DIETARY DIVERSITY AS A MEASURE OF NUTRITIONAL ADEQUACY THROUGHOUT CHILDHOOD

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ABSTRACT

Melissa Christensen Daniels: Dietary Diversity as a Measure of Nutritional Adequacy
throughout Childhood
(Under the direction of Linda S. Adair)

Malnutrition is a widespread concern in developing countries, impacting children's

cognitive and physical development, quality of life and lifetime productivity. Interventions to

improve nutritional status in international contexts require identification of at-risk

populations and correct conclusions about general nutritional needs. Screening tools are

currently being developed to meet these needs.

Dietary diversity indicators are promising tools currently being studied. They are

typically counts of food groups in the diet (i.e. a sum of defined food groups consumed in a

defined time period) and are practical for field use because they are simply measured and

positively correlated with nutrient intakes.

We created age-specific diversity scores (based on a pre-existing tool) for use in both

early childhood and adolescence, and evaluated their relationship to nutritional adequacy,

nutritional status (measured by height for age Z-score), and their combined ability to predict

adult height. Data were taken from the Cebu Longitudinal Health and Nutrition Survey, a

Filipino birth cohort of 3,080 followed from the early 1980s through the present.

We found that using minimum portion requirements improved the relationship of scores

to nutrient adequacy for the 6 nutrients evaluated (vitamin A, iron, calcium, niacin,

riboflavin, iron). Modified scores also reflected amounts of food consumed, i.e. children

with increasing dietary diversity also ate larger amounts of individual food groups. Related increases in nutrient adequacy were largely due to these increased energy intakes, but there were also small increases in the nutrient density of the diet at both ages. Linear models were used to evaluate the relationship of both scores to height for age z-score. Scores at both ages predicted crude increases in height for age z-score, although this relationship was weaker for adolescents. After adjustment for confounders only the early childhood score was significantly related height for age z-score, and only when mother's had greater than 6 y of education. In the crude longitudinal model, combined score increases did not predict ultimate height improvements.

This research provides important insights about how diversity scores may be improved for international malnutrition screening, and provides a basis for future research on the performance of diversity scores across childhood.

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LIST OF ABBREVIATIONS

BCFV	beta-carotene rich fruits and vegetables
CRT	cereals, roots and tubers
CV	coefficient of variation
DASH	dietary approaches to stop hypertension
DD	dietary diversity
DQI-R	revised diet quality index
EAR	estimated average requirement
FVS	food variety score
HAZ	height-for-age Z-score
LPN	legumes, pulses and nuts
MAR	mean adequacy ratio
MPA	mean probability of adequacy
MPF	meat, poultry, fish
NAR	nutrient adequacy ratio
OFRT	other fruits
OVEG	other vegetables
RNI	recommended nutrient intake
SES	socioeconomic status

I. Introduction

A. Background

Adequate nutrition throughout early life is fundamental to proper growth, development and survival. Yet over 150 million children worldwide still suffer from malnutrition, and at least half of childhood deaths under 5y are malnutrition related. Provision of sustainable diets rich in necessary micronutrients and minerals is vital in the effort to combat malnutrition. Efficient methods for assessing the adequacy and quality of existing diets are necessary for rapidly determining existing dietary needs in developing country settings and targeting interventions for the greatest benefit.

Dietary variety instruments (often called dietary diversity scores or food variety scores) have recently become the preferred method for studying dietary adequacy in developing countries. These scores consider the number of different food items or food groups contributing to the diet in a given time period. They are useful because they are correlated with nutrient intakes as well as various anthropometric measures in children; measurements are simple to collect and easily adapted to diet in various settings. They have been used to study diet in both early childhood and adulthood.

Further work is needed to refine dietary variety scores and determine the extent of their usefulness. Current shortcomings with these methods include the use of non-uniform instrumentation from study to study and a resulting lack of clarity in the appropriate

interpretation of dietary variety data. There is a lack of research concerning the determinants of dietary diversity patterns, and a lack of appropriate confounding control in current studies characterizing a relationship between dietary variety and anthropometric measurements. Also, most studies utilizing these instruments are cross-sectional, leaving great uncertainty regarding causality.

With more thoroughly validated instrumentation, broader application of dietary variety scores may provide valuable insights into existing diet patterns. Possible applications include: determining whether dietary variety is related not only to nutrient adequacy but also to nutrient density in early childhood; determining whether dietary diversity is a useful measure of adequacy in adolescence, a largely unstudied population; and determining whether adequacy as measured by dietary diversity instruments is related to long-term childhood development.

In this study we had the opportunity to further develop and validate dietary diversity instrumentation for use throughout childhood, as well as explore the relationship of diversity measurements to long term nutritional status. We utilized rich longitudinal data from the Cebu Longitudinal Health and Nutrition Survey with its 18 years of dietary, growth, and other in-depth data on a birth cohort of over 2000 children.

B. Research Aims

The overarching goal of this study was to improve existing instrumentation for measuring dietary diversity in early childhood, and to introduce instrumentation for use in adolescents. Specific aims were as follows:

1: Conduct a sensitivity analysis on multiple dietary variety instruments; Select the measure most sensitive to nutrient adequacy and nutrient density in early childhood diets. We selected two existing instruments for comparison, and tested these instruments for ability to predict both nutrient adequacy and nutrient density in early childhood. Nutrients evaluated included Iron, Calcium, Vitamin A, Vitamin C, Thiamin, Riboflavin, and Niacin - key nutrients lacking in developing country childhood diets, for which Cebu data are available.

2: Create instrumentation for measurement dietary diversity in adolescence. We created additional diversity measures for use in adolescence and evaluated these measures against the best of the early childhood measures to determine the best formulation. We then evaluated various socioeconomic factors for their potential to predict dietary diversity in adolescence.

3: Determine if long term diet quality predicts cumulative development as measured by adult height. Categories of tracking with respect to diet quality were defined and tested as predictors of adult height. Socioeconomic status is a known correlate of dietary diversity. Therefore, we controlled for various socioeconomic factors, as well as other potential confounders to clarify the effect of long term diet on adult height as a proxy measure of cumulative development.

II. Literature Review

A. Research is Needed to Combat Malnutrition

1. Malnutrition is a Key Concern in Developing Countries

Malnutrition is a widespread concern in developing countries affecting more than 200 million children (UNICEF, 1998). Nutrient deficiencies affect physiologic systems broadly leading to potentially severe developmental consequences (e.g. impaired cognition, stunted growth, reproductive problems, reduced immune function, physical deformities, blindness, etc.) and increased morbidity and mortality (Bhan et al., 2001; PAHO, 2003).

A recent review listing problem nutrients in complementary feeding for infants in developing countries found that according to recent requirements Iron, Zinc, Calcium, and B vitamins (Thiamin, Riboflavin, Niacin, B_6, and Folate) are "problem nutrients" in early childhood diets. Vitamin A and Vitamin C were problem nutrients in "some situations"(Dewey and Brown, 2003). A recent review of research needs on adolescents in developing countries indicated that Iron, Zinc, Calcium, and Vitamin A are also key deficiencies among adolescents (Delisle et al., 2004). There is currently very little research on adolescent needs for B vitamins (FAO/WHO, 2001). Sound strategies for reducing these burdens are greatly needed.

2. Appropriate Programmatic Strategies Depend on Meaningful Research Findings

Past research and programmatic approaches for combating malnutrition have focused largely on understanding and treating individual nutrient deficiencies such as Iron, Vitamin A, and Iodine. However, these efforts have achieved less than optimal results (Tucker, 2001; Gibson, 2004) and the existence of multiple micronutrient deficiencies calls for broader approaches. Increasing dietary variety in developing countries is a promising potential long-term solution to malnutrition because it is food-based and thus able to combat multiple micronutrient deficiencies simultaneously (Tontisirin et al., 2002;Gibson, 2004). Likewise it has greater potential for sustainability than a number of other possible solutions, because interventions can be tailored to promote foods that are native or locally available. In order to be successful, however, interventions will need to be informed regarding optimal dietary patterns, as well as based on a clear knowledge of existing (and thus sustainable) dietary patterns in a wide variety of contexts. Considerable research will be required to meet these needs. This project will begin to address these needs and provide a framework for future studies.

3. Food Studies Fill Gaps Left by Micronutrient Studies

Studies emphasizing patterns of food intake, a relatively new undertaking, allow perspectives on diet not available through studies of individual micronutrients. A pair of studies on Dietary Approaches to Stop Hypertension (DASH) illustrates this well. The initial study (n = 458 adults) considered the effects of the DASH diet (rich in fruits, vegetables) on blood pressure. Subjects were fed a control diet for 3 weeks, and then either the DASH diet, a combination DASH diet (included low-fat dairy) or a control diet for 8 weeks. Sodium levels

were held constant for all groups. Systolic blood pressure was lowered by 5.5 mm Hg
(P<0.001) in the combination diet, and 2.8 mm Hg (P<0.001) in the DASH diet compared to
the control (Appel et al., 1997). A further study (n = 412) contrasted individuals consuming
the DASH combination diet and a control diet across three levels of sodium intake (high ~
150 mmol/day; medium ~ 100 mmol/day; low ~ 50 mmol/day). Sodium reduction from high
to low resulted in a systolic blood pressure decrease of 6.7 mm Hg in those with the control
diet (P<0.001), and 3.0 mm Hg (P<0.01) in those with the combined DASH diet (Sacks et al.,
2001). While the single nutrient effect was apparent, effects from food patterns were larger
and more easily detected. These larger effects may reflect not only additive effects of
multiple nutrients, but also nutrient synergies and interactions that would not be easily visible
in single nutrient studies. Studies of diet patterns are valuable for other reasons as well. They
are less prone to multi-colinearity problems that occur when several individual nutrients are
considered together (Hu, 2002). They are accessible - assessment of diet at the food level
gives results which are easily understood by a wide range of audiences, and easily applied.
These studies are not flawless; for instance, epidemiologic studies of dietary patterns are still
prone to the problem of recall bias (more or less depending on the data collection method),
and are unable to single out clear nutrient-nutrient interactions. Nevertheless, food studies
have potential to yield valuable insights.

4. Diet Quality Instruments are Appropriate for Use in Industrialized Countries

Studies of dietary patterns are often termed "diet quality" studies. The term "diet quality"
was originally used to refer to studies of nutrient adequacy. However, with recent increases
in chronic disease the term has taken on other definitions. Researchers in developed countries

where chronic disease problems are most prevalent have added concepts such as proportion (some food groups receive more weight) and moderation (limits on intake of risk-promoting foods) to adequacy in defining diet quality (Ruel, 2003a). In order to measure these constructs, researchers in industrialized countries have developed complex methods of measuring diet patterns. Composite measures such as the Diet Quality Index (Patterson et al., 1994), Diet Quality Index Revised (Haines et al., 1999), and the Healthy Eating Index (Kennedy et al., 1995), developed in the US, and the Healthy Diet Indicator developed in Europe (Huijbregts et al., 1997) are based on compliance to national or world guidelines for healthy eating. They contain measurements of several different aspects of diet. For instance, the recently revised Diet Quality Index (DQI-R) contains measures of fat, and saturated fat intake (as % of energy), dietary cholesterol (mg/day), servings of fruit, vegetables, and grains per day (as % of recommended servings), Calcium and Iron intake (as % RDA) as well as a dietary diversity score (Haines et al., 1999).

While composite measures are valuable for identifying dietary risks that may lead to chronic diseases, they may be too complex to be used easily in developing country settings. They generally require in-depth dietary assessments which are expensive and difficult to carry out in more remote settings. They are generally based on national standards of diet and nationally available foods and may not be easily adapted to account for ethnic cuisines and differences in food available in international areas. In addition, most existing measures have been designed for measurement of adult diet, making them less useful for analysis of children's diets – a major priority in developing countries.

5. *Dietary Variety Instruments are Well-Suited for Use in Developing Countries*

Dietary nutrient adequacy remains a primary concern in many developing countries; in areas where severe malnutrition is prevalent, inexpensive and simple instruments are needed to identify individuals at greatest risk of nutrient inadequacy. Multiple instruments for measuring dietary variety have been adapted in the last few years in an effort to meet this need (Ruel, 2003b; Onyango, 2003). Methods are straightforward and scores are generally of two main types: food variety scores, utilizing counts of single food items eaten (Brown et al., 2002; Onyango et al., 1998; Ferguson et al., 1993) and dietary diversity scores, summing the number of defined food groups contributing to a persons diet in a given time (Hatloy et al., 1998; Ogle et al., 2001; Tarini et al., 1999). They can be easily applied across all ages after the first year of life (Ruel, 2003b). Dietary variety instruments are also easily adapted to local cuisines and can be tailored to focus on specific nutritional needs. For instance, in Mali a 3 day dietary diversity score was created for early childhood that emphazised high-status animal foods by including them as different food groups (meat, fish, egg, and milk) along with other food groups (Hatloy et al., 1998). In Vietnam, a 7-day food variety score was created for use in rural women that contained special categories for consumption of local wild plants traditionally used as vegetables. The authors found significantly higher intakes of most nutrients when comparing women with a food variety score > 21 to those with a food variety score ≤ 15. Because of their emphasis on nutrient adequacy, dietary variety instruments have also been frequently used in diet quality measures in industrialized countries, but usually as sub-scores. However, they have been shown to be a very useful component of these tools. For example, authors of the DQI-R reported that the dietary diversity score explained proportionately more scoring variability than any other component

measure except percentage of energy from fat (Haines et al., 1999). Given the simplicity, adaptability, and relationship to nutrient adequacy of dietary variety measures, it is appropriate to further investigate their potential as stand-alone adequacy measures in developing country contexts.

6. Dietary Variety Instruments are Associated with Nutrient Intakes

Studies of dietary variety appeared in the early 1980s (Guthrie and Scheer, 1981). Since that time several studies have verified positive correlations between dietary variety scores and nutrient adequacy (Hatloy et al., 1998; Ogle et al., 2001; Mirmiran et al., 2004; Onyango et al., 1998). Two of these (in Mali and Vietnam) were mentioned previously. The Mali study (n=77, 13-58 mos old) used 3 day dietary diversity scores to tally consumption of eight food groups (staples, vegetables, milk, meat, fish, egg, fruits and green leaves) with a max score of 8. The DD score and mean adequacy ratio (MAR) for 9 nutrients [MAR= average of Nutrient Adequacy Ratios (NAR) divided by the number of nutrients; NAR= ratio of actual nutrient intake divided by recommended intake] had a correlation coefficient of 0.39 (P<0.01) although only 3 NARs were positively associated with dietary diversity scores at the P<0.05 level (Hatloy et al., 1998). Another study (n=154) considered a dietary diversity score in Kenyan children ages 1 to 3 years. The score represented the average number of distinct foods eaten on each of 3 non-consecutive days as measured by 24-hour recalls. Nutrient intakes were significantly higher (p = 0.05) among children consuming >5 foods, compared to ≤ 5 foods for all nutrients considered (energy, protein, Vit A, Vit C, Thiamin, Riboflavin, Niacin, Calcium) except Iron (p=0.06) which was borderline (Onyango et al., 1998). A study in Iran used a dietary diversity score adapted from the previously mentioned DQI-R to

consider dietary adequacy in Tehran, Iran (n=304, 10 to 18 years old). They found that the dietary diversity score correlated well with the mean adequacy ratio for 12 nutrients (r = 0.42, P<0.001) and that there was a statistically significant correlation between the nutrient adequacy ratios of most nutrients with the dietary diversity score [r = 0.29 for P and Mg; r = 0.33 for K, r = 0.32 for Zn, r = 0.35 for Ca; P<0.001 for all] (Mirmiran et al., 2004). This appears to be the only developing country study that has investigated dietary variety in adolescents.

7. Dietary Variety Instruments are Associated with Growth

Dietary variety scores have also been associated with nutritional status measures in childhood such as height for age and weight for height z scores. A recent review of studies utilizing these measures concluded "dietary diversity has been consistently associated with child nutritional status and growth in a variety of studies in developing countries" (Ruel, 2003b). Studies supportive of this conclusion include the work of Taren and Chen (2148 children; age 12 -47 mos) in China which found that height for age z score (HAZ) was increased among 1 year olds who had been introduced to ≥ 3 foods compared to < 3 foods by 1 year of age [HAZ = -1.58±0.03 (se) and -1.39±0.06, p<0.01] (Taren and Chen, 1993). A cross-sectional study in Kenyan toddlers found that partially breastfed children who consumed on average more than 5 distinct foods per day (based on 3 24-hour recalls) had significantly lower levels of stunting [HAZ = -1.6±1.1 vs. -1.8±1.0, P = 0.02], wasting [weight for height z score (WHZ) = -0.2±1.0 vs. -0.7±0.9, P = 0.03] and weight for age z score [WAZ =-1.1±1.1 vs. -1.6±1.0, P = 0.005] and larger mid upper arm circumferences (MUAC) [MUAC = 14.7±1.3 vs.13.9±0.8, P = 0.01] than children fed a less diverse diet.

These numbers were even more pronounced among fully weaned children [HAZ = -1.7±1.1 vs. -2.6±1.4, P = 0.02; WHZ = -0.05±0.8 vs. -0.3±0.9, P = 0.3; WAZ = -1.0±1.0 vs. -1.8±1.3, P = 0.005; MUAC = 14.9±1.2 vs. 14.2±1.5, P = 0.01] (Onyango et al., 1998). Ruel's Infant and Child Feeding Index (created for use with DHS data) was based on several components of child diet including whether the infant was breastfed, whether the child used a bottle, a DD score, a food frequency score and a frequency of feeding score. The measure was used to predict HAZ in early childhood in 5 Latin American countries, and later in Ethiopia. In Latin America the feeding index was strongly and significantly associated with HAZ among children 12 to 36 mos of age in all 5 countries in bivariate analysis. After controlling for socioeconomic status in a multiple regression analysis feeding practices were significant as a main effect or in interactions (with maternal ethnicity, household wealth, or maternal schooling) in 5 of the 7 data sets (both Bolivia datasets were non-significant) (Ruel and Menon, 2002). In the analysis using the Ethiopian DHS data, the authors again found a strong association with HAZ and the index, but after examining association with index components, concluded that the significant association between the index and height for age Z-score (HAZ) at age 2 was "driven by a strong positive association between HAZ and one component – dietary diversity." The authors examined both 24-hour and 7-day recall based dietary diversity scores and found both strongly associated with HAZ (Arimond and Ruel, 2002). Due to this association, the authors tested a slight adaptation of the dietary diversity score independently for association with HAZ in Ethiopia and 10 other countries. Dietary diversity was significantly associated with HAZ either as a main effect (7 countries) or in an interaction (3 countries; interactions included child age, breastfeeding status, urban/rural location) in 10 of 11 of these countries (Arimond and Ruel, 2004).

8. Comparing Dietary Variety Instruments, Dietary Diversity Scores are most Versatile

As mentioned above, dietary variety scores are of two basic types, the food variety score (a tally of different foods eaten), and the dietary diversity (DD) score (a count of defined food groups eaten). We prefer to use a dietary diversity score in the current study for several reasons. First, they have been shown to be more strongly related to nutrient adequacy than food counts. A study contrasting the two measures found that a DD Score based on 8 food groups (staples, vegetables, fruits, meat, milk, fish, egg, and green leaves) was more strongly correlated with mean adequacy ratio (MAR) than a food variety score (FVS) (Correlation coefficient = 0.39 and 0.33 respectively ($P<0.01$ for both measures)). The same study also found that in a regression model predicting MAR, the DD score contributed significantly to the fit of the model whereas the FVS did not, indicating that the DD score was a better predictor of MAR than the FVS (in a linear model) (Hatloy et al., 1998). Second, Hatloy also notes that since an FVS counts all unique foods consumed, even condiments, it can give a false impression of the amount of variety in the diet. Dietary diversity scores are based only on distinct nutritionally unique food groups consumed and are therefore more realistically associated increased nutritional quality (Hatloy et al., 1998). Third, DD scores are more appropriate when only one to two days worth of intake data are available because they focus on variability of broad dietary components which are less likely to change from day to day than intakes of individual foods (Haines et al., 1999). Fourth, DD scores are simpler to obtain accurately than FV scores and can be patterned after national and international dietary guidelines more easily (Hatloy et al., 1998).

B. Research is Needed to Refine and Extend the Use of Dietary Diversity Measures

While the studies above indicate that dietary diversity measures may be valuable as tools for assessing nutrient adequacy, further research is needed to clarify the proper interpretation of these tools and determine their potential as research instruments.

1. Clarification is needed of the Relationship of Dietary Diversity to Nutrient Density

Improving interpretability of DD scores will requires investigation of their relationship to nutrient adequacy as well as nutrient density. Intakes of macronutrients and some micronutrients have been shown to correlate strongly with energy intake. For instance, in a cohort of 194 women whose diets were recorded for 28 days, the correlations between energy intake and other nutrients including total fat, total carbohydrate, vitamin B6 and vitamin A were 0.86, 0.82, 0.40 and 0.25 respectively (Willett, 1998). Increases in nutrient adequacy for nutrients strongly related to energy intake may simply reflect increases in overall energy intake; consequently a DD score related to nutrient adequacy may also be a reflection of energy intake. Therefore, it is useful to calculate nutrient density measurements, where nutrient density = nutrient intakes per 1000 kcal of energy intake, for comparison with diversity scores. Detecting increases in nutrient density with increasing diversity is important for determining whether increases in dietary diversity are simply leading to consumption of more food, or to consumption of more nutritious food.

Only a few previous studies have investigated the relationship between DD scores and nutrient density. These have had contrasting results. A study of preschoolers in Ghana and Malawi found that dietary diversity was associated with energy intakes in Malawi [$r = 0.33 - 0.41$; $p<0.02$]; DD was not associated with protein fat, or Calcium density in either country,

was not associated with zinc or iron density in Ghana, and was negatively associated with zinc or iron density in Malawi. However, collection of the Malawi data during a food shortage season may have affected these results (Ferguson et al., 1993). A study among Vietnamese women used a food variety score and found that nutrient density for several nutrients (Zn, Fe, Ca, Vit C, Niacin, B2, B1, Vit A) was higher (significance not calculated) among women with a 7-day food count of >20 vs. <16 distinct foods eaten. This result was among women of Mekong Delta in Vietnam. The study also considered women in the Vietnamese Central Highlands and found little change in most nutrient densities, and somewhat reduced nutrient density for Vit C, B2 and Fe (Ogle et al., 2001).

Clarifying the relationship between dietary diversity and nutrient density has important implications. We may interpret the positive correlations between DD scores and nutrient adequacy, and DD scores and anthropometric indicators to mean that increasing dietary diversity will reduce malnutrition prevalence. But if dietary diversity interventions increase energy intakes in the same proportion as nutrient intakes, then in areas where caloric intakes are adequate while nutrient intakes are low, interventions to increase dietary diversity could lead to problems with overweight. Therefore, the most useful dietary diversity scores will be designed to maximize sensitivity to dietary nutrient density as well as adequacy, assuming it is possible to reflect nutrient density with such a score. If such a score can be created, then it can provide a food group basis for more effective dietary diversity interventions. Our study will perform sensitivity analyses of the effect of using different food groups on the ability of dietary diversity scores to predict nutrient density. This will increase understanding about the possibility of detecting nutrient density with a dietary diversity measure, and allow us to select the best possible tool for the remainder of the project.

2. Tracking Analyses of Dietary Diversity

Given the apparent relationships between dietary diversity, nutrient adequacy and HAZ, DD scores may be useful for studying long term dietary patterns and how they affect adult stature. Studies of long-term DD patterns may also improve identification of children who are at greatest risk of future malnutrition, which would be useful for appropriately targeting interventions.

Tracking analysis is a method that has previously been used to identify individuals maintaining certain characteristics or behaviors over time at consistent high or low levels relative to peers. Comparison to peers is helpful in interpreting an individual's level of dietary diversity, since children naturally increase the number of foods they eat over time, making comparison to their previous diets less than helpful. Peers share a similar environment and therefore lend information about what levels of dietary diversity are achievable as well as appropriate in the given context.

While there are no current studies considering the tracking of dietary diversity scores, a few studies have looked at tracking of whole food intakes. A study by Wang, of diet in Chinese Children ages 6 to 13 years, found significant positive correlations (r=0.28 to 0.51, p<0.05) between 1991 and 1997 intakes of food groups (vegetable, fruit, meat, edible oil) which though not large, were beyond that expected by chance (kappa=0.21 to 0.35) (Wang et al., 2002). A study by Resnicow considered servings of fruit and vegetable intake over a two year period in US youths age 9 to 18 y. Correlations for total fruit and vegetable servings were 0.48 (boys) and 0.40 (girls) [p<0.001 for both]. Using a cut-point of kappa = 0.25 to represent moderate tracking, boys in the bottom quintile (kappa = 0.32) and girls in the upper quintile (kappa = 0.26) had moderate tracking at 2 years (Resnicow et al., 1998). A study by

Mannino of US girls used graphical methods to inspect tracking of food group intakes. They found the strongest evidence of tracking in the fruit and dairy groups. Tracking was defined as quartiles maintaining distinct mean rankings over time (Mannino et al., 2004). Other studies have considered tracking of specific macro and micro-nutrients rather than patterns of intake. Our proposal is innovative in its approach to determine tracking of dietary diversity throughout childhood.

3. Research is needed to Identify Determinants of Dietary Diversity

If increases in dietary diversity have potential to improve the nutritional status of individuals, identifying factors that predict dietary diversity may provide insights into potentially valuable areas for intervention. Relatively little research has been done thus far in developing countries to investigate which factors predict differences in dietary diversity among children of similar ages and contexts. A few studies have shown that socioeconomic status (SES) variables are predictive of dietary variety. A study conducted by Hatloy et al. in Mali considered associations between both dietary diversity and food variety scores. A list of 14 household items was summed, and tertiles of SES were created (low = 0-3 assets, medium = 4-6 assets, high SES = 7 -10 assets). Socioeconomic status was associated with both dietary variety indicators in both rural and urban environments, although the SES category with lowest DD and FV scores in the urban areas still had higher scores than any rural area. The correlation between SES and both dietary diversity scores (DDS) and food variety scores (FVS) in the urban area was about r=0.3 (P<0.01). The correlation in rural areas was about r = 0.13 (P<0.02) (Hatloy et al., 2000). A study in the southern Andes found a similar trend,

with diversity lower in the rural areas, and a correlation between dietary diversity and wealth in urban areas (Leatherman, 1994).

