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Dietary intakes and nutritional status of preschool-aged children in rural China (Nutritional status of children in rural China)

By

©

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Dedication

To my family and to my husband, for believing in who I am.

Abstract

The diet and nutritional status of 196 children aged 1-5 years old in Heqing County, Yunnan Province were assessed in a cross-sectional survey of anthropometry, diet and anaemia. The respective prevalence of stunting, underweight, wasting and low fat/muscle was: 38 percent, 21 percent, 2 percent and 8 percent. One-third (34.5 percent) of children were anaemic. Although the mean age of boys and girls was comparable, more girls than boys were underweight (53.7% vs. 46.3%, $p = 0.109$), and had low fat/muscle (69% vs. 31%, $p=0.039$), whereas more boys than girls were stunted (58.1% vs. 41.9%, $p = 1.000$). Girls had significantly lower intakes than boys of iron, zinc, total energy, carbohydrates, and protein ($p<0.05$). Average daily intakes of linoleic, α-linolenic, arachidonic, and docosahexaenoic acid were $2\,100 \pm 1\,200$, 300 ± 250, 55 ± 35 and 30 ± 140 mg/d, respectively. There is a high prevalence of malnutrition and dietary quality is poor in children in southwestern rural China.

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AA, arachidonic acid (20:4n-6)

CDC, Centres for Disease Control

DHA, docosahexaenoic acid (22:6n-3)

HHB, Heqing County Health bureau

EFA, essential fatty acids

FFQ, food frequency questionnaire

HAZ, height-for-age z-score

IDA, Iron deficiency anemia

LA, linoleic acid (18:2n-6)

LNA, α-linolenic acid (18:3n-3)

LCPUFA, long-chain polyunsaturated fatty acids

MAZ, mid-upper-arm circumference for age z-score

NCHS, National Centre for Health Statistics

PUFA, polyunsaturated fatty acids

SD, standard deviation

VAD, Vitamin A deficiency

WAZ, weight-for-age z-score

WHZ, weight-for-height z-score

WHO, World Health Organization

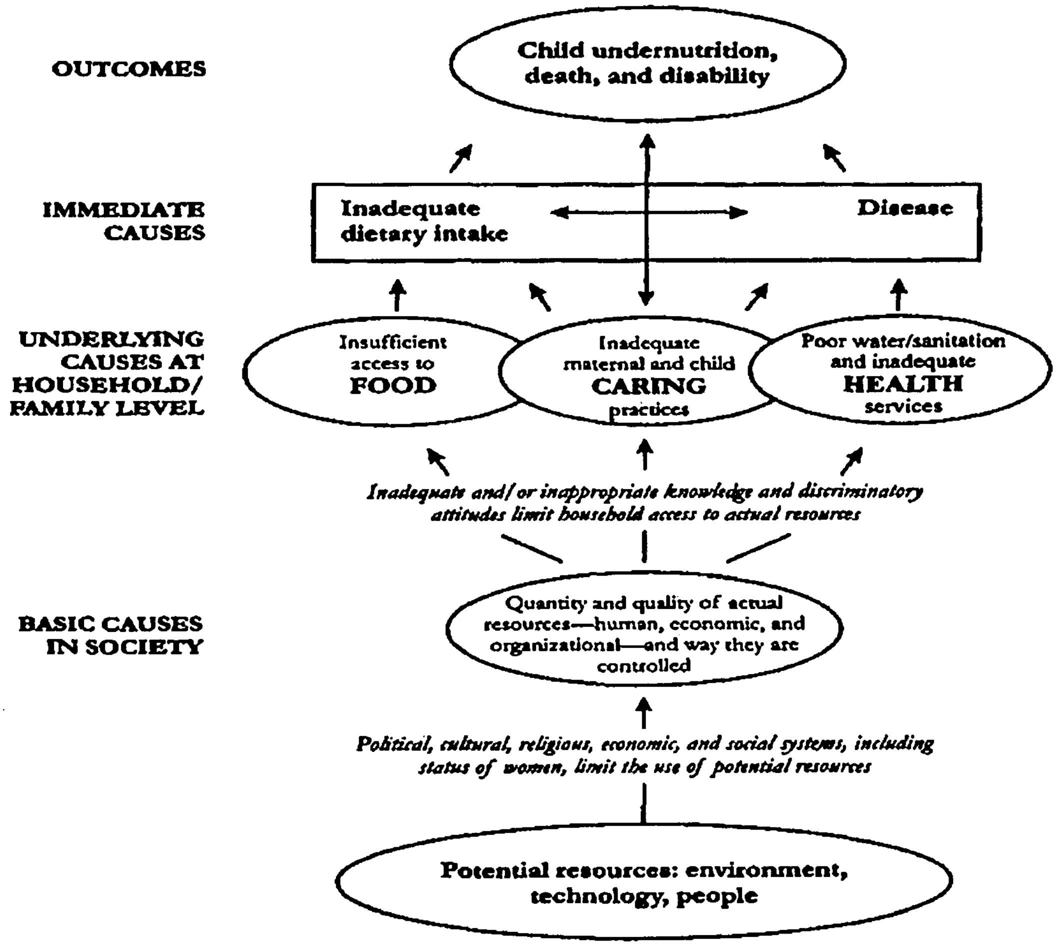
I. Introduction

A. Overview of the determinants of nutritional health

i. Socioeconomic Status

Malnutrition, measured as nutritional status, is a manifestation of a complicated set of ecological, economic, environmental and political interactions (ACC/SCN, 2001). The main causal factors of poor nutritional status include inadequate dietary intake and high prevalence of disease. Food security, the caregiver's education regarding childcare, available health services and the political environment affect dietary intake and disease. These factors are in turn affected by familial relationships that affect control, amount and use of resources. This framework, as depicted in **Figure I-1**, serves as the basis for choosing specific indicators in assessing nutritional status of a population.

Fig I-1 Factors affecting nutritional status (UNICEF, *The state of the World's Children 1998.* Oxford: Oxford University Press)



Nutrition includes not only metabolism and nutritive value of foods, but also qualitative and quantitative food requirements at various ages and stages of development to meet energy demands for growth, maintenance and activity (Krause and Mahan, 1979). Nutritional status of a population is determined by many factors related to metabolism and nutritive value, but also is affected by economic, psychological, social and cultural factors that dictate food selection and dietary intake. Studying nutritional status of a population therefore provides a composite picture of a population's health status, not limited to nutritional status alone. Should nutritional status of a population prove to be sub optimal, as evidenced by the prevalence of malnutrition, knowing what factors are affecting nutritional status would aid in finding methods to improve nutritional health.

There are many studies linking income change with nutritional status indicators, but malnutrition is both a cause and a result of poverty (Gillespie, 1997). Income is a determinant of food intake and food intake is a major factor in determining nutritional status (Mason, 2002). Malnutrition rates are in some cases associated with GDP yet vary by income levels; some countries with the same GDP can have vastly different rates of malnutrition, as measured by the prevalence of stunting or underweight (Gillespie and Haddad, 2001), as explained in the next section. Income cannot independently improve nutrition because more food may not be what is purchased with money, environmental hygiene and health care may not be available to improve health status, and intra-household distribution of food and other resources may not benefit nutritional status indicators.

