Bachelor of Social Science, Development and Health (Honors)
University of Queensland, Australia
2010

Thesis Committee Chair: Reynaldo Martorell, PhD

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Hubert Department of Global Health
2014

ACKNOWLEDGEMENT:

I wish to extend my gratitude and thank the following people who have assisted me and made the writing of this thesis possible:

I would like to sincerely thank my supervisor Dr Reynaldo Martorell for your continuous support and guidance throughout this research. Your extensive academic knowledge and passion for research have been inspiring for my work. Thank you for your positive encouragement, practical approach and valuable feedback during all the stages of the research. They have been highly valued and appreciated. I would also like to express thanks for always being understanding and open to my situation and comments.

A most honest and heartfelt thank you to Dr Yaw Addo for your helpful guidance, constant compassion and understanding that you have provided throughout the semesters. Without your involvement, enthusiasm, fondness in research and earnest advice this research would not be possible. Thank you for your overwhelming support, endless patience and warm encouragement, particularly through difficult times, they have been highly valued and greatly appreciated.

I would like to express my sincere gratitude and appreciation to Dr. Phuong Nguyen and the PRECONCEPT research team. Without your study, data and cooperation I would not be able to carry out this thesis. Finally, and most importantly, the Fulbright scholarship and their staffs for making this thesis and my educational experience possible!

Table of Contents

CHAPTER 1: INTRODUCTION

Context of project:

In recent years due to the global increase in overweight and obesity, much research has focused on its association with various nutritional factors including anemia, due to possible similar causes, such as energy dense diets that are poor in micronutrients (Zeid et al, 2014; Bagni et al, 2013; Winther et al, 2013; Cepeda-Lopez, 2011; Samper-Ternent et al, 2011; Eckhardt et al, 2008; Moayeri et al, 2006; Nead et al, 2004). However, the prevalence of anemia is highest in poorer regions of the world such as in Africa and Southeast Asia where low Body Mass Index (BMI) still continues to be common in many developing nations (WHO, 2002; FAO, 1994). Low BMI and anemia could be associated yet few studies have examined this (Shetty, 2006). In poor countries, diets could be low in energy thereby causing low BMI and also low in micronutrients, causing anemia. The purpose of this study is to investigate the association between low BMI and anemia in non-pregnant women of low socioeconomic status from rural Vietnam.

Anemia and its implications

Anemia continues to be one of the major public health problems worldwide. The World Health Organization (WHO) estimates that over one third of the world's population or around 2 billion people are anemic, which is defined as having hemoglobin levels below the recommended thresholds for each particular age, gender and physiologic group, after adjusting for altitude, if necessary (WHO/CDC, 2007). Anemia has adverse effects on the individual's health ranging from weakness and fatigue to lowered immunity, impaired physical and cognitive functions; and in severe cases, mortality. It is estimated that anemia contributes to 20% of all maternal deaths (WHO, 2014). At a national scale, anemia's burden is centered on work performances. In terms of monetary losses associated with anemia, it is estimated to amount to about US $3.64 per person or 0.81% of the gross domestic product; however, it varies by country depending on the economy's reliance on physical labor. For example, in South Asia, the productivity loss from anemia is estimated to be $4.2 billion annually (Balarajan et al, 2011).

Anemia affects all age, gender and population groups. WHO reports that globally the population groups most at risk for anemia are children under 5 years old (47.4%), followed by pregnant (41.8%) and non-pregnant women (NPW) (30.2%). However, the group with the greatest number of anemic individuals is NPW, which is defined as having a hemoglobin concentration less than 110 g/l, with 468.4 million affected globally. Proportionately, the highest prevalence of anemia is found in Africa, 44.4% or 82.9 million; however, Asia has the largest number of people affected with anemia, 318.3 million (33%) (McLean et al, 2007). Non-pregnant women of reproductive age (15 – 49.9 years) is among the populations groups most affected by anemia ; the highest prevalence , 68%, is found in Asia followed by 45.7% (182 million) in South-East Asia (McLean et al, 2007; WHO, 2008). Anemia in women of reproductive age can lead to increased risk of anemia during pregnancy due to already low iron stores, complications during pregnancy and child birth, low birth weight or premature birth, inadequate iron stores for the newborn, hemorrhage, neonatal mortality and even maternal mortality (Bentley & Griffiths, 2003). In India for instance, 19% of maternal deaths are attributed to anemia (Trinh & Dibley, 2007).

"Anemia is an indicator of both poor nutrition and poor health" (WHO, 2004: 1). Although the factors resulting in anemia can be isolated, they often coexist (WHO, 2008). One of the most common causes of anemia and that accounts for more than half of all cases globally is nutritional deficiencies primarily due to inadequate food intake or low bioavailability of foods rich in iron and other nutrients (including folate, vitamin B_{12}, vitamin A, etc) (Jackson, 2007; WHO, 2004; Ninh et al, 2003; Tatala & Mduma, 1998). Other factors including parasitic infections (e.g. hookworm), malaria, chronic infections or other related illness as well as social economic status, age, education, parity, birth spacing and Body Mass Index (BMI), which all contribute significantly to a woman's anemia prevalence (Pasricha et al,2008; Thompson, 2007; Trinh & Dibley, 2007; Ninh et al, 2003; Hung et al, 2005).

Low body mass index and its implications

Underweight still remains common in many developing countries where poverty is a strong underlying factor contributing to household food insecurity, unhealthy environment, maternal undernutrition, poor child care and poor health care (Shetty, 2006; WHO, 2002). Globally the WHO estimated that 3.7 million deaths worldwide were due to underweight in 2000 (WHO 2002). All ages are at risk, however, children under five years of age and women of reproductive age are most at risk as the global prevalence of underweight with approximately 27% for children under five, and as high as 27-51% among women of reproductive age in 2002 (WHO, 2002). An individual's nutritional status is often defined in public health by person's anthropometric measurements or Body Mass Index (BMI) by diving weight in kilograms by height in metres squared (WHO, 2014; Do, Dibley and D'Este, 2004). Adult low BMI is a defined BMI less than 18.5

kg/m^2, which signifies chronic undernutrition (WHO, 2014; Shetty, 2006). The severity of adult undernutrition or underweight can further be categorized into three grades according to FAO/WHO as (1) mild thinness having a BMI of 17-18.49 kg/m^2, (2) moderate thinness having a BMI of 16-16.99 kg/m2 and (3) severe thinness having a BMI <16 kg/m^2 (WHO, 2014; FAO, 1994).

Undernutrition is defined as having "a dietary energy intake below the minimum requirement level to maintain the balance between actual energy intake and acceptable levels of energy expenditure" (FAO, 2003: 39) Undernutrition or underweight is therefore the consequence of insufficient food caused by an inadequate intake of dietary energy in conjunction with frequent infections resulting to deficiencies in energy, protein, vitamins and minerals (WHO, 2014, 2002; FAO, 2003, 1994). Adults with low BMI or in a chronic state of undernutrition are at risk of poor health and well-being, and impairment of function, including reduced social and cognitive functioning, concentration, lowered physical and work productivity in addition to impaired immune function, thus increasing the tendency to new and repeated infection (Fairbun, 2008; Shetty, 2006; Do, Dibley and D'Este, 2004; Untoro et al., 1998; FAO, 1994). A cohort study on adults, ages 18 to 60 years, in rural northern Vietnam found a positive correlation between BMI and health status. As BMI decreased, the percentage of participants experiencing morbidity with fever increased (Do, Dibley and D'Este, 2004). Furthermore, similar research in Chinese adults found that after adjusting for age, sex, cigarette smoking, alcohol consumption, physical activity, education, geographic region and urbanization, participants who were underweight (BMI < 18.5 kg/m^2) had a significantly increased all-cause mortality rate compared with participants with a BMI of 24.0 -24.9 kg/m^2 in both men and women, with the relative risks of 1.65 (95% CI: 1.54-1.77) (Dongfeng et al, 2006).