In order to improve dietary diversity, it is important to understand which factors are driving dietary diversity patterns. Longitudinal analyses are essential for identifying predictors rather than just correlates of dietary diversity. Therefore, this analysis will investigate a number of socioeconomic and environmental factors measured at birth in order to identify predictors of later dietary diversity. We will also consider variables representing change in SES and some other predictors, to determine to what extent changes may influence DD patterns over time.

4. Longitudinal Research is needed to Establish the Relationship between Diversity and Anthropometry

Previous cross sectional studies have shown that dietary diversity is correlated with several development indicators such as height for age, weight for height, weight for age z scores, and mid-upper arm circumference measures in children ages (Onyango et al., 1998; Taren and Chen, 1993; Arimond and Ruel, 2002). Findings from these studies have been previously discussed. Such findings are not surprising considering the clear correlation between dietary diversity and nutrient adequacy. However, causality in these cases is unclear due to the simultaneous collection of both dietary and anthopometric data. Longitudinal studies are needed to verify the temporality of the diversity and growth relationship.

5. Potential Confounders of the Diversity and Growth Relationship Need Careful Consideration

   Careful statistical control of potential confounders is needed for an accurate representation of the relationship between dietary diversity and growth. Does dietary diversity truly improve a child's growth, or are healthy, growing children a product of other factors more likely to occur in an environment where children will be fed a diverse diet? For instance, children who enjoy more diverse diets may be exposed to a number of other conditions favorable for growth including reduced exposure to infectious agents, greater likelihood of immunization and health care, and environmental stimulation. Also, mothers at different levels of SES may have differences in nurturing behaviors, which have been shown to impact child growth (Grantham-McGregor et al., 1997). Arimond and Ruel argued in their recent analysis of DHS data in 11 countries that most studies of dietary diversity and anthopometric status lack appropriate control for confounding factors, and that this lack of control could lead to false assertion of a strong relationship between dietary diversity and development. The authors adjusted their analysis for child age and gender, and maternal age, height, body mass index, education, parity, attendance at prenatal visits, partner's education, household SES, number of pre-school children, and area of residence (Arimond and Ruel, 2004). However, they did not elaborate on their reasons for controlling for these factors, nor comment on how strongly they were associated with dietary diversity in the sample. Future studies should verify that confounders are clearly correlated with dietary diversity as well as causally related to development, before including them in etiologic models as potential confounders. The current project will consider multiple potential confounders of the relationship between dietary diversity and adult height, including measures of SES, parental characteristics,

healthcare in the early environment, and changes in SES through time. Prior to inclusion of potential confounders in modeling, we will conduct careful tabular analysis to determine the likelihood that each selected variable is a potential confounder.

C. Appropriateness of the data

1. Data Quality

Data from the Cebu longitudinal Health and Nutrition Survey (CLHNS) are well-suited for the proposed study because they contain detailed and diverse longitudinal measurements on a relevant and sizeable population. 3080 singleton births comprised the original survey and since that time 4 additional surveys have been completed. Natural attrition (from death, relocation) has resulted in some loss to follow-up, but over 2000 children have remained in the study for the full 18 years. The survey was originally designed to assess infant feeding patterns including the sequencing of feeding events, factors affecting feeding decisions, and the implications of these feeding decisions on health and nutrition as well as on demographic and economic outcomes (Adair and Popkin, 2001). Because of this, the data include a broad range of individual level measures (including health, diet, anthropometry, schooling), household level measures (e.g. income, assets, household size, cleanliness, parental characteristics of education and occupational status) and community level measures (urbanization index including population density, garbage collection, electricity, proximity to markets) for each child. Each follow-up survey also contained a dietary assessment (generally one or two 24-hour recalls - data at ages 14-15 and 17-18y included 2). Data sets of this size and breadth are a rare and valuable resource. CLHNS data are capable of supporting a study of long-term dietary diversity and its confounders and predictors.

2. Population characteristics

The Philippines provide a useful setting for studies of DD in childhood and its impact on later adult height. Filipino adults generally consume a combination of grains (rice and corn), meats (fish, goat, chicken), eggs, vegetables, roots/tubers, fruit and legumes. Because of the broad range of foods available, within any given age category there is likely to be a broad distribution of dietary diversity. Malnutrition is prevalent in the Philippines with 30% of children under age 5 having either moderately or severely stunted growth (UNICEF, 2004) resulting in meaningful height differences that persist into adult life. Though Filipino diets are in "transition" with increasing overweight among adults, the prevalence of overweight among children and adolescents is still very low, averaging 1.3% under 10 y, and 3.5% among adolescents 11-19 y (Cerdena et al., 2001). The rapid urbanization in metro Cebu over the past 20 years further provides a unique opportunity to consider how changes in socioeconomic status and level of urbanization are able to impact changes in dietary diversity and overall growth.

D. Summary and Significance

In order to achieve sustainable improvements in nutritional status in the developing world it is important for policies and programs to be based on an understanding of broad dietary patterns. Food-based approaches to addressing malnutrition are most likely to be helpful because they target multiple micronutrient deficiencies simultaneously. Understanding how dietary patterns vary within age groups and over time, what the determinants of these patterns are, and which patterns are most likely to supply adequate nutrition will aid program and policy makers in defining appropriate and effective guidelines for change.

III. Methods

A. Survey Design: The Cebu Longitudinal Health and Nutrition Survey

1. Study Design

The Cebu Longitudinal Health and Nutrition Survey provides successive dietary measures on over 2000 children as well as numerous background measures describing their family structure, living conditions, and socioeconomic status. All pregnant women in 33 randomly selected barangays (administrative units) of the 243 comprising Metropolitan Cebu, who gave birth between May 1, 1983 and April 30, 1984 were surveyed, resulting in a total of 3080 singleton births. After birth, anthropometric and dietary data were collected bimonthly until the infants were 24 mo old. Follow-up surveys were conducted in 1991–1992, 1994–1995, 1998–2000, and 2002 (The Cebu Study Team, 1991; Adair and Popkin, 2001).

2. Exclusions

As with all cohort studies, CLHNS had natural attrition as surveys progressed. Of 3080 live births, 816 were lost (due to death, migration or other reasons) prior to 1991 resulting in 2264 participants in the 1991 round of the survey. Study size declined only gradually thereafter, and 2203, 2117, and 2051 participants were retained 1994, 1998, and 2002 respectively. A few children lost during early surveys were relocated in later surveys.

Because our study is interested in sustained diet quality, our sample will include children who were absent in no more than one of the above surveys.

B. Measurement of key variables

1. Breastfeeding data

Breast feeding (BF) data were collected bimonthly from birth to 24 months based on mother's recall of all foods and liquids fed to the infant in the past 24-hours, and of feeding practices in the past 7-days. If women had fed infants other foods or stopped BF since the previous survey they were asked how many days prior this occurred. BF outcomes were censored at 24 months (Fernandez and Popkin, 1988). Breastfeeding in the current analysis will be reflected by a dichotomous measure of whether the child is still breastfeeding at age 24 months.

2. Dietary data

Diet data was collected via bimonthly 24-hour recalls administered at the time of breastfeeding data collection during the first 24 months. Dietary data was also collected via food frequency questionnaire when children were 8 years old, through a single 24-hour recall at age 11, and two 24-hour recalls at ages 16 and 18.

3. Other data

Many other data are also available at successive time points including data at the individual level (age, gender, anthropometry, immunizations, major illnesses), family level (number and ages of present siblings, father's presence, age and education, and mother's age,

height, BMI, education, parity, and level of prenatal care), household level (income,

household assets, electricity, housing quality, water quality, electricity, sanitation and urban

or rural location), and various community level factors. Table 1 indicates the availability of

these variables in each survey. Where variables are completely redundant (i.e. child's gender

and amount of prenatal care) or sufficient information is provided at baseline (i.e. maternal

age and height) variables will be drawn from the baseline 1983 survey.

Table 1. Description of diet data and potential determinants of diet patterns and/or

development

Available Data	1983-85 Surveys Bimonthly from Birth to 24 months	1991 Survey (age 8.5)	1994 Survey (age 11.5)	1998 Survey (age 15.5)	2002 Survey (age 18.5)
Diet Data	Bimonthly 24-hr recalls including Breastfeeding (by Mother)	Food Frequency Questionnaire (by Mother)	One 24-hr recall (by Mother w/ child input)	Two 24-hr recalls (by Child)	Two 24-hr recalls (by Child)
Child Level					
Prenatal Care	✳				
Age	✳	✳	✳	✳	✳
Gender	✳				
Height	✳	✳	✳	✳	✳
Immunizations	✳	✳			
Major Illnesses	✳	✳	✳	✳	✳
Family Level					
Siblings in home	✳	✳	✳	✳	✳
Siblings' Ages	✳	✳	✳	✳	✳
Father in Home	✳	✳	✳	✳	✳
Paternal Age	✳				
Paternal Educat.	✳	✳	✳	✳	✳
Maternal Age	✳				
Maternal Height	✳	✳	✳	✳	✳
Maternal BMI	✳	✳	✳	✳	✳
Maternal Educat.	✳	✳	✳	✳	✳
Maternal Parity					
Household Level					
Income	✳	✳	✳	✳	✳
Household Assets	✳	✳	✳	✳	✳
Electricity	✳	✳	✳	✳	✳
Housing quality	✳	✳	✳	✳	✳
Urban/Rural	✳	✳	✳	✳	✳
Water Quality	✳	✳	✳	✳	✳
Sanitation					
Community Level					
Urbanization Index	✳				

IV. Dietary diversity scores can be improved through the use of portion requirements: an analysis in young Filipino children

A. Introduction

Malnutrition is a widespread concern affecting more than 200 million children under age 5 in developing countries (UNICEF, 1998). Nutrient deficiencies affect physiologic systems broadly leading to potentially severe developmental consequences such as reduced immune function, stunted growth, blindness, retardation, and physical deformities. At least half of childhood deaths under 5 y are malnutrition related (UNICEF, 1998).

Methods for rapidly assessing dietary adequacy and identifying children at risk of malnutrition in developing country settings are needed. Toward these efforts, various dietary variety indicators have been developed. These indicators consider the number of different food items or food groups contributing to the diet in a given time period. They are useful because they are correlated with nutrient adequacy and various anthropometric measures in children; measurements are simple to collect, easily adapted to diet in various settings, and have been used to study diet in early childhood and adulthood. In addition, they are able to help identify key components of diet (foods and food groups) which can be clearly linked to nutritional needs and translated into population-specific nutritional guidelines.

Indicators based on food groups (dietary diversity scores) have been shown to be more valuable in predicting nutrient adequacy than those based on individual foods (Hatloy et al.,

1998). But further research is needed to refine and determine the full utility of these indicators. A recent review of dietary diversity studies suggested that scores might be improved by inclusion of portion size requirements (Ruel, 2003b). This is because diversity scores counting any amount of intake from food groups may overemphasize very small amounts of food and ignore larger, more nutritionally meaningful intakes. Another problem is that dietary diversity scores have been shown to correlate with energy intake (McCrory et al., 1999) so that promoting dietary diversity might increase obesity risks as well as nutrient adequacy. To address this, studies evaluating the correlation of diversity indicators with dietary adequacy should also report energy adjusted correlations, or correlations with dietary nutrient density which is independent of energy intake (Ruel, 2003b). Studies are also needed to further explore the screening capability of diversity scores. Analyses testing the sensitivity and specificity of diversity scores to the presence of nutrient inadequacy in various contexts have been recommended for this purpose (Hatloy et al., 1998; Ruel, 2003b).

This study addresses the above research needs by comparing two scores (one with and one without portion requirements) for the strength of their relationships with regular and energy-adjusted nutrient adequacy as well as nutrient density in children age 2y. Screening capabilities will be compared by calculating sensitivity and specificity to levels of nutrient adequacy in our population. Since non-uniform instrumentation has hindered past comparisons across different studies and settings (Kant, 1996; Ruel, 2003b), both scores are based on a promising diversity score developed and tested extensively elsewhere for its relationship to nutrient adequacy and height for age z-score (Arimond and Ruel, 2004). Data are taken from the Cebu Longitudinal Health and Nutrition Survey.

B. Subjects and Methods

1. Subjects

   The Cebu Longitudinal Health and Nutrition Survey (CLHNS) has collected data from
birth to young adulthood. All singleton offspring (n=3080) of Filipino women who resided in
33 randomly selected barangays (communities) of Metropolitan Cebu and gave birth between
May 1, 1983 and April 30, 1984 were included. After birth, dietary data were collected from
mothers every two months until children were 24 months of age (Cebu Study Team, 1991;
Adair & Popkin, 2001). All CLHNS activities since initiation have been approved by the
University of North Carolina School of Public Health Institutional Review Board for the
Protection of Human Subjects.

   The current analysis uses data from children 24 months of age. Children were absent
(n=622) at 24 months primarily due to death or migration. For this analysis, children were
excluded (n=403) for illness (fever or diarrhea) or poor appetite in the 24 hours previous to
dietary data collection. Children still being breastfed at 24 months (n=282) were also
excluded since nutrient intakes cannot be calculated by 24 hour recall for breastfed children.
Thirty seven non-breastfed children excluded at 24 months who were present and well during
a 22 month dietary survey were included, creating a total sample of 1,810 children. Forty
nine children who received commercial formulas were excluded in the nutrient intake portion
of this analysis because of the potential for fortified foods to obscure the true relationship of
dietary diversity and nutrient intakes.

2. Dietary data

   Dietary data were collected via 24 hour recall by trained study personnel (Adair et al.,

1993). Information was collected on both liquids and semisolid/solid foods. Liquids consumed were assessed by asking mothers to indicate the container used for feeding and how full the container was or how many containers in all the infant drank. Interviewers used measuring cups to convert a similar amount of liquid to milliliters. Dilution ratios for powdered beverages were also measured for each mother and grams of powdered beverages consumed were calculated. Measurements for semisolid and solid foods consumed were obtained by having mothers name the food consumed, amount (volume) eaten, method of preparation, type, description and amount of ingredients in each dish. Food models and measuring cups were used to determine volumes. If foods were prepared away from home, descriptions of ingredients and preparations were obtained where possible from the appropriate vendors. Grams of each food consumed were calculated using volume and density of ingredients, and conversion factors converting raw to cooked ingredients where applicable. Cooking oil consumed was also calculated for each dish.

Food composition data were obtained from the Food and Nutrition Research Institute (FNRI) of the Philippines 1980 Food Composition Table (FNRI, 1980) which did not yet include fortified foods. For foods with partial nutrient data, nutrient values were obtained by hand-matching to similar foods from FNRI (FNRI, 1990), Worldfood Dietary Assessment System (Worldfood, 1996), or the USDA (USDA, 2005) food composition tables. Missing nutrient values for mixed foods were calculated after consulting Filipino colleagues and recipes online to obtain listings of major ingredients.

Values for energy, carbohydrates, protein, total fat, calcium, iron, retinol, beta-carotene, thiamin, riboflavin, and niacin were compiled for all foods. Due to a large number of missing values, vitamin C and zinc intakes were not evaluated. Values for absorbed calcium were

computed according to recommendations from a recently developed validation protocol (Kennedy & Nantel, 2006) for international testing of diversity scores in children ≥2 years, which were informed by the work of Weaver et al. (Weaver et al., 1999). Absorption levels were assigned as follows: 25% for roots, tubers, grains and legumes; 45% for fruits and vegetables; 5% for high oxalate foods and 32% for all other food groups. We used a list of high oxalate foods provided by FAO (Kennedy & Nantel, 2006), and oxalate values from FNRI (FNRI, 1990) to identify fruits and vegetables with high oxalate content which was defined as >5g oxalate per 100g. Absorbed iron was assumed to be 14% from animal products and 6% for plant foods. This assumes animal products to consist of 40% heme iron (Monsen et al., 1978) with an average absorption of 25% and 60% non-heme iron (average absorption of 6%) (FAO/WHO, 2001). A similar method was recommended in the FAO/WHO expert consultation on nutrient requirements in which the validation protocol was developed (Cohen et al., 2005). A lower value of 11% for animal products was suggested in the protocol because of the low bioavailability of iron in dairy products and their frequent consumption in most countries among infants and young children. We chose to use a higher value because dairy intake was limited in our sample: only 35% of our sample consumed dairy, and consumer intake amounted to a mean of 74.3 grams per day.

3. Creation of dietary diversity score

Dietary diversity scores were calculated based on a tally of nine food groups in the diet: cereals/roots/tubers (CRT), β-carotene rich fruits and vegetables (BCFV), other fruits (OFRT), other vegetables (OVEG), legumes/pulses/nuts (LPN), meat/poultry/fish (MPF), fats/oils, dairy and eggs. The original score used by Arimond and Ruel which inspired this

analysis was based on data from seven food groups representing each of the major nutritionally important food groups while balancing plant and animal source foods (Arimond and Ruel, 2004). The expansion of this score to nine food groups follows recommendations from the protocol (Kennedy & Nantel, 2006) mentioned previously. Changes include separating eggs from the meat/poultry/fish/egg group and dividing "other fruits and vegetables" into two groups. The modified score retains the balance between plant and animal source foods of the original score, but expands the score to make it more sensitive to differences in the nutrient contents of these foods. Children were awarded one point for consuming a food at least once from each unique food group. A modified score was also created according to protocol guidelines (Kennedy & Nantel, 2006) and other previous research (Dewey et al., 2005) which required children to eat at least 10 grams from a food group before a point was awarded. A score point for oil was awarded for either score if at least 1 gram of oil was consumed. This was in accordance with protocol recommendations due to the high energy density of oil. Both scores had a potential range of 1 to 9 points.

4. Recommended nutrient intakes

Analyses were based on international nutrient intake recommendations from the World Health Organization (FAO/WHO, 2001) rather than Filipino Required Energy and Nutrient Intakes since the applicability of dietary diversity scores is of interest globally. Estimated Average Intake (EAR) values were back-calculated from Recommended Nutrient Intakes (RNI) values for Thiamin, Riboflavin, Niacin, and Calcium using the formula $EAR = RNI / (1+2*CV)$ where CV is the coefficient of variation for individual nutrient requirement distributions recommended by the Institute of Medicine (Institute of Medicine, 2001). As

recommended we used a CV of 10% for all nutrients other than Vitamin A (CV=20%) and

Niacin (CV=15%). No RNI values were listed for Vitamin A or Absorbed Calcium, but

values approximately equivalent to EARs were given by WHO so equivalents for RNI were

calculated using the above formula. (Note that FNRI retinol equivalents did not account for

carotenoids other than β-carotene (1 RE = 6mcg β-carotene) (FNRI, 1990).) Percent RNI

(%RNI) was calculated as an individuals nutrient intake divided by the RNI for that nutrient

times 100%.

5. *Probabilities of adequacy*

A method for calculating probabilities of nutrient adequacy for a single day was set forth

by Foote et al. (Foote et al., 2004) and uses requirement distributions for each nutrient which

are defined by their mean i.e. Estimated Average Requirement (EAR), and standard deviation

(SD) which is the EAR multiplied by the distribution CV.

The probability of adequacy equals the probability that a child's intake is adequate on a

single day and corresponds to the proportion of the requirement distribution that is below the

child's measured intake. For example, if a child consumes 15 milligrams of thiamin in a day,

we compare this number to the distribution of requirement for thiamin intakes (mean or EAR

= 12.31 and SD = 1.85). Assuming a normal distribution, we can calculate that 92.7 % of this

distribution is below 15 mg. Therefore the child's probability of adequacy for thiamin on the

particular day is 0.93. Probability of Adequacy in this respect does not reflect the adequacy

of a person's usual diet, but is useful in epidemiologic research for assessing adequacy for

larger groups of people. The requirement distribution for Iron is not normally distributed;

therefore probabilities of adequacy were derived from table I-5 in the IOM manual for Iron

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(Institute of Medicine (IOM), 2001) as suggested by the protocol (Kennedy & Nantel, 2006).

Mean probability of adequacy was calculated as the average of individual nutrient probabilities of adequacy (Vitamin A, Thiamin, Riboflavin, Niacin, Absorbed Calcium and Absorbed Iron) the distributions of which were truncated at a probability of 1. Nutrient densities were calculated for each nutrient at the individual level as 100 times the ratio of total nutrient intake (mcg or mg) to total caloric intake (kcal).

6. *Nutrient densities*

Nutrient density per 100 kcal was computed for each nutrient as the day's intake of that nutrient divided by the total caloric intake, multiplied by 100.

7. *Sensitivity/Specificity Analysis*

One of the most important anticipated uses of diversity scores will be in screening populations and determining general dietary improvements that can be recommended. Which of our scores is better for this purpose? To determine this we tested the ability of both diversity scores to detect the prevalence of low and high mean nutrient adequacy (mean probability of adequacy <50% or >=75%, respectively) using a sensitivity/specificity analysis. Increasing sensitivity always results in a corresponding decline in specificity; therefore we depict the relationship between the two through the use of ROC curves to facilitate choosing a score cut point which will optimize both.

8. *Statistical analysis*

Differences in sociodemographic data were computed using one-way analysis of variance

for continuous data. Tabulations and exact p values were used for dichotomous variables. Bivariate methods were used to evaluate relationships between dietary diversity and food group nutrient intake. Probabilities of adequacy were calculated using the normprob function in Stata. Spearman rank correlations were used to test relationships of probability of adequacy and nutrient density with diversity because probabilities of adequacy were not normally distributed. Linear regression analysis was used to model crude predicted increases in grams per food group and %RNI per nutrient with increasing dietary diversity. Sensitivity/specificity analyses to determine the ability of diversity scores to predict high and low probabilities of nutrient adequacy were performed using Stata's "roctab" function and hand-checked with tabular calculations. All statistical analysis were performed using Stata 9 (Statacorp, 2005). Statistical significance was indicated by P<0.05 for all analyses.

C. Results

1. Sample characteristics

We evaluated whether baseline characteristics of our sample (n=1810) differed from those of the original birth cohort. Included children were slightly heavier at birth (3007.7 g vs. 2962.6 g, P=0.005) and had parents who were slightly younger [28.3 vs. 29.6 y (fathers), P<0.001; 25.7 vs. 26.4 y (mothers), P=0.001) and better educated (7.5 vs. 7.1 y (fathers), P=0.002); 7.3 vs. 6.8 y (mothers), P<0.001) with smaller families (2.2 vs. 2.4 live births, P=0.002), than those excluded. There was no significant difference in mean weekly income, mean value of household assets, gender, percent urban, percent with electricity and piped water among included compared to excluded children.

2. Relationship of diversity scores to dietary patterns

Before evaluating score performance, we compared scores to determine whether they would represent dietary patterns differently. We considered both the number of children consuming each food group, and among consumers how much of each food group was being consumed since both of these inform how well a score will correlate with adequacy.

a. Frequency of food group consumption

We represented the numbers of children consuming each food group as percentages of the total at each score level. Percentages across the 10 gram score are presented in **table 2**. Since individual food groups were defined to represent major nutritionally important components of the diet, food groups consumed less frequently indicate potential areas for dietary improvements. For convenience, we use the term "priority" to designate those food groups selected more frequently.

Cereals/roots/tubers formed the basis for the diet and were consumed by nearly all children. Meat/poultry/fish received the next highest priority, and were consumed by half of children with a diversity score of 2, and over ninety percent of children with a diversity score of 5 or greater. β-carotene rich fruits and vegetables, other fruits, and dairy were next in priority consumed by about 10 to 25% of children with scores of 2 or 3. As more food groups were consumed (i.e. scores increased) dairy frequently received the higher priority of these three groups and BCFV the least - at least eighty percent of children with a score of 6 or higher consume dairy, while only about 45 percent of children with a similar score consumed BCFV. Legumes/pulses and nuts, other vegetables, and eggs receive similar low priority among children consuming 1-4 food groups. In contrast, among children consuming 5 or

more food groups LPN and eggs were prioritized over vegetables. BCFV and other vegetables received the lowest priority among children with scores of 7 or higher.

Food group prioritization was also inspected for the 0 gram diversity score (data not shown). As anticipated, the distribution of scores was shifted slightly to the right. Patterns of food group prioritization were similar to those described above, except prioritization of other vegetables and BCFV were greater than prioritization of LPN and eggs for all scores.

b. Average food group intake among consumers

We evaluated whether the amounts of food groups fed to children varied with diversity score. This affects the relationship between dietary diversity and adequacy, but is often disregarded in research on dietary diversity.

The graphs in **figure 1** depict the average grams per consumer of each food group, stratified by each diversity score. The number of children in each score category is depicted across the top of each graph. Note that children in level 1 of each score were generally fed only cereals/roots/tubers and are excluded from the figure. Also, no children consumed other vegetables at level 2 of the 0 gram score. Linear regressions were calculated for each nutrient to determine average rates of increase and the statistical significance of these associations. The group containing cereals, roots and tubers was excluded in these depictions because no significant changes occurred in intakes with either score. Average intake ranged between 360 and 431 grams.

Across levels of the original score only consumption of MPF and fats & oils increased significantly with diversity (3.6 and 0.5 grams per point respectively, P<0.01 for both). Other apparent trends were non-significant including a slight decrease in vegetable consumption.

Across levels of the 10 gram score, intakes increased visibly for all food groups. One child at the 7+ level consumed 480 grams of milk, inflating the average dairy intake from 100 grams to 114 grams since this was a small category (n=27). Regression models predicted increases in other fruits and MPF which were nearly double those of other foods (8.3 & 9.4 grams vs. <5.5 grams per one unit change in diversity for all other groups). Among consumers of LPN, other vegetables, BCFV, and eggs, predicted increases in grams consumed were similar (5.1, 4.6, 4.6, and 5.3 per score point, respectively).

D. Relationship of diversity scores to adequacy

We evaluated how well each diversity score predicted nutrient adequacy represented both as percent of recommended nutrient intakes, and as probabilities of adequacy. Forty nine children fed fortified formula were excluded beginning at this point in the analysis because of the potential for fortified foods to confound the relationship between diversity scores and nutrients.