Other socioeconomic factors also affect nutritional status. Education affects food and childcare choices, as does health care use (Gillespie, 1997, ACC/SCN-IFPRI, 2000). Caregivers may not be educated in how to improve care provision, obtain treatment for disease, and foods may not be purchased that would attenuate nutritional deficiencies. Even with education, if inadequate health facilities are prevalent, infections and diseases that affect cellular utilization of nutrients or increase vitamin and caloric needs will impact nutritional health. The political and ideological structure of a society will determine access to knowledge and disease treatment, of which health care and educational institutions are products. Diet and disease therefore have an intricately linked relationship with economy, politics and education that impacts health status.

ii. Nutritional Status

The prevalence of malnutrition is not evenly distributed throughout a population; inadequate nutritional status is most evident in female and child sectors of a population (Jelliffe and Jelliffe, 1989). In some cultures, women are involved in heavy physical work and, in addition, have biological and nutritional stresses of several pregnancy and breast-feeding cycles, thereby greatly increasing energy expenditure and thus nutritional needs. Childhood is characterized by rapid growth and nutritional requirements are therefore very high. As a result, malnutrition has particularly severe effects on mental, physical and social development of a child. Child malnutrition will herein be explored.

Malnutrition can occur at all stages of life, but demand for nutrients is highest during periods of growth (Gillespie and Haddad, 2001). The association between growth, morbidity and survival is affected by nutrient intake, and is most critical in the early stages of life (Prentice and Paul, 2000). Infections and disease affect energy intake and expenditure, therein affecting growth, while requirements for catch-up growth during the anabolic phase of recovery greatly increase demands on energy needs. This is complicated by the fact that energy can only be efficiently used when all necessary nutrients are adequately present in the diet; a deficiency in one nutrient may decrease the efficacy of energy utilization, and thereby reduce the child's ability to recover from illness and infection, and to grow and function normally. Nutritional status of children can therefore provide a sensitive picture of a population's exposure to infection and of dietary adequacy (Gillespie and Haddad, 2001; Yan et al, 1999; Gillespie, 1997; WHO, 1995). The prevalence of malnutrition in a preschool population therefore becomes a measure of population health.

The prevalence of child malnutrition, a result of inadequate nutritional intake and severe and/or repeat infections, is directly related to energy intake and expenditure (WHO, 1995). Growth deficits, measured by anthropometry, are the most readily available method of assessing nutritional status (WHO 2002). The following will examine how to assess the nutritional status of a preschool population in a developing country.

B. Dietary intakes and nutritional status

i. Assessment of Socioeconomic Status

As mentioned in the introduction, nutritional status is a result of not only nutritional and health factors, but also the economic and political environments in which the population lives. In order to accurately assess the environment contributing to health, it is necessary to obtain demographic, economic and social information. Jelliffe was one of the first experts to describe the impact of socioeconomic factors on nutritional status (1966), which remain similar in present time (Jelliffe and Jelliffe, 1989). He recommended an interview be conducted with the head of the household, most likely to be aware of family issues and income spending, to obtain the socioeconomic data. Health and educational data should be collected from local political, educational and health leaders (Jelliffe, 1966; Jelliffe and Jelliffe, 1989).

1. Socioeconomic status and factors affecting food provision, which in turn affect how much the individual has available to eat and his or her exposure to infectious agents via sanitation and hygiene conditions:

- Population of the community (number, age, sex and geographical distribution), which provides the backdrop for who the population is and where they are located, providing cultural and geographical context.
- Family details (size, relationships, intervals between children), which determine maternal work patterns and suggest how much time is devoted to child care and meal provision.
- Breastfeeding and weaning practices, which impact infant health.
- Education (literacy, school attendance and level of completion), which impacts caregiver's education and indirectly their knowledge of nutrition and feeding practices.
- Housing (type, electricity, ventilation, number of rooms, population/household, owned or rented), which details crowding and hygiene factors.
- Kitchen (location, appliances, fuel, garbage disposal), which explains hygiene and sanitation, and indirectly opportunity for infection.
- Food storage (safety, sanitation).

- Water supply (source, distance, purity, availability), which explains safety and sanitation, and exposure to possible water-borne pathogens.
- Latrine (type, condition), which explains sanitation and possible exposure to infection.
- Family income (wages, cash-crops, debts, intra-familial distribution), which details income level and possibly how much money is available for food.
- Expenditures on food, clothes, shelter, education, transportation, recreation, to provide detail on how money is spent and how much can be allotted for food and health care.
- Food prices (markets, shops, foods bought and/or prepared), which affect food purchasing power.

2. Health and Educational Services

- Hospitals (distribution, distance) impact how easily medical care can be obtained.
- Occurrence of infection and diarrhea impact nutrient demand and absorption.
- Schools (number, type, distribution, curriculum) impact education available for the population.
- Mass media (television, radio, newspapers), details how easily information is accessed, thereby affecting how information and possibly health and nutritional information can be obtained.

It is necessary to make an ecological assessment of various causative and co-existing factors affecting malnutrition in the community in order to explain reasons for malnutrition, and to create a locally appropriate preventative program (Jelliffe, 1966). Depending on the study hypotheses and objectives, the breadth of socioeconomic data gathered varies.

The extent to which socioeconomic factors affect nutritional status differs between and within countries. There are many studies linking income changes with nutritional status indicators, but malnutrition is both a cause and a result of poverty (Gillespie, 1997). Income is a determinant of food intake and food intake is a major factor in determining nutritional status (Mason, 2002). Malnutrition rates are in some cases associated with GDP yet vary by income levels; some countries with the same GDP can have vastly different rates of malnutrition, as measured by the prevalence of stunting or underweight (Gillespie and Haddad, 2001). Income cannot independently improve nutrition. Food price policy however, can improve nutrient intakes (Guo et al, 1999), illustrating the impact of economic and political environments on nutritional status. Attributable risk is a measure of the percentage to which identifiable factors affect the manifestation of an outcome such as nutritional status (Chen, 1996). In a detailed analysis of the 1992 National Nutrition Survey in China, the percent to which health factors influenced stunting were: poverty 32-50%, safe drinking water 16-32%, diarrheal diseases 24%, breastfeeding 35-47%, income 1-3%, child care 34-36%, and gender 5-13% (Chen, 1996). Income is very low on the list, whereas poverty and safe drinking water are two of the biggest factors contributing to chronic malnutrition, evidenced by stunting. Breastfeeding practices, disease and childcare are also relevant factors. These factors must therefore be included when assessing a population's nutritional status and determining how to resolve the issue.

ii. Measuring Dietary Intakes

There are several methods of assessing dietary intake, each having an array of advantages and disadvantages that determine in what situation which method would be best. For large-scale surveys where resources, time and equipment are limited, the 24-hr recall is considered the preferred method for assessing dietary intake (Berti and Krasevec, 2002; Ferguson et al, 1994). It is quick and simple to administer for both the researcher and subject, it is inexpensive, objective and has no impact on usual diet. If more than one 24hr recall is performed, it can provide an accurate picture of usual intake (Ferguson, 1994; Baranowski et al, 1991; Persson and Carlgren, 1984). However if performed only once, it tends not to be representative of usual intake, especially for micronutrients where rich sources of the vitamins or minerals are not eaten every day (Beaton et al, 1983). One-day intake data, no matter how accurate, cannot describe an individual's usual intake (Beaton et al, 1983). Three to five 24-hr recalls are necessary to reduce measurement error and provide accurate data of usual intake (Rimm et al, 1992; Treiber et al, 1990). Because individual intake varies greatly from day to day, especially in children, the variability of the 24-hr recall results reflect actual differences in food consumption in addition to the impact of memory on the intake data provided (Treiber et al, 1990). The 24-hr recall relies on memory, which may not be accurate, under- and over-reporting are documented to occur, and items are often omitted (Lee et al, 1989; Beaton et al, 1983). Data entry is also labour intensive, and accurate assessment depends on availability of accurate recipe data for calculating nutrient content of individual ingredients in composite dishes (Ferguson et al, 1994). Despite these disadvantages, many nutritional assessments continue to use the 24-hr recall as a measure of dietary intake. A sufficiently large number of 24-hr recalls, at least three, may provide a reasonable estimate of mean nutrient intake of a group (Feskanich and Willett, 1993; Lee et al, 1989). It is important to remember that no ideal dietary method exists, and there may only be preferred methods for particular purposes (Beaton et al, 1983).

