ASSOCIATION BETWEEN DIETARY INTAKE AND NUTRITIONAL STATUS AMONG ADOLESCENT GIRLS IN KILOSA DISTRICT, TANZANIA

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ABSTRACT

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Underweight and stunting are highly prevalent public health problems in developing countries, particularly among populations exposed to food insecurity and chronic malnutrition. Underweight results from relatively recent malnutrition whereas empirical research has shown that early childhood malnutrition is a strong predictor of stunting. Dietary diversity has been recognized as an indicator of food security, with consumption of more food groups suggesting better nourishment. Greater dietary diversity has been associated with better nutritional outcomes and improved micronutrient intake. Zinc, an essential mineral, plays a critical role in child growth and development. A deficiency in Zinc may contribute to increased risk for stunting in childhood and adolescence.

This cross-sectional study examined the independent associations between underweight, stunting, dietary diversity, and dietary intake of zinc among a sample of never-married adolescent girls (n=307) living in Kilosa District,

Tanzania. Dietary, anthropometric, physical activity, morbidity and demographic data were collected. The associations between underweight (determined as weight by age less than 5th percentile of WHO reference) and dietary diversity (defined by the number of food groups consumed by adolescent girls); as well as stunting (determined as height by age less than 3rd percentile of WHO reference) and dietary intake of zinc were tested using multivariate analyses.

We found that adolescent girls' diets were largely deficient in macronutrients and micronutrients, with the mean intake of energy and protein being 810kcals/d and 21.9g/d, respectively. The rates of underweight and stunting were 16.2% and 62.2%, respectively. Greater dietary diversity was associated with decreased risk of underweight among adolescent girls, after adjusting for confounders including age, village location, school enrollment, pubertal status, socioeconomic status and energy intake, (OR, 0.55, 95%Cl 0.39-0.98, p<0.05). Similarly, higher intake of zinc was found to be associated with lower risk of stunting, after controlling for age, physical activity, BMI, energy intake and individual's dietary diversity (OR, 0.87; 95%Cl, 0.76-0.99, p<0.05). In conclusion, these findings suggest that dietary diversity and nutrient intake, especially intake of zinc, may play an important role in the long-term nutritional health of adolescent girls. Longitudinal studies examining these associations in developing countries settings are needed.

Keywords: dietary diversity; nutritional status; adolescent girl; zinc.

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CHAPTER 1

INTRODUCTION

Adolescents are tomorrow's adults, and they comprise approximately 20% of the world's population, of which more than 85% reside in developing countries (UNICEF, 2000; Rosen JE, 2004; Ashford L, 2006). Adolescence is an intense anabolic period when requirements for energy and nutrients increase (WHO, 1986). It is also a time of tremendous growth and development, during which 20% of final adult height, 45% of increments in bone mass and 50% of adult weight are attained (Giuseppina D, 2000). Girls gain tremendous physical, mental and emotional maturity during this period of time (Whiting SJ, 2004), while facing systematic disadvantages over a wide range of welfare indicators, including nutrition, health, and labor force participation (Levine R, 2008). With menstruation, pregnancy or lactation, girls experience greater nutrient demands (Gizis FC, 1992). Overall, the nutritional status of adolescent girls is critical given close associations that their growth status and reproductive health have with birth outcomes and child survival (Kapil U, 2002).

Malnutrition is highly prevalent in developing countries. It is defined as failure to consume adequate energy, protein and micronutrients to meet basic bodily requirements for maintenance, growth and development (Dewan M, 2008).

Malnutrition encompasses stunting (low height-for-age), underweight (low

weight-for-age), wasting (low weight-for-height), and deficiencies of essential micronutrients. Of the different forms of malnutrition, underweight and stunting are the two most common manifestations (De Onis M, 2000). It is known that malnutrition is typically associated with low-income, linked to poverty, food insecurity, limited access to health care and exposure to unsanitary conditions. These associations are particularly salient in Africa, where malnutrition continues to be a major public health issue (Cleave K, 2006; UNICEF, 2006). For example, 41% of children in Eastern/Southern Africa and 35% of children in West/Central Africa were stunted (UNICEF, 2006). In sub-Saharan Africa, 28% and 42% of children were classified as underweight and stunted, respectively (UNICEF, 2010). Another multicountry study, conducted in Ghana, Tanzania, Indonesia, India and Vietnam, reported a prevalence of 51% for stunting and 48% for underweight among children (Partnership for Child Development, 1998). While statistics on child malnutrition are widely available, limited research on adolescent nutritional health has been conducted in developing countries (Cordeiro L, 2007).

Within the past few years, emerging research on adolescent health in Sub Saharan Africa describes a high prevalence of malnutrition, especially among girls (Hadley C, 2008, Kurz K 2006, Benefice 2001, Cordeiro L 2007). Benefice et al. (2001) found that physical activity was closely related to the growth and development of West African adolescent girls and gender bias was a

contributor to food insecurity among Ethiopian adolescent girls (Hadley, 2008).

Setting of the study

Tanzania is located in central East Africa. It was ranked the 4th among the 10 poorest countries in the world (World Bank, 1996). Over one third of Tanzanians live below the poverty line (World Bank, 2005) with almost 60% of Tanzanian households reporting difficulty in meeting food needs (NBS and ORC, 2005). The prevalence of poverty is especially high in rural areas of this country, where 87% of the population lives, and is highest among households who solely depend on agriculture (Ministry of Agriculture Food Security and Cooperatives of Tanzania, 2006). Food insecurity in Tanzania is both transitory and chronic in nature. Chronic food insecurity is common among poor urban households and rural households with little or no land, regardless of agricultural season (Ministry of Agriculture Food Security and Cooperatives of Tanzania, 2006).

Malnutrition remains a major problem in the nation (Ministry of Health of Tanzania, 1992; Poverty and Human Development Report, 2005). According to the Poverty and Human Development Report in 2005, there was no significant nutritional status improvement for children under five in Tanzania. Stunting, though on decline, continues to affect a large proportion of children in the country. In 1999, 40% of children were found to be underweight (UNICEF,

2009); in 2004, 38% of children were stunted (UNICEF, 2009). Overall, malnutrition is much worse in rural areas than in urban areas (Ministry of Health of Tanzania, 1992). Despite the long-term consequences of malnutrition, there is little literature on the sociodemographic and dietary contributors to poor nutritional status among adolescent girls in Tanzania, and we aim to investigate these critical associations in this study in Kilosa District.