1. Relationship with % recommended nutrient intakes

We calculated %RNI per nutrient for each child. Percentages were then averaged for children at each diversity score level. To allow visualization of total increases across score levels, percentages were not truncated at 100%. Mean percent RNI increased monotonically across the 0 gram diversity score for all nutrients (see **figure 2**), except niacin declined slightly between levels 6 and 7+. Similar analysis were performed for the 10 gram score and also yielded monotonic increases. While children in level 1 of both scores had similar mean percentages, percentages increased more dramatically across categories of the 10 gram score,

resulting in percentages being 26 to 78% higher for the 10 gram score comparing children

with 7+ for both scores. Differences were as follows: 25.6 (thiamin), 29.5 (niacin), 32.9

(absorbed calcium), 52.2 (riboflavin), 56.1 (calcium), 59.3 (vitamin A), 73.8 (absorbed iron).

These sharper increases across the 10 gram score reflect the scores greater sensitivity to

adequacy.

2. Correlation with probability of adequacy

Spearman correlations between diversity scores and probabilities of adequacy are shown in

table 3. For comparison with other analyses, the table also depicts mean nutrient intakes and

EAR values used. Unadjusted correlations reflect the strength of the linear relationship

between ranked diversity scores and ranked adequacy. Energy adjusted correlations reflect

the strength of this relationship once energy intake is held constant (i.e. after correlations

between nutrients and energy intake, and between diversity and energy intake have been

removed). Nutrient density is an alternative method of energy adjustment and spearman

correlations with nutrient density are also included.

Comparing across the two scores, the 10 gram diversity score performed more favorably.

The 10 gram score achieved higher correlations with probabilities of adequacy (both adjusted

and unadjusted) and nutrient density for most nutrients. Coefficients were at least 45%

greater in all three comparisons for niacin, 30-45% percent greater for absorbed iron

comparisons, and 14% to 21% greater in all comparisons for thiamin and riboflavin.

Coefficients for vitamin A, calcium, and absorbed calcium were 12-15% higher for the 10

gram score in unadjusted correlations, but the difference between score was less clear after

energy adjustments (i.e. adjusted correlations and correlations with nutrient density).

Comparing within each score, energy adjusted correlations were lower than unadjusted. This was expected given the known correlations of energy with nutrient intakes and diversity scores. Adjusted coefficients were reduced most dramatically for niacin (-76% for the 0 gram and -55% for the 10 gram score) followed by absorbed iron (-51% and -45%, respectively). Since these reductions were greater for the 0 gram score, mean probability of adequacy was also more reduced (45% vs. 38% in the 10 gram score). This seems to suggest greater resilience to energy adjustment in the 10 gram score for these two nutrients. Percent reductions for other nutrients were similar.

3. Linear increases in probabilities of adequacy

We also evaluated the average rate of increase in probabilities of adequacy across diversity through linear regressions (see **figure 3**). Relative increases in probability of adequacy ranged between 5.0% (absorbed calcium) to 12.1% (riboflavin) per point on the 0 gram diversity score, and from 5.6% (absorbed calcium) to 14.4% (riboflavin and vitamin A) per point on the 10 gram diversity score. Predicted increases in adequacy were greater for every nutrient using the 10 gram diversity score, reflecting a better ability to differentiate children with differences in nutrient adequacy. Note that the confidence intervals depicted are applicable to individual coefficients only, and cannot be used for comparison of changes in probability of adequacy due to the correlated nature of the two diversity scores. To evaluate whether this correlation of the scores affected the pattern of regression coefficients we randomly selected a 50% sample, and compared models using each score on opposite sample halves. Similar patterns were observed.

Energy adjusted versions of these models were also created (data not shown). While

holding energy constant, increases in dietary diversity continued to predict statistically significant increases in probability of adequacy for all nutrients, though coefficients were somewhat attenuated. Coefficients for models based on the 10 gram score remained higher than for models based on the 0 gram score for all nutrients except absorbed calcium.

E. Sensitivity/Specificity Analysis

We used sensitivity/specificity analysis to evaluate which score would perform better in our population if used to screening for low and high mean nutrient adequacy.

1. Roc Curves

Receiver operator curves to visualize the relationship between sensitivity and specificity appear in **figures 4** and **5**. Each point along the curve represents a diversity score cutoff, and a greater perpendicular distance from points on the curve to the diagonal indicates greater utility of the indicator at that cutoff. Likewise, a greater total area between the curve and the diagonal suggests a better overall indicator. From the figures, we selected a range of cutoffs for each score which maximized sensitivity and specificity for determining both low and high mean nutrient adequacy: for determining low intake (panel A) we selected cutoffs at ≤ 2 - 5 for further evaluation; for determining high intake we selected cutoffs of ≥ 4 - 6. We also evaluated total area under the curve and found that it was greater for the 10 gram cutoff indicator in both outcomes tested (Area = 0.7535 vs. 0.8023 testing MPA <0.50, and 0.7814 vs. 0.8221 testing MPA >=0.75).

2. *Selecting cutoffs and a preferred score*

The cutoffs we selected above for each score are presented in **table 4,** with corresponding sensitivity and specificity values. In order to reflect the full extent of misclassification we also investigated the proportions of all children tested who would be classified as "false positives" and as "false negatives" (children who are misclassified by the score cutoffs), and the "positive predictive value" which can be interpreted as the true likelihood of having the outcome among those testing positive.

Comparing scores for detecting low adequacy (MPA<0.50) the 10 gram score had considerably higher sensitivity at all cutoffs, but lower specificity. A cutoff of 4 was most favorable for maximizing sensitivity and specificity for both scores. In both cases most of those identified as "at risk" truly were at risk (i.e. positive predictive value was high). A cutoff of 3 also resulted in relatively high sensitivity and specificity for the 10 gram score, but false negatives and overall misclassification were increased. Screening projects generally prefer to identify more of those "at risk", which means reducing false negatives though false positives may be increased. This is especially true if the intervention is affordable, and safe if given to those not at risk. Given this, we preferred cutoffs of 4 for both scores, but preferred the 10 gram score over the 0 gram score since the 10 gram score resulted in many fewer false positives.

Comparing scores for detecting high adequacy (MPA≥0.75), the 10 gram diversity score had lower sensitivity at all cutoffs, but higher specificity. For the 0 gram score, a cutoff of 5 maximized sensitivity while maintaining acceptable specificity. Only a small proportion of children with highly adequate diets were not identified (2% false negatives). However, only 18% of those identified as "high" were actually high (positive predictive value). The other

82% misclassified comprised about 30% of the total sample (false positives). The 10 gram score had similar difficulties identifying children with "high" adequacy. A score of 4 identified 87% of these (see sensitivity) with few false negatives, but resulted in many false positives (38%). A score of 5 had a lower number of false positives, but only identified 66% of those with "high" adequacy. Given these tradeoffs, a "preferred" score for identifying high adequacy was not clear.

F. Discussion

Early childhood malnutrition is a pressing international concern which dietary diversity scores may be helpful in assessing and addressing. This study focused on three current research needs surrounding diversity scores: the impact of portion size on score function, the relationship of scores to nutrient adequacy before and after energy adjustment, and the ability of scores to function as screening tools. We found strong evidence that applying a 10 gram minimum portion requirement to the diversity score could improve its performance by increasing the strength of its relationship to nutrient adequacy (both with and without energy adjustment) and nutrient density, and improving its capabilities in screening for nutrient adequacy.

The difference in the performance of the two scores is due to their different sensitivity to very small amounts of food in the diet. Ideally scores may be used to help identify food groups which are under-consumed in a population. However, when any intake at all is counted for individual food groups, scores are inflated and may not give a clear picture of diet. Children consuming tiny amounts of multiple food groups are classified in higher score categories even though their nutrient intakes may not be appreciably higher than children

consuming only one or two food groups. By requiring children to consume 10 grams of every food group (except oil) before receiving credit, the modified score reassigned a portion of these misclassified children to lower score categories. We demonstrated the improved sensitivity of the 10 gram score to amounts of foods consumed in figure 1. Increases in the 10 gram score reflected increases in intake of most food groups. In contrast, with the 0 gram score these trends were not visible due to the averaging in of many very small amounts food. Note that some exceptions and misclassifications are inevitable, for instance very small amounts of organ meat, or dried fish may be very nutrient dense and could appropriately be counted at low levels. However, modifying minimum portion requirements on a food-specific basis would add a great deal of complexity to scores and reduce their field practicality.

This study also evaluated whether applying a 10 gram minimum portion requirement could improve a scores' sensitivity to nutrient adequacy. Previous studies have demonstrated the relationship between scores similar to this and adequacy in several contexts (Arimond and Ruel, 2004; Hatloy et al., 1998; Ruel, 2003b). We also found significant relationships between dietary diversity and adequacy, and found that adding a minimum portion requirement further strengthened these relationships. Portion requirements strengthened relationships most dramatically for niacin and iron. This may be due to increases in the 10 gram score reflecting strong increases in intake of meat/poultry/fish as mentioned in the results for figure 1.

Scores must relate to nutrient adequacy in order to be useful, but a positive correlation can mean two things: either children with higher diversity are getting more nutrient rich diets, or they are simply getting absolute nutrient increases through more food. If diverse diets are

more nutrient rich, then diversity scores should reflect this. However, previous studies have not consistently demonstrated this relationship (Ruel, 2003b). We found that energy adjustment reduced the relationships between dietary diversity and adequacy somewhat, but that positive relationships were still present and significant. We also found that the inclusion of portion requirements at this level did not reduce these energy adjusted relationships. Energy adjusted correlations were reduced more strongly for some nutrients (i.e. thiamin, niacin, absorbed iron) than for others. When comparisons were made of mean nutrient intakes across food groups, we found that these nutrients varied somewhat less across food groups than calcium, vitamin A and riboflavin, which may explain their greater vulnerability to energy adjustment.

The sensitivity/specificity analysis clearly highlighted the benefits of the 10 gram score for detecting low mean probability of adequacy (MPA<0.50). Using a cutoff of 4 for the 10 gram score identified 87% of the children who had low MPA, with only a modest number of false positives and negatives (10 and 11%, respectively). While these numbers are highly context specific, the evidence that adding portion requirements to the score may improve screening capabilities is important and invites further research.

The choice of scores for detecting high mean probability of adequacy (≤0.75) was a less clear judgment call. In general both scores had more difficulty detecting high adequacy than low adequacy. This is because fewer children had high adequacy, and large numbers were misclassified as false positives in attempting to identify them. Large numbers of "false positives" can inflate the cost of screening based interventions if those identified positively are intervention targets. However, in our case "testing positive" was a good thing and populations with large numbers of children thus identified may need less intervention.

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While these analyses provide much evidence supporting the use of a minimum portion requirement, many questions remain to be answered. Initially, it is important that similar comparisons be made in other populations. The benefits gained must be balanced against the practicality of using indicators with cutoffs. No-cutoff diversity scores are simple because only information on food types consumed must be collected. Introducing a cutoff into the score will require that fieldworkers ask questions about amounts consumed as well. This could be relatively simple if interviewers presented models for typical volumes of required food group amounts to interviewees, but work will need to be done to determine the accuracy of estimation for total volumes consumed. In addition, more work needs to be done to determine whether minimum cutoffs should vary across food groups or by age of children. This could also be combined with studies on within-food group variety, to determine whether more than one cutoff should be applied within food groups for foods of varying nutrient densities. Although energy adjustment is impractical in fieldwork, further research is needed in score validation to understand the relationship between dietary nutrient density and diversity.

Aside from our main questions, the analysis also reveals important information about dietary patterns in early childhood for this Filipino population. Both diversity scores revealed similar patterns in food intake (see **table 2** and results) - a cereal/root based diet (commonly rice and/or corn) with meat, fish or poultry as the most common second food group. Dairy, fruits, and beta-carotene rich vegetables were consumed less frequently (by 25-40%), and other vegetables seldom (13%). Contrasting the 0 and 10 gram diversity scores, prioritization of BCFV and other vegetables was higher than LPN and eggs only in the 0 gram score indicating that when BCFV and other vegetables are consumed it is often in miniscule

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amounts. Even averaging only consumers, mean grams of BCFV, other vegetables, LPN and eggs eaten did not exceed 45 grams at any diversity score level. Increasing both the frequency and amount of consumption for these foods will be helpful in improving diet quality. Consumers of other fruits tended to eat larger amounts, with average gram intake equaling that of meat/poultry and fish but these other fruits were most almost exclusively different types of bananas which are grown commercially in several varieties in the Philippines. Bananas were most often eaten boiled, fried or raw. Green papaya and lemon were also eaten frequently, but were consumed in very small amounts (mean consumption of 10.0 and 11.2 grams, respectively). Foote et al. recently demonstrated the importance of within-group variety of fruits, vegetables, dairy and grain contributing to probability of adequacy in a US population (Foote et al., 2004). Therefore, increasing the within-group variety of fruits consumed in this population is likely to yield improved nutritional adequacy.

Children in this analysis were slightly better off at baseline in a few respects (higher birth weight, younger and better educated parents) than cohort children excluded from this analysis. Through analyzing individual subsets excluded we found that loss to follow up came from both extremes of the socioeconomic spectrum (i.e. children from the poorest homes had higher mortality, children from the wealthiest were more likely to migrate). Among children present at 24 months, children excluded due to illness were not significantly different for any of the characteristics considered. Children excluded for breastfeeding at 2 years were from poorer circumstances with lower income households in spite of larger families, older and less educated parents, and poorer housing conditions (less access to toilets, running water, electricity). The slight differences between our analysis sample and the original cohort are unlikely to reduce the applicability of our findings. Children from our

sample were somewhat shorter than those of similar age from a nationally representative sample taken in the same year (-2.8 cm girls, - 3.9 cm boys) (Florentino, 1992), and are clearly nutritionally disadvantaged. Our sample is typical of the nutritionally challenged populations which dietary diversity scores are being developed to help identify and assist.

The study has several strengths. The sample is of respectable size and located in an area where nutritional improvements are needed. Data collection for the Cebu study has been extensive with follow-up surveys conducted in 1991–1992, 1994–1995, 1998–2000, and 2002, which will allow for further research on this topic. The study uses a proven instrument and has been informed by recent FAO guidelines (Kennedy & Nantel, 2006) in an effort to be comparable with forthcoming analyses by FAO/WHO researchers and others referring to the protocol. The study makes a detailed comparison of two versions of the diversity score which have been recommended for comparison in future analyses. Sensitivity/specificity analysis has been used in only a few studies to date (Hatloy et al., 1998), but was recommended by Ruel (Ruel, 2003b) for future use in evaluating the functionality of dietary diversity indicators.

Weaknesses in this study include those inherent in the collection of dietary data. Nutrient variation within foods and food nutrient analysis error lead to imperfections in food composition information, as do difficulties in matching foods to obtain missing nutrient information. In spite of precautions in data collection and analysis, we recognize that some error in reported intakes inevitably occurs due to error in reported recipes, portion sizes, and dish ingredient. In addition, uncertainty about the actual shape of nutrient requirement distributions remains.

Dietary diversity scores are a promising method for identifying populations at increased

risk of malnutrition. The study contains valuable findings - namely that dietary diversity score function can be improved by applying a 10 gram minimum portion requirement. Improvements using the 10 gram score included stronger correlations with nutrient adequacy as well as energy adjusted nutrient adequacy and nutrient density, greater increases in overall nutrient intakes across score levels, and better functionality in screening tests. However, much more work is needed to further refine these indicators. Refinements strengthening the relationship of scores to nutrient adequacy and density remain a priority, as does further testing of scores as screening tools in a variety of populations. Care should be taken that scores remain practical for field use, i.e. as affordable and simple to administer as possible. Also, research is needed assessing the potential of scores to detect inadequacy in older children and teens. As dietary diversity scores are improved, studies evaluating predictors of dietary diversity will become important guidance for targeting diversity interventions. We encourage further research in these and related areas.

Table 2. Percent of children consuming ≥10 grams of each food group by diversity score level at 24 months

Dietary Diversity Score	n	Cereals Roots & Tubers	β-carotene rich Fruits & Vegetables	Other Fruits	Other Vegetables	Legumes Pulses & Nuts	Fats & Oils	Meat Poultry Fish	Dairy	Eggs
1	132	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0
2	372	1.00	0.16	0.09	0.01	0.03	0.03	0.51	0.15	0.01
3	469	1.00	0.23	0.25	0.09	0.09	0.3	0.75	0.26	0.02
4	426	1.00	0.29	0.35	0.15	0.21	0.6	0.88	0.41	0.1
5	268	1.00	0.34	0.54	0.24	0.33	0.78	0.94	0.6	0.23
6	114	1.00	0.47	0.68	0.39	0.43	0.89	0.92	0.8	0.43
7+	23	1.00	0.52	0.86	0.59	0.66	0.97	1.00	0.93	0.72
Total	1.81	1.00	0.25	0.3	0.13	0.16	0.41	0.72	0.35	0.11

Table 3. Correlations of dietary diversity with probability of nutrient adequacy and nutrient density

	Intake	EAR	Probability of Adequacy				Nutrient Density	
			Correlation	Adjusted Correlation[a]	Correlation	Adjusted Correlation[a]	Correlation	Correlation
Diversity Score Cutoff			0 gram	0 gram	10 gram	10 gram	0 gram	10 gram
Vitamin A, mcg RE	233.82(478.64)	200	0.4763	0.3484	0.5348	0.3717	0.3535	0.3617
Thiamin, mg	0.28(0.26)	0.4	0.4832	0.2594	0.5823	0.2945	0.3736	0.4258
Riboflavin, mg	0.40(0.51)	0.4	0.5092	0.3128	0.6172	0.3785	0.4335	0.5062
Niacin, mg	5.11(3.91)	4.6	0.3447	0.0844	0.5073	0.2298	0.0574	0.1691
Calcium, mg	303.48(362.10)	417	0.5196	0.3453	0.5998	0.3776	0.3766	0.3945
Absorbed Calcium, mg	91.48(116.00)	220	0.5343	0.3684	0.6126	0.3985	0.4179	0.4382
Absorbed Iron, mg	0.50(0.49)	na	0.4188	0.2074	0.5461	0.3025	0.1462	0.1989
Mean PA[b]			0.484	0.2655	0.6268	0.3917		

Correlations are Spearman Rank for nonparametric analysis. $P<0.001$ for all correlations;
[a]energy adjusted correlations;
[b]mean probability of adequacy for all nutrients (uses absorbed calcium).

Table 4. Sensitivity and specificity analysis evaluating dietary diversity scores for ability to detect high and low MPA

DDS	n	Cutoff	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
					MPA<0.50			
0 g	n≤cutoff	≤						
	236	2	16.57%	97.92%	96.61%	0.45%	65.19%	65.64%
	645	3	43.82%	89.09%	93.49%	2.39%	43.90%	46.28%
	1111	4	71.58%	67.27%	88.66%	7.16%	22.20%	29.36%
	1475	5	89.90%	38.18%	83.86%	13.52%	7.89%	21.41%
10 g								
	501	2	35.61%	97.14%	97.80%	0.62%	50.31%	50.94%
	969	3	64.75%	81.82%	92.72%	3.98%	27.54%	31.52%
	1372	4	86.56%	52.99%	86.81%	10.28%	10.51%	20.78%
	1624	5	96.58%	23.38%	81.83%	16.75%	2.67%	19.42%
					MPA ≥0.75			
0 g	n≥cutoff	≥						
	1116	4	93.42%	39.47%	12.72%	55.31%	0.57%	55.88%
	650	5	76.32%	66.81%	17.85%	30.32%	2.04%	32.37%
	286	6	49.34%	86.89%	26.22%	11.98%	4.37%	16.35%
10 g								
	800	4	86.84%	58.48%	16.50%	37.93%	1.14%	39.07%
	389	5	66.45%	82.10%	25.96%	16.35%	2.90%	19.25%
	137	6	35.53%	94.84%	39.42%	4.71%	5.57%	10.28%

DDS=Dietary Diversity Score; MPA=Mean Probability of Adequacy. Total n=1,761.

Sensitivity = (top) percent ≤ cutoff, among children with MPA<0.50; (bottom) percent ≥ cutoff, among children with MPA>=0.75.

Specificity = (top) percent > cutoff, among children with MPA>=0.50; (bottom) percent < cutoff among children with MPA<0.75.

Positive predictive value = (top) percent with MPA <0.50, among children below cutoff. (bottom) percent with MPA>=75 among children at or above cutoff.

Proportion of false positives = (above) proportion of all children (n=1761) who have MPA>=50 and are classified below cutoff. (below) percent of all children who have MPA <0.75 and are classified above cutoff.

Proportion of false negatives = proportion of all children (n=1761) who have MPA < 0.50 and are classified above the cutoff. (below) percent of all children who have MPA >=0.75 and are classified above the cutoff.