Beaton et al (1983) studied the 24hr recall in 60 adults. The recalls were obtained on 6 different days, covering almost all days of the week. They found that quantity, rather than mix of foods, changed on the weekend. Beaton et al stressed that care must also be taken when evaluating vitamin A intake; it cannot be interpreted at the individual level as the individual's intake of this vitamin has extreme variations. Calcium intake remained reasonably stable throughout the week. Beaton et al concluded that the researcher must therefore be conscious of the limitations inherent in interpretation of dietary data. It is therefore critical that intended use of dietary data be the major consideration in deciding methodology.

Weighed and/or observed food records are often used to validate or assess accuracy of food recalls (Zhai et al, 1996; Ferguson et al, 1994; Baranowski et al, 1991; Klesges et al, 1987). For a food record, the subject or the observer records at time of consumption what the subject eats for a specified period of time (Lee et al, 1989). This method does not depend on memory and it can provide detailed intake data representative of usual intake if recorded over several days. The weighed or observed food record requires a high amount of cooperation (Ferguson, 1994; Kigutha, 1997). The subject must be literate or the observer must spend an extended period of time with the subject, and diet may be altered as food is weighed and/or written down. It is labor intensive for both respondent and researcher. Food records are therefore difficult to perform in remote rural areas where illiteracy, time and expenses may be an issue in considering which method to use for researching a population.

Ferguson et al (1994) interviewed 72 children (mean age 56.2 months) in rural Ghana to assess relative validity of repeated 24-hr recalls for preschool children. Two consecutive 24-hr recalls were compared to a weighed food record for the same days. There was no significant difference between the two methods for percentage of energy from cereals, roots, animal products, vegetables or fats, but percentage of energy from fruits was significantly lower in the recall. Energy, protein, iron and zinc intakes were also underestimated with the recall. A disadvantage of this methodology is the impact that the observers and food weighing may have had on food eaten and/or served; the observers' presence and consciousness drawn to portion sizes are also likely to alter the caregiver's ability to recall foods on the next day. The authors determined that the discrepancy between assessment methods was due to under-reported snack food consumption and inaccurate portion size assessment of staple foods. Ferguson et al concluded that the repeated 24-hr recall could be substituted for the weighed record in assessing overall diet quality and consumption patterns, and where snack foods were not the dietary factors of interest. Dietary staples provided the majority of nutrients. Ferguson et al suggested that accurately defining portion sizes is vital; using common measures and food items in the household during the interview were helpful methods to improve accuracy. Finally, 24-hr recalls are more appropriate for estimating the average intakes for a group, provided portion sizes of staple foods are accurately recorded. The 24-hr recall can therefore define types of nutritional problems in a population, and can provide approximate estimates of the percentage of children at risk for inadequate intakes of most nutrients.

Persson and Carlgren (1984) evaluated different dietary assessment techniques using data from studies on dietary habits of 477 Swedish children, 4- and 8-years-old. They found that group mean estimates of dietary intake obtained in a single 24-hr recall in comparison to seven-day records were generally close. The 24-hr recall, however, did not accurately estimate individual recall. Intra-individual variation was too large to be represented by one 24-hr recall however for group estimations, in agreement with Ferguson et al (1994). The 24-hr recall may be a quicker and easier method than weighing, observing and recording to obtain group intake data. Persson and Carlgren conclude that all methods of dietary data collection must be judged upon their own merits in selecting a dietary assessment technique; the 24-hr recall is only useful for group estimations.

Zhai et al (1996) also evaluated the validity of the 24-hr recall against a household inventory weighing technique. 13 606 individuals from 3 563 households representing diverse cultural and geographical areas of China were interviewed in the 1991 China Health and Nutrition Survey. For three consecutive days, observers weighed all ingredients in the house, and also obtained 24-hr recalls for the same three days for all members of the household. The researchers could therefore compare the 24-hr recalls to changes in inventory for determining accuracy of stated intakes. Dietary recalls were conducted on various days throughout the week to accurately represent all days and to account for these differences.

A difficulty in assessing Chinese dietary intake is due to the complexity of the mixed dishes (Zhai et al, 1996). This can be overcome if the fieldworkers were from China, and therefore familiar with patterns of eating and types of foods. Misinterpretation or misunderstanding, likely if a foreign researcher conducted the studies without local input, can thereby be reduced. Fieldworkers in Zhai et al's study were also well trained in obtaining dietary intake information and therefore inter-interviewer variation was reduced. Zhai et al found considerable agreement between the 24-hr recall and the household inventory data for energy, protein and fat. Individual nutrients were not analyzed. With the large sample size, this study is encouraging; 24-hr recall can accurately assess population dietary intake if carefully administered.

Dietary assessments must be sensitive to local customs, to methods used to prepare and eat foods, and to the literacy and comfort level of the subjects (Kigutha, 1997). Malnutrition is most often found in rural areas of developing countries, and the large proportion of research in this area is vastly different owing to different cultural and economic impacts on food consumption. Dietary methods must therefore consider these factors, and the researcher must realize that methods working in one population or age group may not have the same statistical significance in other groups. However dietary data, by whichever means of collection, is useful in identifying the type, severity and location of malnutrition. Multiple day weighed records and 24-hr recalls are the most widely used methods in poor, rural areas of low literacy. As well, dietary patterns in rural areas of developing countries tend to be monotonous and simple, therefore data collection is somewhat easier to collect than in developed countries where brands, packaged foods, and a large diversity of foods from the entire world are consumed.

Food frequency questionnaires (FFQ) are also a common method for assessing dietary intake. A list of common foods and frequency of intake of each item is created, and the respondent either performs the questionnaire his or herself, or a trained interviewer administers it (Sempos, 1992; Rimm et al, 1992). FFQs are machine-readable for analysis and less labor intensive to analyze than 24hr recalls. However, FFQs must be validated for specific populations and there is a risk that foods that are significant sources of a nutrient can be mistakenly excluded from the list (Lee et al, 1989). The choice and accuracy of portion sizes are limited, and assessing nutrient composition of the diet is limited to foods listed in the FFQ. FFQs therefore provide information different from a daily food record or a 24-hr recall; the information about preparation, mixed dishes, and size of individual portions is generally lost in an FFQ (Sempos, 1992). Information for the nutrients not on the FFQ cannot be obtained.

The China Health and Nutrition Survey (1999) is a longitudinal assessment of more than 10 000 people considered representative of the entire country of China. Individual dietary intake for 3 consecutive days is obtained from caregivers for all children aged one to six years using 24-hour recalls. Data is also collected for all members of the household and is compared to household food consumption, determined by changes in food inventory from the beginning to end of each day with a weighing and measurement technique. The 24-hr recall technique is used in all CHNS. Berti and Krasevec (2002) recommend focusing on children, being the most vulnerable to malnutrition, in dietary assessment. A 24-hr recall is listed as appropriate for field study of populations, provided results are presented in detail (Berti and Krasevec, 2002).