Women of reproductive age are among those at increased risk for being underweight as the prevalence of undernutrition is estimated to be as high as 27-51% in some regions, especially in Africa and South Asia (WHO, 2002). Implications for women with BMI < 19 kg/m^2 are increased risk of poor health and tiredness, decreased vitality, poorer mental health and increased use of health services. Even among young women there is evidence to suggest that fertility and bone density, which can develop into osteoporosis, can be attributed to low BMI (Brown, et al 2000). A study on underweight (BMI < 18.5 kg/m^2) among12-14 year old girls in China found delayed growth and development, late breast and pubic hair development, delayed menarche, lower bone age, width and mineral density compared with those with a normal weight (BMI of 18 – 21 kg/m^2) (Du et al, 2003). Additionally, non-pregnant women (NPW) of reproductive age with low pre-conception BMI (BMI<18.5 kg/m^2) are at greater risk of obstetric complications, infant morbidity, premature births, fetal growth deficits and low birth weight (Nguyen et al, 2013; Ronnenberg et al., 2003; Brown et al, 2000).

Problem statement:

The link between BMI and anemia is well documented, however, much of the research has focused on the association between anemia and overweight and/or obesity due to its increasing global prevalence (Bagni et al, 2013; Winther et al, 2014; Cepeda-Lopez, 2011; Samper-Ternent et al, 2011; Eckhardt et al, 2008; Moayeri et al, 2006; Nead et al, 2004). Nead et al’s study using the US National Health and Nutrition Examination Survey III (1988-1994) on children 2-26 years old found that those who were either overweight or at risk of being overweight were twice as likely to be iron-deficient compared to those who were not (OR: 2.0; 95% CI: 1.2–3.5; and OR: 2.3; 95% CI: 1.4 –3.9; respectively) (2004). Similarly, a study in Israeli children also found higher prevalence of anemia (iron levels below 8 µmol/l or 45 mcg/dl) among obese (38.8%) and overweight (12.1%) children compared with normal weight group (4.4%) ($p<0.01$) (Pinhas-Hamiel et al, 2003).

Studies on the co-occurrence of anemia and low BMI are lacking. Biologically, anemia represents a reduction in circulating red cell mass either due to blood loss from disease or infection or a change in balance between the rates of red cell synthesis and degradation. The role of red cells to deliver oxygen and remove carbon dioxide is an essential function of the body. However, when the body is faced with inadequate food intake food either due to poor appetite or limited food availability, in order to maintain red cell mass the body's metabolic demands fall and the need for energy and oxygen is reduced resulting in a wasting syndrome, best captured as a relative loss of weight and reduced lean body mass. Therefore, anemia is also an outcome of wasting syndromes, directly related to poor diets, chronic disease or inflammation (Thompson, 2007; Jackson, 2007). As a result, we hypothesize that people who are underweight (BMI <18.5 kg/m^2) are also likely to be anemic especially when faced with food insecurity. This claim is supported in various studies in both developed and developing nations confirming the positive correlation between Body Mass Index (BMI) and anemia (Hausman et al, 2011; Thompson, 2007; Deshmukh et al, 1998; Verma & Shrimali, 2012). A longitudinal study on young women (18-23 years) in Australia found that women with low BMI were more likely to have low iron stores (Brown et al, 2000); and similarly a study on NPW in

Tanzania also showed that women with low BMI had higher prevalence of anemia (Massawe et al, 2002).

Conversely, there are also some conflicting studies showing no association between BMI and anemia. One study by Bentley and Griffiths that looked into the prevalence of anemia and BMI on women of reproductive age, 15-49 year, in Andhra Pradesh, India by using the National Family Health Survey 1998/99 (NFHS-2) data found a high prevalence of anemia in all three categories of BMI: 52% in low BMI, 50% in normal BMI and 41% in the overweight group (2003). Bagni et al's (2013) school-based cross sectional study in Brazil found that although overweight adolescent girls (11-19.9 years old) had lower hemoglobin levels than their normal weigh counterparts (12.2 g/dL vs. 12.8 g/dL, $p < 0.01$), the likelihood of developing anemia did not change according to changes in BMI. Furthermore, another study in female university students in the Kingdom of Saudi Arabia showed that anemia was actually more prevalent in normal weight (45.7%) than underweight (40%) students, and that there was no significant association between their hemoglobin levels and BMI (Hanafi et al, 2013). As a result, due to inconsistent research on the association of Low BMI and anemia, this research aims to explore the likelihood of the co-occurrence of anemia, low BMI and food insecurity, by using data from the PRECONCEPT study on NPW in the Northeastern mountainous region, Thai Nguyen province, Vietnam.

Vietnam Context

Anemia and low BMI remain major public health issues in many developing nations in Southeast Asia including Vietnam (Ninh et al, 2003). In the 1990s, the prevalence of underweight (BMI < 18.5 kg/m^2) among non-pregnant women (NPW) of reproductive age was 48% (in 1990) (Nguyen et al, 2013), and anemia prevalence was 40.2% (in 1995), which categorized anemia as severe public health problem following WHO criteria (more than 40%) (Trinh & Dibley, 2007; Ninh, et al, 2003). However since then, Vietnam has gone through rapid social and economic changes that have improved anemia prevalence and health status. One of these contributing factors included the successful implementation of national nutrition policies in Vietnam (Nguyen et al, 2013). The first policy on nutrition (The National Plan of Action for Nutrition 1995–2000) focused on food insecurity, maternal and child malnutrition; while the follow-up policy (The National Nutrition Strategy 2001– 2010) added additional strategies to deal with nutrition related health problems including reducing micronutrient deficiency, increase food supplementation, food diversity and fortification (Laillou et al, 2012; Tuan, Tuong and Popkin, 2008). The other underlying influence was the country's emphasis on economic reform and development, moving from a centrally planned system to a free market economy, contributing to its rapid economic growth. This transition saw a reduction in poverty from 37.4% in 1998 to 16% in 2006, which increased per capita income from US $300 to more than US $400 in the late 1990's to 2005 (Laillou et al, 2012). Increased income often leads to improvement in health status and nutrition due to increased purchases of meat, fruits and vegetables and greater access to health care. Consequently, according to the latest statistics from the General Nutrition Survey (GNS) undernutrition or underweight among NPW dropped to 18% in 2010 and the prevalence of anemia was reduced to 28.8% in the same year (National Institute of Nutrition, 2012; Nguyen et al, 2013). Nevertheless, the prevalence of underweight was still higher compared to women in Laos (15%) in 2006, the Philippines (14%) in 2003 and China

(9.7%) in 2002 (Tuan, Tuong and Popkin, 2008; OECD/WHO, 2012). Additionally, based on the WHO epidemiological criteria, anemia in Vietnam still remains a moderate public health concern (having a prevalence of 10% to 39%) (Trinh & Dibley, 2007).