Figure 1. Average grams per food group consumer by diversity score. Children with score values 7 or greater were combined. BCFV: beta carotene-rich fruits and vegetables; OFRT: other fruit; OVEG: other vegetables; LPN: legumes, pulses & nuts; MPF: meat, poultry & fish.
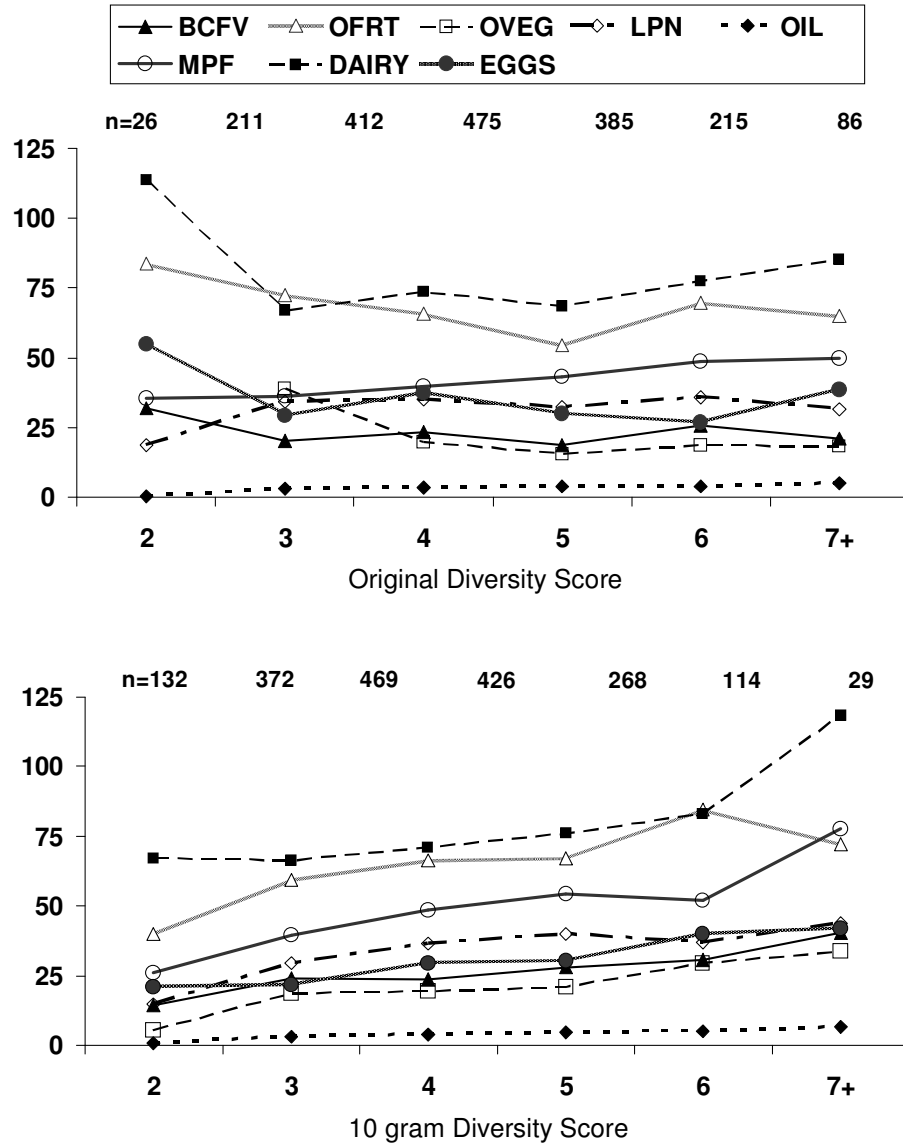
Figure 2. Mean percentages of recommended nutrient intakes achieved across dietary diversity. Based on the 0 gram dietary diversity score. %RNI=percent of recommended nutrient intake.
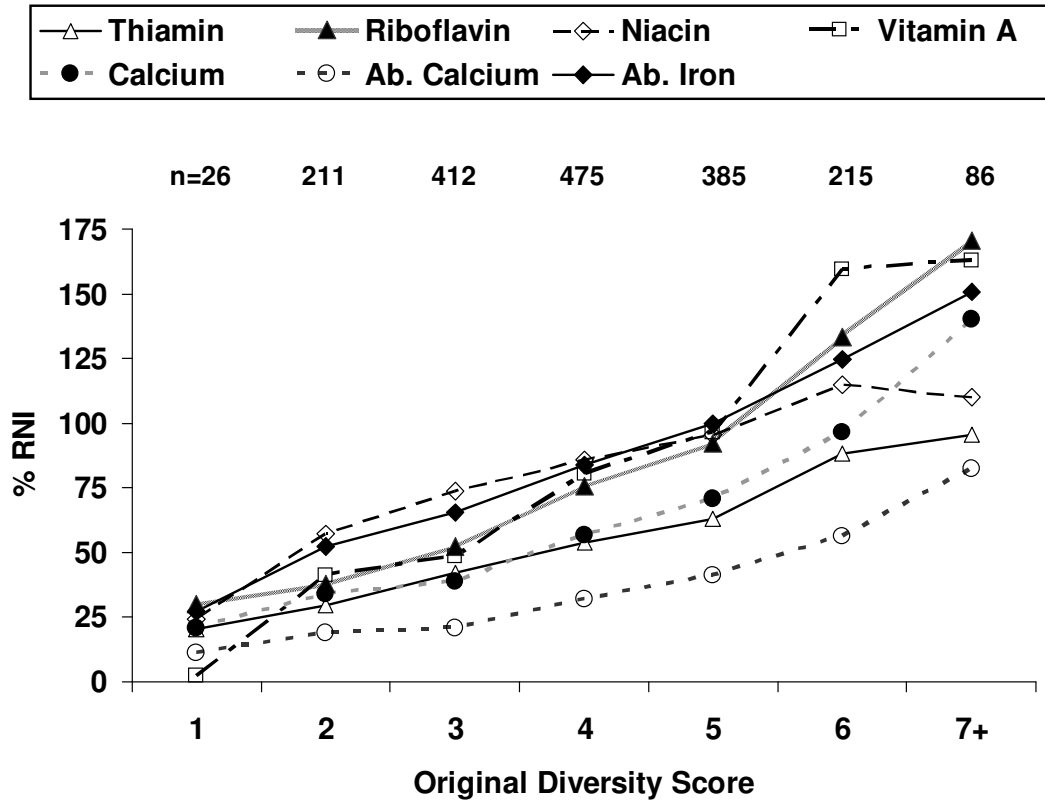
Figure 3. Increases in probability of nutrient adequacy per one unit change in diversity scores. PA=probability of adequacy. Mean PA = mean probability of adequacy for all nutrients (uses absorbed calcium). Data points represent coefficients from linear regressions using diversity scores to predict probability of adequacy for each nutrient. Error bars correspond to 95% confidence intervals. N=1761 non-breastfed, well children who were not receiving fortified formula.
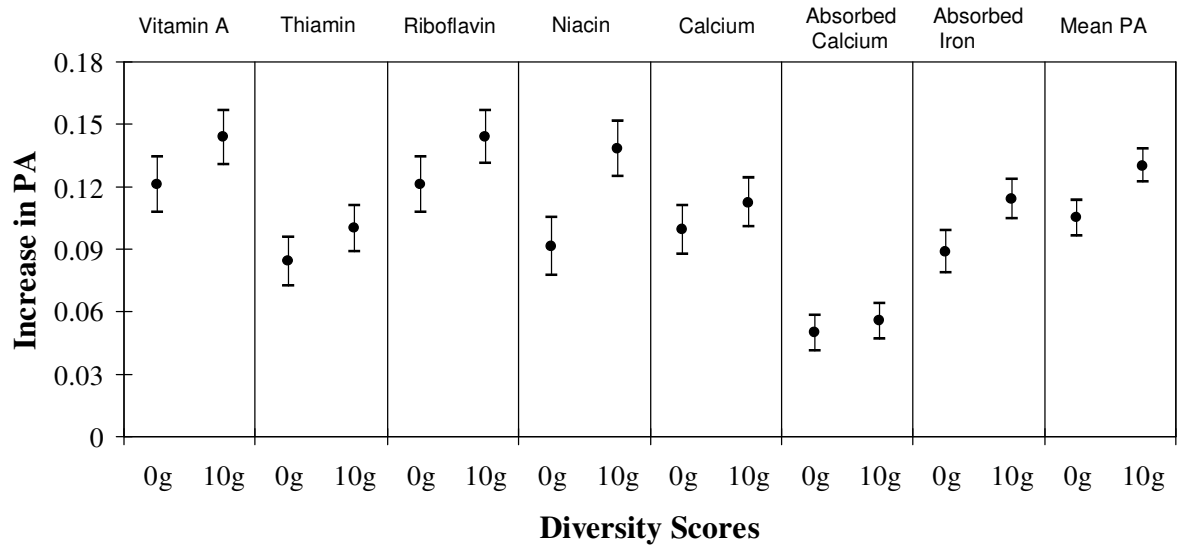
Figure 4. Roc Curves depicting sensitivity and specificity of 0 and 10 gram diversity scores for detecting MPA. MPA=mean probability of adequacy. This figure evaluates scores for detecting low MPA (<0.50).
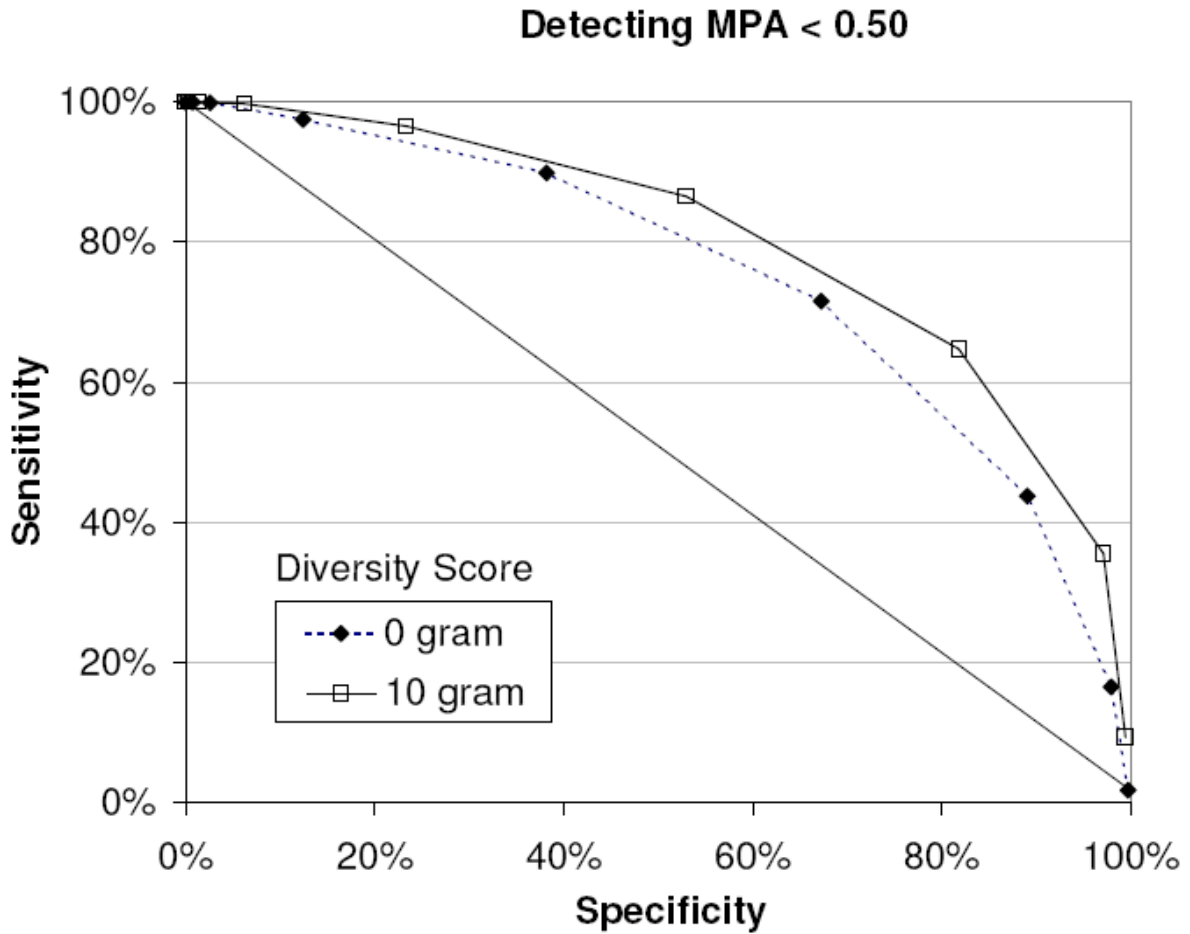
Detecting MPA < 0.50

Figure 5. Roc Curves depicting sensitivity and specificity of 0 and 10 gram diversity scores for detecting MPA. MPA=mean probability of adequacy. This figure evaluates scores for detecting high MPA (>=0.75).
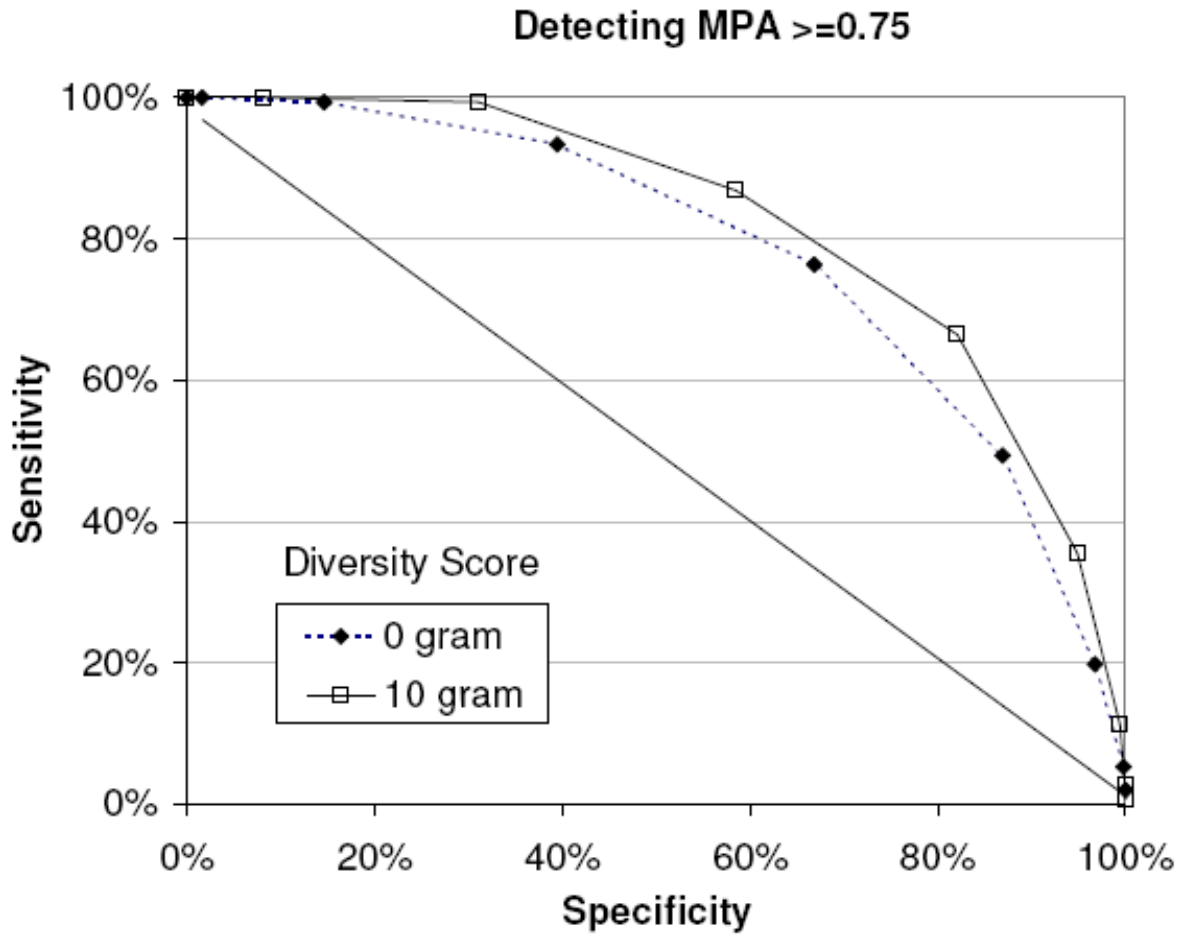
V. Dietary diversity among Filipino adolescents is related to dietary adequacy

A. Introduction

Adolescence is an important period of growth in which children accrue 50% of adult weight, 15% of adult height and undergo considerable changes in body composition (Giovannini et al., 2000). The rate of growth during puberty is only exceeded during the first year of life (ACC/SCN , 2000) and adequate intakes of protein, energy and micronutrients are necessary to sustain it. In spite of this, the need for adequate nutrition in adolescence has received little emphasis internationally. Nutritional status information on adolescents is scarce (ACC/SCN , 2000) and adolescents (as a category) are notably absent from major continuing reports on world health such as UNICEF's State of the Worlds Children (UNICEF, 1998), and UN's report on the World Nutrition Situation (ACC/SCN , 2000; ACC/SCN, 2005). Teens have typically been viewed as having fewer health risks than other populations (e.g. infants, pregnant women, elderly) because pivotal health outcomes rarely occur during adolescence with the exception of pregnancy (WHO, 2005). While the increased needs of pregnant girls are somewhat better recognized because of their impact on offspring, nutritional needs are increased in all teens and better appreciation of this is warranted.

Energy deficits and undernutrition during adolescence result in slowed maturation. Though the growth spurt may be prolonged in these cases, resulting in similar ultimate height, slowed

growth heightens risks in adolescent pregnancies (ACC/SCN , 2000).

Micronutrient deficiencies during adolescence contribute to both acute and long term health effects and economic repercussions. Anemia prevalence for both genders has been estimated at 27% in developing countries (vs. 6% in industrialized nations) and appears to be even higher in poorer Asian nations (42% in Nepal, 55% in India) (Kurz and Johnson-Welch, 1994). Anemia reduces work capacity and cognitive performance in teens and this hinders school achievement and economic contributions (WHO, 2005). Adolescent Vitamin A deficits have not been assessed globally but rates have been shown to be high in several African countries, and this is thought to exacerbate iron deficiency and delay growth and sexual maturation (WHO, 2005). Calcium and Zinc are also particularly important for adolescent growth and development though little has been done to assess deficiency prevalence in this age group (WHO, 2005). Other micronutrient deficits are likely to exist as well, although prevalence data are not available. In addition to acute effects, undernutrition in adolescence has been shown to predispose individuals to chronic disease such as obesity, diabetes, CVD and cancer (WHO, 2005).

Screening tools are needed to evaluate nutritional status among adolescents internationally. An estimated 87% of adolescents currently reside in the less developed regions of the world (UN , 2004) where nutritional risks are more extreme. Cost-efficient tools capable of rapidly screening large numbers will be invaluable in identifying at-risk populations and assessing their nutritional needs. Such tools are being developed for use in other age groups. Dietary diversity scores are currently receiving considerable attention as a potential method for identifying dietary inadequacy in developing countries, particularly among infants and small children. Scores are simple counts of the number of specified food groups contributing to the

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diet in a given time period. They are simply assessed and correlated with nutrient adequacy in early childhood in multiple developing country contexts.

Research is needed to determine whether dietary diversity scores (DDS) may be useful screening tools for adolescents. Adolescents have greater nutrient requirements and larger dietary intakes than young children, and modifications may be necessary for scores to reflect nutrient adequacy in the teenage years. Applying portion requirements to food groups is one potentially helpful modification. Studies to date have largely avoided the concept of portion size; instruments have counted food group intakes in any amount toward score points. In 2003, a major review of dietary diversity studies by Ruel called for studies evaluating whether use of portion requirements can improve dietary diversity scores, since scoring very small amounts of food might reduce a score's sensitivity to more nutritionally meaningful amounts of food (Ruel, 2003b). Recently we showed that requiring 10 g of intake for any food group to be counted improved reflection of nutrient adequacy in 2 year old children (Daniels et al., 2007). In adolescents even larger portion requirements may be needed to help scores reflect intakes meaningful for their greater nutrient needs.

This study will address two major questions. First, can an existing diversity score with demonstrated usefulness in childhood still reflect adequacy when applied to adolescents? Second, can the scores relationship to adequacy be improved by shifting the minimum portion requirement upward in response to adolescents higher nutrient intakes and requirements? We will use 24 hour recall data from Filipino adolescents in the Cebu Longitudinal Health and nutrition survey to address these questions.

We will also briefly address a third question: what are some of the main socioeconomic factors that can help predict dietary diversity in adolescents? This is important from a

programmatic perspective - if factors can be identified that clearly relate to dietary diversity then populations with reduced dietary diversity can be more quickly identified and helped. Given the lack of data on adolescents worldwide, this drives toward a major need. However, a focus on socioeconomic correlates is only relevant if dietary diversity is a meaningful indicator of dietary adequacy; therefore we spend the majority of our focus on determining the strength of the relationship between dietary diversity and dietary adequacy.

B. Subjects and Methods

1. Subjects

Data are from the Cebu Longitudinal Health and Nutrition survey, a cohort study which has followed Filipino children from birth to young adulthood (Adair and Popkin, 2001; The Cebu Study Team, 1991). All singleton offspring (n=3080) of Filipino women who resided in 33 randomly selected barangays (communities) of Metropolitan Cebu and gave birth between May 1, 1983 and April 30, 1984 were included. Follow-up data were collected throughout the first 2 years of life, and again in 1991-92, 1994-95, 1998-99 and 2002-03. Children were in their mid teens in 1998-99 survey (n=2089). Girls were interviewed primarily in 1998 (mean age=15y), and boys in 1999 (mean age=16y). Individuals were lost to follow-up due to death and migration (n=991). We also excluded individuals if they reported that their diet on the day of the 24 hour recall was not "usual" (n=651) leaving a sample of 1,438 from the original 3080. The protocol for testing diversity scores in early childhood recommends exclusion of individuals who are ill or who are otherwise not consuming a usual diet (Kennedy & Nantel, 2006). We lacked data on acute illness for this sample, but assumed that individuals with reduced or altered appetite due to illness would report that their diet was not

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usual. The final sample was comparable in baseline characteristics (birthweight, birth order, gender, parental age and education, maternal height, household income, value of household assets, percent with electricity, percent urban) to those excluded. Children excluded specifically for non "usual" diet also did not differ, except slightly more lived in an urban areas (77.4% vs. 71.8% urban, p=0.007).

2. Dietary data

Children were interviewed by trained study personnel to obtain two 24 hour recalls on nonconsecutive days. Information regarding each food type, portion size, amount consumed, and cooking method were collected. Food models and measuring cups were used to determine volumes of each food consumed. Grams of each food consumed were then calculated using volume and density of ingredients, and conversion factors converting raw to cooked ingredients where applicable. Cooking oil consumed was also calculated for each dish. We used only one day of intake for this analysis to approximate data availability under screening conditions. However, data were taken from both recalls to maximize the number of children reporting "usual" intake. Where "usual" intake was available for both days, data were taken from the second round of recalls because recalls from the first round had an overrepresentation of Sundays which may not be representative of more typical weekday diet.

Food composition data were obtained from the Food and Nutrition Research Institute of the Philippines Food Composition Tables (FNRI, 1980). Using this early food composition data allowed for comparability with our previous analysis of diversity scores in early childhood. To determine comparability with later food composition data, changes published

in 1997 were compared for foods consumed and minimal discrepancies were found (FNRI, 1997). In the case of fortified foods, FCT data did not include added nutrients. Exclusion of fortified foods is important in diversity score testing since fortified foods could alter naturally occurring relationships. Nutrient profiles for foods not listed in FNRI tables at the time of the survey were assigned profiles from comparable foods. Foods with partial nutrient data at the time of our analysis were hand-matched to similar foods from FNRI (1990), Worldfood Dietary Assessment System (1996), or the USDA (2005) food composition tables. Missing nutrient values for mixed foods were calculated after consulting Filipino colleagues and recipes online to obtain listings of major ingredients.

Nutrient profiles compiled for all foods included energy, carbohydrates, protein, total fat, calcium, iron, retinol, beta-carotene, thiamin, riboflavin, and niacin. Vitamin C was excluded from the analysis due to a large number of missing values. We also estimated absorbed calcium since this was recommended by a recent FAO/WHO protocol for diversity score testing in children (Kennedy & Nantel, 2006) Regular calcium values were also tested for comparative purposes. Absorbed calcium values were computed according to FAO/WHO recommendations which were based on the work of Weaver et al. (Weaver et al., 1999) Calcium absorption is strongly affected by food levels of oxalate. Therefore, absorbed calcium was estimated based on oxalate levels as follows: 25% for roots, tubers, grains and legumes; 45% for fruits and vegetables; 5% for high oxalate foods and 32% for all other food groups. High oxalate fruits and vegetables were defined as having >5g oxalate per 100g and were identified using lists provided by FAO and FNRI (1990). Absorbed iron was assumed to be 14% from animal products and 6% for plant foods. This assumes animal products consist of 40% heme iron (Monsen et al., 1978) with an average absorption of 25%, and 60%

non-heme iron with an average absorption of 6% (FAO/WHO, 2002). A similar method was recommended by FAO/WHO (Kennedy & Nantel, 2006) using a lower value of 11% for animal products because of the low bioavailability of iron in dairy products and their frequent consumption in most countries among young children. Since our sample is adolescent and has limited dairy consumption we chose to use a higher value of 14%.

3. Dietary Diversity Scores

Dietary diversity scores were calculated by totaling the number of defined food groups each child consumed over 24 hours. Food groups were cereals/roots/tubers (CRT), β-carotene rich fruits and vegetables (BCFV), other fruits (OFRT), other vegetables (OVEG), legumes/pulses/nuts (LPN), meat/poultry/fish (MPF), fats/oils (FAT), dairy and eggs, giving potential scores of 1-9. These food groups were recommended by FAO/WHO (Kennedy & Nantel, 2006) for use in children (ages 2-5y) with the suggestion to contrast a basic score (no minimum amounts) with one requiring 10g of intake for each food group to be counted. (One gram intakes of added oil were suggested as a requirement for both scores because of the high energy density of oil and because it is generally consumed in small amounts.) We previously compared these two standard scores in this sample at 24 months of age, and found that the 10 gram requirement improved score performance considerably (Daniels et al., 2007). Given these findings and the increased nutrient needs of adolescents, for this analysis we created a new score based on a larger required portion size. We used recommended Filipino serving sizes for each food group to derive this (FNRI, 2006) since no internationally recommended serving sizes existed. The weights of several representative foods in each food group were averaged to obtain the mean weight (in grams) for one serving

for each food group. The mean weight of a serving was then averaged for all food groups (mean=90g), and half of this value (45g) was used for the minimum requirement. In other words, youth received one point for each food group in which they consumed at least 45 grams during the 24 hour period. Our rationale was that 45g would be low enough to detect nutritionally meaningful intakes (with respect to requirements) but high enough to screen out individuals whose individual food group intakes were negligible. The use of a similar requirement across all food groups was to maintain the score's simplicity for field use.

4. Recommended nutrient intakes

Analyses were based on international nutrient intake recommendations from the World Health Organization (FAO/WHO, 2001) rather than Filipino Required Energy and Nutrient Intakes since the applicability of dietary diversity scores is of interest globally. Estimated Average Intake (EAR) values were back-calculated from Recommended Nutrient Intakes (RNI) values for Thiamin, Riboflavin, Niacin, and Calcium using the formula $EAR = RNI / (1+2*CV)$ where CV is the coefficient of variation for individual nutrient requirement distributions recommended by the Institute of Medicine (Institute of Medicine, 2001). As recommended we used a CV of 10% for all nutrients other than Vitamin A (CV=20%) and Niacin (CV=15%). No RNI values were listed for Vitamin A or Absorbed Calcium, but values approximately equivalent to EARs were given by WHO so equivalents for RNI were calculated using the above formula. Percent RNI (%RNI) was calculated as an individuals nutrient intake divided by the RNI for that nutrient times 100%.

5. *Probabilities of adequacy*

A method for calculating probabilities of nutrient adequacy for a single day was set forth by Foote et al. (Foote et al., 2004) The method relies on the use of requirement distributions for each nutrient assessed. Each distribution is defined by its mean (i.e. the EAR) and standard deviation (SD) which is the EAR multiplied by the distribution CV. Methods for obtaining these values were described above.

Probabilities of adequacy as defined by Foote et al. (Foote et al., 2004) represent the likelihood that a child's intake is adequate on a single day. This is calculated as the proportion of the requirement distribution that is below the individual's intake. For example, if a child consumes 15 milligrams of thiamin in a day, we compare this number to the distribution of requirement for thiamin intakes (mean or EAR = 12.31 and SD = 1.85). Assuming a normal distribution, we can calculate that 92.7 % of this distribution is below 15 mg. Therefore the child's probability of adequacy for thiamin on the particular day is 0.93. Probability of Adequacy in this respect does not reflect the adequacy of an individuals usual diet, but is useful in epidemiologic research for assessing population adequacy. The requirement distribution for Iron is not normally distributed; therefore probabilities of adequacy were derived from table I-6 in the IOM manual for Iron (Institute of Medicine, 2001) as suggested by the protocol (Kennedy & Nantel, 2006). All other probabilities of adequacy were calculated using the normprob function in Stata. Mean probability of adequacy was calculated as the average of individual nutrient probabilities of adequacy (Vitamin A, Thiamin, Riboflavin, Niacin, Absorbed Calcium and Absorbed Iron) the distributions of which were truncated at a probability of 1.

6. Selection of socioeconomic status variables

A relationship between dietary diversity and general socioeconomic indicators has been demonstrated elsewhere (Ruel, 2003b). We hypothesized that diversity would be related to several individual, family, and community level factors. Individual factors included the age, education, and gender of the youth. Family or household factors included the age and education of the mother, the total household income or household income per capita (tested independently), the price of food in the community (we used a correlated representative measure: the cost of edible oil), the presence of electricity in the home, the presence of a refrigerator, and as a general measure of affluence: the presence of other key household assets (ownership of a motor vehicle, an electric fan, electric iron, television) for which a summary score was created. At the community level we anticipated that dietary diversity would be related to population density, proximity to markets, and quality of local transportation. These along with other community variables were used to create a general index of urbanicity for the community which was tested in models independent of the previous three variables.

7. Statistical analysis

Anova and tabular comparisons were used to determine baseline sample characteristics and to test for sample selectivity. Tabular methods were also used to summarize dietary data across diversity score distributions, including the percent consuming each food group, average grams consumed, and percent of RNI. Non-parametric (Spearman's rank) correlations were used to evaluate the relationship of dietary diversity to nutrient-specific probabilities of adequacy, because probabilities of adequacy were not normally distributed.

Partial correlations with the effect of energy removed were also calculated using ranked data. Simple and multivariable linear regression models were used to evaluate the relationship between dietary diversity and potential socioeconomic predictors. Prior to regression analysis relationships of all variables and DDS were tested for normality and linearity and, where necessary, indicator variables were used. Income variables were log transformed for normality. Collinearity checks were performed and correlations greater than 0.7 avoided. Statistical significance was based on P<0.05. All statistical analysis were performed using Stata 9 (Statacorp, 2005).