The choice of method for determining dietary intake is complex. It depends on information required from dietary intake, whether it will serve as a general picture of intake for the population or if accurate assessments of individual nutrients are necessary. All methods of measuring dietary intake are subject to error (Beaton et al, 1983). It is important to consider this error in analysis and to acknowledge why the particular method was chosen. Most importantly, the method must be consistent between subjects. Caution must be used in interpreting data, and the researcher must acknowledge that whatever method is chosen, it is only an approximation of intake (Zhai et al, 1996).

iii. Anthropometrical Measurements

Anthropometry is a universally applicable, economical, and non-invasive method to assess body size and growth (WHO, 1995). Data on underweight, stunting and wasting are obtained using measurements of height and weight to assess body size and composition, which reflect inadequate or excess dietary intake and overall health and welfare. When discussing anthropometrics, it is important to remember that a deficit in one or more of the indices is evidence of malnutrition, but not solely because of inadequate nutrient or energy intake. A deficit can indicate both past and/or current malnutrition at the cellular level due to a primary lack of food, to a higher rate of nutrient use as in infectious diseases, or to impaired utilization or assimilation of one or more nutrients. **Table I-1** explains common measures of nutritional status and the possible etiology. The most commonly used anthropometric indices are weight, height and mid upper arm circumference.

Table I-1 Definitions, pathology and indices of malnourishment

Term	Definition	Index	Cut-off	
			Moderate	Severe
Wasting	Losing weight or gaining insufficient weight relative to height; implies short term diet inadequacy or illness	WHZ	<-2 SD	<-3 SD
Stunting	Insufficient height gain relative to age; implies long-term inadequate dietary intake or illness	HAZ	<-2 SD	<-3 SD
Underweight	Insufficient weight gain or weight is lost relative to age; composite measure of chronic and/or acute malnutrition	WAZ	<-2 SD	<-3 SD
↓Muscle/Fat	Mid-upper-arm-circumference: alternative index of nutritional status, often used where height and weight measurements are difficult to obtain; provides comparable information to wasting	MAZ	<-2 SD	<-3 SD

Adapted from: De Onis et al, 1997; WHO Working Group, 1986

To designate a child as growth-impaired implies comparison to a reference; the international reference population developed and approved by WHO currently serves as such (WHO, 2002). The database uses the National Center for Health Statistics (NCHS) growth reference, which are growth curves formulated from the Ohio Fels Research Institute Longitudinal Study and three representative cross-sectional surveys in the United States in the 1970s (De Onis and Habicht, 1996; WHO, 1995; Dibley et al, 1987; Waterlow et al, 1977). The single-most important criteria that determine compilation of a reference population is that the population is well fed and healthy, therefore meeting its potential for growth (WHO, 1995). Child growth in early years is generally similar across countries, regardless of ethnicity or gender. Disparities in growth, where a child's growth is significantly lower than growth curves of the reference population, are therefore due to environmental factors such as malnutrition or disease.

The recommended technique (Cogill, 2003; Gibson 1993; Gordon et al, 1988) for obtaining height is as follows. Using a stadiometer, the subject wears thin socks or is barefoot, and stands on a flat surface with weight evenly distributed over both feet. With heels, buttocks, scapulae and superior aspect of the head (in Frankfurt plane) against a vertical board, a horizontal headboard is brought to the superior point on the head, after the subject inhales deeply. Measurements should be to the nearest 0.1 cm. For children who cannot stand, recumbent length is used. The subject lies on his or her back, knees are held firmly with feet flat against a vertical board. The head is held firmly and a headboard is lowered to the subject's head. This measurement requires two people. It is important to note whether the subject is measured lying down or standing up, as there are systematic differences. Subjects under 3 years of age are most often measured in the recumbent position. However, in a recent publication, Mei et al (1997) recommend children up to 85cm be measured recumbently to maintain consistency with currently changing international recommendations. It is most important however, to be consistent when taking measurements, and recording what method is used (Cogill, 2003; WHO, 1995).

Weight, like height, can be measured in two ways: an infant (nude or in a dry diaper) or toddler (in light clothing without shoes), who cannot stand firmly to take measurements, can be placed on a calibrated scale with a pan large enough to hold a child (Cogill, 2003). Weight is recorded to the nearest 100g. The mother can also hold the child while standing on a scale and the mother's weight is then subtracted from the total weight of the mother and child to obtain the child's weight. If the subject can stand freely, his or her weight can be recorded on a levelled platform scale. Again, it is important to record how the measurement was taken. All measurement should be taken two to three times for accuracy, where possible.

Weight for Height (WHZ)

Wasting, measured by weight-for-height (WHZ), indicates tissue and fat mass deficits, and results from failure to gain weight or a recent loss of weight (WHO, 1995; Gorstein et al, 1994; WHO Working Group, 1986). It is usually precipitated by infection or general crisis, often evident in seasonal episodes, where food supply may be limited and intake therefore low (WHO, 1995). A reflection of body weight relative to height, WHZ does not require the sometimes difficult and inaccurate task of obtaining age data. WHZ cannot be substituted for height-for-age or weight-for-age, explained below, as each index is a measurement of different biological processes (WHO, 1995). 'Wasting' is also used to describe this measure, and implies a recent and severe weight loss due to starvation or disease. The highest prevalence of wasting occurs in the post-weaning period, from 12-23 months (WHO, 1986). Low (-2SD) WHZ is commonly seen in most populations in less than five percent of the population. For this reason, a prevalence of wasting less than 5.0 percent is considered low (Gorstein et al, 1994). Medium prevalence is where 5.0-9.9 percent of the population is wasted, 10.0-14.9 percent is high and ≥15.0 percent is a very high prevalence (Gorstein et al, 1994).

Height for Age (HAZ)

Height for age (HAZ) reflects achieved linear growth (WHO, 1995; Gorstein et al, 1994; WHO Working Group, 1986). Growth stunting is a risk factor for increased mortality, impaired cognition, impaired motor development, reduced IQs and increased risk of adult chronic disease (Gillespie and Haddad, 2001). Stunting, measured by HAZ, is related to a slowing of skeletal growth, and is often precipitated by poor overall economic conditions related to chronic or repeated infections in addition to inadequate nutrient intake for long term needs (WHO Working Group, 1986). Even when energy intakes are sufficient, low content and/or bioavailability of nutrients such as iron, calcium and zinc, common to diets in developing countries, may contribute to growth faltering (Bhandari et al, 2001). If the prevalence of stunting is substantial, it can be assumed that shortness is not a factor, rather consistent health and/or nutritional deficits are affecting the population. For preschool aged children, a prevalence of stunting less than 20 percent is considered low, 20-29 percent is a medium prevalence, 30-39 percent is high, and greater than 40 percent is a very high prevalence (Gillespie and Haddad, 2001; Gorstein et al, 1994).

Stunting is associated with many environmental factors such as insufficient food intake, infectious disease, care quality, family size, socioeconomic status and feeding practices (Hautvast et al, 1999; Umeta et al 2003). The prevalence of stunting increases from the period of 0-3 months of age to 6-12 months, which are thought to coincide with decreased breast milk intake and the introduction of supplementary foods that may be inadequate for growth (Hautvast et al, 1999).