Although the overall national statistics shows a decrease in anemia and underweight in Vietnam, these statistics vary among region as studies in Vietnam have shown that adults living in rural areas had a higher prevalence of underweight and anemia compared to those living in urban areas (Laillou et al, 2012; Tuan, Tuong and Popkin, 2008; Trinh & Dibley, 2007). According to the latest statistics from the National Institute of Nutrition (2012) the actual prevalence of anemia is lowest in the Red River Delta regions with 22.7% among NPW and the highest in the Northern midlands and mountain regions with 37.5%. One explanation for the differences is that the Northern midlands is considered the rural region of the country while and the Red River Delta is urban, and there is a widening income gap between rural and urban residents (Tuan, Tuong and Popkin, 2008). The Northern midlands and mountain regions are among the poorest areas of the country and experience food insecurity; 13.1% of households reported experiencing food shortages during the last year in these regions compared to 3% in the Red River Delta regions (National Institute of Nutrition, 2012). Another reason is that the main inhabitants in this region are minority ethnic groups, which tend to be poorer. One study in a remote mountainous district in Vietnam found ethnic minorities have higher anemia prevalence (OR=2.7; 95%CI=1.4-5.0) compared to the majority Kinh ethnic group (Trinh & Dibley, 2007). Additionally, the traditional Vietnamese diet, especially of the rural poor, is mainly based on starches with low protein and fat content and high amounts of inhibitors of absorption (due to high tea consumption), than urban diets

(Nugyen et al, 2013). High phytate contents foods such as whole grains, seeds, legumes, soy based products; tea, coffee, etc. tend to bind iron, making them unavailable for absorption (Zijp et al, 2000). Consumers of these traditional Vietnamese diets do not meet the recommended daily allowances for the Vietnamese population (Laillou et al, 2012; Nugyen et al, 2006)

Purpose of project:

This research uses baseline data collected as part of a cluster randomized controlled trial known as PRECONCEPT, in the Northeastern mountainous region, Thai Nguyen province, Vietnam (Nguyen et al., 2012). This analysis aims to investigate the co-occurrence of three common nutrition problems: anemia, low BMI and food insecurity among NPW in Vietnam. Our hypothesis is that any two nutritional problems and all three problems would co-occur at a greater frequency than would be expected by chance. The specific focus of the study is to 1) describe characteristics of NPW with anemia only, low BMI only and having both, anemia and low BMI; 2) analyze the coexistence of anemia, low BMI and food insecurity and 3) we will also examine the association of age, socioeconomic status, education, hookworm and parity on the presence of anemia, low BMI and food insecurity. Results from the study will contribute to the limited information about anemia and low BMI in NPW in the most disadvantageous and poorest area of Vietnam as well as add to the global knowledge surrounding anaemia and BMI.

CHAPTER 2: METHODOLOGY

Research Design

The overarching goal of this study is to better understand associations among low BMI, anemia and food insecurity. Data analyzed for this study are from baseline data collected as part of a randomized controlled study known as PRECONCEPT; which aimed to improve maternal and child iron status and health outcomes in Thai Nguyen province, Vietnam (Nguyen et al., 2012). The PRECONCEPT study collected data in two phases, October to December in 2011 and then March to May, 2012 to ensure the target sample size enrolled in the study would be more than 5,000 non-pregnant women. At baseline, data collection included anthropometry, hemoglobin concentrations, serum ferritin, transferrin receptor (TfR), serum C-reactive protein (CRP) and alpha-1-acid glycoprotein (AGP) as well as stool samples to assess helminthes infestation from *Ascaris lumbricodes*, *Trichuris trichura* and hookworm. Household surveys were conducted using questionnaires to capture information on (1) demographics; (2) socioeconomic status, using a locally adapted version of the World Bank's asset questionnaires (Gwatkin et al, 2000); (3) household food insecurity, measured using Food and Nutrition Technical Assistance/ US Agency of International Development's (FANTA/USAID) Household food insecurity access scale (HFIAC) (Coates et al, 2007); (4) reproductive histories; (5) maternal mental health; (6) maternal morbidity; (6) dietary intake gained from Vietnam National Institute of Nutrition's (NIN) food frequency questionnaire (Tran, 2009); and (7) maternal workload (Nguyen et al, 2013). Only data on anthropometry, demography, social economic status, household food insecurity, hemoglobin, and hookworm infection were used in the current study.

Sample population

The PRECONCEPT study was carried out in Thai Nguyen province in the northern mountain region of the country, which is considered one poorest rural region in Vietnam. Participants of the study were non-pregnant women of reproductive age, 18-35 years old, currently married and intending to get pregnant within a year from 20 communes located in 4 of the 9 districts in Thai Nguyen province and consented to participate in the PRECONCEPT study. A total of 5011 women were recruited in 2012; however 4972 were used for this analysis as they had complete demographic, social economic status and household food insecurity data. Ethical approval for the PRECONCEPT study was granted by the Ethical Committee of Institute of Social and Medicine Studies in Vietnam and Emory University's Institutional Review Board, Atlanta, Georgia, USA.

Study variables

Demographic data and risk factors

Participant's age is categorized into three age groups similar to Nguyen et al's (2013) paper. Ethnicity is divided into the majority Kinh and the remaining minority ethnic groups. As farming is the main occupation in many rural areas in Vietnam (Nugyen et al, 2006), participant occupation was categorized as farmer or other. Education attainment was based on the women's highest grade completed, which was grouped into primary school (0-5 years), secondary school (6-9 years), high school (10-12 years) and some tertiary school education (greater than 12 years). Risk factors (or covariates) such as number of previous pregnancies or parity and hookworm infestation were considered based on a theoretical framework (Nyugen et al, 2006).

Body Mass Index

Height and weight of participants were measured twice and collected at baseline. Body Mass Index (BMI) was calculated by dividing the average weight in kilograms by the average height in meters squared. This study used the World Health Organization's cut-off for BMI categories where underweight for non-pregnant adults is having a BMI < 18.5 kg/m^2; normal as BMI of 18.5-24.9 kg/m^2 and overweight as BMI $\geq$ 25 kg/m^2 (WHO, 2014). As we are interested in low BMI, this category is further broken down into mild thinness with BMI of 17-18.49 kg/m^2, moderate thinness having a BMI of 16-16.99 kg/m^2 and severe thinness having a BMI <16 kg/m^2 (WHO,2014).

Anemia

Anemia status was determined from hemoglobin (Hb) concentrations collected at baseline using *Hemocue*. Hemoglobin concentrations below 12 g/dl are considered anemic; between 11-11.9 g/dl are considered mild anemia, moderate anemia are Hb between 8-10.9 g/dl and severe is Hb lower than 8.0 g/dl (WHO, 2011).

Socio-economic status (SES)

SES data was collected from asset questionnaire developed by the World Bank for developing countries which was adapted to suit the local context. The SES status calculations for this paper are based on Nguyen et al's (2013) study using data on home and land ownership, housing quality, access to services and household assets; and calculated by using principal components analysis (PCA) (Vyas & Kumaranayake, 2006). In brief, the household variables were first dummy coded and composite orthogonal factors were then calculated from all them with the SAS procedure PROC PRINCOMP. The first component derived from the PCA, (with highest proportion of explained variance for all items) was then categorized into quintiles of poorest, poorer, average, richer and richest using percentile rankings.