C. Results

1. Preliminary Analysis of Diversity Scores

Prior to investigating score performance we contrasted the differences in what the scores represented to give context to our comparison. First we evaluated the number of children consuming each food group given their diversity score ranking (**Figure 6**). Second we considered the amount of each food group consumers were eating given their diversity score (**Figure 7**). Visualizing both how many children are consuming different food groups, and how much they are consuming is helpful for interpreting score performance since both factors contribute to dietary nutrient adequacy.

a. Comparability of score distributions

The number of children in each diversity score category is presented across the top of each graph in figure 1. Scores ranged from 1-9 for the 10 gram score [mean(sd)=4.43(1.25) food groups consumed] and from 1-7 for the 45g score [mean(sd) =3.21(1.03)]. Small numbers of

children in the extreme categories of each score were grouped into their adjacent categories for graphic depictions. Though some of the categories in the two scores are of similar size it is important to recognize that the subsets of children in these categories are not necessarily overlapping. The scores subset children differently, with the 45 gram score focusing on larger intakes that are more nutritionally substantial. For example, of the 64 children with a score of 1 on the 45 gram DDS, only 24 scored 2 or less on the 10 gram score. Sixteen received a score of 3, 17 a score of 4 and 7 a score of 5. Those with higher totals on the 10 gram score still did not consume more than 45 grams (~1 ½ ounces) of anything other cereals, roots and tubers which are relatively nutrient poor compared to other food groups. The 45 gram score, by design, retains these children in a low score category since we hypothesize that they are likely to have lower dietary adequacy. Similar differences in stratification occured among the 252 children receiving a score of 2 on the 45 gram diversity score. These children were distributed across the entire range of the 10 gram score. Since it is impossible for a child's ranking on the 10 gram score to be lower than on the 45 gram score, scores are less discrepant for those ranked high on the 45 gram score.

b. Percent consuming food groups by score

Some important trends in food groups consumed are visible in figure 6. Consumption of Cereals/Roots and Tubers was consistently seen across all categories of both scores. In both graphs intake of other food groups rose monotonically across score categories (the sole exception is BCFV in the last two categories of the 45 gram graph). Percentages of children receiving credit for consuming oils and other fruits were relatively similar across the 6 categories of each score, and the percentages consuming legumes were only slightly

decreased across the 45 gram score. This consistency indicates that when these food groups were consumed, children generally consume larger portions (i.e. more than the required minimum portion). In contrast, the percent credited for consuming other food groups (other vegetables, eggs, BCFV, and dairy) increased more gradually when 45 grams of these foods were required, indicating that consumption of these foods for many children was in very small portions. The percentage of children consuming >45 grams of other vegetables, eggs and BCFV more closely resembled the percentage consuming >45 grams of legumes. The most dramatic difference was in the rates of increase for meat. The percentage of children consuming 10 grams of meat rose little across score categories (consumed by 80% of the lowest group), but the percent consuming at least 45 grams varied greatly across categories [range = 0 to 95%].

c. Grams of food groups per consumer

We explored whether the two scores were sensitive to groups of children consuming different amounts of food. The average grams of each food group consumed among consumers is depicted in figure 7. Average gram intakes of CRT (not depicted) increased substantially across both scores (range = 668-821g and 647-913g for 10g and 45g scores respectively.) Average gram intakes of all food groups except dairy were largely consistent across categories of the 10 gram score (lower intakes of OFRT and OVEG in the ≤ 2 category represent only 2 and 3 children, respectively). In contrast, across levels of the 45 gram score consumption of all plant food groups rose. The most pronounced increase was among consumers of other fruit (range= 19 to 138 grams), followed by similar smaller increases for BCFV and legumes (range= 24-86 grams and 38-94 grams respectively).

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Intakes of animal products increased only slightly for dairy and eggs across levels of the 10 gram score, and not at all for MPF. However, we saw a pronounced increase in grams of MPF consumed across levels of the 45 gram score (range=19-119g), and smaller increases among dairy and eggs (ranges = 11-46g, and 22-66g respectively). The relationship of the 45 gram score to increases in the intake of most food groups makes it a likely candidate for an improved relationship with nutrient adequacy.

2. Relationship between Diversity and Adequacy

Our first study objective was to determine whether the 10 gram dietary diversity score previously validated in this sample during early childhood (Daniels et al, 2007) would also reflect adequacy well in adolescence. In **Figure 8** we used the mean percentage of recommended nutrient intakes (mean % RNI) achieved by individuals to represent dietary nutrient adequacy. Means were depicted within diversity score levels to visualize how well score categories would distinguish between groups of children with differential mean nutrient intakes.

Mean % RNI stratified across the 10 gram diversity score (upper graph) did not display a high degree of variation. Mean percentages of several nutrients rose initially, and then leveled or nearly leveled thereafter, particularly the B vitamins. Mean % RNI of niacin rose from 62 to 88% between the first two score levels (scores ≤2 and 3), but fluctuated between 82 and 85% thereafter. Mean thiamin % RNI increased from 27 to 39% between scores ≤2 and 3, but rose only ten percent thereafter (to 49% at scores above 5). Mean riboflavin % RNI climbed from 28 to 47% between scores ≤2 and 3, but rose only to 54% by a DDS of 6 points, and 60% at a DDS of 7. The score also found little difference in mean absorbed iron

% RNI which rose from 32 to 51% in the first comparison, but then leveled at about 50% until a score of 5, and at 65% at scores above 5. Though mean percentages RNI of calcium were low, the 10 gram score did reflect a monotonic rise in mean intakes from 10 to 33% of RNI for absorbed calcium, and from 19 to 57% of RNI for total calcium. Mean Vitamin A % RNI rose monotonically across a moderate range with percentages of 53, 65, 80, 84, 86, 100.

a. Comparison of scores - % RNI

   Contrasting gains in mean % RNI across the 10 and 45 gram scores (figure 8) helps answer our second study question - can the score better reflect adequacy if we require children to consume larger minimum amounts of food groups before awarding score points? Larger increases in mean % RNI which are visible across categories of the 45 gram score reflect an improved relationship with adequacy for several nutrients. Increases were least pronounced for absorbed calcium which rose from a mean of 10 to 39 % RNI across the DDS. Total calcium, thiamin and riboflavin rose slightly more over the score categories: from means of 19, 18, and 19% RNI to means of 67, 64 and 67% RNI respectively. Absorbed Iron, Niacin, and Vitamin A exhibited the largest increases rising from means of 21, 34, and 33% RNI respectively to means of over 100% RNI (i.e. 116, 117, 117%) in the highest category of the 45 gram DDS.

   We could not test whether the difference in these trends was statistically significant because of the correlated nature of the two diversity scores. However, mean % RNI differences at each score level are depicted in **figure 9**. Increasing differences moving up the graph reflect the more pronounced increases in mean % RNI across the 45g score. Differences at similar score levels increased most rapidly for iron and niacin, and moderately

for riboflavin and thiamin. Vitamin A differences did not increase consistently because both scores contained plateau areas where score increases reflected little change in mean % RNI. However, the plateau was less pronounced for the 45g score (see figure 8). Differences in calcium and absorbed calcium were generally similar at scores of 4, 5 & 6 indicating that the 45g score reflects higher levels of mean % RNI than the 10g score, but is not discriminating more variation across these levels.

b. Comparison of Scores - Probability of Adequacy

Does increasing the minimum intake cutoff to 45 grams improve the relationship of the diversity score to individual probabilities of adequacy? We used correlations to quantify the strength of these relationships; results are presented in **table 5**. Correlations with the 10 gram diversity score were lower for all nutrients than those with the 45 gram score. These differences were smallest for calcium and absorbed calcium where both scores achieved correlations of at least 0.4. As we would expect, correlations with the 10 gram score were worst for those nutrients which were not visibly related to the 10 gram score in figure 8. Niacin, absorbed iron, thiamin and riboflavin exhibited the least change in mean %RNI over the range of the 10 gram score. These nutrients again performed poorly. Total and absorbed calcium and vitamin A exhibited clearer increases in figure 8 and also had higher correlations. Correlations with the 45 gram score are favorable ranging between 0.32 and 0.51 for all nutrients. Absorbed iron had the lowest correlation (r=0.32), and absorbed calcium the highest (r=0.51). The correlation with mean probability of adequacy for all nutrients (including absorbed calcium, not total calcium) was far higher for the 45 gram score (2.6 times as great) compared to the 10 gram score.

We further questioned whether the correlation between diversity scores and probability of adequacy was simply a function of more food being consumed. This seemed plausible since increases in the diversity score also reflected increased portions consumed from food groups. To answer this we tested the strength of correlations between DDS and probabilities of adequacy adjusted for energy (i.e. the partial correlations after that portion attributable to energy had been removed). We found correlations remained statistically significant for both scores (again with the exception of Niacin in the 10 gram score). The two scores performed similarly for calcium, absorbed iron and vitamin A. But correlations for B vitamins were improved with the 45 gram score, and correlation with mean probability of adequacy was much greater for the 45 gram score.

Also included in **table 5** is a synopsis of mean nutrient intakes for the sample, as well as mean PA. Note that since PA is calculated on an individual basis, these mean PA values are a sample average and do not specifically correspond to the mean intakes presented. The values are presented to allow comparison with other adolescent populations and to further illustrate the extent of nutrient inadequacy among sample youth. On average, youth in our sample had only a 10% daily probability of receiving an adequate intake of thiamin and riboflavin, and <1% probability of obtaining adequate calcium. Probabilities for adequate absorbed Iron, Vitamin A, and Niacin were somewhat higher, but still far from sufficient.

c. Relationship of score to SES

We present an analysis of the relationship between dietary diversity and several socioeconomic factors in **table 6**. We selected the 45 gram diversity score for this analysis based on the strength of its apparent relationship with dietary adequacy. Variables with p>0.2

were excluded from the final model. Factors that positively and significantly predicted increased dietary diversity included the child's education (range = 0 years through 11th grade), male gender, the presence of electricity in the household, and the general level of urbanicity of the surrounding community. DDS was negatively correlated with the price of food represented by the price of 375 mL edible oil. The relationship with maternal education became non-significant only after controlling for child's education. We also found no relationship with household income and the presence of other household assets (both excluded from final model) once the presence of electricity in the home was accounted for. Compared to the group of variables assessing population density, proximity to markets, and quality of transportation in the community, the summary urbanicity variable explained a similar amount of variance but was slightly more statistically significant than a joint test of the three variables. Independently, only the variable representing distance to markets reached statistical significance (p=0.001). Both it and the summary index explained a similar amount of variance, but the two were strongly correlated (r=0.88) and were not included in models simultaneously. In general, the explanatory power of the model was low (adjusted R^2=0.09).

D. Discussion

In this study we explored whether a food group dietary diversity score could be reflective of nutrient adequacy among adolescents. Our findings affirmed a relationship with two similar diversity scores, and confirmed our hypothesis that applying a larger minimum portion size than that suggested for early childhood would improve this relationship.

Our initial study question was whether an existing diversity score with demonstrated usefulness in childhood still reflect adequacy when applied to adolescents. We found that a

diversity score with a 10 gram cutoff, which we had previously shown to be correlated with

nutrient adequacy in early childhood, functioned poorly in adolescence. Increases in score

did not correspond with mean increases in mean % RNI for all nutrients. Correlations

between youth's scores and their single day probability of adequacy for individual nutrients

were statistically significant for all nutrients except Niacin, but were generally low (<0.30),

although performance was better for total and absorbed Calcium. We hypothesized that poor

performance of the score in adolescence was due in part to the scoring of very small and

nutritionally insignificant intakes from individual food groups over the 24 hour recall period.

Secondly, we questioned whether the existing relationship to adequacy might be improved

by increasing the scores minimum portion requirements. We tested a score designed to

counter this problem by counting only food group intakes ≥45 grams. We found the score's

performance was sensitive to these minimum intake requirements. The 45 gram score

reflected increases in % RNI across score levels for all nutrients. Unadjusted correlations

were higher in all cases, above 0.40 for all nutrients except Vitamin A and absorbed Iron

(0.38 and 0.32, respectively). These increases occurred because children were categorized

more appropriately in the second score. Children in the lowest score categories of the 45

gram score were dispersed across all score categories of the 10 gram score because of intakes

of very small amounts of individual food groups. When these nutritionally minimal intakes

were no longer counted, the score had greater sensitivity to dietary adequacy.

Adequacy is measured with recommended nutrient intakes which differ by age. Since

these recommended intakes are higher for adolescents, scores must be sensitive to larger

nutrient increases to correlate well with recommendations. Likewise, early childhood scores

must be sensitive to smaller intakes, proportional both to reduced dietary intake and lower

nutrient recommendations. Given these differences it may be difficult to create one diversity score which is useful at all ages. We chose to focus on a 45 gram requirement (based on half an average serving size) in adolescents, only after finding it superior in functionality to other score variants. Others tested included a 25 gram score (¼ of an average serving) and a score using ½ serving sizes which were food group specific (data not shown). Various requirements should also be evaluated elsewhere. While using a similar portion requirement for all food groups is most practical, it may not be best for assessing to relationship of individual food groups to adequacy.

In considering why correlations were not consistently improved for all nutrients it is helpful to recognize the food sources of individual nutrients. We briefly evaluated average nutrient intakes for each food group and found that foods from CRT followed by MFP and BCFV were the top contributors for all nutrients. These were the strongest contributors either because of high levels of intake (CRT and MFP) or high nutrient density in the foods (BCFV and MFP). However, since high levels of CRT were consumed by adolescents in every score level, variation in nutrients from other sources still contribute meaningfully to trends in correlations. Unadjusted correlations were strongly improved for iron and niacin using the 45g score. Since MFP foods are rich in both of these, this probably reflects the greatly increased variation in intake of meat/poultry and fish across score levels. The energy adjusted correlations for iron may be similar between the two scores because meat/poultry and some fish are energy dense, and large increases in intake will also reflect large increases in energy. The less dramatic attenuation for niacin may reflect its greater prominence in fish which is generally less energy dense than other meat sources. Correlations for Vitamin A were probably also driven by MPF foods, but also largely by BCFV. Since BCFV intakes did

not differ as dramatically over the two scores, correlations also differed less. Calcium intakes were highly correlated with both scores and only moderately attenuated by energy adjustment. Dairy intakes were low and calcium accumulated in low levels from many foods. Dried boned fish and leafy greens were consumed frequently and even in small amounts can contribute meaningfully to calcium - which helps explain why both scores were able to detect differences in calcium intake, and also why correlations with calcium were not strongly attenuated by energy adjustment. Correlations for Thiamin and Riboflavin were driven by a variety of foods, but riboflavin contributions from dairy and eggs were somewhat higher. Since these foods were consumed by a smaller percentage of the population this helps explain somewhat higher correlations for Riboflavin.

There are also other reasons why the early diversity score may not have performed as well in our adolescent sample. When adding foods groups to the diet, adolescents may be less prone to select nutrient dense foods than mothers of infants. Also, sample selection differed slightly. Our analysis of early childhood excluded children who were ill with fever or diarrhea or who did not consume a usual diet due to illness. In the current paper we excluded children reporting non "usual" diet as a proxy for illness (illness data not available). These excluded children had a similar macronutrient profiles and average probabilities of adequacy were similar for all nutrients. In sensitivity analysis we found correlations with probabilities of adequacy did not differ for the 45gram score in children excluded for non "usual" intake. Correlations for the 10 gram score were marginally higher in this group, but not sufficient to affect our conclusions.

Given a functional diversity score, what are the socioeconomic predictors of dietary diversity in adolescence? In response to this third question we tested the ability of a variety

of socioeconomic characteristics to predict dietary diversity (45 gram). We anticipated that maternal education would be strongly related to dietary diversity, but found that this became marginally non-significant when controlled for the youth's education. It is customary for Filipino youths to eat at home where the mother determines which meals are cooked and served. The strong relationship of adolescent education to diversity may be related to increased autonomy or independence in eating among adolescents, with better educated youth choosing a more varied diet or eating more broadly from among the choices provided at home or at school. We also hypothesized that income would be a strong predictor of dietary diversity. Instead we found that it was not statistically significant after inclusion of electricity in the model, and further reduced with inclusion of refrigeration. However, electricity and refrigeration may be strong proxy indicators for income (mean income among those with electricity vs. those without is 585 vs. 298 pesos/month; mean income among those with refrigeration vs. those without is 826 vs. 385 pesos/month). In addition to reflecting income, electricity and refrigeration are basic needs for preserving and preparing many types of food and are likely to influence food choice independent of income. The explanatory power of the model was low, and there are likely many other factors that are predictive of dietary diversity. Research for understanding these relationships will facilitate identification of individuals and families at risk of low diversity and nutrient adequacy and improve targeting for localized screening and interventions.

Another important finding of this study was the increasing amount consumed from all food groups as the 45 gram diversity score increased. The correlation between dietary diversity and total energy intake was 0.39. Previous research has also shown that dietary diversity is positively related to energy intake within individual food groups (McCrory et al., 1999).

Recommendations to increase dietary diversity could lead to problems in contexts where energy intakes border on excess. In our sample mean energy intake was 1643 kcal (SD=825) and low energy intakes were more likely. Obesity and overweight is low in the sample (prevalence <3% overweight or obese by International Obesity Task Force definition). However, caution is justified when recommending dietary diversity as a strategy for dietary improvement. Recommendations for diversifying low-energy, nutrient-rich food groups (such as fruits and vegetables or legumes) may be more appropriate than general recommendations to diversify overall diet.

In the Philippines 15.5% of adolescents 11-19y are underweight, and 3.6% overweight (Barba, 2004). In the general population intakes for calcium, iron and riboflavin were reportedly very low (57%, 60% and 68% of recommended values) (Constantino, 2005). Adolescent nutrient intakes are likely to be low in this and many other populations and much data are needed to identify and assist this important age group in the transition to healthy adulthood.

This diversity score may be used for screening likelihood of overall adequacy, adequacy for specific nutrients, and consumption of food groups contributing to adequacy. The score is particularly sensitive to calcium and riboflavin intakes in this population, largely independent of energy intakes. Since the score is based on average Filipino serving sizes, further changes in the required minimum intake may be useful in other settings. Variations in food groups may also be useful, though we have used a standardized set of food groups suggested by FAO/WHO for validation testing of scores in many settings (FNRI, 1990). These food groups may therefore be readily applied elsewhere, and serve as a framework within which local foods may be grouped. Also, it should be emphasized that scores such as

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these based on one day of intake are appropriate for broad population level inferences, but not for determining adequacy of individuals.

Several study weaknesses should be noted. Error is inherent in the collection and analysis of dietary data. Random error due to nutrient variability within foods or portion measurement error is likely to have reduced the strength of our findings. Food data collected from 24 hour recalls minimized the likelihood of recall bias, though some selective misreporting of food intakes may still have occurred. Incomplete recommendations for dietary requirements were another challenge. Recommendations for B vitamin intakes and calcium were available but back-calculation of EARs was necessary based on estimated coefficient of variation from another source. An RNI was not listed for Vitamin A or available calcium, but approximate EARs were available from which we calculated RNIs. The approximate EAR for available calcium was only available based on a protein intake of 60 to 80 grams per day (mean intake for our sample was ~ 40 grams, basis for total calcium RNI was 20 to 40 grams). This may have made our estimates of available calcium intake overly conservative. It is difficult to estimate the effects of these limitations on our findings.

E. Conclusions

Adolescents are at a critical stage of development yet have received little attention from researchers. Much further research is needed to determine whether dietary diversity can be a helpful measurement tool to assess the adequacy of adolescent diets and formulate local recommendations for nutritional improvements. It is hoped that this analysis provides some basis for future research of dietary diversity scores in adolescents, as well as workable recommendations for improving scores in field use.

Table 5. Correlations between probability of nutrient adequacy and diversity scores among Filipino Adolescents

| | Nutrient Intakes | | Spearman Correlations | | | |
| | | | Unadjusted[b] | | Energy Adjusted[c] | |
Nutrients	Mean ± SD	PA[a]	10g DDS	45g DDS	10g DDS	45g DDS
Energy, kcal	1642.61 ± 825.11	na	0.190	0.420	na	na
Vitamin A, mcg RE	403.73 ± 967.87	26.6	0.296	0.375	0.218	0.229
Thiamin, mg	0.51 ± 0.36	10.1	0.213	0.405	0.108	0.178
Riboflavin, mg	0.57 ± 0.45	10.6	0.251	0.476	0.194	0.299
Niacin, mg	13.34 ± 9.11	44.6	0.061	0.402	-0.032	0.190
Calcium, mg	368.53 ± 475.43	3.9	0.422	0.475	0.390	0.363
Absorbed Calcium, mg	110.68 ± 151.86	0.5	0.428	0.509	0.403	0.404
Absorbed Iron, mg	1.16 ± 1.01	25.4	0.143	0.322	0.116	0.135
Mean (all Nutrients)[d]	na	19.6	0.169	0.446	0.103	0.246

DDS=Dietary Diversity Score, PA=Probability of Nutrient Adequacy
[a]Numbers are mean percentages
[b]p <0.001 for all correlations except Niacin (with 10g DDS) where p=1.0
[c]p<0.001 for all correlations except Niacin (with 10g DDS) where p=0.042
[d]absorbed calcium is used

Table 6. Linear regression of DDS (45g) on demographic and socioeconomic factors of Filipino adolescents

	Coefficient (95% CI)	P Value
Maternal Education (yrs)	0.02 (0.00, 0.03)	0.068
Child's Education (yrs)	0.05 (0.03, 0.08)	0.000
Child is Male	0.24 (0.13, 0.35)	0.000
Household has Electricity (vs. none)	0.26 (0.08, 0.43)	0.004
Household has Refrigerator (vs.none)	0.11 (-0.01, 0.23)	0.068
Community Price of edible Oil[a]	-0.18 (-0.31, -0.04)	0.012
Urbanicity Score	0.07 (0.03, 0.11)	0.001