Measuring HAZ can become complicated when trying to obtain an accurate age (Gibson, 1993; Jeliffe, 1966). Special events are often recorded in communities, which may assist in identifying the birth date of a child (Jeliffe, 1966). If birth certificates are not available, a local calendar can be used and converted (Gibson, 1993; Jeliffe, 1966).

Weight for Age (WAZ)

Weight-for-age (WAZ) is a reflection of body mass, a composite measure influenced by HAZ and WHZ (WHO, 1995; Gorstein et al, 1994). Underweight, measured by weight-for-age (WAZ), is a less sensitive indicator than WHZ or HAZ. WAZ is a composite of the two measures, yet with low specificity and sensitivity (Gorstein et al, 1994). When the prevalence of stunting is high but the wasting prevalence is comparatively low, as in China, this generally indicates a low socioeconomic status (WHO, 2002; WHO Working Group, 1986). Efforts to improve nutritional status should be directed at increasing food availability, improving dietary quality, hygiene, potable water adequacy, and treatment and prevention of disease and infection. In the absence of significant wasting, WAZ reflects similar information to HAZ in that they both are influenced by long-term health and nutritional factors. A WAZ prevalence less than 10 percent is considered low, 10-19.9 percent is medium prevalence, 20.0-29.9 percent is high prevalence and ≥30 percent is very high (Gorstein et al, 1994).

Mid-upper arm circumference

The arm contains both subcutaneous fat and muscle, and a decrease in mid-upper arm circumference (MUAC) may reflect a change in one or both of those tissues (WHO, 1995; Gibson, 1993). MUAC can be used as an alternative index where obtaining height, weight and/or age are difficult, and it has also been used as an additional screen due to its power to predict childhood mortality (De Onis et al, 1997; Mei et al, 1997; WHO, 1995). MUAC can be used as a complement to other indices and for further characterization of a population (De Onis et al, 1997). MUAC for age (MAZ) provides comparable information to WHZ in the context of nutritional surveillance of populations (WHO Expert Committee, 1995). In situations where obtaining an accurate age is difficult, a MUAC for height (MHZ) can be used (Mei et al, 1997). Previously, analyzing MUAC measurements was constricted to comparing the measurement to a cut-off (12.5-13.5 cm), however using NHANES I, NHANES II and NCHS data, WHO developed growth reference curves for MUAC for age and MUAC for height (De Onis et al, 1997; WHO, 1995). The cut-off was previously based on the assumption that MUAC was independent of age, but the WHO Expert Committee has since deemed assuming MUAC as age independent does not reflect the true pattern of mid-upper arm growth, and the Committee recommended interpretation using reference data (De Onis et al, 1997). In developing and comparing the reference to other anthropometric indices, the authors found that both MAZ and MHZ are better predictors of WHZ than MUAC compared to the fixed cut-off (Mei et al, 1997).

MUAC is comparably easy to obtain; it requires only a flexible, non-stretch measuring tape. The mid-point between the acromion process and tip of the olecranon of the left arm is identified with the arm bent to 90 degrees (Cogill, 2003; Gibson 1993; Callaway et al, 1988). For measurement, the arm is hanging loosely by the side with the palm facing inwards. The tape is wrapped firmly around the arm without squeezing it, and the measurement taken to the nearest millimeter.

C. Nutrients and Growth

Nutritional status is often defined by growth measurement (WHO, 1995). Growth, specifically stunting, involves not only macro but micronutrients as well (Umeta et al, 2003). The following section examines calories, fat, protein, zinc, vitamin A, iron, and essential fatty acid intakes in relation to nutritional status and growth.

i. Energy intake: Calories, protein and fat

Stunting is the most commonly measured evidence of malnutrition (Rosado 1999). Protein and/or energy deficiency were initially targeted as the causes for stunting, however it is difficult to ascertain if micronutrients play a role apart from calories, fat or protein to improve growth. Findings from studies of secular trends and migration analysis have found strong correlations between meat and fat intake and growth. For instance, Japanese migrants to Hawaii and California were significantly taller than Japanese living in Japan (Kaplan and Toshima, 1992). These height differences were attributed to higher intakes of animal protein and more fat in the nearly isocaloric diets of migrated Japanese compared to native Japanese. Fossil records suggest the game hunting *homo sapiens* who consumed greater amounts of meat than their agricultural descendants were unquestionably taller. Despite this evidence however, it is impossible to ascribe changes in height in relation to secular and migrational effects to protein and fat intake alone. Animal protein is an excellent source of many micronutrients and components that improve immunity, work capacity and general health. Health care, socioeconomic improvements and sanitation have also improved over the centuries. With such improvements, children are less often exposed to infection which impacts intake and use of nutrients, reducing prevalence of disease that impact child growth (Gillespie and Haddad, 2001).

The impact of energy, fat or protein alone on growth is difficult to identify, however several studies have addressed this question. Using food balance data sheets from nineteen countries in South America, Uauy et al (2000) found significant negative correlations between available energy, food-energy ratios and animal fat with stunting. Wasting showed no relation to diet. The authors suggested that diets providing less than 22% of energy from fat or diets low in animal fats negatively impact growth. Despite this conclusion, interpretations of food balance sheets are limited and they are useful only for population studies; calculations using food balance sheets cannot define the intricacies of dietary intake.

In a longitudinal study comparing arbitrarily-assigned levels of low, medium and high fat intakes, there was no significant difference between groups for height, weight or skin-fold thicknesses of children at any age from infancy to 8 years (Boulton and Magarey, 1995). More specifically, a one-year trial of high fat versus high carbohydrate supplements in stunted children aged three to nine years found no effect on catch-up growth (Krahenbuhl et al, 1998). Higher fat intake resulted in greater fat deposition compared to the control and high carbohydrate groups, as measured by sum of four skinfolds and of MUAC. Weights were not significantly different between any of the three groups. A non-intervention study examining dietary patterns to address this issue was also undertaken in Zambia (Hautvast et al, 1999). Fat, carbohydrate, and protein intakes were not different between stunted and non-stunted infants and toddlers.

Conversely, in a longitudinal study of dietary intakes comparing stunted and non-stunted children, the stunted children actually consumed more energy and protein per kg of body weight than the non-stunted children (Walker et al, 1990). This could possibly be explained if the non-stunted children consumed a greater variety of foods, and consumed higher concentrations of micronutrients than the stunted children. It is also possible that parents may have been aware of their child's poor growth and were compensating by increasing their intakes during the course of the study.

While there are some studies concluding that energy intake improves weight gain but not height, there are also several studies deducing that height and weight are indeed impacted by energy or protein intake, keeping micronutrient content constant (Allen, 1994). Allen (1994) reviewed several studies that examined increased energy intake and growth, and found that energy increased weight gain in two studies, increased height gain in another study, increased both weight and height in a fourth study, and had no impact in the final study. Additionally, in studies examining protein intake, inclusion of micronutrients associated with protein sources complicated interpretation of the results. Such inconsistent conclusions regarding energy, protein or fat intake reveal there are much more complicated nutrient interactions involved in growth than macronutrient composition alone.

ii. Zinc Intake and Deficiency

Zinc is ubiquitous in sub-cellular metabolism (Hambridge, 2000). Zinc deficiency will therefore result in a generalized impairment of metabolism and many metabolic functions related to epidermal, gastrointestinal, central nervous, immune, skeletal and reproductive systems. Also, it is this ubiquity that complicates elucidation of both the prevalence of Zn deficiency and assessing Zn status.