Food insecurity

Data on household food insecurity was collected and measured using FANTA/USAID's Household Food Insecurity Access Scale (HFIAS) of (1) secure, (2) mildly insecure, moderately or (3) severely insecure (see Coates et al, 2007). The questionnaire used to collect household food insecurity was adapted to suit the Vietnamese context and was based on participants' self-report on their behavior and perceptions on household food insecurity, its characteristics and consequences (Nguyen et al, 2013). This study however, grouped the food insecurity variable into two categories: secure and insecure (mild, moderate and/or severe).

Statistical analysis

Descriptive characteristics like demographic, socio-economic and food insecurity information were presented as means (SD) or as percentages for continuous and categorical variables respectively. Chi square and T-test, where appropriate, were used to examine the relationships between individual and household characteristics (age, ethnicity, occupation, education, parity, hookworm, SES and food insecurity) and the prevalence of four nutritional conditions only-anemic, only- underweight, anemic and low BMI and not anemic and not underweight. To assess the co-occurrence of the main outcomes within the study population for the two-way (i.e., anemia co-occurring with underweight, anemia with food insecurity, and underweight with food insecurity) and three-way on (i.e., anemia, underweight and food insecurity) test of mutual dependence or variation in prevalence among the 3 dependent variables was performed. This was implemented through a log-linear model in the SAS procedure PROC CATMOD. This approach examines enables comparison of observed and expected prevalence of the two and three way combinations of the outcomes, accounting for their joint probabilities. To examine conceptual models of what may be driving the interdependencies of these outcomes, logistic regression models were used to identify which of the independent variables, age, education, socio-economic status, hookworm and parity, are likely to be predictors of anemia, underweight and food insecurity. Furthermore, the study tested two conceptual models (1) anemia as the outcome while having food insecurity and low BMI as predictors and (2) food insecurity as the outcome with anemia and low BMI as predictors, adjusting for all confounders and covariates to see if they are related. All statistical analyses were performed with the statistical package software SAS version 9.3 (SAS institute, Cary, NC). P-values of <0.05 were considered significant.

CHAPTER 3: RESULTS

Descriptive characteristics

Background characteristics of the study participants are presented in **Table 1**. The mean age was 26.3 ± 4.6 years, with a range of 15 to 44 years. Nearly half (49.5%) of the women identified themselves as ethnic minorities and farmers represented 80.6% of the sample. The mean highest level of education obtain was 9.6 ± 2.9 years. Less than 8.2% of the women had less than primary school education (0-5 years) while, more than half (54.75%) completed some or all middle school (6-9 years), 25.1% completed at least some high-school (10-12 years) and 12% had some tertiary education or higher (over 12 years). Around a third (31.5%) of the women had low BMI (<18.523 kg/m^2) and comprised of 24% were mildly thin (BMI: 17-18.49 kg/m^2), 6 % moderately (BMI: 16-16.99 kg/m^2) and 1.5% severe thin (BMI <16 kg/m^2). Prevalence of overweight (BMI > 23 kg/m^2) was low at 6%.

The mean hemoglobin in the sample was 12.95 ± 1.36 g/dl. Anemia (Hb < 12 g/dl) was present in 19.6 % of the women, with 12.6% of them being mild anemic (Hb: 11-11.99 g/dl), 6.9% moderately (Hb: 8-10.9 g/dl) and less than 1% had severely (Hb< 8 g/dl) anemic. In terms of perceived household food insecurity, around a third (31.3%) reported having mild, moderate and/or severe food insecurity. The average parity was 1.3 ± 0.8, with more than half of the women (60.5%) reported prior pregnancy. Hookworm infestation was found in less than a quarter (21.5%) of the sample.

Table 1: Background characteristics of the study participants

	n	%	P-values
Participant Characteristics			
Age of women (mean± SD: 26.3 ± 4.6)			
< 25 years old	2139	43.3	
26-30 years old	1822	36.9	< 0.01
> 30 years old	983	19.9	
Ethnicity			
Kinh	2507	50.6	
Minority	2452	49.5	0.43
Occupation			
Farmer	4001	80.7	
Other	960	19.4	< 0.01
Education (highest grade completed) (mean± SD: 9.6 ± 2.9)			
0-5 years	406	8.2	
6-9 years	2716	54.8	< 0.01
10-12 years	1246	25.2	
Greater than 12 years	593	11.9	
BMI (mean ± SD: 19.6 ± 2.0)			
Underweight (BMI<18.5 kg/m^2)	1561	31.5	
Normal(18.5 < BMI <23 kg/m^2)	3096	62.5	< 0.01
Overweight (BMI > 23 kg/m^2)	295	6.0	
Anemic (HB<12g/dl)			
Yes	974	19.6	< 0.01
Household Characteristics			
Food Insecurity			
Mild, moderate or severe	1555	31.3	< 0.01
Socioeconomic Status			
Poorest	1004	20.2	
Poorer	992	19.9	
Average	992	19.9	0.99
Richer	992	19.9	
Richest	992	19.9	
Risk Factors			
Number of pregnancies/parity (mean ± SD: 1.3 ± 0.8)			
0	448	9.0	
1	3000	60.5	< 0.01
2 or more	1510	30.5	
Hookworm infestation			
Yes	954	21.5	< 0.01

Results of the cross-tabulation analyses on the different nutritional status groups (i.e. anemic-only, low BMI-only and anemic and low BMI) and their association with demographic factors, household characteristics including food insecurity and socio-economic status, parity and hookworm are presented in **Table 2**. Data show that women's age is associated with the prevalence of anemia-only, such that younger women (< 25 years old) were more likely to be anemic compared to older women (>30 years old) at 8.2% and 4.5% respectively. Similarly the prevalence of low BMI was higher in younger aged women (14.9%) than older women (5.3%). However, there were no differences between age groups in anemia and low BMI prevalence ($p = 0.55$). Anemia prevalence was higher among women identifying as belonging to ethnic minority groups (11.6%), though low BMI was more common in the Kinh ethnic group (17.1%). The level of education, being a farmer, higher socioeconomic status and the presence of hookworm infestation differed significantly for women with anemia-only whereas only education and parity differed for women with low BMI. Women from food secure households had significantly higher prevalence of anemia (12.6% vs. 6.9%) in comparison to those from food insecure households ($p < 0.01$). Similarly in women with both anemia and low BMI (3.4% vs. 2.1%) ($p=0.01$). Lastly, although not statistically significant ($p=0.06$), higher prevalence of low BMI was also observed in food secure than insecure households (21% vs. 10.4%).