DDS=Dietary Diversity Score
[a]units are pesos per 375 mL of edible oil

Figure 6. Percent consuming required portions of food groups. Intakes within each score category are stratified to show the percent of children consuming each food group. LPN: legumes, pulses & nuts; OFRT: other fruit; BCFV: beta carotene- rich fruits and vegetables; OVEG: other vegetables ; MPF: meat, poultry & fish; CRT: cereals, roots & tubers.
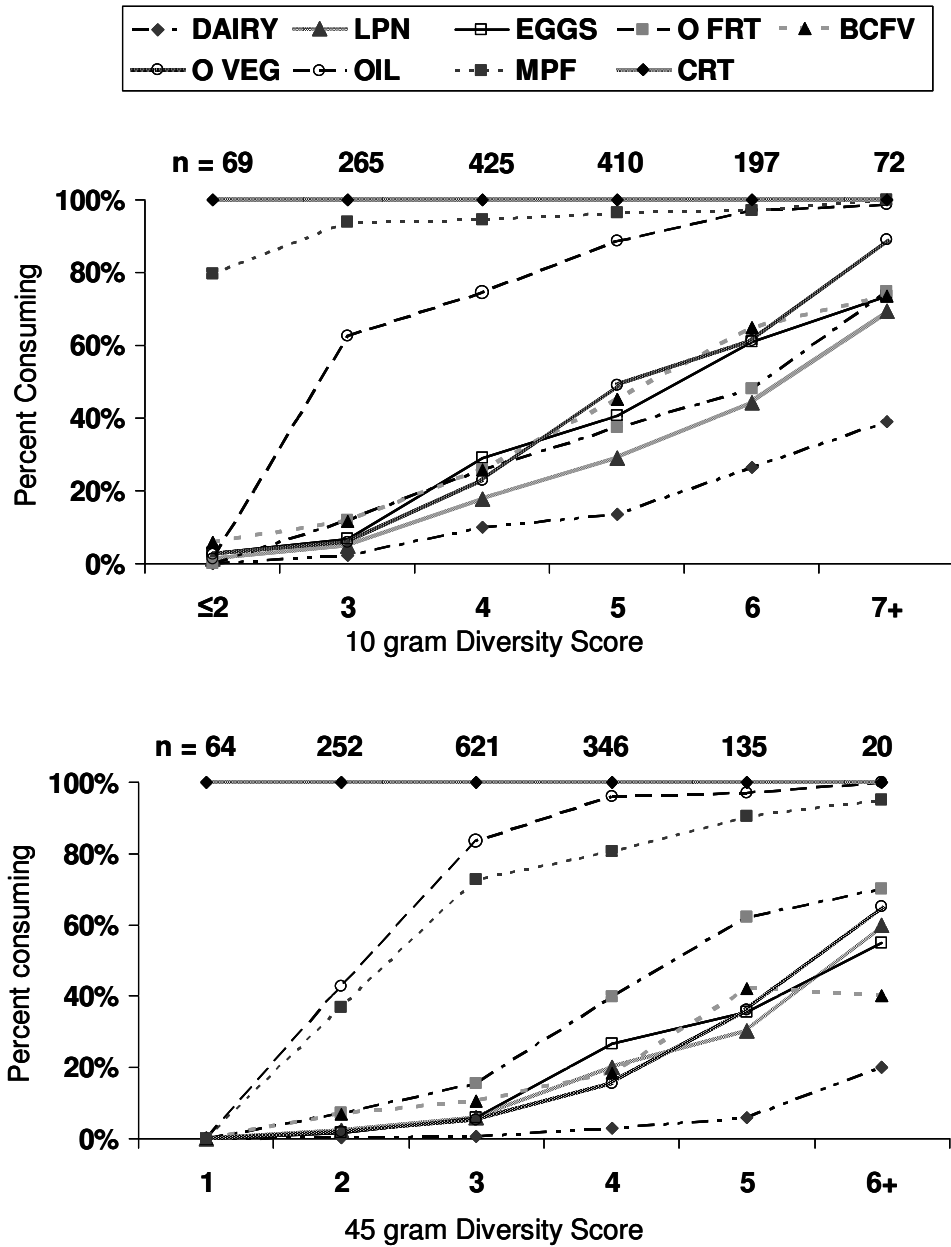
Figure 7 Average grams per food group consumer by diversity score. Intakes within each score category are stratified to show the average grams consumed among consumers of each food group. LPN: legumes, pulses & nuts; OFRT: other fruit; BCFV: beta carotene- rich fruits and vegetables; OVEG: other vegetables; MPF: meat, poultry & fish; CRT: cereals, roots & tubers.
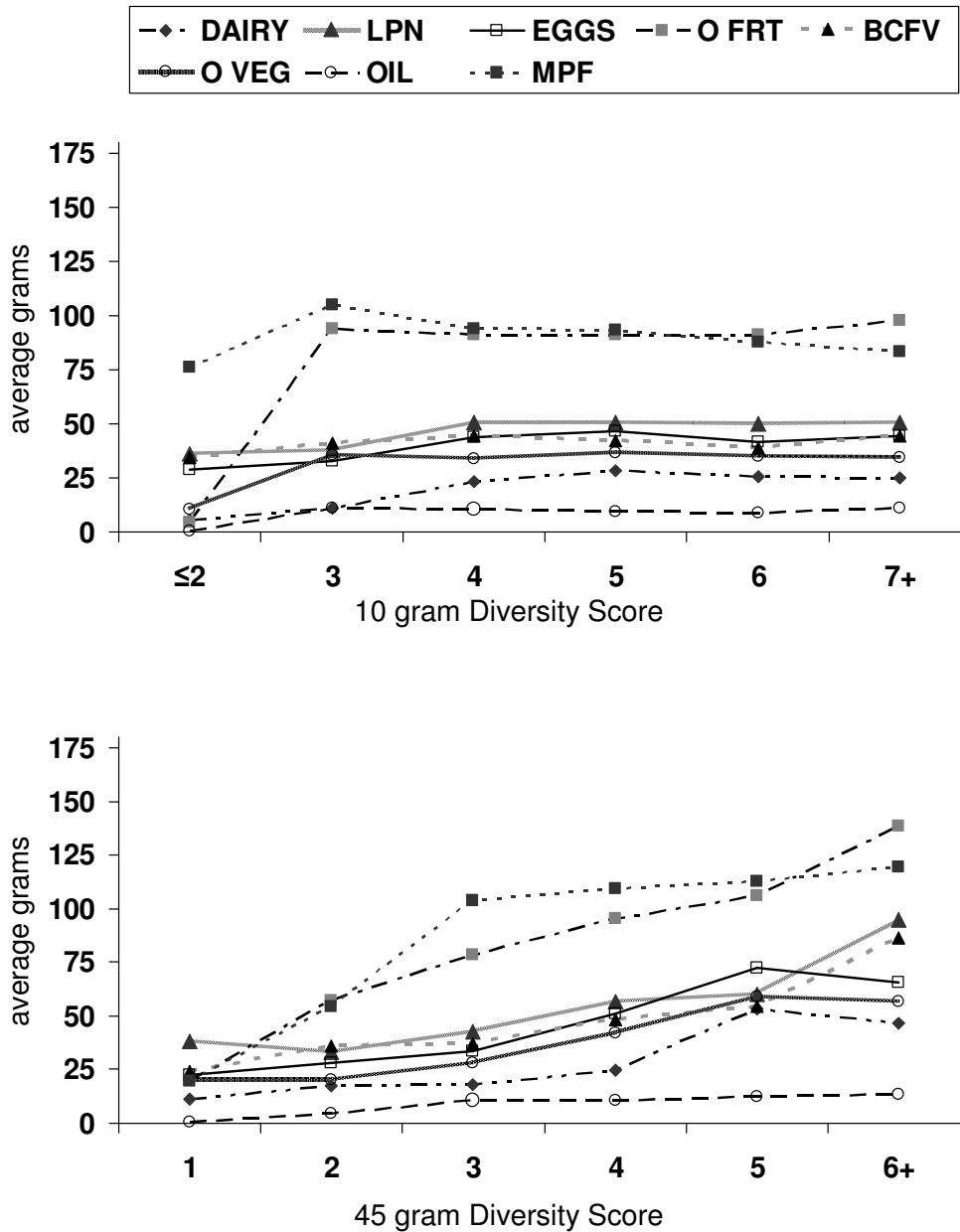
Figure 8. Mean percent of recommended nutrient intake. Numbers are Mean Percentages within each diversity score category. % RNI: percent recommended nutrient intake; A Calc: absorbed calcium; Calc: calcium; A Iron: absorbed iron; Thia: thiamin; Ribo: riboflavin; Nia: niacin; Vit A: vitamin A.
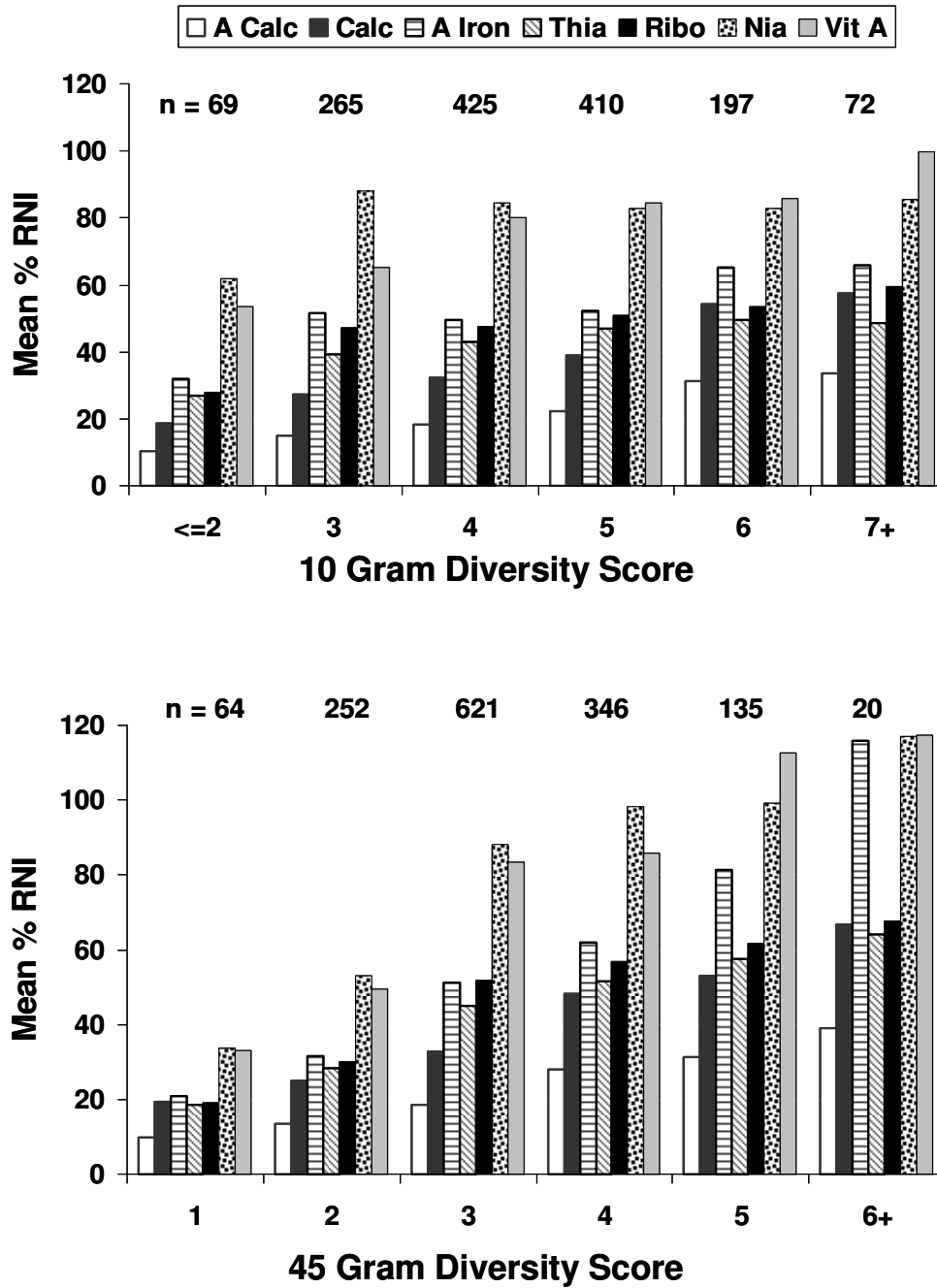
Figure 9. Difference in mean %RNI (45g – 10g DDS) by score category. % RNI: percent recommended nutrient intake; A Calc: absorbed calcium; Calc: calcium; A Iron: absorbed iron; Thia: thiamin; Ribo: riboflavin; Nia: niacin; Vit A: vitamin A.
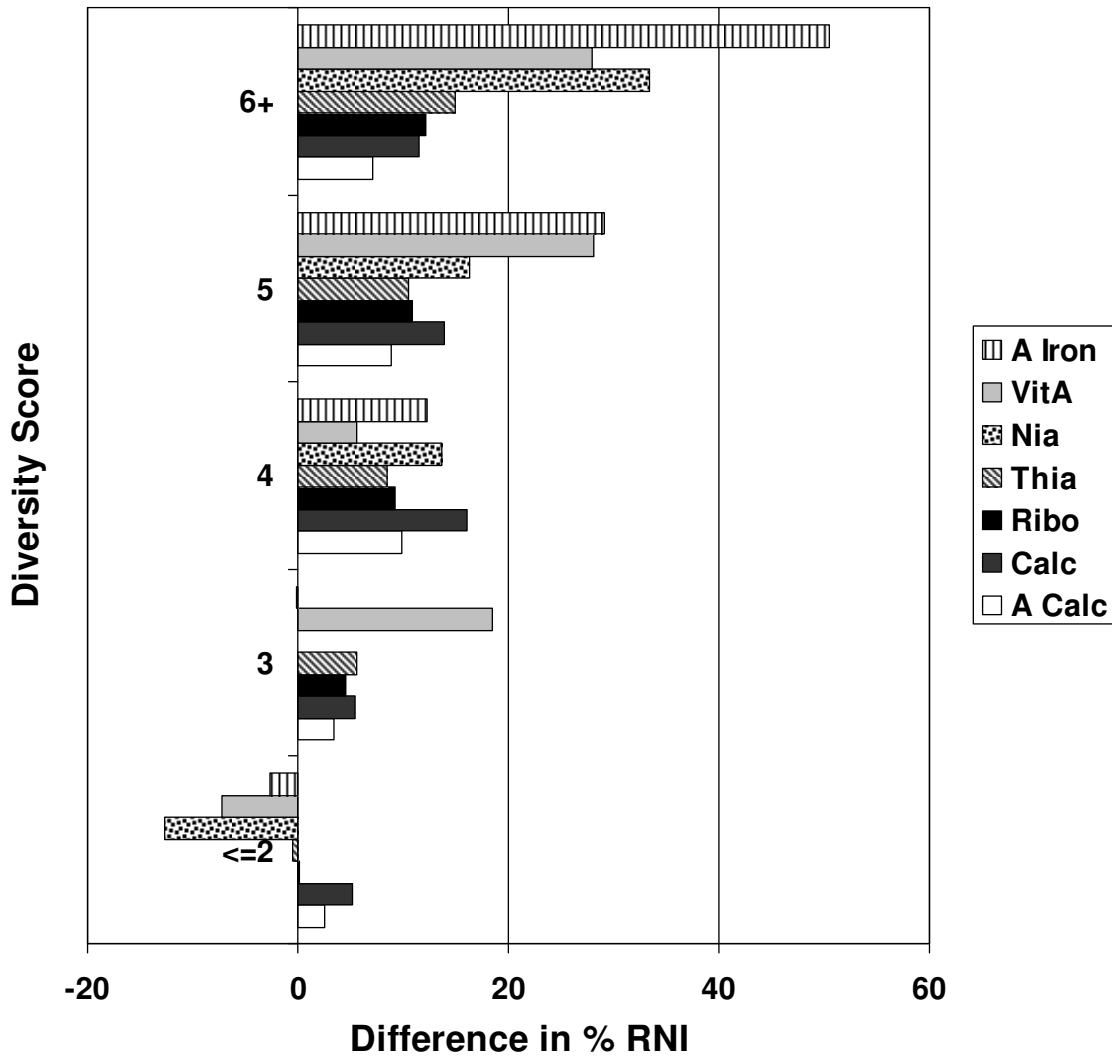
VI. Using 24 hour diversity at two time points is not sufficient to predict adult height

A. Introduction

A number of previous cross-sectional studies have shown a relationship between dietary diversity measurements and height for age Z-score among infants and young children in developing countries (Arimond and Ruel, 2004; Arimond and Ruel, 2002; Ruel, 2003b; Hatloy et al., 2000; Onyango et al., 1998). This has fueled the hope that dietary diversity based screening and resulting interventions may improve nutritional status among children in these countries. Various methods for measuring diversity have been explored, but the necessary characteristics and ideal construction of functional screening tools are still being defined. Improved definition of these tools depends on a clear understanding of their relationship to nutritional status, but a number of questions regarding this relationship remain.

A recent review of studies linking dietary diversity to height for age z-score (HAZ) voiced concern that attention to potential confounders has been limited (Ruel, 2003b). A variety of socioeconomic factors correlate with dietary diversity and are independently able to affect HAZ. Factors such as income, hygienic environments, and parental education have the potential to increase dietary diversity but may be related to height through other pathways such as illness. If these factors are held constant does dietary diversity still predict HAZ?

Studies are also needed that evaluate whether there is a persistent effect of dietary diversity on HAZ, and whether consistently better diets translate into taller adult stature. Dietary diversity instruments have not been evaluated for their ability to predict HAZ in later childhood and adolescence, nor their ability to predict later nutritional status. However, demonstrating sensitivity to these outcomes is an important step in establishing the value of these instruments for nutritional screening.

The current study has two major purposes: first, to evaluate whether the association of dietary diversity and height for age Z score persists once confounding has been accounted for; second, to determine whether children with high and low diversity at 2 points in time are taller or shorter as adults. Longitudinal data from >2000 Filipino children is used to evaluate these questions. We previously validated dietary diversity scores in both early childhood (age 24 mo) (Daniels et al., 2007) and adolescence (age 15.5y) (unpublished results) for their relationship to adequacy . Here we present the ability of each score to detect HAZ in cross sectional models, and the ability of diversity at two time points to predict adult height. All models are presented both crude and adjusted for potential confounders.

B. Subjects and Methods

1. Sample

The Cebu Longitudinal Health and Nutrition survey began collecting data on a one year birth cohort of Filipino children (n=3080 singleton births) from Metropolitan Cebu in 1982-1983. The study sample was drawn from 33 randomly selected barangays (communities) of Metro Cebu. Anthopometric and dietary data were collected bimonthly from birth until the infants were 24 mo old, and through follow-up surveys conducted in 1991, 1994, 1998, 2002,

and 2005; Surveys also gathered data on a large variety of socioeconomic factors and other correlates of maternal and child health. Each round of the CLHNS has been approved by the University of North Carolina School of Public Health Institutional Review Board for the Protection of Human Subjects. Further details on the survey design and sampling strategy were published previously (The Cebu Study Team, 1991; Adair and Popkin, 2001).

We use data from the initial survey (age 24 months, n=2,457), 1998 (mean age=15.5 years, n=2,089) and 2002 (mean age = 18.2 years, n=2,018). Loss to follow-up was due to both death and migration outside of Cebu during early childhood, and primarily to migration in adolescence. Children lost to follow-up had slightly better educated mothers, slightly smaller households, and were slightly more likely to come from urban areas, but came from families with similar baseline income, per capita income, and assets and appear unlikely to bias finding significantly. Children with full data for this analysis included 2,433 in early childhood and 2,059 in 1998. 1,866 children had full data for all three time periods.

2. Anthopometric Data

Anthropometric data were collected in children's homes by study personnel trained in standard techniques. Length data were collected in infancy using custom-designed length measuring boards. Adolescent and early adult heights were assessed using portable stadiometers. Height for age Z-scores (HAZ) were calculated at 24 months and in adolescence using the World Health Organization reference (WHO , 1995).

3. Dietary Data

Dietary data were collected via 24 hour recall by trained study personnel (Adair et al., 1993). Bimonthly 24 hr recalls were available from birth to age 2, and two non-consecutive 24 hour recalls were available in adolescence at 15.5y. Information about food type, portion size, amount consumed and cooking method were collected. Grams of foods consumed were calculated using volume and density of ingredients, and conversion factors converting raw to cooked ingredients where applicable. Cooking oil was calculated for each dish.

Dietary diversity scores were a count of the number of food groups in the diet. Nine food groups were defined [cereals/roots/tubers (CRT), β-carotene rich fruits and vegetables (BCFV), other fruits (OFRT), other vegetables (OVEG), legumes/pulses/nuts (LPN), meat/poultry/fish (MPF), fats/oils (FAT), dairy and eggs] giving scores with 9 possible points. These food groups have been recently recommended by an FAO protocol for international comparisons of dietary diversity (Kennedy & Nantel, 2006). Previously we demonstrated that this diversity score is more strongly related to adequacy if very small intakes of food groups are not scored. We found that in early childhood, requiring at least 10 grams intake per scored food group improved score function, compared to requiring > 0 grams. In a separate study, adolescents, who have higher nutrient requirements and consume larger volumes of food, were better served by a score requiring at least 45 grams intake per scored food group, compared to > 10 grams. Further details of these comparisons are forthcoming (Daniels et al., 2007). This study, therefore, used minimum requirements of 10g per food group in early childhood, and 45g per food group in adolescence. Because of the high energy density of oil, and according to protocol, only 1 gram of intake was required to receive credit for the oil group in either score.

Several previous studies of diversity and height for age z-scores have been based on 7 day diversity scores (Arimond and Ruel, 2002; Arimond and Ruel, 2004) However, 1 day and 7 day indicators were strongly correlated and diversity from one day of intake has also been strongly correlated with height for age z-scores (Arimond and Ruel, 2002). We used data from 1 day of intake at each time point in order to realistically portray the functionality of these diversity indicators as rapid screening tools. In adolescence the second recall was selected since the first recall reflected a disproportionate number of Sundays. A small number of first recalls were used when second recalls were unavailable (n=4).

4. Socioeconomic Status Data

Socioeconomic status variables thought to be independently related to both dietary diversity and HAZ were identified as potential confounders via literature review. We used baseline measurements for gender, birth order, mother's height, and father's and mother's education in all analyses since these did not change over time. Measurements in both early childhood and adolescence were available for several dynamic factors: i.e. household income, household size, income per capita (household income/household size), level of crowding (persons/room), family ownership of a motor vehicle, electricity and refrigeration. Child's education, and number of proximate younger siblings (i.e. siblings born by 1991) were also evaluated, but only in 1998. Factors less proximately related to diet were also evaluated at both time points. We created an index of other household assets (0 - 5 points for possession of 5 assets: electric fan, air conditioning, television, tape player, iron) as a further indicator of wealth. We also used an index representing environment hygiene (0 - 9 points: 2-3 points each given for the presence of a toilet, community garbage disposal, lack of excreta

in the yard, and cleanliness of the food area). Urbanicity within each barangay (community) was represented by a 7 component index (0-70 points) representing population density, total population, presence of local health services, type of educational facilities, access to markets, available methods of communication, and available local transportation (Dahly and Adair, 2006).

5. *Analytical Methods*

Univariate distributions of all variables were checked for outliers and normality. Highly skewed distributions (income, per capita income) were normalized with log transformations. All explanatory variables were first assessed as potential effect modifiers and second as potential confounders. Effect modification was determined initially by including each variable (plain and interacted with diversity) in a crude model of diversity and HAZ. Significant effect modifiers were also tested in adjusted models, and assessed as confounders if effect modification did not persist. Potential confounders were assessed for the strength of their bivariate relationships with both dietary diversity and HAZ. Variables moderately correlated with both dietary diversity and HAZ, and which exerted more than a 10% change in crude coefficients were considered to be confounders and included in full models. Variables with poor predictive power in adjusted models (P>0.20) were then eliminated provided this did not strongly influence the adjusted relationships between diversity and HAZ.

The relationship of dietary diversity to HAZ was evaluated at each time point for linearity using lowess smoothers. Lowess smoothers were also used to check the linearity of all other covariates with HAZ. All variables were linearly related except the hygiene index.

Correlations between all variables were assessed. Only income and per capita income had a correlation greater than 0.7. These were compared for confounding potential and per capita income was used in adjusted models.

Linear regressions were used to model the cross sectional relationship between dietary diversity and height for age z scores in early childhood and adolescence. We also estimated linear predictions of HAZ with low and high diversity scores for the early childhood model, to allow visualization within strata of mother's education which was an effect modifier. Because of the strong relationship of SES variables to dietary diversity and to HAZ, we wanted to further explore the relationships of diet diversity and HAZ within strata of SES. Since we have a variety of SES indicators, we used factor analysis to define a composite SES indicator. Stratification was by thirds of the distribution of factor scores based on parent's education, electricity, refrigeration, crowding, assets, per capita income, urbanicity index, and the hygiene index.

Linear regression was also used to model the long term relationship between diversity and adult height using combinations of diversity at both time points.

Significance was set to $p < 0.05$ for all comparisons, except interactions which were considered significant at $p < 0.10$. All analyses were performed using Stata 9 (Statacorp, 2005).

C. Results

1. Sample characteristics

Basic sample characteristics in 1983 and 1998 are presented in **table 7**. Non-time varying characteristics are presented only once. The rapid development occurring in Metro Cebu is

reflected in our sample. Standards of living increased over the 15 years, with a 66% increase in per capita income and only a marginal increase in the cost of edible oil (a proxy for food price). Urbanization, reflected as an increase in the urbanicity score from 1983-1998, paralleled other improvements: the percentage of households with electricity increased 78%, and the percentages with motor vehicles, electricity, refrigeration, piped water, and flush toilets more than doubled. Average HAZ also improved simultaneous to these improvements in living conditions.

2. Crude relationship between dietary diversity and HAZ

The cross sectional association of dietary diversity and HAZ in early childhood is shown in **Figure 10.** The association for adolescents is in **Figure 11.** The figures display HAZ at each level of diversity, with small categories on the extreme end collapsed. The adolescent score has a smaller range because it is based on a higher threshold of consumption (45g vs. 10g) before a food group is counted. While both scores had a potential range of 9 points, this difference in construction resulted in a narrower distribution of measured scores for adolescents. At both ages, mean HAZ is higher in groups with higher diversity scores. The relationship in early childhood is linear, but in adolescence height did not increase above a score of 4. Therefore, in adolescent models dietary diversity was represented using indicator variables, and early childhood models used a continuous measure of diversity.

Crude linear models of HAZ regressed on dietary diversity at the two ages are presented in **tables 8** and **9.** At both ages diversity was a significant predictor of HAZ, although the association was clearly stronger in early childhood. The HAZ and diversity relationship in early childhood varied with mother's education in both crude and adjusted models.

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Therefore, we also present (in **table 8**) the crude early childhood model including this interaction. The effects of diversity within two categories of mother's education (≤6y, >6y) are depicted in **figure 12.** We estimated linear predictions of HAZ with low and high diversity scores (score of 2 = 10th percentile, score of 6 = 90th percentile of diversity). Based on the crude model there is nearly a half standard deviation predicted improvement in HAZ with this change in diversity, among children whose mothers completed more than a grade school education. Children of less educated mothers tend to be shorter, and have a smaller predicted response to improvements in diversity.

3. Factors explaining cross sectional relationships

a. Caloric Increases

We tested whether the relationship between dietary diversity and HAZ was explainable by energy intake. Models at both ages were adjusted for energy intake calculated from the 24 hr recall (see tables 8 and 9). In early childhood, after adjusting for energy the dietary diversity coefficient was substantially reduced (from 0.13 [95% CI 0.10, 0.16] to 0.04 [0.01, 0.07]) but remained significant. The effect within strata of mothers education was also greatly reduced, but remained significant when mothers had > 6yrs of education (0.058 [0.012, 0.103]). In adolescents the effects remained positive, but were greatly attenuated and became non-significant. The high degree of attenuation at both ages reflects the strong relationship between dietary diversity and energy intakes measured the same day. Correlations for these two variables were 0.54 in early childhood 0.42 in adolescence.

b. Confounding

We assessed various potential confounders for their influence on the diversity and HAZ relationship at both ages. Adjusted linear models are presented in the lower portions of tables 8 and 9. In early childhood, dietary diversity remained a significant predictor of HAZ in children of better educated mothers. Linear predictions for this model are again presented in figure 12, and show a small predicted increase in HAZ (~0.18 sd) with high vs. low diversity in the higher stratum of mother's education. In adolescence we found no interactions that persisted after adjustment for confounders, and no relationship of diet diversity to HAZ in any strata after adjustment. The association of dietary diversity to HAZ appears to be robust in early childhood, but weaker and potentially artifactual in adolescence.

Underlying SES factors are likely to affect linear growth through more proximate biological variables such as diet and morbidity. As another approach to understanding the role of diet diversity, we then evaluated the dietary diversity and HAZ relationship within terciles of socioeconomic status (see **figure 13**). In early childhood, the association of dietary diversity with HAZ differed within levels of SES. In the lowest tercile, dietary diversity was not significantly associated with HAZ. However, in the two higher terciles diversity was significantly related to increases in HAZ (tercile 2: 0.08 [0.03, 0.13]; tercile 3: 0.05 [0.001, 0.10]). In adolescents we found no significant relationship between dietary diversity and HAZ within strata of SES.

4. Longitudinal analysis of adult height

We evaluated whether our screening tools measuring dietary diversity at two points in time would be sensitive to differences in adult height. To evaluate this we created a longitudinal

model which predicted height in early adulthood, and considered the ability of different diversity patterns to predict height. Each diversity score was divided into three categories, and indicator variables representing each of the 9 possible combinations between the two scores were created. Categorical comparisons were made to children with combined diversity scores of 1-3 in early childhood and 1-2 in adolescence. Since height was used in this model rather than height for age z-score, results adjusted for gender and age are presented in **table 10.** 1 day diversity scores from 2 time points were not capable of predicting adult height. Although coefficients for higher combinations of diversity appear to be somewhat in the expected direction, clear patterns did not remain visible when results were gender stratified. Neither adjustment for energy nor confounders revealed significant associations (data not shown).

D. Discussion

Instruments for measuring dietary diversity are related to height for age Z-score cross-sectionally in early childhood, but to our knowledge have not been previously evaluated for this relationship in adolescence. Developing instruments which capably predict nutritional status at ages across childhood, and which can ascertain nutritional trajectories by anticipating long term nutritional outcomes is an ambitious goal. But tools with these capabilities will greatly facilitate identification of populations at risk of malnutrition, and allow targeted interventions based on location-specific dietary patterns. We evaluated two age-specific dietary diversity scores for these capabilities in this paper.

We confirmed a crude cross-sectional relationship between dietary diversity and HAZ in both early childhood (24 months) and adolescence (15.5 yrs) in our sample although the

relationship in adolescence was much weaker. We are aware of only two developing country studies on adolescents to date. The first study, in Iran, evaluated a different 2-day diversity score among 10-18yr old individuals, and found increased adequacy as well as increased BMI among adolescents with a diversity score >6, but did not evaluate HAZ (Mirmiran et al., 2004). The second, a longitudinal study (age 2-18y) conducted recently in our sample, found that a diversity-score based on reported "usual intake" predicted 0.33 cm height increase in boys, per unit increase in diversity. No association was found in girls, however these associations were controlled for energy which may account for this. Energy intake predicted height increases in both boys and girls (100kcal energy resulted in 0.05 and 0.02 cm height increases for boys and girls). Findings were also controlled with an index variable representing socioeconomic status (Eckhardt et al., 2005). These confirmed relationships between diet and height in our sample provide a useful framework in which to test the sensitivity of more standardized diversity scores to adolescent HAZ and determine their usefulness for screening. The relatively weak cross-sectional relationship between adolescent diversity and HAZ in this paper underscores the need for further work to develop adolescent screening tools.