Zinc supplementation has been shown to improve linear growth in children, and this growth improvement is often used as a method of determining whether a population or individual is zinc deficient (Umeta et al, 2000; Whitaker, 1998). In a randomized double-blind zinc supplementation trial, 100 stunted and 100 non-stunted infants received zinc or a placebo for 6 months (Umeta et al, 2000). Growth was improved by >4 standard deviations for stunted infants, and slightly less than 2 SD for non-stunted infants. In a meta-analysis of 22 zinc supplementation trials, zinc supplementation was found to significantly increase growth (Bhandari et al, 2001). Zinc is therefore an important linear growth limiting micronutrient in zinc deficient populations.

The approximate Zn intake of Chinese preschool children in urban areas is 4.5-5.5mg/d (Ge and Chang, 2001; Chen et al, 1992), which is only half of the Dietary Reference Intake (DRI) Recommended Dietary Allowance (RDA) of 10mg/d (National Academy of Sciences, 2000) and the Chinese Recommended Nutrient Intake (RNI) of 9-12 mg/d. It is important to note that phytate content of diets also greatly impact the absorption of zinc, similar to the effect of phytate on iron bioavailability (Ferguson et al, 1995).

iii. Vitamin A and Vitamin A Deficiency

Vitamin A interacts with several nutrients, including zinc, iron and iodine (Bhaskaram, 1995). Zinc is needed for mobilization of vitamin A from the liver and influences the oxidation-reduction reactions of vitamin A (Munoz et al, 2000; Solomons and Russel, 1980). Vitamin A possibly influences utilization of iron, which is important to consider when assessing a population where both deficiencies may exist (Bhaskaram, 1995; Hodges et al, 1978), as in China.

Severe forms of vitamin A deficiency (keratomalacia) are most common in young children and occur during preschool years at two times the rate of older children (Rahmathullah et al, 1997). The prevalence in infants less than 6 months is thought to be related to poor maternal nutrition and decreased breastfeeding, while the prevalence in children approximately 3-4 years of age is likely due to poor weaning practices. Both causes are affected by an insufficient compensatory diet when weaning occurs (Ramakrishnan et al, 1999). Vitamin A supplementation is also associated with decreased risk of morbidity and mortality, increasing immunocompetence and reducing severity and incidence of both diarrhoeal and respiratory infection (Beaton et al, 1994).

The DRI/RDA for vitamin A is 400ug RE for children aged 1-3 years, and 500ug RE for children aged 4-6 years (National Academy of Sciences, 2000), while the Chinese RNI is higher at 500 and 600ug RE for 1-3 and 4-6 year old children, respectively. Preformed vitamin A is found in red palm oil and in animal products (liver, fish oils, dairy products and eggs), and carotenoids come from fruits, green leafy and yellow vegetables (Basu and Dickerson, 1996). Carotenoids make up the majority of vitamin A intake for developing countries (Ramakrishnan et al, 1999), including rural areas in China (Ge and Chang, 2001). Vitamin A deficiency is mostly subclinical in China, with 55% of children under six consuming significantly less than 50% of the Chinese RDAs for retinol equivalents (Ge and Chang, 2001).

iv. Iron and Iron Deficiency Anemia

Iron depletion and microcytic anemia occurs in three stages (Groff and Gropper, 1999; Johnson, 1990):

1) Iron storage decreases in the liver, spleen and bone marrow, and is paralleled by a decrease in plasma ferritin. Ferritin values <12ug/dL in adults are associated with iron deficiency. Serum ferritin, also an acute phase protein, will rise in the presence of inflammation or infection. This rise is unrelated to iron stores, and it must therefore be noted if the child has an infection when serum ferritin is analyzed. The presence of infection, inflammation and chronic disease is suspected if C-reactive protein (CRP), zeta-sedimentation rate (ZSR) or erythrocyte sedimentation rate (ESR) are elevated (Johnson, 1990). It is important to measure these values in order to differentiate between anemia of chronic disease and iron deficiency anaemia (IDA), to accurately measure the prevalence of IDA.

2) Transport iron is decreased, evidenced by lower serum iron (<50ug/dL) and increased total-iron binding capacity (TIBC) (>400). The ratio of iron to TIBC is transferrin saturation, which also decreases at this stage. Transferrin saturation <15-16% indicates iron deficiency.

3) Erythrocyte protoporphyrin is elevated in the final stage, when supply of transport iron is decreased, and consequently hemoglobin production is hindered. Blood hemoglobin concentrations below 130 g/L for adult males, 120 g/L for menstruating women, and 110 g/L in pregnancy or childhood is considered evidence of iron deficiency anemia (Sadler et al, 1999).

IDA can be diagnosed using any of the above mentioned biochemical parameters, and accuracy of prevalence studies is improved by the concurrent measurement of hemoglobin with one or more specific tests for iron status, such as serum ferritin, free erythrocyte protoporphyrin or transferrin saturation (WHO, 2001). For public health and population-based assessments of nutritional anemia however, hemoglobin is often used as the only measure of iron status in developing countries due to its ease of collection.

The DRI/RDA of iron for children aged 1-6 years is 10mg/day (National Academy of Sciences, 2000). In China, the RNI is 12mg/d. Heme iron is found in meat, fish and poultry, while non-heme iron is found in fortified cereal products, nuts, fruits, vegetables, grains, beans and tofu. Heme iron is more efficiently absorbed than non-heme, as non-heme iron must be enzymatically liberated in the gastrointestinal tract for absorption to occur (Groff and Gropper, 1999). Iron absorption is enhanced by ascorbic, citric, lactic and tartaric acids, and cysteine-containing peptides, while it is inhibited by polyphenols, oxalic acid, phytates, and several nutrients (high concentrations of calcium, zinc, manganese and nickel) (Groff and Gropper, 1999). The impact of bioavailability on iron status is an important issue in China: daily iron intake in adults is approximately 177% of the Chinese RDA and 209% of the value dictated by the National Academy of Sciences, while IDA remains a national problem (Du et al, 2000).

In an analysis of the dietary intake obtained from three 24-hr recalls for 42, 606 adults aged 18-60 years in the Third Chinese National Nutrition Survey (1992), the authors examined dietary factors which may affect iron bioavailability using three different methods (Du et al, 2000). Non-heme iron was the main form of iron intake for the Chinese, although heme iron intakes were significantly higher in urban populations than in rural areas. Interestingly, non-heme and overall iron intakes were higher in rural populations, while the prevalence of IDA in rural areas was similar to that in urban areas. All three methods investigated in the study indicate that bioavailability of iron, in urban but especially in rural Chinese diets, is "strikingly low". Infections and parasitic diseases have not consistently been identified as major causes of IDA.

IDA affects 8-28% of rural male and female children under 6 years of age based on blood hemoglobin levels (Ge and Chang, 2001). Absolute requirements, including considerations of basal losses, are adjusted according to diet bioavailability (WHO, 2001). In areas of low bioavailability (5%), the daily requirement for children aged 1-3 years is 11.6mg and for 4-6 year old children is 12.6mg/d. In areas of high bioavailability, the absolute requirement is considerably less: 3.9mg/d and 4.2mg/d for the younger and older age groups, respectively. China would not be considered an area of high bioavailability. Bioavailability may not be the only factor affecting IDA in China. Iron deficiency is associated with a decrease in serum selenium concentration, which is a concern for Chinese children, as manifested in the high prevalence Keshan disease in the country (Alfthan et al, 2000). The relationship between selenium and iron however, is not fully elucidated (Groff and Gropper, 1999). Alternately, reduced vitamin A status alters iron distribution between tissues and may affect iron status (Groff and Gropper, 1999). As previously mentioned, both selenium and vitamin A deficiency are prominent issues in China.