Table 2: Characteristics of study participants based on anemia, BMI, anemia and low BMI and not anemic and normal BMI in women of reproductive ages (15-44y) in Vietnam

Variable	Anemic Only (%)	P value	Low BMI Only (%)	P value	Anemic and low BMI (%)	P value
Sample size (N, %)	974 (19.6)	<0.01	1561 (31.4)	< 0.01	277 (5.6)	< 0.01
Age (Mean± SD)	***(26.5 ± 4.8)***		***(25.8 ± 4.3)***		***(26.4 ± 4.4)***	
< 25 years old	405 (8.2)		737 (14.9)		119 (2.4)	
26-30 years old	344 (6.9)	0.04	555 (11.2)	<0.01	95 (1.9)	0.55
> 30 years old	220 (4.5)		261 (5.3)		61 (1.2)	
Ethnicity						
Kinh	396 (8.0)	<0.01	847 (17.1)	<0.01	135 (2.7)	0.62
Minority	575 (11.6)		708 (14.3)		140 (2.8)	
Occupation						
Farmer	834 (16.8)	<0.01	293 (5.9)	0.53	233 (4.7)	0.07
Other	137(2.8)		1263 (25.5)		42 (0.9)	
Education (Mean± SD)	***(9.2 ± 2.8)***		***(9.6 ± 2.8)***		***(9.3 ± 2.6)***	
0-5 years	107 (2.2)		119 (2.4)		22 (0.4)	
6-9 years	555 (11.2)	<0.01	848 (17.1)	0.04	163 (3.3)	0.09
10-12 years	233 (4.7)		423 (8.5)		70 (1.4)	
Greater than 12 years	76 (1.5)		166 (3.4)		20 (0.4)	

Food Insecurity						
Secure	628 (12.6)		1045 (21.0)		171 (3.4)	
Mild, moderate or severe	345 (6.9)	<0.01	516 (10.4)	0.06	106 (2.1)	0.01
Wealth Index (SES)						
Poorest	252 (5.1)		324 (6.5)		74 (1.5)	
Poorer	218 (4.4)		307 (6.2)		60 (1.2)	
Average	174 (3.5)	<0.01	308 (6.2)	0.21	43 (0.9)	< 0.01
Richer	193 (3.9)		335 (6.7)		61 (1.2)	
Richest	137 (2.8)		287 (5.8)		39 (0.8)	
0	80 (1.6)		145 (2.9)		19 (0.4)	
1	619 (12.5)	0.07	975 (19.7)	0.02	171 (3.5)	0.45
2 or more	272 (5.5)		434 (8.8)		85 (1.7)	
Hookworm^						
Yes	219 (4.9)	<0.01	287 (6.5)	0.18	51 (1.2)	0.75

*Z-value are significant at P<0.05 as obtained from Chi Square tests. ^ 11% of the data is missing

Mutual dependency among Anemia, Low BMI and Food Insecurity

Mutual dependencies between observed and expected proportions of women with two-way and three-way co-occurrence of the nutritional statuses, anemia, low BMI and food insecurity, are shown in **Table 3**. The observed proportion of the two-way and three-way co-occurrence in the four groups was somewhat similar. Statistical significant differences between the observed and expected co-occurrence was observed in the co-occurrence of anemia and low BMI, where the expected prevalence (6.2%) slightly exceeded the observed (5.6%); and with anemia and food insecurity, with the observed slightly greater than the expected 6.9% vs. 6.2%. Although the two-way co-occurrence of low BMI and food insecurity was not statistically significant, it showed a tendency to do so (p=0.06). The three-way co-occurrence showed no statistical significance (p=0.76).

Table 3: Observed and expected co-occurrence of two-way and three-way nutritional issue (anemia, low BMI and food insecurity) in women of reproductive ages (15-44y) in Vietnam (N=4970)

Nutritional Status	Observed % (95% CI)	Expected % (95% CI)	P-value
Anemia and Low BMI	5.6 (5.2 – 5.9)	6.2 (5.8 - 6.5)	0.03
Anemia and Food Insecurity	6.9 (6.6 – 7.3)	6.2 (5.8 – 6.45)	<0.01
Low BMI and Food Insecurity	10.4 (9.9 – 10.8)	9.8 (9.4 – 10.3)	0.06
Anemia, Low BMI and Food Insecurity	2.1 (-8.1 - 12.3)	2.1 (-8.05 - 12.31)	0.76

Predictors of Anemia, Low BMI and Food Insecurity in Vietnamese women

Results of multivariate logistic regression showing the factors associated with anemia, low BMI and food insecurity are presented in **Table 4**. While our data show that anemia was not significantly related to women's age, hookworm infestation and parity, it was inversely associated with both socioeconomic status (SES) (OR= 0.82 (95% CI: 0.74 - 0.89) and education (OR= 0.87 (95% CI: 0.78 - 0.98)). As for low BMI status, women's age was the only significant predictor, with a 14% reduction (OR= 0.86 (95% CI: 0.79 - 0.94)) per increase in age category, while the other four factors had no significant association. Lastly, for food insecurity, almost all tested factors except for hookworm had a significant relationship. These predictors include women's SES (OR = 2.77 (95% CI: 2.51-3.05), education level (OR= 1.15 (95% CI: 1.04 – 1.28)), parity (OR= 0.83 (95% CI: 0.73 - 0.94)) and age (OR= 0.74 (95% CI: 0.67 - 0.81)).

Table 4: Logistic regression models describing predictors of anemia, low BMI and food insecurity in women of reproductive ages (15-44y) in Vietnam

Model predictors	**Anemia**		**Low BMI**		**Food Insecurity**	
	OR (95% CI)	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Age category	1.12 (1.02 – 1.24)	0.86	0.86 (0.79 - 0.94)	< 0.01	0.74 (0.67 – 0.81)	< 0.01
Socioeconomic Status	0.82 (0.74 - 0.89)	< 0.01	0.94 (0.87 - 1.02)	0.12	2.77 (2.51 – 3.05)	< 0.01
Education	0.87 (0.78 - 0.98)	0.01	1.04 (0.95 - 1.14)	0.41	1.15 (1.04 – 1.28)	< 0.01
Hookworm	1.17 (0.98 -1.39)	0.08	0.88 (0.75 – 1.03)	0.10	1.02 (0.87 – 1.21)	0.77
Parity	0.92 (0.80 - 1.05)	0.20	0.94 (0.84 – 1.06)	0.31	0.83 (0.73 – 0.94)	< 0.01

Table 5 shows the results of logistic regression assessing associations between anemia as the outcome, and food insecurity and low BMI as predictors with adjustment for the selected potential confounders. Compared to low BMI, normal BMI women with

were 20% (OR=0.8 (95% CI: 0.6-0.9, $p < 0.01$)) less likely to be anemic whiles food insecurity and parity were not significant predictors of anemia. Women's age, socioeconomic status and education were significant predictors of anemia. Although hookworm was not statistically significant, there was a trend ($p = 0.09$) for hookworm to be associated with anemia among these women. There was no interaction between anemia related to low BMI and food insecurity in this study population ($p = 0.51$).

Table 5: Associations between Anemia and low BMI and food insecurity in women of reproductive age (15-44y) in Vietnam (N=4970)

.Model predictors	**Anemia**	
	OR (95% CI)	**P-value**
Low BMI	0.8 (0.6-0.9)	<0.01
Food Insecurity	0.9 (0.8 – 1.1)	0.61
Age category	1.1 (1.0-1.2)	0.03
Socioeconomic Status	0.8 (0.7-0.9)	< 0.01
Education	0.9 (0.8-1.0)	0.01
Hookworm	1.2 (1.0-1.4)	0.09
Number of pregnancy/ parity	0.9 (0.8-1.0)	0.18

Effect modification by Low BMI interacting with Food Insecurity in their relation with anemia was tested, found non-significant (p=0.51) and dropped out of the final model

Lastly, results from the multivariate logistic regression exploring food insecurity as the outcome while having anemia and low BMI as predictors as well as adjusting for potential confounders and covariate are presented in **Table 6**. There were no significant interaction between anemia and low BMI in relation to food insecurity (p=0.28). Even though low BMI was not statistically significant, it had tendency towards predicting food insecurity status (p=0.06). Similar to the findings in table 4, age, SES, education and parity are all significantly associated with food insecurity.