The study recruited adolescent girls aged 10 to 19 years, scattered into 28 rural and mixed wards villages across Kilosa District in Tanzania. Kilosa is one of the 6 districts of the Morogoro Region of Tanzania, located 300 km west of Dar es Salaam with 135 registered villages. The initial design and data collection of this study was conducted by Dr. Lorraine Cordeiro and her research team, under the auspices of United Nations Children Fund (UNICEF)/Tanzania, and funding from Tufts University School of Nutrition Science and Policy.

Conceptual framework

The conceptual framework for this study was based on the understanding that malnutrition in adolescent girls is a chronic health issue in developing countries (Figure 1.1). The framework centers on the theory of causes and consequences of malnutrition (UNICEF,1998), which integrates community and household factors, long term origins and short term contributors of

nutritional status and reproductive health among adolescent girls. The conceptual framework details the implications of current dietary patterns and nutrient intake on the presence of underweight and stunting among adolescent girls. We also considered the influence of diet on the onset of menarche. The framework considers these associations in the context of potential influential factors including but not limited to age, physical activity, and socioeconomic status.

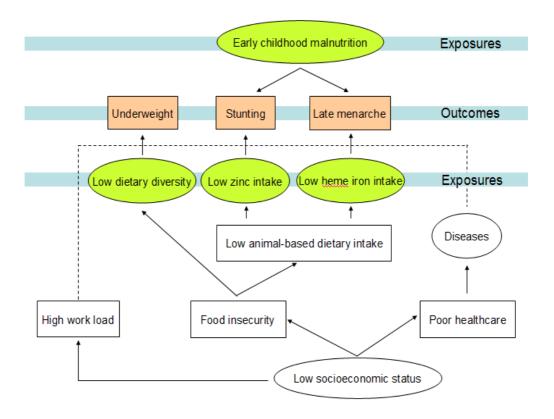


Figure 1.1 Conceptual framework

Specific aims

The primary specific aim of this study was to examine the independent role of current dietary diversity in predicting underweight among adolescent girls aged 10-19 years living in Kilosa District, Tanzania. We described the macro- and micro- nutrient profile of this sample. The secondary specific aim was to

determine the independent association between current dietary zinc intake and the risk of stunting. In this study, zinc was of particular research interest due to the important role it plays in growth (Brown KH, 2002; Brown KH, 2009). In addition, we described the difference in nutritional status and dietary intakes across levels of pubertal attainment. Understanding these associations is of critical importance for rectifying malnutrition among adolescent girls and improving their reproductive health. The findings of this study will inform the development of future public health policies.

The outcomes in the study were underweight and stunting among adolescent girls. Exposures in this study were current dietary patterns including dietary diversity and dietary intake of zinc. The choice of variables was made because of the fact that adolescent girls in developing countries experience chronic food insecurity over childhood, which suggests a limited fluctuation in dietary patterns within rural households over time. Thus gives rise to the possibility that measures of current dietary intake might act as a proxy for past dietary intake (Rohan et al, 1984; Byers et al, 1986).

Research Questions

1: Is adolescent girls' current dietary diversity (IDDS) associated with underweight?

Hypothesis: Adolescent girls are more likely to be underweight if their

current dietary diversity (IDDS) is low, after controlling for age, socioeconomic status, physical activity, morbidity, and daily energy intake.

2: Is current dietary zinc intake associated with the presence of stunting among adolescent girls?

Hypothesis: Adolescent girls are more likely to be stunted if their current dietary zinc intakes are low, after controlling for age, BMI, socioeconomic status, physical activity, and daily energy intake.

3: Does dietary intake differ between pre-pubertal and pubertal girls?

Hypothesis: Adolescent girls who have reached puberty are more likely to consume a more nutritious current diet, compared with those pre-pubertal girls, after controlling for age, BMI, socioeconomic status, physical activity, morbidity and daily energy intake.

CHAPTER 2

BACKGROUND

Adolescent girls in developing countries

Adolescent girls, aged 10 to 19 years (WHO, 1986a), stand at the threshold of a transition to adulthood. In 2009, there were 1.2 billion adolescents in the world, half of which were girls (UNICEF, 2011). The vast majority (88%) of adolescents live in developing countries (UNICEF, 2011). However, adolescents in developing countries remain a largely neglected, difficult to measure, and hard to reach population, in which the needs of adolescent girls are often ignored (WHO, 2003). In recent years, there has been greater attention paid to this age group due to their demographic weight and the increasing awareness of problems among this population.

Dietary requirements for girls increase during adolescence because of pubertal growth and menarche (Ahmed F, 1998; Dimeglio G, 2000). Nutrient needs parallel the rate of growth, with the greatest nutrient demands occurring during peak growth velocity (Story M, 1992). At the peak of growth spurt, the nutritional requirements may be twice as high as those of the remaining period of adolescence (Forbes GR, 1992). However, malnutrition has been observed among many adolescent girls in developing countries (International Labor Organization, 2010), due to poverty and gender bias (WHO, 1993). The direct

cause of malnutrition is dietary inadequacy, with immediate and long-term complications including underweight, short adult height and delayed sexual maturation (Dimeglio G, 2000). Therefore, accelerated growth among adolescent girls may be particularly influenced by dietary inadequacy, although the impact of the timing, duration, and severity of food deprivation that lead to compromised adult growth remains unclear.

Dietary diversity

Dietary diversity is defined as the number of different foods or food groups that are consumed over a given reference period (WHO, 1996). It reflects household access to a wide variety of foods, and is used as a proxy of the nutrient adequacy for individuals (Swindale and Bilinsky, 2006; Mirmiran P, 2004). Dietary diversity has long been recognized as a key element of high quality diets because all people need a variety of foods to meet requirements for essential nutrients (Hoddinot and Yohannes 2002). Lack of dietary diversity is a particularly severe problem in developing countries where diets are predominantly based on starchy staples and little or no animal products (Ruel MT, 2003). These plant-based diets tend to be low in a number of micronutrients including zinc, and those micronutrients often exist in the forms with low bioavailability (Ruel MT, 2003).

The most commonly used method to measure dietary diversity is to sum the

number of individual foods or food groups, known as dietary diversity score (DDS) (Kreb-smith S,1987; Lowik M, 1999; Swindale and Bilinsky, 2006), consumed over a reference period, usually ranging from 1 to 3 days, sometimes 7 days (Drewnowski A, 1997). In developing countries, this is the most popular measurement of dietary diversity (Ruel MT, 2003), due to its simplicity. The calculation of score is different if used at household or individual level. The household dietary diversity score (HDDS) reflects the economic ability of a household to consume a variety of foods, whereas individual dietary diversity score (IDDS) aims to capture nutrient adequacy. IDDS has been positively correlated with increased mean micronutrient density adequacy of complementary foods (FANTA, 2006) and micronutrient adequacy of the diet in non breastfed children (Hatloy, 1998; Ruel, 2004; Steyn, 2006; Kennedy, 2007) and in adolescents (Mirmiran, 2004).