We evaluated whether adjusting for energy intake would explain our crude findings. Aside from the previous research in our Cebu sample, we know of no previous studies which have tested the ability of energy intake to explain findings. This is because most studies have not had adequate dietary information to evaluate this. E.g. several recent papers have been based on international data from Demographic and Health Surveys which do not contain energy data (Arimond and Ruel, 2004; Arimond and Ruel, 2002; Ruel and Menon, 2002). Energy intake explained a large proportion of the diversity variation relevant to HAZ in early

childhood, and all of that relevant to HAZ in adolescents. This level of attenuation was not surprising because dietary diversity scores were highly correlated with and thus a good proxy for energy intake. We previously demonstrated that these diversity scores correlate significantly with nutrient adequacy after energy adjustment. Therefore, the remaining association in our early childhood model after energy adjustment may be related to nutrient density.

We adjusted our models for several demographic and socioeconomic status variables. These are potential confounders since they may change HAZ through other pathways. For instance, factors such as mother's education, healthcare, hygiene, or crowding may protect against or predispose children to illness. Social and intellectual stimulation are another possible confounding pathway since stimulation has effects on growth and is likely to vary with SES (Walker et al., 1991). However, our understanding of this is still limited. Most studies adjusting for potential confounders have not reported a systematic process of confounder selection and may be controlling for some unnecessary factors. A few studies have expressed concern about incomplete confounding control (Arimond and Ruel, 2004; Ruel, 2003b; Ruel, 2003a). Ruel (Ruel, 2003b) warned that failure to control adequately for socioeconomic confounders "could lead to gross overestimations of the magnitude of this association." However, an earlier study warned that controlling for SES gives conservative estimates of an effect because "SES is allowed to explain variation in child's size that also could be explained by diet. In other words, this approach overcontrols . . . since the effects of SES-related higher quality diets are attributed to SES" (Allen et al., 1991). We questioned whether rigorously controlling for confounders was entirely appropriate, since most potential confounders could influence HAZ *through* their impact on diet as well as other pathways.

This is of particular concern if dietary influences are the primary pathway through which a supposed "confounder" influences HAZ, because adjusting might remove meaningful variation in dietary diversity and artificially limit its relationship with HAZ.

In this study, controlling for potential confounders explained much of the association in infants and all of the association in adolescents. Systematic selection of confounders revealed different confounders at the two ages and models were adjusted accordingly, but this does not eliminate the possibility of over-controlling and masking a true association. It is questionable whether it is appropriate to control for factors whose primary influence on HAZ may be through the variation they allow in diet, but in many instances it is difficult to determine where the primary influence lies. For instance, birth order qualified as a strong confounder in the early childhood model (it was not a confounder in the later model). Whether birth order affects early HAZ more through exposure to illness or competition for food is difficult to judge, but it is likely a combination of the two. Refrigeration, a confounder in the adolescent model, could also affect HAZ through either pathway - either by preventing food spoilage and related illness, or by increasing the ability to store diverse types of food. Adjusting for previous illness rather than SES should be considered as a way around these problems. However, we did not have illness data for adolescents. Our findings in early childhood were robust in spite of the possibility of over-adjusting. Our findings in adolescence did not persist after confounding control. The lack of an effect in adolescence after adjusting for SES and other factors does not mean diversity has no impact on stature; rather, that once diversity has been explained by these factors, the remaining variation cannot predict HAZ. Potentially, interventions to improve diversity might still have an impact on HAZ if they can improve diversity in spite of socioeconomic barriers to diversification.

We used factor analysis as another method of confounding control, to see if results were similar and found that they were. In early childhood we found that diversity generally had a stronger influence among children with higher SES. This supports our finding of a stronger relationship between dietary diversity and HAZ at higher levels of mother's education, since mother's education is likely to parallel a number of other socioeconomic advantages. The specific interaction with mother's education in the linear model is somewhat more telling, however, in suggesting that protective care-giving behaviors may be responsible for the improved impact of diversity. The lack of effect in the lower strata of SES may also reflect conditions among the poor that predispose them to illness, associated increases in nutrient needs, and a resulting decrease in the impact of diversity. Mean diversity and its standard deviation increased across terciles of SES, and this reduced variation in the low SES tercile also may help explain the lack of effect. In adolescence we found no effect of dietary diversity on HAZ within levels of SES, which corresponded with our null results after confounding control in linear models. Eckhart et al. (Eckhardt et al., 2005)who studied growth curves in this sample found that over the entire post infancy period energy adjusted (ages 2-18y) diversity had greater effects on the height of children with lower SES. However, our cross sectional findings did not confirm this.

Our crude longitudinal model showed no relationship between diversity score combinations from the two ages and height in early adulthood, indicating that persistant diversity as measured by our 1-day diversity scores are not sensitive to long-term nutritional effects. This was contrary to our expectations since crude associations were visible in both of our cross sectional models, and persisted after confounding control in early childhood. Further work is needed to determine if diversity scores are able to identify persistent

nutritional effects on development. Studies which are able to measure diversity at more than two ages are likely to give a better representation of persistent diversity. Also, diversity indicators based on more than one day of diet are likely to represent "usual" diversity better (though having reduced field practicality). However, studies measuring variation in food group diversity over time have not been conducted as far as we know. One problem with using height at 18.5y for this model is that the adolescent growth spurt may be prolonged in cases of malnutrition (ACC/SCN, 2000). However, this is not likely to have obscured a diversity benefit since those with the lowest diversity would have been both delayed and shorter, leading to an exaggerated apparent benefit.

  The study has several weaknesses: 1) Scores were not entirely equivalent in scale and the narrower distribution in adolescence may have made it more difficult to detect an effect. As mentioned above, this was due to differences in minimum requirements (10g vs. 45g). When the 10 gram score was previously evaluated for adolescents the range was similar to that in early childhood, but the score was poorly related to adequacy. 2) Dietary diversity was only measured at two time points and the longitudinal association with height may be stronger if measured across more time points. Dietary data were available at other time points, but diversity scores have not yet been developed or validated for these ages. 3) Controlling for illness rather than SES may have been useful, but these data were not available in adolescence. 4) HAZ in early adulthood was not measurable because WHO growth curves are truncated at age 18. Therefore, we used height and adjusted within the model for age and sex. Units are in cm height rather than standard deviations Z-score and not directly comparable to the cross-sectional models. 5) Large amounts of non-systematic error are

inherent in the collection of dietary data, and are likely to have reduced the strength of our findings.

The study is useful for several reasons. Previous studies have used a broad array of diversity scores. Our diversity scores were based on a set of food groups recommended for international comparisons, with minimum food group requirements imposed to improve their relationship to nutrient adequacy. The study represents some of the earliest work testing diversity scores for screening capabilities in adolescence, as well as combining diversity measurements across time to predict long-term nutritional outcomes. It is also unique in considering the impact of energy intake on the diversity and HAZ relationship. This relationship with energy intake certainly reflects increased likelihood of meeting energy requirements with increased diversity. However, given the rising epidemic of over-nutrition worldwide, recommendations to increase diversity should be targeted carefully, and may need to include advice to focus diversification on nutrient rich, lower calorie foods. Another strength was that we used a clear methodology in selection of confounders and comprehensively evaluated all possible two way interactions with diversity. From this, we found a strong interaction with mother's education which has not been reported in other populations. We also discussed at length the implications of confounding control with these associations. Since dietary diversity scores are designed for screening purposes, maximal sensitivity to dietary variation is needed, regardless of the source of that variation.

The usefulness of dietary diversity screening tools depends on whether they can capture meaningful differences in dietary intake which can then be translated into specific interventions which will influence nutritional status. Much further research is needed to improve the functionality of these tools. This will include creating, validating and refining

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tools at various ages throughout childhood, evaluation of their relationship to a variety of nutritional indicators, and evaluating their relationship to long-term nutritional status. We hope that this study will encourage further discussion and work on this important topic.

Table 7. Sample characteristics at baseline and age 15 years

	1983 (baseline)				1998 (age 15.5 y)			
	n	**mean**	**±**	**sd**	**n**	**mean**	**±**	**sd**
mother's education	2457	7.44	±	3.70				
father's education	2383	7.27	±	3.49				
mother's height	2457	150.58	±	4.98				
birth order	2457	2.33	±	2.26				
height for age	2457	-2.43	±	1.11	2088	-2.02	±	0.90
household size	2457	5.73	±	2.81	2076	6.99	±	2.56
weekly income[a]	2444	281.12	±	545.34	2076	545.12	±	492.48
per capita income[b]	2444	51.08	±	73.20	2076	85.02	±	77.26
urbanicity index score	2457	29.90	±	12.81	2076	39.08	±	13.69
price of edible oil[c]	2423	2.39	±	0.63	2071	2.43	±	0.39
% male	2457	52.63%						
% breastfed at 2 yrs	2457	13.72%						
% with motor vehicle	2457	4.31%			2076	12.57%		
% with electricity	2457	49.08%			2076	87.43%		
% with refrigerator	2457	6.55%			2076	37.28%		
% with piped water	2457	6.11%			2076	37.14%		
% with flush toilet	2457	12.05%			2074	73.00%		

[a]deflated weekly household income
[b]deflated weekly household per capita income
[c]deflated average barangay (community) price of 375 mL edible oil.

Table 8. Regressions of height for age z-score at 24 months on dietary diversity

Model	Variables	Coef.	P>t	joint P	95% CI	
crude (R^2=0.032)						
	diversity score (range=1-9)	0.128	<0.001		0.100	0.156
crude (R^2=0.076)						
	diversity score	0.052	0.008	<0.001	0.013	0.091
	mothers education (≤6y, >6y)	0.196	0.144		-0.067	0.458
	mothers edu. X diversity score	0.068	0.021	<0.001	0.010	0.126
energy adjusted (R^2=0.098)						
	diversity score	0.000	0.993	0.043	-0.041	0.040
	mothers education	0.141	0.286		-0.119	0.402
	mothers edu. X diversity score	0.058	0.047	0.043	0.001	0.115
adjusted for confounding[a] (R^2=0.236)						
	diversity score	-0.013	0.498	0.022	-0.049	0.024
	mothers education	-0.211	0.092		-0.456	0.034
	mothers edu. X diversity score	0.067	0.013	0.022	0.014	0.120

Based on a 10 gram diversity score. Range=1-9.

[a]Adjusted for birth order, mother's height, crowding, environmental hygiene, electricity, assets, per capita income, fathers education

Table 9. Regression of height for age z-score at 15.5 years on dietary diversity

Model	Dietary Diversity	Coef.	P value	95% CI	
Crude (R^2= 0.007)					
	score=1	ref	ref	ref	ref
	score=2	0.147	0.148	-0.052	0.347
	score=3	0.223	0.021	0.034	0.413
	score=4	0.309	0.002	0.112	0.507
	score=5+	0.179	0.111	-0.041	0.399
Energy adjusted (R^2= 0.014)					
	score=1	ref	ref	ref	ref
	score=2	0.114	0.263	-0.086	0.314
	score=3	0.141	0.152	-0.052	0.335
	score=4	0.202	0.052	-0.002	0.407
	score=5+	0.047	0.690	-0.183	0.276
Adjusted[a] (R^2= 0.301)					
	score=1	ref	ref	ref	ref
	score=2	0.006	0.948	-0.164	0.176
	score=3	0.020	0.812	-0.144	0.183
	score=4	0.064	0.463	-0.107	0.235
	score=5+	-0.075	0.438	-0.266	0.115

[a]adjusted for age, gender, child's education, maternal height, father's education, younger siblings, electricity, refrigeration, per capita income

Table 10. Crude[a] adult height regressed on combinations of dietary diversity

Score Combinations				
24 mos.	**15.5y**	**n**	**coeff**	**95% CI**
≤3	≤2	193	ref	ref
	3	269	-1.27	[-2.67, 0.57]
	4+	190	0.43	[-1.36, 2.14]
4-5	≤2	203	-0.45	[-2.12, 1.32]
	3	387	-0.17	[-1.38, 1.65]
	4+	264	1.61	[-0.30, 2.96]
6+	≤2	70	1.12	[-1.02, 3.75]
	3	151	1.34	[-0.59, 3.14]
	4+	139	1.68	[-0.27, 3.55]

[a]adjusted for age and sex

Figure 10. Height for age Z-score among Filipino children at 24 months, by dietary diversity score. HAZ = height for age Z-score. A minimum portion size of 10 grams was required to receive credit for each food group. Possible score range was 1-9. Five children with a score of 9 were collapsed into category 8.
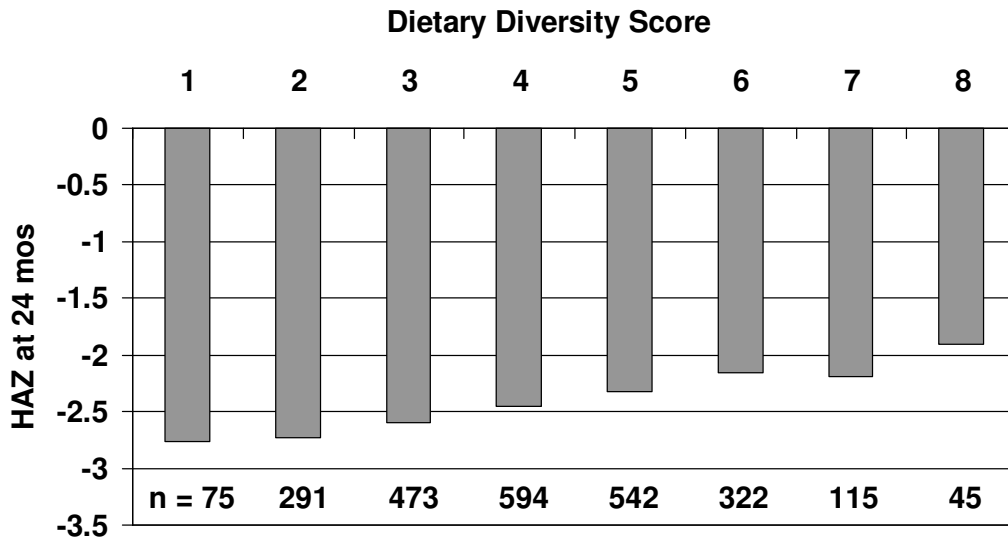
Figure 11. Height for age Z-score among Filipino adolescents at 15.5y, by dietary diversity score. HAZ = height for age Z-score. A minimum portion size of 45 grams was required to receive credit for each food group. Two children with a score of 7 were collapsed into category 6.
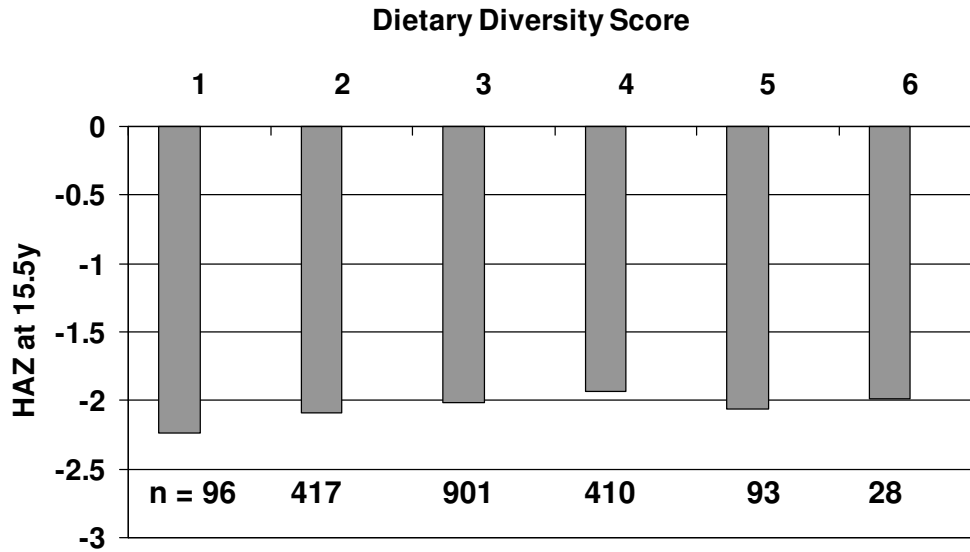
Figure 12. Predicted HAZ at 24 months for low and high diversity scores, stratified by mothers education. DDS = dietary diversity score (10 gram); HAZ = height for age Z-score. Predictions generated from crude and adjusted linear models (adjusted fro birth order, mother's height, father's education, crowding, electricity, assets, per capita income, hygiene index). Low (score = 2) and high (score = 6) diversity correspond to the 10th and 90th percentile.

Figure 13. Predicted increases in height for age Z-score (HAZ) per unit increase in dietary diversity at age 24 months, stratified across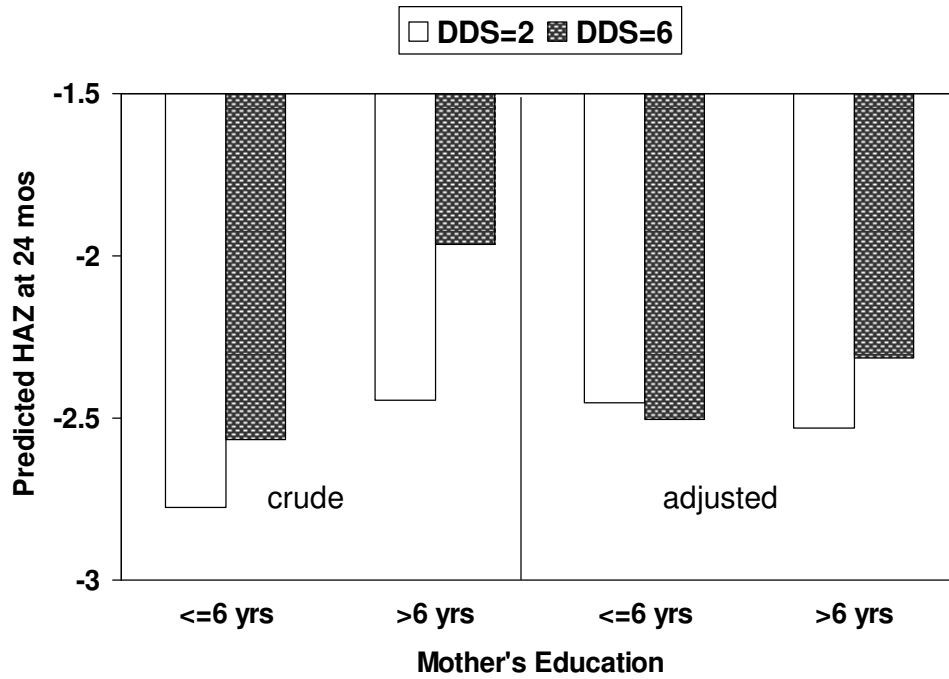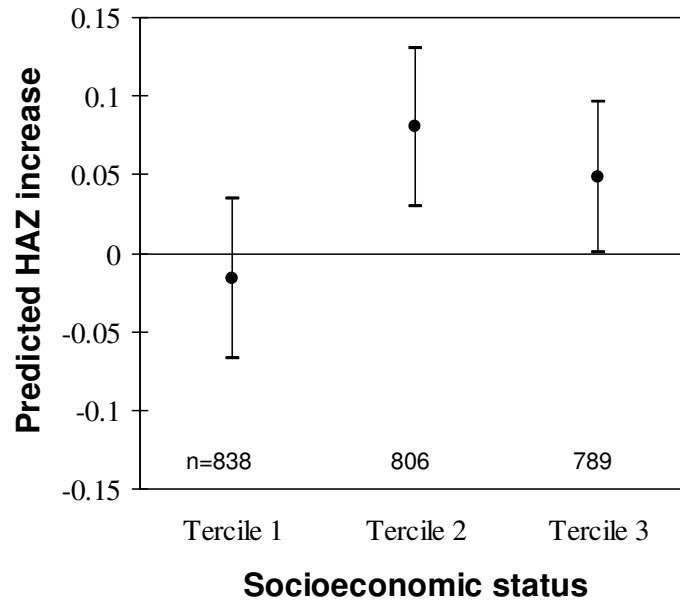 terciles of socioeconomic status. Factor analysis was used as a data reduction strategy to create socioeconomic terciles from parent's education, electricity, refrigeration, crowding, assets, per capita income, the urbanicity index and the hygiene index.

VII. Synthesis

A. Overview of Findings

This research used data from the Cebu Longitudinal Health and Nutrition Survey (CLHNS), a cohort study of 3080 Filipino children, to improve dietary diversity scores as screening tools for malnutrition. Using an internationally recommended measure of dietary diversity as a basis for comparison, we created modified age-specific diversity scores for use in both early childhood and adolescence, and evaluated these scores for ability to reflect nutritional adequacy. Scores were then evaluated for their ability to predict differences in height for age Z-score, and their combined ability to predict differences in adult height.

1. Dietary diversity scores can be improved through the use of portion requirements

Using data from children, age 24 months, we evaluated whether the relationship of a 9 food group diversity score to adequacy could be improved by raising the threshold of intake recognized by the score from >0 grams (typically used) to >10 grams. FAO recently recommended making this comparison to researchers in an international protocol for validation of diversity scores. The rationale for this is that a higher threshold of intake would reduce score misclassification of individuals consuming very small amounts of food which were not nutritionally important.

We found that the 10 gram score was more strongly correlated with dietary adequacy in all 6 nutrients we evaluated (vitamin A, calcium, iron, thiamin, riboflavin, niacin). Increases in the 10 gram score also paralleled increases in grams consumed from every food group, a trend not seen with the 0 gram score. This did not strongly effect score correlations with energy intake; both scores were moderately correlated with energy intake (r=0.43, 0 gram score; r=0.54, 10 gram score). Energy adjusted correlations and correlations with nutrient density were somewhat higher for the 10 gram score (differences were least for calcium and vitamin A), indicating that the 10g score also differentiated diets which are more nutrient rich for reasons other than energy intake. We tested both scores for their ability to discriminate between children meeting different levels of recommended intake. We found increases in diversity predicted significant improvements in % RNI for all nutrients, but estimates were generally higher for the 10 gram score. We conducted sensitivity/specificity analysis using the scores to predict low mean probabilities of adequacy and found improved performance in the 10 gram score.

2. Dietary diversity in Filipino adolescents is related to dietary adequacy

We evaluated dietary diversity scores for ability to predict nutrient adequacy in adolescents, which are a largely unstudied population. We hypothesized that given their greater dietary intake and increased nutrient requirements, a higher minimum threshold of intake would be needed to create a score sensitive to adequacy. Using recommended Filipino serving sizes as a guide for amounts of food that would be nutritionally important, we estimated average gram weights for a half serving of each food group. In preliminary analysis we tested a score with food-group specific thresholds based on these ½ serving sizes,

as well as scores based on ½ and ¼ average serving size, and the 10 and 0 gram scores for correlations with adequacy. Our final analysis was an in-depth comparison similar to that done on young children, of the best of these new scores (average ½ serving = 45 gram) with the best of the previously studied scores (10 gram).

We found that the 45 gram score improved crude correlations with adequacy for all nutrients. As dietary diversity measured by the 45 gram score increased, there was a concomitant rise in grams intake from all food groups. This resembled the patterns seen with the 10 gram score in early childhood; however in adolescence the 10 gram score was much less sensitive to this trend. In adolescence the higher threshold score was substantially more correlated with energy intake (r=0.19, 10 gram score; r= 0.42, 45 gram score). This resulted in greater attenuation when correlations were adjusted for energy intake. Energy adjusted correlations with adequacy were higher for the 45 gram score for all B vitamins, but were similar for the two scores for Vitamin A, Iron, and Calcium. We also evaluated both scores for their ability to differentiate individuals achieving different levels of recommended nutrient intake (RNI). Mean percent RNI rose much more dramatically across levels of the 45 gram score, indicating much greater ability to differentiate, particularly for adequacy of iron and niacin.

3. Using 24 hour diversity at two time points is not sufficient to predict adult height

We examined our early childhood and adolescent scores for their cross-sectional relationship to nutritional status represented by height for age z-scores. We further evaluated whether the combined information from diversity at two time points could predict differences in adult height. Cross sectional analyses were presented crude and energy adjusted to

determine whether the relationship to height for age z-scores may be explainable by energy and associated nutrient intakes. Models were also adjusted for a variety of socioeconomic confounders to determine whether variations in diversity which were independent of socioeconomic factors could explain nutritional status differences.

We found a strong relationship between diversity and HAZ in early childhood that persisted after controlling for confounders. Dietary diversity significantly interacted with maternal education and this relationship was only significant when mothers had >6 years of education. In adolescence, diversity was significantly related to HAZ in crude models but attenuated after adjustment for confounders. Adjustment for energy did not completely explain the relationship of dietary diversity to height for age z-score at either age. Combining scores from both ages did not predict increases in adult height in either crude or adjusted models, indicating that 1 day diversity indicators may not be sensitive to long-term nutritional effects.

B. Public Health Significance

1. Our findings support minimum portion requirements as an important improvement to dietary diversity scores.

A variety of diversity scores have appeared in research, with little discussion of their general insensitivity to portion size. Scores counting any amount of food eaten have typically been oversensitive to very small intakes coming from condiments, garnishes, beverage additives and other minor ingredients which are of questionable nutritional importance. We demonstrated that scores were more strongly correlated with nutrient adequacy, slightly more correlated with nutrient density, and score increases represented greater increases in nutrient

intake when scores included a minimum portion requirement of 10 grams in early childhood and 45 grams in adolescence. Applying minimum portions should be tested for feasibility in field studies. It may be achievable by showing subjects small models or weights representing the minimum portion size and asking if at least this amount has been consumed. Establishing minimum requirements for scores appears to be a simple way to improve their functionality.

2. Our findings provide important groundwork for dietary diversity-based nutritional screening among adolescents

Very few studies of dietary diversity have been conducted among adolescents in developing countries. However, improving nutritional status among adolescents has important implications for future generations. The transition to adulthood is a pivotal period when many lifelong habits and behavior patterns are formed. It provides a window of opportunity for nutritional improvements which will improve both the health and productivity of the rising workforce as well as the health of new mothers, and the next generation of children. Our finding that dietary diversity in adolescence was related to adolescent and adult height prior to confounding control invites further research to explore this relationship. If diversity scores can be created which are more strongly related to adequacy in adolescence, scores may become useful in assessing adolescent nutritional status. If catch-up growth occurs during adolescence, diversity scores may also become useful in determining its likelihood. Though our findings with height were negative, we demonstrated that requiring minimum portion sizes can clearly improve their functionality as measured by adequacy for this age-group. This provides important groundwork for future studies.