Table 6: Associations between Anemia, Food insecurity and low BMI in women of reproductive ages (15-44y) in Vietnam

Model predictors	Anemia	
	OR (95% CI)	**P-value**
Low BMI	0.9 (0.7-1.0)	0.06
Food Insecurity	1.0 (0.8-1.1)	0.63
Age category	0.7 (0.7-0.8)	< 0.01
Socioeconomic Status	2.8 (2.5 – 3.0)	< 0.01
Education	1.2 (1.0 – 1.3)	< 0.01
Number of pregnancy / parity	0.8 (0.7 – 0.9)	< 0.01

Effect modification by Low BMI and Anemia on Food Insecurity was tested, found non-significant (p=0.28) and dropped out of the final model

CHAPTER 4: DISCUSSION AND RECOMMENDATION

Discussion and key findings

The purpose of this study was to examine associations between anemia, low BMI and food insecurity as well as assess co-occurrence of these common nutritional issues in non-pregnant women in rural Vietnam using data from the PRECONCEPT study. Similar to previous studies our study found significant differences in characteristics of women who were anemic, had low BMI and women with both anemic and low BMI (Samper-Ternent et al, 2011; Pasricha et al,2008; Ninh et al, 2003;). Interestingly, although the prevalence of anemia and low BMI was statistically higher in younger women (< 25 years old) than older women (>30 years old) (8.2% vs. 4.5% and 14.9% vs. 5.3% respectively), women with both nutritional conditions (anemia and low BMI) showed no significant difference in prevalence in relation to age. Observations on ethnicity and anemia from our data are consistent with the literature that ethnic minority groups in Vietnam have higher anemia prevalence (11.6% vs. 8%) than the Kinh ethnic group (Trinh & Dibley, 2007). Surprisingly, women from food secure households had significantly higher prevalence of anemia (12.6% vs. 6.9%) in comparison to those from food insecure households. This association was also similar in women with both anemia and low BMI (3.4% vs. 2.1%). Similarly, although not statistically significant (p=0.06), higher prevalence of low BMI was also observed in food secure than insecure households (21% vs. 10.4%). These results contradict prior research linking low BMI, a wasting syndrome, and anemia, an outcome of poor diets and food insecurity (Eicher-Miller et al, 2009; Thompson, 2007; Jackson, 2007; Skalicky, A. et al, 2006). Nevertheless, our study is similar to the findings by Osei, et al (2010) on food security and nutritional status of children (6 to 23 months of age), which found no significant association between household food insecurity and stunting, underweight, or anemia in children. Furthermore, the Food Agriculture Organization (FAO) reports that household food security and access to food does not necessarily result in improvements in nutritional status, rather, there are other key determinants that can influence women's nutritional status including nutritional knowledge and skills, workload, frequent infection, intra-household food allocation and utilization, access to health services, healthy environment and conditions such as good hygiene and sanitation (FAO, 2001, 1997).

As literature on nutritional issues suggests shared underlying causes including poverty and lack of nutritious diet, it is expected that there could be co-occurrence of these conditions within individuals. This paper examined the possible co-occurrence of anemia, low BMI and food insecurity. The comparison of expected and observed values in table 3 showed evidence for co-occurrence in the two-way combinations of 1) anemia and low BMI and 2) anemia and food insecurity in NPW in Vietnam. Despite appearing statistically significant, the actual differences between observed and expected co-occurrence of nutrition problems were very small (< 1%). As a result, our findings suggest that for the nutrition problems considered in this analysis, having one or two problems does not appreciably increase the probability of having another. One observation for such findings may be due to the fact that the mutual dependency for the probability of occurrence in this population may be the driven by demographic factors. Furthermore, determinants and predictors for anemia, low BMI and food insecurity may be due to other unforeseeable factors such as genetics, culture, household dynamics and structures etc., (FAO, 1997) which can influence the likelihood of co-occurrence of these nutritional problems.

Our study moves beyond earlier studies of the association and co-occurrence of the three common nutritional problems to analyze interdependencies of anemia, low BMI and food insecurity with predictors such as age, education, SES, hookworm and parity. A multivariate logistic regression from this study population showed that only SES and education were significant predictors of anemia while age was the only meaningful relationship with women's low BMI status. The significance of these factors support the literature on non-biological factors influencing anemia and BMI including education, household size, income, age, parity and birth spacing (Trinh & Dibley, 2007; WHO, 2002). However, almost all predictive factors (SES, education, age and parity) except for hookworm indicated a significant relationship with food insecurity. (FAO, 1997) As the World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life"; thus, three direct factors influencing food insecurity and nutritional status are access to adequate nutritious foods based on household income and SES, individual's knowledge and education, and good health and well-being through access to health services and healthy environment (WHO, 2014; FAO, 1997).

Furthermore, when the interaction of food insecurity and low BMI term was considered as a joint predictor of anemia with adjustment for the same selected confounders, we found no significant interaction ($p = 0.51$). Women's low BMI status, age, SES and education were however found to be significant predictors of anemia and consistent with extensive literature on the associations of anemia (Pasricha et al,2008; Thompson, 2007;

Trinh & Dibley, 2007; Ninh et al, 2003; Hung et al, 2005). In addition, no significant interaction (p=0.28) was found between anemia and Low BMI as a predictors food insecurity. Therefore, our findings may suggest that determinates of both anemia and low BMI from this population may not relate to food insecurity. Nevertheless, as expected, age, SES, education and parity were all significant predictors of food insecurity (Shetty, 2006; WHO, 2002).

Strengths and limitations

One of the strengths of the study is the high-quality data collection process and large sample size (n=4972) of women of reproductive age from the PRECONCEPT study, which enabled a high statistical power for studying the hypothesized nutritional issues of interest, anemia and low BMI. The use of a standardized data collection method and surveys including the World Bank asset questionnaire for SES data and FANTA/USAID's questionnaire and guideline for household food insecurity status; and adapting them to suit the local context in the PRECONCEPT study was another strength of the study in terms of validity and reliability of the data. Additionally, the data from PRECONCEPT also allowed accounting for potential confounders such as age, ethnicity, occupation, socioeconomic status, food insecurity, parity and hookworm in all models considered. Furthermore, the participants of the study were from the rural mountainous region of Vietnam, representing an ethnically diverse, lower socioeconomic status and hard to reach group where available information and data on this population is scarce. Moreover, to our knowledge there has not been ant previous study of co-occurrence between anemia and low BMI in NPW of reproductive age especially in low income countries such as Vietnam. One of the limitations of the study was the use of only hemoglobin concentrations to determine anemia status. Additionally, the study population although carried out in the mountainous region, there was no data on altitude in the dataset; this could influence our observed associations as people living in high altitudes tend to have lower hemoglobin concentrations (WHO/CDC, 2007). The study would have been more rigorous if we included other measurements of iron status such a serum ferritin levels, transferrin receptors etc. In addition, our analysis was based on cross-sectional data that were collected during one season of the year, therefore not able to capture seasonal trends needed to fully understand the relationship between anemia, low BMI and household food insecurity. The nature of the cross-sectional study of the data also limits our ability to draw any causal conclusions. Another weakness could arise from l reporting and recall bias from the data collected from questionnaires. Even though this study accounted for several conceptual variables, residual confound is still possible.