Individual dietary diversity is a useful indicator of food security (Hoddinott, 2002; Ruel MT, 2003), and may also play a key role in the nutritional status of different populations. For example, a strong association between dietary diversity and height for age was observed among non-breastfed children in Kenya and Peru (Onyango A, 1998; Marquis GS, 1997). Studies conducted separately in China, Mali, and Haiti found positive associations between dietary diversity and nutritional status in young children (Taren D, 1993; Hatloy A, 2000; Ruel MT, 2004). In a West African study, the rate of underweight was

found to be much higher among women with low dietary score compared to women with higher dietary scores (Savy M, 2005). Based on these findings, we hypothesized that adolescent girls' current dietary diversity would be associated with the risk of underweight in this study.

Malnutrition

The United Nation's Food and Agriculture Organization (FAO) estimated that, approximately 1 billion people worldwide were undernourished in 2009. Food insecurity and malnutrition have devastating effects on adults and children within households. Adolescent girls are vulnerable to changes in household food consumption and consequential food insecurity. These factors can exacerbate poor health outcomes among this population. Malnutrition during early childhood and chronic nutritional inadequacy, often a consequence of household food insecurity, could lead to impaired bodily capacities, such as growth retardation, inability to resist infections or recover from disease, cognitive and physical work output, etc (Alderman H, 2006). Overall nutritional status has been shown to be poor among adolescent girls in developing countries (Bryce J, 2005; Kurz K, 2006). Girls from less educated families were also more likely to be thin and short for their age and to have diets of poorer nutritional quality in Nigeria (Brabin et al, 1997). Two manifestations of malnutrition presented in this study are underweight and stunting.

Underweight

Underweight represents depleted body fat and/or lean tissue stores; it remains a major public health problem and is a leading contributor to the disease burden in low income countries (Ezzati M, 2002). The most common cause of underweight is malnutrition caused by the unavailability of adequate food.

Although there are no expert guidelines for classifying underweight based on body mass index (BMI) for adolescent girls, the WHO defines underweight as a BMI below the 5th percentile for age (2006). Poor nutritional status afflicts a significant proportion of adolescents in developing countries (Fig 2.1).

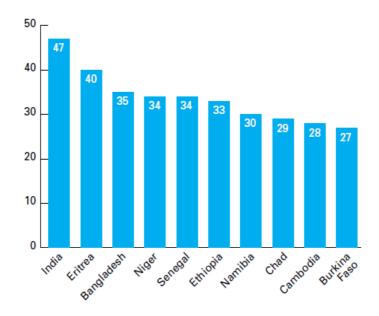


Figure 2.1 percentages of underweight girls aged 15-19 years in some developing countries (UNICEF, 2011)

Underweight is linked to growth faltering and is associated with increased morbidity and mortality among adolescents (Luder E, 2005). Affected individuals may have poor physical productivity and a weak immune system, leaving them prone to infections that further compromise nutritional status. There is an extensive literature base for underweight in infants and young

children, but limited information on this nutritional state exists for adolescent girls. Given the high prevalence of underweight among adolescents, and its implications for health and productivity, studies examining social and dietary determinants of underweight in this population are of primary importance.

Stunting

Stunting is defined as height below two standard deviations from median height-for-age of a reference population (UNICEF, 2006). Stunting reflects a state of chronic malnutrition, often coupled with disease, in early childhood (Caputo A, 2003). Approximately 15% of adult height is gained during adolescence (Brasel, 1982), with over 80% of girls attaining their adult heights during adolescence (10-15 years), and a marked deceleration in velocity in the post-pubertal phase (Srikantia, 1989). Empirical evidence suggests that optimal nutrition during the prepubertal growth spurt, ranging from 18 to 24 months immediately preceding menarche, results in a marginal level of catch-up growth from nutritional deficits suffered earlier in life (Spears BA, 2002).

It is important to recognize that the potential for significant catch up growth is limited beyond the age of two years (Gillespie S, 2000). Stunting is particularly pronounced when children remain in food insecure and malnourished conditions (Bassey J, 2002). For example, a study in Guatemala found that

nearly 67% of severely stunted and 34% of moderately stunted three-year-old girls later became stunted adult women (Ruel MT, 1995).

Menarche

Menarche, defined by the first menses, is an important experience in a woman's reproductive career. There is a large variation in the average timing of menarche, which ranges from 12.5 years in developed countries, to 15 and above in developing countries (Becker, 1993). Several factors are likely to be involved in this variance, out of which nutritional status is considered to be a major one (Riley AP, 1993; Karlberg J, 2002).

Generally, it is believed that the accumulation of a critical degree of fatness triggers the onset of menses (Frisch RE, 1973). The female hormone estrogen plays a key role in menarche, as well as in epiphyseal maturation among prepubertal girls (Cutler GB, 1997). Estrogen is produced primarily by the ovaries, with significant quantities also released from fat cells. Thus, variability in the degree of fatness influences peripherally produced estrogen levels, which might explain why menarche can be delayed in undernourished girls compared to those who are better nourished (WHO, 2003). A recent longitudinal study in Ethiopia found that food insecure girls had menarche one year later than their food secure peers (Belachew, 2011). Low iron stores throughout childhood may also contribute to delays in the onset of menarche

(Brain L, 1997).

Menarche is considered a late marker of sexual maturation (Marshall and Tanner, 1969). There is a large body of literature on growth and menarche. The growth spurt in girls typically occurs between 12 and 18 months before the onset of menarche, with much slower growth in height continuing for up to 7 subsequent years. Growth of pelvic bones continued for another 2-3 years after final height is reached (Moerman 1982). Menarche is considered a valid indicator of pubertal attainment in adolescent girls (Hagger U, 1982).

Micronutrients

Zinc intake

Zinc is an essential trace mineral and a cofactor for nearly 200 metallo-enzymes that are involved in numerous biochemical processes such as skin integrity, immunity, bone formation, tissue growth and development (Food and Nutrition Board, 2001). Zinc deficiency results in depressed immunity, impaired taste, poor wound healing, delayed sexual maturation and growth retardation (Polysangam A, 1997).