IDA cut-offs are affected by altitude (WHO, 2001; Nestel, 2002). Above 1000m, hemoglobin concentrations increase in adaptation to lower oxygen saturation and partial pressure of oxygen, and red blood cell production thereby increases to compensate for lower oxygen supply to tissues and hemoglobin values are increased (Dirren et al, 1994; Hurtado et al 1945). Over the long term, populations living in higher elevations, from 1000m to 5500m, have hemoglobin values approximately 1-67 g/L higher than below 1000m. At sea level, the cut-off is 110g/L hemoglobin for children aged 6-59 months and 115g/L for children aged 5-11 years (Nestel 2002; WHO 2001). An adjusted hemoglobin value for populations living at high elevations should therefore be obtained (**Table I-2**). For example: for a 4 year-old child whose hemoglobin at 2200m is 113 g/L, subtract the adjustment factor of 7g/L (Nestel 2002) from the measured hemoglobin value to obtain the hemoglobin value at sea level: 113 – 7 g/L = 106 g/L. Conversely, compare the obtained value (113 g/L) to the adjusted cut-off level, where elevations are rounded to the nearest 500m (117g/L at 2000m). Thus, considerable differences in the prevalence of anemia are identified when adjusted hemoglobin values are applied. Altitude is therefore an important consideration when determining the prevalence of IDA in higher-altitude areas.

Table I-2 Adjustment factors used to predict the prevalence of anaemia in 6 month to 5 year-old children using hemoglobin values at different altitudes (WHO, 2001; CDC, 1989)

Altitude	1000m	2000m	2500m
Adjustment factor*	0	+7	+12
Hemoglobin value (g/L)	110	117	122

*Added to value used at sea level of 110g/L

v. Essential Fatty Acids (EFA) and Long-chain Polyunsaturated Fatty Acids (LCPUFA)

The essential fatty acids (EFA) α-linolenic acid (LNA; 18:3n-3) and linoleic acid (LA; 18:2n-6) are precursors to docosahexaenoic acid (DHA; 22:6n-3) and arachidonic acid (AA; 20:4n-6), respectively (**Figure I-2**). LNA and LA are exclusively diet-derived, whereas DHA and AA can be endogenously synthesized via desaturation and elongation (Salem et al, 1999), or consumed in food (Innis, 1991; Zollner, 1986; Wolff et al, 1984).

Figure I-2: Endogenous desaturation and elongation of dietary LNA to DHA and LA to AA (*Adapted from* Innis, 1991)

C18:2n-6 (LA)		C18:3n-3 (LNA)
↓	Δ-6 Desaturase	↓
C18:3n-6		C18:4n-3
↓	Elongase	↓
C20:3n-6		C20:4n-3
↓	Δ -5 Desaturase	↓
C20:4n-6 (AA)		C20:5n-3
	Elongase	↓
		C22:5n-3
	Elongase	↓
		C24:5n-3
	Δ -6 Desaturase	↓
		C24:6n-3
	β-Oxidation	↓
		C22:6n-3 (DHA)

EFA are essential for growth and development; DHA and AA have been shown to enhance growth in term and preterm infants (Clandinin et al. 2005; Clandinin et al. 1981). DHA and AA have been shown to improve affect visual acuity and improve vision (Hoffman et al, 2003; Birch et al, 2002), affect cell signalling, maintain optimal states of fluidity and enhance neurovascular membrane integrity (Crawford et al, 2003; Larque et al, 2002; Giovanni et al, 1998; Jorgensen et al, 1996; Hardy and Kleinman, 1994). DHA and AA also enhance brain development (Clandinin et al, 2005; Birch et al, 2002; Birch et al, 2000; Agostoni et al. 1995), yet research investigating vision and brain development beyond 2 years of age is limited. Considering that brain and eye continue to develop throughout childhood (Chugani, 1998), EFA and LCPUFA may play a very important role in growth and development in later childhood. Intake data by preschool children are sparse, especially in developing countries. There are few studies describing the effects of EFA deficiency on growth. In a study of 40 children aged 2-24 months with protein-calorie malnutrition compared to 48 healthy 1-48 month old children, Holman et al (1981) examined serum lipid profiles to investigate the impact of protein-energy malnutrition on EFA status, hypothesizing low protein intake affected EFA utilization. When LA content was low as in EFA deficiency, LA and its metabolic derivations were diminished. Compensatory increases in other fatty acids, which can be synthesized endogenously, were also identified. Thus, EFA status is compromised in malnutrition (Holman et al, 1981) and this compromise may manifest in the functions of EFA and LCPUFA, such as growth, visual acuity and cognitive development.

Conversion of LA and LNA to their metabolites is limited, therefore provision of AA and DHA, and possibly EPA, are necessary to achieve optimal EFA status. Indeed, Bjerve et al (1987) estimated the minimal amount of LNA needed to prevent deficiency is 0.2-0.3%, or 0.1-0.2% EPA + DHA, indicating EPA and DHA may be more effective and efficient in preventing EFA deficiency than LNA alone. The Chinese Recommended Nutrient Intakes (RNIs) do not specify specific levels of LNA or LA, but the National Academies of Science (2002) recommend 1-3 year old children consume 0.7mg LNA/d and 7g LA/d and 4-6 year old children should consume 0.9mg LNA/d and 10g LA/d. Currently, polyunsaturated fat (PUFA) intake data in China is lacking. The national 1992 survey in China revealed that average fat intake by children totalled 16-20 percent of total energy intake, without describing EFA or PUFA intake (Cheming, 2000).

vi. Conclusion

The evidence is not definite that single micronutrients play individual roles in causing growth impairment most often measured as stunting. It is more likely that stunting, underweight or wasting are a result of a combination of micronutrient deficiencies. It is reasonable to suggest however, that if a child is not meeting his or her caloric or protein requirement for growth, the child is also more likely to be missing individual or combinations of micronutrients, in addition to inadequate protein or caloric intake. If that is the case, then stunting or other manifestations of nutritional status may be caused by a combination of macro and micronutrient deficiency. For children given multiple micronutrients and no extra energy or protein, the amelioration in height is attenuated by the lack of macronutrients or energy intake (Rosado 1999), suggesting that reducing the prevalence of malnutrition as measured by stunting requires attention to all the micro and macronutrients required for healthy growth. Insufficient food energy intake combined with inadequate micronutrient intakes due to poor variety, preparation method and food combinations are exacerbated by unsanitary conditions. Poor hygiene contributes to chronic infection and diarrhea accompanied by reduced appetite and absorption (Gillespie and Haddad, 2001). These factors further enhance poor health where insufficient access to medical treatment and inadequate education are prevalent.

E. Nutritional Status and Dietary Deficiencies in China

Differences in growth of preschool children between urban and rural areas of China are substantial (Chang et al, 1996). Due to geographical diversity and unbalanced economic development throughout the country, prevalence of underweight infants in rural areas ranges from 6.9 to 23.1% compared to 2.2 to 7.1% in urban areas. Prevalence of stunting in rural children under-4 is approximately 40% versus 11.5% in urban children. While prevalence of wasting nationally is relatively low in China (less than 5%), several provinces in the southwest have a prevalence of greater than 8%. The southwest fares consistently worse than most of the country, with a prevalence of severe underweight greater than 10% compared to less than 2% in more affluent regions. Due to the higher prevalence of malnutrition, preschool children in rural southwestern areas of China will serve as the focus of this report.