Recommendations

Findings from this study provide insight and have important programmatic implications for nutrition interventions in NPW of reproductive age in rural Vietnam. Results from the co-occurrence analysis suggest that one nutritional problem does not substantially increase the probability of having another even though they may have similar predictors. Additionally, significant predictors associated with anemia, low BMI and food insecurity, were mostly related age, SES and education. Thus although a lot of programs focusing on nutritional issues target nutritional causes such as food security and diversity, this study suggests that programs should also focus on the underlying social causes and empowering women to reach their full potential through promoting and ensuring equal access to education, preventing early marriages, birth spacing, increase skills and opportunities to increase household incomes etc. Some suggestions for future research would be to include more indicators for iron status, replicate these findings in other settings to see the relevance and validity of the findings as well as having a longitudinal study instead of a cross-sectional analysis to examine changes over time.

REFERENCE:

Bagni, U.V., Luiz, R.R., & Da Veiga, G.V. (2013). Overweight is associated with low hemoglobin levels in adolescent girls. *Obesity research and clinical practice*, 7: e218-e229.

Balarajan, Y., Ramakrishnan, U., Ozaltin, E., Shankar, A.H. & Subramanian, S.V. (2011). Anaemia in low-income and middle-income countries, *Lancet*, 378: 2123-2135.

Bentley, M.E. & Griffiths, P.L. (2003). The burden of anemia among women in India. *European Journal of Clinical Nutrition*, 57: 52-60.

Bentley, M.E. & Griffiths, P.L. (2001). The nutrition transition is underway in India. *Journal of nutrition*, 131 (10): 2692-2700.

Brown, W.J., Mishra, G., Kenardy, J & Dobson, A. (2000). Relationships between body mass index and well-being in young Australian women. *International journal of obesity*, 24: 1360-1368.

Cepeda-Lopez, A.C., Osendarp, S.J., Melse-Boonstra, A., Aeberli, I., Gonzalez-Salazar, F., et al. (2011). Sharply higher rates of iron deficiency in obese Mexican women and children are predicted by obesity-related inflammation rather than by differences in dietary iron intake. *American Journal of Clinical Nutrition*, 93(5): 975–983.

Coates, J., Swindale, A., & Bilinsky, P. (2007). *Household Food Insecurity Access Scale (HFIAS) for Measurement of Household Food Access: Indicator Guide (v. 3).* Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

Deshmukh, J.S., Motghare, D.D., Zodpey, S.P., & Wadhva, S.K., (1998). Low birth weight and associated maternal factors in an urban area. *Indian pediatrics*, 35: 33-36.

Do, T.T., Dibley, M.J., & D’Este, C., (2004). Receiver operating characteristic analysis of body mass index to detect increased risk of functional morbidity in Vietnamese rural adults. *European journal of clinical nutrition*, 58: 1594-1603.

Dongfeng, G., Jiang, H., Xiufeng, D., Reynolds, K., Wu, X., et al., (2006). Body weight and mortality among men and women in China. *Journal of American medical association,* 295(7): 776- 783.

Du, X., Greenfield, H., Fraser, D.R., Ge, K., Zheng, W., et al. (2003). Low body weight and its association with bone health and pubertal maturation in Chinese girls. *European journal of clinical nutrition*, 57: 693-700.

Eckhardt, C.L., Torheim, L.E., Monterrubio, E., Barquera, S. & Ruel, M.T. (2008). The overlap of overweight and anaemia among women in three countries undergoing the nutrition transition. *European journal of clinical nutrition*, 62: 238-246.

Ehrenberg, H.M., Dierker, L.R.N., Milluzzi, C. & Mercer, B.M. (2003). Low maternal weight failure to thrive in pregnancy and adverse prenatal outcomes. *American Journal of Obstetrics and Gynecology,* 189:1726-1730.

Eicher-Miller, H.A., Mason, A.C., Weaver, C.M., McCabe, G.P., & Boushey, C.J. (2009). Food insecurity is associated with iron deficiency anemia in US adolescents. *The American Journal of Clinical Nutrition,* 90:1358-1371.

Fairburn, C.G. (2008). *Cognitive behavior therapy and eating disorders,* Guilford Press: New York.

Fernald, L.C.H. (2007). Social-economic status and body mass index in low-income Mexican adults, *Social science & medicine*, 64: 2030-2040.

Food and Agriculture Organization (FAO), (2003). *Measurement and assessment of food deprivation and undernutrition*, FAO: Rome. Vietnam. Accessed on February 10th 2014, available at http://www.fao.org/docrep/005/Y4249E/y4249e00.htm#Contents

Food and Agriculture Organization (FAO), (2001). *Gender and Nutrition: Gender and development fact sheets*. FAO: Rome. Vietnam. Accessed on April 13th 2014, available at http://www.fao.org/sd/2001/PE0703a_en.htm

Food and Agriculture Organization (FAO), (1997). *Agriculture food and nutrition for Africa*, Rome: Italy: Publishing Management Group, FAO Information Division.

General Statistics Office (GSO) of Vietnam, (2014). Statistical data: education, health, culture and living standard. General Statistics Office (GSO) of Vietnam. Accessed on February 10th 2014, available at http://www.gso.gov.vn/default_en.aspx?tabid=474&idmid=3

Griffiths, P.L. & Bentley, M.E., (2001). The nutrition transition in underway in India. *The journal of nutrition*, 131: 2692-2700.

Gwatkin, D.R, Rustein, S., Johnsin, K., Pande, R.P., & Wagstaff, A. (2000). *Socio-economic*

differences in health, nutrition, and population in Bangladesh. Washington, DC: The World Bank's Health and Population Advisory Service.

Hanafi, M.I., Abdallah, A.R., & Zaky, A. (2013). Study of hemoglobin level and body mass index among preparatory year female students at Taliban University, Kingdom of Saudi Arabia, *Journal of Taliban University Medical Sciences*, 8 (3): 160-166.

Hausman, D.B., Johnson, M.A., Davey, A. & Poon, L.W. (2011). Body mass index is associated with dietary patterns and health conditions in Georgia centenarians. *Journal of aging research, 2011: 1-10*

Hung, L.Q., De Vries, P.J., Giao, P.T., Binh, T.Q., Nam, N.V., & Kager, P.A. (2005). Anemia, Malaria and Hookworm infections in a Vietnamese ethnic minority. *Southeast Asia Journal of Tropical Medicine and Public Health.* 36(4): 816-821.

Jackson, A.A. (2007). Anemia in severe undernutrition (malnutrition). In K.Kraemer & M.B. Zimmermann, *Nutritional Anemia* (pp. 215-230). Basel: Sight and Life Press.

Laillou, A., Pham, T.V., Tran, N.T., Le, H.T., Wieringa, F., et al. (2012). Micronutrient Deficits Are Still Public Health Issues among Women and Young Children in Vietnam. *PLoS ONE*, 7(4): e34906- e34906.

Liabsuetrakul, T. (2011). Is international or Asian criteria-based body mass index associated with maternal anaemia, low birth weight, and preterm births among Thai population? – An observational study, *Journal of health population and nutrition*, 29(3): 218-228.

Massawe, S.N., Urassa, E.N., Nystrom, L., & Lindmark, G. (2002). Anaemia in women of reproductive age in Dar-es-Salaam, Tanzania, *East African Medical Journal*, 79(9): 461-466.