The global prevalence of zinc deficiency is not known, largely because zinc status is difficult to determine (Brown KH, 2002). Animal products are the major sources of zinc, and are consumed in very low amounts by children in

developing countries (Bryce J, 2005). Therefore the risk of zinc deficiency is high in these areas.

Impaired linear growth is a prominent feature of zinc deficiency among children in both developed and developing countries (Hambridge, 2000; Brown KH et al, 2002). Gibson et al (2007) also reported a significant and positive relationship between stunting and serum zinc concentrations among children. In addition, Prentice et al (1994) found that increased dietary zinc intake resulted in height gains in certain vulnerable groups, indicating the importance of dietary zinc adequacy in linear growth among children in developing countries. Similarly, a preventive zinc supplementation trial among prepubertal adolescents revealed that zinc supplements increased linear growth and weight gain by a small, but highly significant, amount (Brown 2002).

A recent review analyzing results from 36 studies assessing the effect of zinc supplementation on linear growth found a significant positive effect of zinc supplementation on linear growth, particularly when administered alone, among children under 5 years in developing countries (Imdad A, 2011). Recommendations for interventions to improve children's zinc intake should be considered in populations at risk of zinc deficiency, especially where there are elevated rates of underweight or stunting (Brown KH, 2002; Imdad A, 2011). Based on these findings, we proposed that dietary zinc intake would be

associated with stunting in this sample.

Iron intake

Iron is vital for the synthesis of hemoglobin (Hb), which transports oxygen in the bloodstream (Broady T, 1999). Nutritional iron is usually divided into two types (Theil EC, 2004): heme, for which iron is absorbed as the stable porphyrin complex unaffected by other food components, and non heme iron, as in relatively weak complexes, which can be trapped by food components such as phytate or tannins during digestion, thus reducing the bioavailability of iron. Heme iron, which comes from hemoglobin and myoglobin, usually exists in animal products such as meat (Monsen ER, 1978), and non-heme iron is always seen in other foods such as vegetables, grains and legumes. Actually, instead of the total amount of dietary iron consumption, it is the distribution among different chemical forms of iron and the reactivity among different types of iron ingested that determines the bioavailability of iron. A large proportion of individuals in developing countries rely on starchy staples and other plant-based foods, with little or no animal products in their diet (Ruel MT, 2003). It is very likely that adolescent girls in these areas are consuming diets low in heme iron content.

As for adolescent girls, the need for iron increases with rapid growth and the expansion of blood volume and muscle mass. Because the onset of

menstruation increases iron losses, dietary iron requirements are highest after menarche in girls (Story M, 1992). Iron requirements of adolescent girls in developing countries may be further increased because of infections such as malaria, schistosomiasis, and hookworm (Brabin, 1992), which also increase iron losses.

Low availability of dietary iron and high iron requirements are closed linked to depleted iron status (Brabin,1997). Brabin et al (1997) found that Nigerian adolescent girls who had low Hb <10g/dl) were more likely to have a low BMI that those who had higher Hb levels, suggesting that overall malnutrition is also associated with iron status. Iron deficiency may represent a high loss of productivity in physically demanding work and in less strenuous labor (Ross, 1998). It may alter cognitive function in children (Pollitt et al, 1985) and adolescents (Ballin et al, 1992), and the effects may be only partly reversible with severe or prolonged deficiency. The contribution of maternal iron deficiency anemia to poor pregnancy outcomes are well-documented (Allen LH, 2000; Scholl TO, 2000; Ronnenberg AG, 2004).

CHAPTER 3

METHODOLOGY

Participants

The study recruited 791 adolescents aged 10 to 19 years, from 28 villages in Kilosa District, Tanzania. Permission to carry out the study, ethical clearance and approval were obtained from the Tufts University Human Subjects Board and the Government of Tanzania (COSTECH). Permission and written consent were obtained from the households and from each adolescent prior to the survey administration.

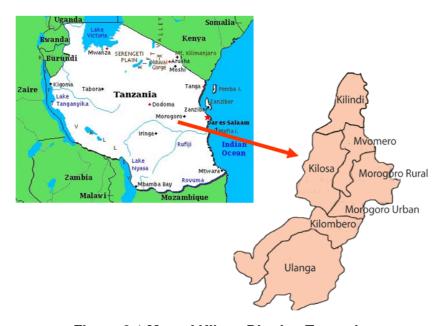


Figure 3.1 Map of Kilosa District, Tanzania

Sample Selection

Never married girls ages 10-19 years were included in this analysis because we were interested in examining the association between dietary intake and

nutritional status, excluding potential influences from early marriage, pregnancy or lactation. Furthermore, BMI is not an accurate measure of nutritional status among pregnant and early postpartum women, due to variations in maternal weight gain, fetal growth, and other gestational factors.

Protocol

A survey questionnaire was administered by the research team to adolescents and their households. Demographic information such as age, school enrollment, orphan status, puberty, and health status was collected. Heads of households completed surveys on demographics, socioeconomic status and household food security, while primary food preparers provided dietary intake information. Anthropometric data were measured at a central location in the villages, including height (cm), weight (kg), MUAC (cm) and BMI (kg/m²). The height of each adolescent girl was measured to the nearest 0.1 cm, whereas weight was measured to the nearest 0.1kg in the morning. Dietary nutrient intake was assessed from 24-hour dietary recalls using methodology from Nutrition Data System for Research (NDSR) and Harvard University School of Public Health. Dietary diversity on both household and individual levels, together with food frequency was also collected from participants. All data were collected by trained personnel in Swahili.

Dietary assessment

The data from 24-hour dietary recalls were collected from every household and adolescent girl. The research team used 2D food portion booklets to assist in estimation of portion sizes. Additionally, common standardized household measures (e.g. spoons, bowls, glasses and plates) were used to generate actual quantities of ingredients. Food models allowed the team to quantify portion sizes. Due to the limitation of the NDSR food portion booklet, which was designed for the US population, new images describing particular portion sizes of specific cultural foods such as sweet potatoes, bananas, and other indigenous African vegetables were added by the Harvard University Tanzania research team. The reported food intake was converted into units of g/d, with subsequent calculation and verification of dietary diversity and nutrient analyses completed by Harvard School of Public Health. Dietary diversity was computed by summing the number of food groups consumed on individual or household level during the past 24 hours. Food frequency categories were estimated as never, less than once per week, 1-2 times per week, 3-6 times per week, and every day, in the areas of meal skipping, meat consumption, and vegetable consumption.