3. Our findings confirm the value of dietary diversity scores as a measure of nutritional

status in early childhood

Our findings confirm a persistent relationship between dietary diversity and height for age z-score which has been demonstrated in previous studies. We found that the impact of dietary diversity varies with the level of maternal education, with diversity having a greater impact on height for age z-scores when mothers have more than 6 years of education. This effect was independent of income and a number of other socioeconomic factors, and implies that better educated mothers may have protective care-giving behaviors which permit diversity in the diet to have a greater impact on children's growth and development.

4. Our study is one of the earliest considering the impact of a persistent pattern of dietary

diversity on long-term nutritional status

Studies assessing the persistence of dietary diversity throughout childhood and its ultimate effects on development will be useful for discerning the true importance of dietary diversity-related screening and the potential for diversity based interventions. Though we did not find a relationship to adult height in our study we hope our research generates further interest in exploring these relationships. It is hoped that with the development of valid diversity scores at multiple ages across childhood research may be carried out which will better address this question.

C. Strengths and Limitations

One major limitation in this research was the difficulty of accurately measuring dietary intake. Filipino dishes are typically a mixture of many ingredients served on rice. Deconstructing intakes of these complex mixtures to intakes of individual foods is likely to result in large amounts of error because individuals are unlikely to consume all ingredients in proportion to their recipe amounts. This results in diversity score error, since minimum portion requirements depend on the accuracy of individual food intakes. We were also challenged by incomplete food composition data from the Philippines Food and Nutrition Research Institute. Vitamin C and Zinc data were largely incomplete, and these nutrients were excluded from our analysis. Other nutrients were closer to complete, but most had a number of missing values which we attempted to fill in using equivalent foods from other databases (predominantly the World Food System database, and the USDA national nutrient database). Conversion factors were used to convert raw nutrient profiles to cooked, but this only accounted for nutrient changes proportional to changes in water content and did not account for nutrients destroyed in processing.

Another major difficulty was estimating adequacy given the many factors affecting the bioavailability of calcium and iron. An individuals calcium absorption is affected by other components in food (oxalates, phytates), internal calcium balance (affected by vitamin D & phosphorous levels etc.), and rates of calcium excretion (affected by protein and sodium intakes, etc). We calculated both regular and absorbed calcium intake, basing absorbed intake on differences in food oxalate values provided by FAO and FNRI. And we used calcium requirements estimated for developing countries (with lower protein intakes) but we were unable to account for differences in other factors. Iron absorption differs depending on

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animal (heme & non-heme) or plant (non-heme) food source, and many factors inhibit (phytates, phenols) or enhance (vitamin C, citric acid) absorption. We used a simple algorithm to account for absorption of heme vs. non-heme iron, but were unable account for other factors.

Another limitation was the incompleteness of the international nutrient requirement distributions which were used in adequacy calculations. Requirement distributions, defined by a mean (the estimated average requirement (EAR)) and standard deviation, were hand calculated for B-vitamins and calcium using required nutrient intakes (RNI) provided by FAO/WHO, but depended on coefficients of variation derived from the institute of medicine (IOM, 2001). An approximate EAR was listed for bioavailable calcium, but was based on a higher protein intake than the calcium RNI. A bioavailable iron requirement distribution was not able to be derived from FAO/WHO recommendations because the distribution is not normal, therefore estimates for available iron adequacy were also borrowed from IOM.

The longitudinal analysis of height was limited in considering dietary diversity at only two ages. Our original intention was to use a similar score to consider profiles of diversity across several ages, but the poor performance of the early childhood diversity score in adolescence made it necessary to create and validate another diversity indicator for use in adolescence. Given the apparent need for validating different diversity indicators at different ages, obtaining appropriate estimates of diversity at other ages became less feasible. We therefore restricted our longitudinal analysis to two ages.

This research also has a number of notable strengths. The CLHNS dataset is an uncommonly good resource because of its detailed dietary information and rich information on community, household and individual characteristics of subjects. This allowed us to

consider dietary adequacy in our first two studies, as well as a number of socioeconomic factors from various points in time as potential confounders in our last study. The study has continued for over 20 years, with the most recent data collection occurring in the past year. This length facilitated consideration of dietary diversity and height for age z-scores at more than one time point, as well as later adult height. In addition, the richness of the data will provide many more opportunities for similar research.

The study instrument and several of the validation procedures harmonized with current guidelines (2006) for international comparison and validation of dietary diversity instruments. We also used measures for bioavailable calcium and bioavailable iron which were in accordance with current guidelines. Previous studies have used diverse instruments, making findings difficult to compare and hindering development of standard screening procedures for international use. While the broad array of instruments used in the past has supported a robust association between dietary diversity and adequacy, refinement and identification of best practices depends on comparative studies of the best of these tools.

Another strength of the study is the attention we paid to the relationship of scores with energy intake. Previous studies on dietary diversity's relationship to adequacy have not adequately considered whether score-related increases in adequacy are a reflection of nutrient density or simply a function of increased food intake (in which case increases in nutrients and energy intake are proportional). We evaluated these relationships and found modest increases in adequacy after accounting for energy, indicative of nutrient density improvements. We also considered whether increased energy intake was able to entirely account for the relationship of dietary diversity to nutritional status (height for age z-scores),

and found that it was not, although confounding remains a potential explanation for the remaining relationship.

There is also a scarcity of research on adolescents, who are a major focus in this study. Only two previous studies of dietary diversity in adolescents exist, to our knowledge. In general adolescents have been overlooked in major international studies of nutritional status. Yet adolescents are in a period of rapid growth and development with increased nutrient needs. The limited existing research has verified the presence of increased nutritional risk in this age group. Therefore, screening tools for identifying at-risk adolescent populations deserve foremost attention.

D. Directions for Future Research

Dietary diversity scores are a promising tool for detecting nutritional risk in developing country contexts, but much further research is needed to evaluate their full capabilities. Because of the poor comparability of previous studies, we used an existing and internationally recommended diversity score for comparison. Future research in score functionality should also be anchored by comparison to previously validated diversity instruments. On this basis, modifications to a large variety of score aspects have potential to definitively improve score functionality.

Further work is needed to explore the improvements possible through adding minimum portion requirements to scores. Our work indicated that portion requirements may need to increase with age (in conjunction with increasing nutrient requirements) for scores to have appropriate sensitivity to nutritionally meaningful intakes. However, more research is needed to confirm this in other contexts. Also the ideal threshold for these requirements is still

largely unexplored and is likely to vary by region due to differences in food availability and food preparation. And since food groups differ in their overall nutrient density, further work is also needed to determine if varying minimum portion requirements by food group may be helpful in increasing sensitivity to adequacy.

Specifying food groups differently also has potential to improve diversity scores. A wide variety of food group specifications exist in the literature. Other food groups used have included wild vegetables, leafy greens, whole grains, vitamin C rich fruits and vegetables, drinks, fish/seafood, etc. Ideally for purposes of nutrient adequacy, food groups should be defined by combining foods with similar nutrient profiles; although in practical terms taxonomy often dictates which foods are grouped together. This is not always a problem since foods which appear similar are often nutritionally similar. Therefore, consideration should be given to balance these two criteria when defining food groups. The 9 standardized food groups in this research were based on these criteria. However, modifications, substitutions and additions to these should be explored to determine if there are more optimal grouping schemes. In addition, it may be practical to vary groups depending on location and available foods.

Most scores at present have focused only on measuring diversity between food groups, but very recent work points to potential benefits of identifying diversity *within* food groups for determining adequacy for specific nutrients. Since diversifying the number of food groups eaten increased the grams consumed of each food group in our study, it seems likely that diversifying within a food group could increase intake for specific food groups. This has important implications for dietary recommendations given the burgeoning obesity epidemic. If recommendation to diversify low-calorie, nutrient-rich foods like fruits and vegetables can

naturally increase intake of these foods, dietary nutrient density may be improved without the associated costs of increased energy intake. In populations where energy requirements are largely unmet, broader recommendations for dietary diversification may remain appropriate. Further work is needed to evaluate whether measuring diversity within food groups should become a permanent component of dietary diversity screening.

Work is also needed to assess the optimal duration of diversity measurements. Measures of individual food diversity has been shown to vary for up to two weeks before "usual" diversity can be established, but variation in food groups eaten may be somewhat more modest, making "usual" food group diversity apparent more quickly. However, no studies that we know of have evaluated this. These types of studies will be vital before dietary diversity instruments can be created which will reflect individual adequacy rather than simply population adequacy.

There are many ways to gauge the value of score improvements. In all recommended changes, care should be taken that scores remain practical for field use, i.e. as affordable and simple to administer as possible. Score relationships to nutrient adequacy have been cited frequently as important indicators of score function, and they should continue to be ascertained; but much more emphasis is needed on the ability of scores to reflect nutrient density. Further studies are also needed to evaluate the relationship of dietary diversity to measures of nutritional status - not only how scores reflect height for age z-score, but comparisons with also other measures of nutritional status such as weight for height, weight for age, and BMI for age may be informative. Comparisons should be made at various ages throughout childhood, particularly there is a need for further studies in adolescence. Our adolescent diversity score performed poorly in predicting nutritional status, but was

reasonably associated with adequacy and provides a basis for comparison in future research. Longitudinal studies are also needed to understand to what extent persistently low or high dietary diversity can impact long term nutritional outcomes.

In summary, the usefulness of dietary diversity screening tools depends on their capturing meaningful differences in dietary intake, which can then be translated into specific interventions which will influence nutritional status. As dietary diversity scores are improved, we anticipate that targeted interventions based on score screening will become feasible and meaningful ways to address the burden of malnutrition.

REFERENCES

ACC/SCN. 4th Report on the World Nutrition Situation: Nutrition throughout the Lifecycle. Geneva (Switzerland): ACC/SCN in collaboration with IFPRI; 2000.

ACC/SCN. 5th Report on the World Nutrition Situation: Nutrition for Improved Development Outcomes. Geneva (Switzerland): ACC/SCN in collaboration with IFPRI; 2005.

Adair LS, Popkin BM, VanDerslice J, Akin J, Guilkey D, Black R, Briscoe J, Flieger W. Growth dynamics during the first two years of life: a prospective study in the Philippines. Eur J Clin Nutr. 1993; 47:42-51.

Adair LS, Popkin BP. The Cebu Longitudinal Health and Nutrition Survey: History and Major Contributions of the Project. Philippine Quarterly of Culture and Society. 2001; 29:5-37.

Allen LH, Black AK, Backstrand JR, Pelto GH, Ely RD, Molina E, Chavez A. An analytical approach for exploring the importance of dietary quality versus quantity in the growth of Mexican children. Food Nutr Bull. 1991; 13:95-104.

Appel LJ, Moore TJ, Obarzanek E, Vollmer WM, Svetkey LP, Sacks FM, Bray GA, Vogt TM, Cutler JA, Windhauser MM, Lin PH, Karanja N. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. N Engl J Med. 1997; 336:1117-24.

Arimond M and Ruel M. Progress in Developing an infant and child feeding index: An Example from the Ethiopia Demographic and Health Survey 2000. Food Consumption and Nutrition Division Discussion Paper. Washington (DC): International Food Policy Research Institute; 2002.

Arimond M and Ruel MT. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. J Nutr. 2004; 134:2579-85.

Barba CVC. The 6th National Nutrition Survey: Initial Results. FNRI Writers' Pool Corner [on the internet]. 2004 [cited 2006 Nov 14]. Available from: http://www.fnri.dost.gov.ph/wp/6thnnsreports.htm

Bhan MK, Sommerfelt H, Strand T. Micronutrient deficiency in children. Br J Nutr. 2001; 85 Suppl 2:S199-203.

Brown KH, Peerson JM, Kimmons JE, Hotz C. Options for achieving adequate intake from home-prepared complementary foods in low income countries. In: Black RE, Michaelsen KF editors. Public Health Issues in Infant and Child Nutrition. Philidelphia: Nestec, Vevey/Lippincott Williams and Wilkins; 2002. p. 239-256.

Cerdena CM, Lana RD, Molano WL, Chavez MC, Nones CA editors. Philippine Nutritional

Facts and Figures Supplement 1: 2001 Update of the Nutritional Status of 0-10 year-old Filipino Children. Manilla, Philippines: FNRI-DOST; 2001.

Cohen R, Arimond M, Dewey K, Ruel MT. Developing and Validating Simple Indicators of Complementary Food Intake and Nutrient Density for Infants and Young Children in Developing Countries: Protocol for Data Analysis. Final Report. Washington (DC): Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED). 2005.

Constantino A. Pinoy diet lacks essential nutrients. FNRI Writers' Pool Corner [on the internet]. 2005 [cited 2006 Nov 14]. Available from: http://www.fnri.dost.gov.ph/wp/dietlack.htm

Dahly D and Adair LS. Quantifying the Urban Environment: A scale of urbanicity outperforms the traditional urban-rural dichotomy. Population Association of America 2005 Annual Meeting Program [on the internet]. 2005 [cited 2006 Nov 14]. Available from: http://paa2005.princeton.edu/abstractViewer.aspx?submissionId=51162.

Daniels MC, Adair LS, Popkin BM, Truong YK. Dietary diversity scores can be improved through the use of food group cutoffs: an analysis in young Filipino children. EJCN. 2007 (In Press).

Delisle H (Department of Nutrition, Faculty of Medicine, University of Montreal, Canada). Nutrition in Adolescence - Issues and Challenges for the Health Sector. Final Report. Geneva (Switzerland): WHO; 2006.

Dewey KG and Brown KH. Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. Food Nutr Bull. 2003; 24:5-28.

Dewey KG, Cohen RJ, Arimond M, Ruel MT. Developing and Validating Simple Indicators of Complementary Food Intake and Nutrient Density for Breastfed Children in Developing Countries. Final Report. Washington (DC): Food and Nutrition Technical Assistance Project (FANTA)/Academy for Educational Development (AED); 2005.

Drewnowski A, Henderson SA, Driscoll A, Rolls BJ. The Dietary Variety Score: Assessing Diet Quality in Healthy Young and Older Adults. J Am Diet Assoc. 1997; 97:266-271.

Eckhardt CL, Suchindran C, Gordon-Larsen P, Adair LS. The association between diet and height in the postinfancy period changes with age and socioeconomic status in Filipino youths. J Nutr. 2005; 135:2192-8.

Ferguson EL, Gibson RS, Opareobisaw C, Oseiopare F, Lamba C, Ounpuu S. Seasonal Food-Consumption Patterns and Dietary Diversity of Rural Preschool Ghanaian and Malawian Children. Ecol Food Nutr. 1993; 29:219-234.

Fernandez MaE and Popkin BM. Prelacteal feeding patterns in the Philippines. Ecol Food Nutr 1988; 21:303-314.

Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). Human Vitamin and Mineral Requirements. Report of a joint FAO/WHO Expert Consultation Bangkok, Thailand. Rome (Italy): FAO Rome, Food and Nutrition Division; 2001.

Food and Nutrition Research Institute (FNRI). Food Composition Tables. Manila (Philippines): Department of Science and Technology; 1980.

Food and Nutrition Research Institute (FNRI). Food Composition Tables: Recommended for use in the Philippines, Handbook 1. Manila (Philippines): Department of Science and Technology; 1990.

Food and Nutrition Research Institute (FNRI). Food Composition Tables. Manila (Philippines): Department of Science and Technology; 1997.

Food and Nutrition Research Institute (FNRI). FNRI-PPS Anthropometric Tables and Charts for Filipino Childres. Manila (Philippines): Department of Science and Technology; 1992.

Food and Nutrition Research Institute (FNRI). Nutritional Guide for Young Filipino Adults: Eating Plan for Healthy Living. [figure on the Internet]. Manilla (Philippines): FNRI-DOST; 2000 [cited 2006 May 2]. Available from: www.fnri.dost.gov.ph/ngpyramid.ppt.

Foote JA, Murphy SP, Wilkens LR, Basiotis PP, Carlson A. Dietary variety increases the probability of nutrient adequacy among adults. J Nutr. 2004; 134:1779-85.

Gibson RS. Strategies for preventing micronutrient deficiencies in developing countries. Asia Pac J Clin Nutr. 2004; 13:S23.

Giovannini M, Agostoni C, Gianni M, Bernardo L, Riva E. Adolescence: macronutrient needs. Eur J Clin Nutr. 2000; 54 Suppl 1:S7-10.

Grantham-McGregor SM, Walker SP, Chang SM, Powell CA. Effects of early childhood supplementation with and without stimulation on later development in stunted Jamaican children. Am J Clin Nutr. 1997; 66:247-53.

Guthrie HA and Scheer JC. Validity of a dietary score for assessing nutrient adequacy. J Am Diet Assoc 1981; 78:240-5.

Haines PS, Siega-Riz AM, and Popkin BM. The Diet Quality Index Revised: a Measurement Instrument for Populations. J Am Diet Assoc 1999; 99:697-704.

Hatloy A, Hallund J, Diarra MM, Oshaug A. Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). Public Health Nutr 2000; 3:57-65.

Hatloy A, Torheim LE, Oshaug A. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. Eur J Clin Nutr. 1998; 52:891-8.

Hu FB. Dietary Pattern Analysis: a New Direction in Nutritional Epidemiology. Curr Opin Lipid. 2002; 13:3-9.

Huijbregts P, Feskens E, Rasanen L, Fidanza F, Nissinen A, Menotti A, Kromhout D. Dietary pattern and 20 year mortality in elderly men in Finland, Italy, and The Netherlands: longitudinal cohort study. BMJ. 1997; 315:13-7.

Institute of Medicine (IOM). Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silver, vanadium, and zinc. Washington (DC): The National Academies Press; 2001.

Kant AK. Indexes of overall diet quality: a review. J Am Diet Assoc. 1996; 96:785-91.

Kennedy ET, Ohls J, Carlson S, and Fleming K. The Healthy Eating Index - Design and Applications. J Am Diet Assoc 1995; 95:1103-1108.

Kennedy, G. and Nantel, G. Basic guidelines for validation of a simple dietary diversity score as an indicator of dietary nutrient adequacy for non-breastfeeding children 2-6 years. Final Report. Washington (DC): Food and Agriculture Organization of the United Nations; 2006 [cited 2006 Nov 15]. Available from: http://www.fao.org/ag/agn/nutrition/assessment_en.stm.

Kleinbaum DG, Kupper LL, Muller KE, and Nizam A. The correlation coefficient and straight-line regression analysis. In: Applied Regression Analysis and Other Multivariable Methods. Pacific Grove (CA): Brooks/Cole Publishing Company; 1998. pp. 88-103.

Krebs-Smith SM, Smiciklas-Wright H, Guthrie HA, Krebs-Smith J. The effects of variety in food choices on dietary quality. J Am Diet Assoc. 1987; 87:897-903.

Kurz, KM, and Johnson-Welch C. The Nutrition and Lives of Adolescents in Developing Countries: Findings from the Nutrition of Adolescent Girls Research Program. Washington, (DC): International Center for Research on Women; 1994.

Leatherman TL. Health implications of changing agrarian economies in the Southern Andes. Human Organization. 1994; 53:371-380.

Mannino ML, Lee Y, Mitchell DC, Smiciklas-Wright H, Birch LL. The quality of girls' diets declines and tracks across middle childhood. Int J Behav Nutr Phys Act. 2004; 1:5.

Martorell R, Khan LK, Schroeder DG. Reversibility of stunting: epidemiological findings in children from developing countries. Eur J Clin Nutr 1994; 48 Suppl 1:S45-57.

McCrory MA, Fuss PJ, McCallum JE, Yao M, Vinken AG, Hays NP, Roberts SB. Dietary variety within food groups: association with energy intake and body fatness in men and women. Am J Clin Nutr 1999; 69:440-7.

Mirmiran P, Azadbakht L, Esmaillzadeh A, Azizi F. Dietary Diversity Score in Adolescents - a Good Indicator of the Nutritional Adequacy of Diets: Tehran Lipid and Glucose Study.

Asia Pac J Clin Nutr 2004; 13:56-60.

Monsen ER, Hallberg L, Layrisse M, Hegsted DM, Cook JD, Mertz W, Finch CA. Estimation of available dietary iron. Am J Clin Nutr 1978; 31:134-41.

Ogle BM, Hung PH, Tuyet HT. Significance of wild vegetables in micronutrient intakes of women in Vietnam: an analysis of food variety. Asia Pac J Clin Nutr 2001; 10:21-30.

Onyango A, Koski KG, Tucker KL. Food diversity versus breastfeeding choice in determining anthropometric status in rural Kenyan toddlers. Int J Epidemiol 1998; 27:484-9.

Onyango AW. Dietary diversity, child nutrition and health in contemporary African communities. Comp Biochem Physiol A Mol Integr Physiol 2003; 136:61-9.

Pan American Health Organization and the World Health Organization. Guiding Principles for Complementary Feeding of the Breastfed Child. Washingtion (DC): PAHO/WHO; 2003.

Patterson RE, Haines PS, Popkin BM. Diet Quality Index - Capturing a Multidimensional Behavior. J Am Diet Assoc 1994; 94:57-64.

Resnicow K, Smith M, Baranowski T, Baranowski J, Vaughan R, Davis M. 2-year tracking of children's fruit and vegetable intake. J Am Diet Assoc. 1998; 98:785-9.

Ruel MT. Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs. Food Nutr Bull. 2003a; 24:231-2.

Ruel MT. Operationalizing Dietary Diversity: a Review of Measurement Issues and Research Priorities. J Nutr. 2003b; 133:3911S-3926S.

Ruel MT and Menon P. Child feeding practices are associated with child nutritional status in Latin America: innovative uses of the demographic and health surveys. J Nutr. 2002; 132:1180-7.

Sacks FM, Svetkey LP, Vollmer WM, Appel LJ, Bray GA, Harsha D, Obarzanek E, Conlin PR, Miller ER 3rd, Simons-Morton DG, Karanja N, Lin PH. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. N Engl J Med. 2001; 344:3-10.

StataCorp. Stata Statistical Software Release 9.0. College Station, TX: Stata Corporation; 2005.

Taren D and Chen J. A positive association between extended breast-feeding and nutritional status in rural Hubei Province, People's Republic of China. Am J Clin Nutr. 1993; 58:862-7.

Tarini A, Bakari S, Delisle H. The overall nutritional quality of the diet is reflected in the growth of Nigerian children. Sante. 1999; 9:23-31.

The Cebu Study Team. Underlying and proximate determinants of child health: the Cebu

Longitudinal Health and Nutrition Study. Am J Epidemiol. 1991; 133:185-201.

Tontisirin K, Nantel G, Bhattacharjee L. Food-based strategies to meet the challenges of micronutrient malnutrition in the developing world. Proc Nutr Soc. 2002; 61:243-50.

Torheim LE, Ouattara F, Diarra MM, Thiam FD, Barikmo I, Hatloy A, Oshaug A. Nutrient Adequacy and Dietary Diversity in Rural Mali: Association and Determinants. EJCN. 2004; 58:594-604.

Tucker KL. Eat a variety of healthful foods: old advice with new support. Nutr Rev. 2001; 59:156-8.

Twisk JW. The problem of evaluating the magnitude of tracking coefficients. Eur J Epidemiol. 2003; 18:1025-6.

UN World Population Prospects: The 2004 revision [database on the Internet]. New York: United Nations, Department of Economic and Social Affairs, Population Division. c2005 - [cited 2006, May 1]. Available from: http://esa.un.org/unpp/

UNICEF. The State of the Worlds Children: Focus on Nutrition. New York: Oxford University Press; 1998. [cited 2006 Nov 9]. Available from: http://www.unicef.org/sowc98/

Unicef Global Database on Child Malnutrition [database on the Internet]. New York: UNICEF. 2006 - [cited 2006 Nov 14]. Available from: http://www.childinfo.org/eddb/malnutrition/database1.htm

National Nutrient Database for Standard Reference [database on the Internet]. Washington (DC): United States Department of Agriculture (USDA), Agricultural Research Service. c2005 - [cited 2006 Nov 9]. Available from: http://www.nal.usda.gov/fnic/foodcomp/search/

US Department of Agriculture Pyramid Servings Database [database on the Internet]. Washington (DC): Agricultural Research Service. 2004 - [cited 2004 Jan 13]. Available from: http://www.ba.ars.usda.gov/cnrg/services/toc.html.

Walker SP, Powell CA, Grantham-McGregor SM, Himes JH, Chang SM. Nutritional supplementation, psychosocial stimulation, and growth of stunted children: the Jamaican study. Am J Clin Nutr. 1991; 54:642-8.

Wang Y, Bentley ME, Zhai F, Popkin BM. Tracking of dietary intake patterns of Chinese from childhood to adolescence over a six-year follow-up period. J Nutr. 2002; 132:430-8.

Wang Y and Wang X. How do statistical properties influence findings of tracking (maintenance) in epidemiologic studies? An example of research in tracking of obesity. Eur J Epidemiol. 2003; 18:1037-45.

Weaver CM, Proulx WR, and Heaney R. Choices for achieving adequate dietary calcium with a vegetarian diet. Am J Clin Nutr. 1999; 70:543S-548S.

Willett W. and Stampfer M. Implications of Total Energy Intake for Epidemiologic Analysis. In: Nutritional Epidemiology (Willet, W., ed), pp. 273-301. New York: Oxford University Press; 2003.

World Health Organization. Nutrition in Adolescence - Issues and Challenges for the Health Sector. Geneva (Switzerland): WHO Press. c2005 - [cited 2006 Nov 9]. Available from: http://www.who.int/child-adolescent-health/NUTRITION/adolescent.htm.

WHO Expert Committee. Physical status: the use and interpretation of anthopometry: Report of a WHO Expert Committee. Geneva (Switzerland): World Health Organization; 1995. WHO Technical Report Series 854.

Worldfood Dietary Assessment System [database on the Internet]. Rome (Italy): Food and Agricultural Organization of the United Nations (FAO). c1996 - [cited 2006 Nov 9]. Available from: http://www.fao.org/infoods/software_worldfood_en.stm