McLean, E., Egli, I., Cogswell, M., de Benoist, B., & Wojdyla, D. (2007). Worldwide prevalence of anemia in preschool aged children, pregnant women and non-pregnant women of reproductive age. In K. Kraemer, & M. B. Zimmermann, *Nutritional Anemia* (pp. 1-12). Basel: Sight and Life Press

Ministry of Health National Institute of Nutrition and United Nations Children's Fund (MOH/UNICEF), (2012). *Summary report: General Nutrition Survey 2009-2010 – National Nutrition Strategy for 2011-2020, with a vision toward 2030.* Hanoi: Ministry of Health National Institute of Nutrition

Moayeri H., Bidad K., Zadhoush S., Gholami N., Anari S. (2006). Increasing prevalence of iron deficiency in overweight and obese children and adolescents (Teheran Adolescent Obesity Study). *European Journal of Pediatrics*. 165: 813-814.

Nead, K.G., Halterman, J.S., Kaczorowski, J.M., Auinger, P. & Weitzman, M. (2004). Overweight children and adolescents: A risk group for iron deficiency. *Pediatrics*, 114 (1): 104-108.

Ninh, N., Khan, N.C., Vinh, N.D., & Khoi, H.H. (2003). *Successful micronutrient programs: Micronutrient deficiency control strategies in Vietnam.* Hanoi: National Institute of Nutrition.

Nguyen, P.H., Nguyen, K.C., Le, M.B., Nguyen, T.V., Ha, K.H., et al,. (2006). Risk factors for anemia in Vietnam, *Southeast Asian Journal of tropical medicine in public health*, 37 (6): 1213-1223

Nguyen, P.H., Strizich, G., Lowe, A., Nguyen, H., Pham, H., et al. (2013). Food consumption patterns and associated factors among Vietnamese women of reproductive age, *Nutritional Journal*, 12: 126-136.

Osei, A., Pandey, P., Spiro, D., Nielson, J., Shrestha, R., et al, (2010). Household food insecurity and nutritional status of children aged 6 to 23 months in Kailai district of Nepal. *Food and Nutrition Bulletin,* 31 (4): 483-494.

Pasricha, S., Caruana, S.R., Phuc, T.Q., Casey, G.J., Jolley, D., et al. (2008). Anemia, iron deficiency, meat consumption and hookworm infection in women of reproductive age in Northwest Vietnam. *American Journal of Tropical Medicine and Hygiene*, 78(3): 375-381.

Pinhas-Hamiel, O., Newfield, R.S., Koren, I., Agmon, Lilos, L., et al. (2003). Greater prevalence of iron deficiency in overweight and obese children and adolescents. *International journal of obesity*, 27: 416-418.

Qin, Y., Melse-Boonstra, A., Pan, X., Yuan, B., Dai, Y., et al.,. (2013). Anemia in relation to body mass index and waist circumference among Chinese women, *Nutrition Journal*, 12 (10), pp: 1-3.

Ronnenberg, A.G., Wang, X., Xing, H., Chen, C., Chen, D., et al.,. (2003). Low preconception body mass index is associated with birth outcome in a prospective cohort of Chinese women. *The journal of nutrition*, 133: 3449-3455.

Samper-Ternent, R., Michaels-Obregon, A., & Wong, R., (2011). Coexistence of obesity and anemia in older Mexican adults. *Ageing International*, 37(1): 104-117.

Shetty, P., (2006). Malnutrition and undernutrition. *Medicine*, 34 (12) : 524-529.

Skalicky, A., Mayers, A.F., Adams, W.G., Yang, A., Cook, J.T., et al,. (2006). Child food insecurity and iron deficiency anemia in low-income infant and toddlers in the United States. *Maternal and Child Health Journal*, 10 (2): 177- 185.

Tatala, S., & Mduma, B., (1998). Low dietary iron availability is a major cause of anemia: a nutrition survey in the Lindi District of Tanzania. *American journal of clinical nutrition*, 68: 171-178.

Thompson, B. (2007). Food-based approaches for combating iron deficiency. In K. Kraemer, & M. B. Zimmermann, *Nutritional Anemia* (pp. 215-230). Basel: Sight and Life Press.

Tran, D.T. (2009). FFQ for adult in rural Vietnam. In "An examination of the relationship between low body mass index and micronutrient malnutrition and the risk of morbidity in adults aged 18 to 60 in rural Vietnam", PhD thesis, The University of Newcastle, Australia.

Trinh, L.T.T. & Dibley, M. (2007). Anaemia in pregnant, postpartum and non pregnant women in Lak district, Daklak province of Vietnam. *Asian Pacific journal of clinical nutrition*, 16 (2) : 310 – 315.

Tuan, N.T., Tuong, P.D. & Popkin, B.M. (2008). Body mass index (BMI) dynamics in Vietnam. *European journal of clinical nutrition*, 62: 78-86.

United Nations System Standing Committee of Nutrition (UNSCN). (2010). *Progress in Nutrition: 6th report on the world nutrition situation.* UNSCN: Geneva. Accessed on February 28th 2014. Available at: http://www.unscn.org/files/Publications/RWNS6/html/

United Nations System Standing Committee of Nutrition (UNSCN). (1992). *Progress in Nutrition: 2nd report on the world nutrition situation.* UNSCN: Geneva. Accessed on February 28th 2014. Available at: http://www.unsystem.org/scn/archives/rwns02vol1/ch07.htm

Untoro, J., Gross, R., Schultink, W. & Sediaoetama, D. (1998). The associatin between BMI and hemoglobin and work productivity among Indonesian female factory workers. *European journal of clinical nutrition*, 52: 131-135.

Verma, A. & Shrimali, L., (2012). Maternal body mass index and pregnancy outcome. *Journal of clinical and diagnostic research*, 6(9): 1531-1533

Winther, S.A., Finer, N., Sharma, A.M., Top-Pedersen, C. & Andersson, C. (2014). Association of anemia with the risk of cardiovascular adverse events in overweight/obese patients. *International journal of obesity*, 38 (3): 432-437

World Health Organization (WHO), (2014). *Trade, foreign policy, diplomacy and health: Food Security*. World Health Organization: Geneva. Accessed on April 13th 2014. Available at: http://www.who.int/trade/glossary/story028/en/

World Health Organization (WHO), (2013). *World health report 2013: research for universal health coverage*, World Health Organization: Geneva. Accessed on February 28th 2014. Available at: http://www.who.int/whr/en/

World Health Organization (WHO), (2011). Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. *Vitamin and Mineral Nutrition Information System (VMNIS)*, Geneva: World Health Organization.

World Health Organization (WHO), (2008), *Worldwide prevalence of anemia 1993–2005: WHO global database on anemia* / Edited by Bruno de Benoist, Erin McLean, Ines Egli and Mary Cogswell. Geneva: Switzerland.

World Health Organization (WHO), (2004), *Focusing on Anaemia: Towards an integrated approach for effective anaemia control*, WHO, Geneva: Switzerland.

World Health Organization (WHO), (2002). *The world health report 2002: Reducing risks, promoting health life*, WHO, Geneva: Switzerland. Accessed on February 28th 2014. Available at: http://www.who.int/whr/2002/en/

World Health Organization (WHO), (1972), *Nutritional Anemia: Report of a WHO group of experts*. Geneva: Switzerland.

World Health Organization and Centers for Disease Control and Prevention (WHO/CDC), 2007, *Assessing the Iron Status of populations*, 2nd edition, Geneva: Switzerland.

Zijp, I. M., Korver, O. & Tijburg, L.B.M. (2000). Effect of Tea and Other Dietary Factors on Iron Absorption, *Critical Reviews in Food Science and Nutrition*, 40 (5): 371-398