Furthermore, this study used current dietary intake as a proxy indicator for chronic dietary intake. Based on rates of malnutrition across childhood in Sub Saharan Africa, as well chronic experiences with food insecurity at the

household and national level in Tanzania, we propose that dietary patterns are consistent across the course of a child's life in this region of the world. As such, consideration of current dietary intake as a proxy for past dietary intake allowed us to investigate the associations between this variable and adolescent nutritional status. This has specific relevance to stunting, which stems from nutrient insults experienced in utero and in early childhood.

Physical Activity assessment

The importance of physical activity for promoting health and preventing disease is well known (Bauman A, 2009). However, the relationship between physical activity, dietary intake and nutritional status among adolescent girls has not been studied in a developing country context. The assessment of physical activity is considered an important aspect of energy expenditure.

The International Physical Activity Questionnaire (IPAQ) has been developed and validated to enable the measurement of all dimensions of physical activities among individuals aged 15 years and older (Health and Human Services, 2008). The types of physical activity measured cross all domains of leisure time, work, transportation and household tasks. Levels of physical activity of this sample were estimated using IPAQ short forms. Self-reported minutes per week in each category were weighed by a metabolic equivalent named MET (i.e., multiples of resting energy expenditure) resulting in a

physical activity level estimation. The summary indicator was used to categorize a population into three levels of physical activity: low, moderate and high. These categories were based on the standard criteria from http://www.ipag.ki.se in the table below.

Table 3.1 The categorizing standards of physical activity

Category	Standard	
Low	Meets neither 'moderate' nor 'high' criteria	
Moderate	5 days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving at least 600 MET-minutes/week	
High	>5 days of any combination of walking, moderate-intensity, or vigorous-intensity activities achieving at least 3000 MET-minutes/week	

Statistical analysis

Statistical analysis was performed using the SPSS statistical software package version 16.0 (SPSS Inc., Chicago, IL, USA) and the level of significance was set at P<0.05. Descriptive characteristics of the study population were presented as means with standard deviations, and medians.

Student's t-test was used to compare mean values of anthropometric data and dietary intakes between prepubertal and pubertal girls. A chi-squared analysis was applied to determine associations between dietary parameters and the prevalence of underweight and stunting among adolescent girls.

Associations between current dietary patterns, nutrient intake, and poor nutritional status (i.e. underweight and stunting) were assessed using logistic regression and expressed as odds ratios with 95% confidence intervals.

Outcome variables were modeled as dichotomous events (e.g, underweight vs. not; stunting vs. not). Our exposures of interest were current individual dietary diversity and intakes of zinc. The association between potentially confounding variables, including age, geographic locations, school enrollment, socioeconomic status, physical activity, morbidity, BMI, energy intake and our outcomes of interest were assessed using univariable logistic regression models. Variables significant at the level of P <0.25 were then included in multivariable models, with their influence on odds ratio estimates assessed.

Covariates associated with our outcomes at the level of P<0.10 were included in final multivariable logistic regression models.

CHAPTER 4

RESULTS

Demographic characteristics of the study sample are shown in Table 4.1. The mean age of girls was 13 years (n=301). The mean age of first menses was 14 years (n=81). An estimated 10% (n=30) were orphans. The mean number of household members was 6, indicating that most families were large in Kilosa District. Over half (52.8%) of girls reported working, predominantly in agricultural labor. Almost all (93.2%) had moderate or high levels of physical activity. Nearly half (43.2%) of girls reported at least one symptom of illnesses such as coughing, diarrhea, or fever. Most (78.2%) girls were enrolled in schools.

Table 4.1 Demographic characteristics of girls (10-19 years) in Kilosa District,

Tanzama			
Characteristic	n	Mean ± SD	
Age (years)	301	13.1 ± 2.4	
Age of menarche (years)	81	14.3 ± 1.4	
Number of household members	307	6 ± 2	
		%	
School enrollment	240	78.2%	
Orphan status	30	9.8%	
Work (paid or unpaid)	161	52.8%	
High physical activity (meds/week>3000)	295	96.1%	
With at least one symptoms	95	43.2%	

In this sample, the mean weight was 34.5kg (n=296) and the mean height was 140.5cm (n=294) (Table 4.2). The mean BMI of the girls was 17.1kg/m²

(n=294). Younger girls has a high prevalence of underweight than older girls (19.4% vs. 10.7%, P<0.05) (Figure 4.1). The prevalence of stunting was 66.9% among 10-13 year olds and 54.5% among girls aged 14-19 years (Figure 4.2)

Table 4.2 Anthropometric characteristics and nutritional status of girls (10-19 yrs) in Kilosa District, Tanzania

Characteristic	n	Mean ± SD
Weight (kg)	296	34.5 ± 9.3
Height (cm)	294	140.5 ± 10.8
BMI (kg/m2)	294	17.1 ± 2.4
		%
Underweight (BMI for age < 5 th percentile WHO)		
10-13 years	35	19.4%
14-19 years	12	10.7%
Stunting (Height for age < 3 rd percentile WHO)		
10-13 years	119	66.9%
14-19 years	60	54.5%

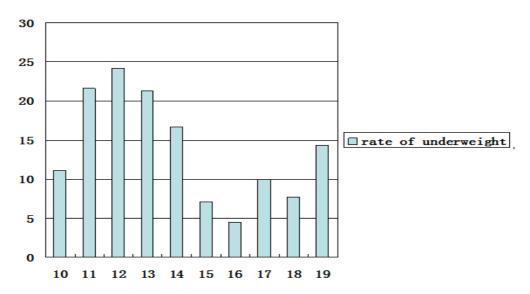


Figure 4.1 prevalence of underweight across adolescent girls (10-19 years) in Kilosa District, Tanzania

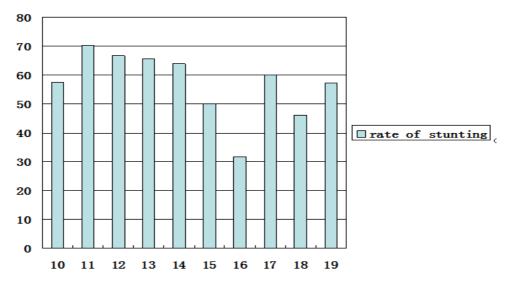


Figure 4.2 Prevalence of stunting across adolescent girls (10-19 years) in Kilosa District, Tanzania

Dietary Characteristics

Table 4.3 shows the dietary characteristics of this sample. The mean energy intake was 810.9kcals/day. The mean values of carbohydrate, protein and fat intake were 135.6g/day, 21.9g/day, and 25.6g/day, respectively. A majority of these adolescent girls' diets were energy deficient. 9.7% (n=27) of girls met

80% of their calories requirement and 21.9% (n=61) of girls met 60% of their calories requirement by age. Over half (59%) of the sample met the vitamin A intake requirements for their ages, and about one third met their folate intake recommendations (which was 34.3% for those aged 10-13 years and 28.6% for girls aged 14-19 years). Calcium intakes were extremely low, with 8.4% of girls aged 10-13 years and 4.5% of 14-19 years meeting their requirements for calcium. Similarly, 7.3% of younger and 4.5% of older girls met their zinc requirements. The percentage of dietary iron adequacy was 41% among girls aged 10-13 years and 15.4% among girls aged 14-19 years.

Table 4.3 Dietary characteristics of girls (10-19 years) in Kilosa District,

Tanzania (continued onto the next page)

Characteristic	n	Mean ± SD	% of girls with adequate intake
Energy (kcals/d)	296	819.5 ± 620.4	
Carbohydrate (g/d)	296	135.6 ± 1.2	
Protein (g/d)	296	21.9 ± 17.4	
Fat (g/d)	296	25.6 ± 2.7	
Energy/weight (kcals/kg/d)			
10-12 years	116	31.4 ± 25.4	12.1%
13-19 years	164	21.1 ± 15.5	28.7%
80% of energy requirement met	27		9.7%
60% of energy requirement met	61		21.9%
Macronutrients			
Carbohydrate (g/d)			
10-13 years	178	123.0 ± 99.7	32%
14-19 years	112	158.7 ± 143.4	41.1%

Protein/weight (g/kg/d)			
10-13 years	173	0.78 ± 0.69	39.9%
14-19 years	107	0.54 ± 0.4	18.7%
Energy from fat (%)	292		25.5%
Micronutrients			
Vitamin A (ug/d)			
10-13 years	178	875.4 ± 98.4	59%
14-19 years	112	1075.7 ± 128.7	59%
Folate (ug/d)			
10-13 years	178	275.7 ± 184.1	34.3%
14-19 years	112	319.3 ± 244.6	28.6%
Calcium (mg/d)			
10-13 years	178	535 ± 666.6	8.4%
14-19 years	112	439.3 ± 416	4.5%
Iron (mg/d)			
10-13 years	178	8.0 ± 4.7	41%
14-19 years	112	9.0 ± 6.0	15.2%
Zinc (mg/d)			
10-13 years	178	3.4 ± 2.9	7.3%
14-19 years	112	3.5 ± 2.5	4.5%

Two thirds (65.4%) of girls reported eating less due to food scarcity in the past 7 days, and one third (33.2%) reported skipping meals due to food scarcity in the past 7 days (Table 4.4). In contrast to heavy consumption of green vegetables everyday in past 7 days (83.4%), more than half (50.2%) of girls reported not consuming any meat or fish in past 7 days. On average, adolescent girls consumed one less food group than the average household

(Table 4.4).

Table 4.4 Food frequency characteristics of girls (10-19 years) in Kilosa District,

Tanzania

Tunzuma		
Food frequency variable	n	%
Eat less due to food scarcity in past 7 days	195	65.4%
Skip meal due to food scarcity in past 7 days	88	33.2%
No meat or fish to eat during past 7 days	154	50.2%
Green vegetables everyday in past 7 days	256	83.2%
Dietary diversity		
Adolescent dietary diversity	303	3 ± 0.9
Household dietary diversity	307	4 ± 1.3

<u>Descriptive analysis of characteristics of prepubertal and pubertal adolescent girls</u>

Nearly all sociodemographic and dietary characteristics were similar between prepubertal and pubertal groups. The mean values of individual dietary diversity and household dietary diversity was also similar between two groups (Table 4.5). As expected, adolescent girls who had reached puberty were significantly older than their prepubertal peers. In addition, the mean values of weight, height and BMI of pubertal girls were all significantly larger than girls who had not experienced menarche. These results were consistent with previous findings that well nourished girls tend to reach puberty earlier than their undernourished peer (Frisch RE, 1973; WHO, 2003).

Table 4.5 Comparison of characteristics of girls (10-19 years) in puberty and pre-pubertal groups from Kilosa District, Tanzania

	Pubertal group	Pre-pubertal group	
	(n=74) Mean ± SD	(n=212) Mean ± SD	P value
	Wear I 3D	Wear 1 3D	i value
Anthropometric Charac	cteristics		
Age (yrs)	15.9 ± 1.8	12.1 ± 1.1	<0.001
Weight (kg)	45.8 ± 6.2	30.2 ± 6.2	<0.001
Height (cm)	151.4 ± 4.9	136.2 ± 9.6	<0.001
MUAC (cm)	23.9 ± 2.2	19.4 ± 1.9	<0.001
BMI (kg/m2)	19.7 ± 1.9	16.1 ± 1.7	<0.001
Dietary Characteristics			
Adolescent dietary diversity (ADDS)	3.1 ± 1.0	3.2 ± 0.9	0.80
Energy (kcals/d)	834.1 ± 609.5	778.6 ± 584.0	0.49
Protein (g/d)	21.5 ± 13.7	22.0 ± 18.8	0.83
Fat (g/d)	27.6 ± 29.6	24.9 ± 26.8	0.46
Carbohydrate (g/d)	152.1 ± 140.5	125.7 ± 103.8	0.08
Vitamin A (ug/d)	1099 ± 1416.1	849.2 ± 795.1	0.06
Folate (ug/d)	309.9 ± 218.0	284.1 ± 204.6	0.35
Calcium (mg/d)	467.8 ± 409.9	505.2 ± 637.8	0.63
Iron (mg/d)	8.4 ± 5.2	8.1 ± 5.0	0.68
Zinc (mg/d)	3.3 ± 2.2	3.4 ± 2.9	0.72
% of energy requirement met	37.2 ± 28.3	39.8 ± 30.1	0.52

Multivariate Analysis

Underweight

Univariable logistic regression revealed significant associations between underweight and the variables rural location, school enrollment, pubertal status and individual dietary diversity (p < 0.05) (Table 4.6). Age, socioeconomic status, energy intake, carbohydrate intake and household dietary diversity were significant at the level P<0.25 in univariable logistic regression analysis. Variables were selected for inclusion in the multivariable logistic regression models if they were significant at or below the P<0.25 level. Carbohydrate intake and household dietary diversity were eliminated from multivariable models due to multicollinearity with energy intake (p<0.001) and individual dietary diversity (p<0.001), respectively. Univariable logistic regression analysis is included in Appendix 1.

Multivariable logistic regression revealed three significant predictors of underweight: age, rural location, and individual dietary diversity after adjusting for potential confounders (Table 4.6). For every year increase in adolescent girl's age, the odds of being underweight increased by 31%, after adjusting for covariates (OR 1.31, p<0.05). Similarly, living in rural villages was associated with increased odds of being underweight by 5.88 times, after adjusting for covariates (OR 5.88, p<0.05). In addition, consumption of every one additional food group at the individual level decreased the odds of being underweight by

45%, after adjusting for covariates in the model (OR 0.55, p<0.05).

Table 4.6 Logodd associations between underweight and dietary indicators among adolescent girls (10-19 yrs) from Kilosa District, Tanzania ^{1,2}

	N=291	
Dietary indicators	OR	P value
Energy/100 (kcals)	0.99	0.91
Adolescent dietary diversity (ADDS)	0.55	0.011
Covariates		
age	1.31	0.021
Rural	5.88	0.006 ¹
Enrollment	1.45	0.65
Puberty	11.74	0.72
Socioeconomic status		
Quartile 1	Ref	
Quartile 2	0.70	0.50
Quartile 3	0.53	0.24
Quartile 4	1.53	0.38
puberty * age ²	0.69	0.41
ADDS * energy intake ²	0.99	0.27
constant	0.03	0.06
Nagelkerke R-Square		0.218

¹ Statistical significance assessed by P<0.05; P<0.01

² The interaction term was significant at P<0.10

Stunting

Univariable logistic regression revealed significant associations between pubertal status, school enrollment, BMI and energy intake and the presence of stunting, with p < 0.05 (Table 4.7). Age, rural location, physical activity were significant at the P<0.25 level in univariable logistic regression analyses (Appendix 2). Covariates retained in multivariable logistic regression included variable significant at the P<0.25 level. Multivariable logistic regression revealed three significant predictors of stunting: age, BMI, and dietary zinc intake (Table 4.7). For every year increase in adolescent girl's age, the odds of being stunted increased by 42%, after adjusting for covariates (OR 1.42, p<0.05). However, every 1 kg/m2 increase in BMI decreased the odds of being stunted by 20%, after adjusting for covariates (OR 0.80, p<0.05). Similarily, every 1 mg increase in daily dietary zinc intake at the individual level decreased the odds of being stunted by 22%, after adjusting for covariates in the model (OR 0.78, p<0.05).

Table 4.7 Logodd associations between stunting and dietary indicators among adolescent girls (10-19 yrs) from Kilosa District, Tanzania ^{1,2}

	N=288	
Dietary indicators	OR	P value
Energy/weight (kcals/kg)	1.02	0.14
Zinc (mg)	0.78	0.04 ¹
Covariates		
Age (yrs)	1.42	0.0011
Puberty	0.75	0.72
Enrollment	0.81	0.64
BMI (kg/m²)	0.80	0.02 ¹
puberty * age ²	1	0.04
zinc intake * energy intake ²	1.00	0.34
constant	3.57	0.48
Nagerkerke R-Square		0.164

¹ Statistical significance assessed by P<0.05; P<0.01

² The interaction term age(centered)*puberty was significant at P<0.10

CHAPTER 5

DISCUSSION

The vast majority (78.2%) of these girls were enrolled in school, which was lower than the rate of primary school enrollment (99%) for girls across the country (UNICEF, 2005-2009). However, primary school enrollment is mandatory in Tanzania, and may have influenced the responses. It is also not known whether enrolled girls attended school on a daily basis. The rate of HIV infection and prevalence of AIDS in Tanzania may account for the high ratio of orphan girls found in this study. The high prevalence of self-reported illness observed in this study is corroborated by previous research in Sub Saharan Africa, which indicates that over 50% of children suffer from infectious and other diseases (UNICEF, 2006-2009).

A significant proportion of these adolescent girls had inadequate diets and poor nutritional status. The prevalence of stunting was much higher than that of underweight, suggesting chronic undernourishment experienced during early childhood. Previous findings in Tanzania indicate an overall higher prevalence of stunting (44%) than underweight (17%) (UNICEF, 2003-2009). Close examination of this cross-sectional data indicates a decline in the prevalence of underweight and stunting across age cohorts. This decline is substantial for underweight and marginal for stunting, thus supporting

empirical findings that height growth is programmed before the age of 2 years and the catch up in linear growth was only partial during adolescence (Gillespie S, 2000). Studies have found that adolescent girls experience better nutritional status as they transition into adulthood (Bangladesh study, Andrew Thompson) Improved nutritional status in late adolescence is important for child-bearing women who wait until early adulthood to begin their families. The risk for poor maternal nutrition is significant for Tanzanian women, most of whom give birth to their first child before the age of 18 years (DHS 2005).

In this study, adolescent girls' diets were generally deficient in both macronutrients and micronutrients. This is consistent with previous findings because it is known that diets that place people at risk for malnutrition are those deficient in macronutrients (leading to protein-energy malnutrition), or micronutrients (minerals and vitamins, leading to specific micronutrient deficiencies) or both (Mulle O, 2005; Millward DJ, 2004).

The intakes of vitamin A and folate were the highest two among all micronutrients, and this could be explained by the fact that these girls' diets were basically plant based, especially consisting of green leafy vegetables. Although intake of vitamin A was sufficient, the lack of biomarkers in this dataset limits our ability to infer the serum status of vitamin A. The poor consumption of fat in the diet would compromise bioavailability and absorption

of vitamin A. Folate was only sufficient for one-third of the girls, raising concerns about the risk for low birth weight and premature infants, and infants with neural tube defects among women who become pregnant while experiencing folate deficiency (Green NS, 2002).

The low calcium and zinc intakes pose significant risks for growth and bone health. These findings are also within our expectations because the consumption of dairy products (the major source of calcium) and animal products (the major source of dietary zinc) was extremely low among these girls. Overall, dietary iron adequacy was better than that of both calcium and zinc. This may be due to the reason that most of the girls' iron intakes were in the form of non-heme iron, existing in the vegetables and legumes in their diets. Again, we are unable to infer iron status in this study and intake levels do not accurately affect iron availability and iron stores in the body. Since dietary intake of iron did not vary across adolescence, increased iron requirements for older girls (Story M, 1992) explains the relatively greater inadequacy of iron requirements found among 14-19 year olds in this study. Overall, adolescent girls lived in highly food insecure environment, with frequent experience of food shortage at the household level, especially in the form of animal products.

Further examination of the data is necessary to determine the pattern of consumption between adolescents and their respective households. Hadley et

al (2008) found gender disparities in experiences of individual food security among Ethiopian adolescents, with girls faring worse than boys. Uneven distribution of food within the household may be a contributor to disparities in food consumption. A large proportion of girls were eating less and skipping meals due to food scarcity, and the lack of animal proteins in the diets existed in more than half of this sample. These findings raise concerns about overall nutritional health and well-being of adolescents and potential risks to their reproductive, as well as future maternal and fetal health (Gillespie, 2000). Nutrition and health programs typically address the needs of these girls after they are pregnant or when they enter the health system for prenatal care; these interventions may come too late in the reproductive cycle considering the results presented here.

This study demonstrates that that higher dietary diversity was associated with lower risk of underweight, after adjusting for potential confounders. Also, higher intake of zinc was associated with lower risk of stunting, controlling by potential confounders. Research investigating the role of zinc supplementation on linear growth of adolescent girls, particularly in developing countries, is recommended.

In conclusion, our results add to the literature base on two persistent nutritional problems among adolescent girls in developing countries (Maiti S,

2011). Tanzanian adolescent girls living in rural areas face a great risk from nutritional stress that could adversely impact their growth and development, and ultimately their economic productivity. Early childhood intervention, as well as persistent nutrition efforts throughout childhood could result in marked difference in nutritional status among adolescents. This in turn can lead to improved pregnancy, birth, and infant outcomes, which is central to national development.

Limitations and Strengths

Limitations of this study include a relatively small sample size of pubertal girls (n=74) and the potential underreporting of adolescent girls' dietary diversity and nutrient intake. A larger sample size of girls who have reached puberty would have increased the statistical power to detect the differences between girls of different pubertal status. Secondly, this study was a cross-sectional survey, which collected only the most recent dietary practices by adolescent girls and their households, and the degree to which their previous 24-hour diets could represent their habitual or normal dietary practices is limited. Multiple 24 hour dietary recalls may have provided better information on adolescent diets.

Furthermore, blood samples would have been desirable to assess serum micronutrients concentrations and correlate these findings with dietary intake

information. This analysis was a secondary data analysis, and we were not involved in the survey and interview development and methods, nor did we have any control over data collection process and errors. Overall, it is possible that a larger sample size of pubertal girls and the collection of biomarkers may have revealed other significant associations between current dietary pattern, nutrient intake, nutritional status, and puberty timing.

Notably, one major and unproven assumption underlying our use of 24-hour recall for dietary diversity and nutrient intake is that recent quality of diet is a good proxy for long term dietary diversity and nutrients intake. Note that a failure of this assumption would result in a lack of association between dietary diversity, nutrient intake and nutritional status. Another issue was that this study was conducted during the drought months in Tanzania, when the types and amount of foods available to these adolescent girls were the least available across the year. Thus the timing of the data collection may reflect worse dietary practices and nutrient intake than the average intake throughout a period of time among the adolescent girls. However, the selected season was appropriate given the study's intention to capture food insecurity. In addition, food insecurity is chronic in the Tanzanian context. It is likely that dietary patterns would have maintained across seasons given the relative scarcity of food and high levels of poverty in rural areas of Kilosa District. Finally, causal links cannot be made due the study design.

The major strengths of this study include the high response rate (94%) of the participants, the detailed characteristics of adolescent girls and the rigorous design which considered multiple confounding variables. NDSR was also used for the 24 hour dietary recall, which improved the accuracy of dietary data as well.

APPENDIX A

ASSOCIATIONS OF UNDERWEIGHT AND COVARIATES

Table A.1. Univariable logistic regression of underweight by covariates (continued onto the next page)

	Univaria	Univariable model	
	OR	P value	
Age (yrs)	0.91	0.19 ¹	
Rural	3.29	0.031	
Enrollment	0.29	0.021	
Puberty	0.15	0.002 ¹	
Socioeconomic status			
Quartile 1	Ref		
Quartile 2	0.83	0.68	
Quartile 3	0.50	0.16 ¹	
Quartile 4	1.08	0.86	
Height (cm)	0.95	0.002 ¹	
Weight (kg)	0.84	0.000^{1}	
MUAC (cm)	0.47	0.000^{1}	
BMI (kg/m2)	0.08	0.000^{1}	
Energy/100 (kcals)	0.96	0.19 ¹	
Protein (g)	0.99	0.45	
Carbohydrate (g)	0.99	0.14 ¹	
Fat (g)	0.99	0.35	
Vitamin A/100 (ug)	0.99	0.60	
Iron (mg)	0.98	0.43	
Calcium/50 (mg)	1.00	0.96	
Zinc (mg)	0.95	0.40	
Folate (ug)	1.00	0.15 ¹	

Number of symptoms	1.15	0.44
Number of household members	1.03	0.71
Physical activity		
Low + moderate	Ref	
high	1.17	0.76
Coping strategies	1.00	0.34
Adolescent dietary diversity (ADDS)	0.65	0.02 ¹
Household dietary diversity (HDDS)	0.66	0.07 ¹

^{1.} variables with p values < 0.25

APPENDIX B

ASSOCIATIONS OF STUNTING AND COVARIATES

Table B. 1. Univariable logistic regression of stunting by covariates (continued onto the next page)

	Univ	Univariable	
	OR	P value	
Age (yrs)	0.92	0.09 ¹	
Rural	1.15	0.63	
Puberty	0.30	0.000^{1}	
Enrollment	0.43	0.0041	
Socioeconomic status			
Quartile 1	Ref		
Quartile 2	0.69	0.28	
Quartile 3	1.19	0.63	
Quartile 4	1.02	0.96	
Height (cm)	0.90	0.000^{1}	
Weight (kg)	0.92	0.000 ¹	
MUAC (cm)	0.81	0.000^{1}	
BMI (kg/m2)	0.83	0.000 ¹	
Energy/100 (kcals)	0.99	0.74	
Energy/weight (kcals/kg)	1.01	0.041	
Protein (g)	0.99	0.48	
Carbohydrate (g)	1	0.89	
Fat (g)	0.99	0.48	
Vitamin A/100 (ug)	1.01	0.27	
Iron (mg)	0.99	0.79	
Calcium/50 (mg)	1.00	0.82	
Zinc (mg)	0.98	0.71	

Folate/50 (ug)	0.99	0.69	
Number of symptoms	1.13	0.38	
Number of household members	0.97	0.64	
Physical activity			
Low+moderate	Ref		
High	1.66	0.25 ¹	
Coping strategies	1.00	0.27	
Adolescent dietary diversity (ADDS)	1.13	0.40	
Household dietary diversity (HDDS)	0.95	0.74	

^{1.}variables with p values <0.25

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