The Chinese diet is lacking in many nutrients (Ge, 1999). National and provincial surveys have described low intakes of total fat (Chen, 2000), vitamin A, zinc, vitamin D (Ge and Chang, 2001; Chen et al, 1992), riboflavin (Qi, 1999), selenium (Alfthan et al, 2000) and while iron intake is high, the bioavailability is low (Du et al, 2000). National calcium intake is only 400mg per day, or 50% of the RDA (800mg for adults), and milk consumption estimated at zero in many of the provinces (Ge and Chang, 2001). For the purposes of this study, vitamin A, iron, zinc, calcium, EFA and PUFA, energy and macronutrient intakes will be examined.

F. Conclusion

A population's health is affected by several factors (Hamilton and Bhatti, 1996; Jelliffe and Jelliffe, 1989). Education and social status affect social and lifestyle choices, and also provide the opportunity for knowledge, skill, and increased income. Income provides the ability to buy adequate food, clothing and shelter. The general physical and political environments significantly affect access to and quality of health services.

Similarly, nutritional status of a population is also determined by many factors (WHO, 1995; Krause and Mahan, 1979). Nutrition includes metabolism and nutritive value of foods, alongside requirements of macro and micronutrients at different stages of the life cycle to meet physical demands for growth and activity. Measuring nutritional status and identifying micronutrient deficiencies helps to determine the health of a population and what factors may specifically need improvement.

China faces the daunting task of addressing a wide variety of micronutrient deficiencies in populations confounded by geographical access and economic constraints. Due to the large population and size of the country, policies and infrastructure that can address and adequately meet the needs of remote, rural populations will be difficult to create and implement, as well as evaluate and maintain. To improve the health of the Chinese people, diets need to be adequately assessed, biochemical, clinical and anthropometrical assessments need to be accurately quantified, and culturally acceptable and sustainable methods to address identified micronutrient deficiencies must be implemented and supported by all sectors of the government and population in order to improve the health and well-being of the nation.

G. Purpose and objectives of the study

In view of the prevalence of poor nutritional status in rural China, it is hypothesized that a proportion of preschool children in northern Yunnan Province have poor dietary intakes of several nutrients and are stunted and/or anaemic. The specific objectives are to:

1. Determine the nutritional status of preschool children aged 1-5 years from 3 non-consecutive 24-hr food recalls and anthropometric measures:

    a. Assess the prevalence of stunting (height for age), underweight (weight for age), wasting (weight for height) and low fat/muscle (MUAC for age) using the NCHS/WHO growth reference charts
    b. Assess the prevalence of anemia using hemoglobin measurement
    c. Determine if anthropometrics and haemoglobin status are related to socio-economic status
    d. Assess intakes of essential fatty acids, iron, zinc, vitamin A and calcium, known to be low in rural Chinese diets

2. Determine if socio-economic status and dietary intake are related

i. Hypotheses

Growth. Chronic undernutrition, measured as the prevalence of stunting in comparison to NCHS/WHO growth charts, is an indicator of poverty. While the applicability of the NCHS/WHO growth charts is controversial due to differing ethnic backgrounds and possibly genetic potential, trends in the growth of well-nourished Hong Kong Chinese children reveal similar final heights to Western children (Luo et al, 1999), and Chinese infants in more affluent compared to less affluent environments show less deviation from international references (He et al, 2001; Shen et al, 1996). Comparisons of growth status among preschool children in China reveal that those living in the poor southwest have the poorest status (Guldan et al, 2000; Ying et al 1994). In Yunnan province, the respective prevalence of moderate and severe malnutrition, measured by HAZ, was 31.8% and 19.2% in children under 7 from rural ethnic minority groups (Yan et al, 1999).

Diet. Iron deficiency is the most common nutritional disorder in the world. As many as 2 billion people – over 30% of the world's population – are anaemic, mainly due to iron deficiency (http://www.who.int/nut/ida.htm). Throughout the developing world, children of poor families are at greater risk of being anemic than children from wealthier families. In China, IDA is the most common nutritional deficiency problem; up to 28% of children aged 6 months to 5 years are anemic (Ge and Chang, 2001). Despite a higher intake of iron compared to urban residents, rural residents have a higher prevalence of iron deficiency, owing to lower bioavailability of iron in rural diets (Du et al, 2000).

EFA and LCPUFA are found in select foods; nuts, seeds and vegetable oils are sources of α-linolenic and linoleic acids, whereas chicken, eggs, pork and some species of fish are sources of LCPUFA (USDA, 2004). Fat intake in rural China is reported to be low, attributable to relatively low intakes of meat and animal products in rural areas (Chenming, 2000).

1. There will be a high prevalence (>30.0%) of stunting in rural mid-northern Yunnan province.

   Related Hypotheses:
   a. *There will be a relationship between measures of economic status (income per capita) and nutritional status (HAZ or WHZ).*
   b. *There will be a high prevalence of anaemia, measured by haemoglobin status.*
   c. *Dietary intakes of iron will be low.*

2. Growth will be related to essential fatty acid intakes.

   Related Hypothesis:
   a. *Dietary intakes of essential fatty acids will be low.*

G. References

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II. Subjects and Methods

A. Study Context

The standard of living in China is increasing rapidly. Through widespread economic reforms, the GDP has steadily risen by approximately 8% each year since 1999 (World Development Bank, 2005). Despite advances in urban areas, which comprise less than 25 percent of China's population in a vast territory containing over 1.3 billion people, infrastructure in remote areas of China lags far behind urban standards. As of 2002, improved water sources had reached only 66 percent of the rural population, behind the average of 69.5 percent of the rural population in developing countries. Only 27 percent of rural Chinese had access to improved sanitation measures, in comparison to an average of 35.5 percent in other developing countries (World Development Bank, 2005).

Nutritional status of children can be used as a public health indicator; childhood growth is retarded due to poor diets and/or recurrent infections, factors in direct relation to the child's environment (De Onis and Blossner, 2003; Li et al, 1999). While the heights and weights of children in urban China are currently comparable to the growth reference population (WHO 2005), rural Chinese children are predominantly shorter and thinner (Chenming, 2000; Chang et al, 1996; Ying et al, 1994). The WHO Global Database on Child Growth and Malnutrition estimated that nationally, 18.2, 2.4 and 11.2 percent of children aged 0-6 years in China were stunted, wasted and underweight, respectively (WHO, 2005). Children in rural areas however, fared worse. Poverty-stricken rural areas in China comprise 40 percent of the country's territory (Qu, 1994) and the national rural average prevalence of stunting, wasting and underweight in rural areas were 27.1, 2.6 and 15.5 percent, respectively (WHO, 2005).

China's national income per capita, 9023 RMB (1100 USD), is over four times greater than in Heqing County, Yunnan Province (WDB, 2005) where the mean annual income per capita was 2042 ± 1299 RMB. However, the average annual income per capita for two villages, Ruyi and Shuanlun, located in Heqing County and chosen for the study location, was higher than for the average of rural Yunnan, 1310 RMB (160 USD) (Yunnan Provincial Statistics Bureau, 2005) but considerably less affluent in comparison to the overall provincial average (4851 RMB; 592 USD). According to HHB officials, the average annual income in Heqing County was similar to the rural provincial average, approximately 1 300 RMB in 2002.

B. Challenges in Cross Cultural Research

To work effectively with people it is necessary to view the world from their perspective. This is particularly important when dealing with people from cultures different from one's own.

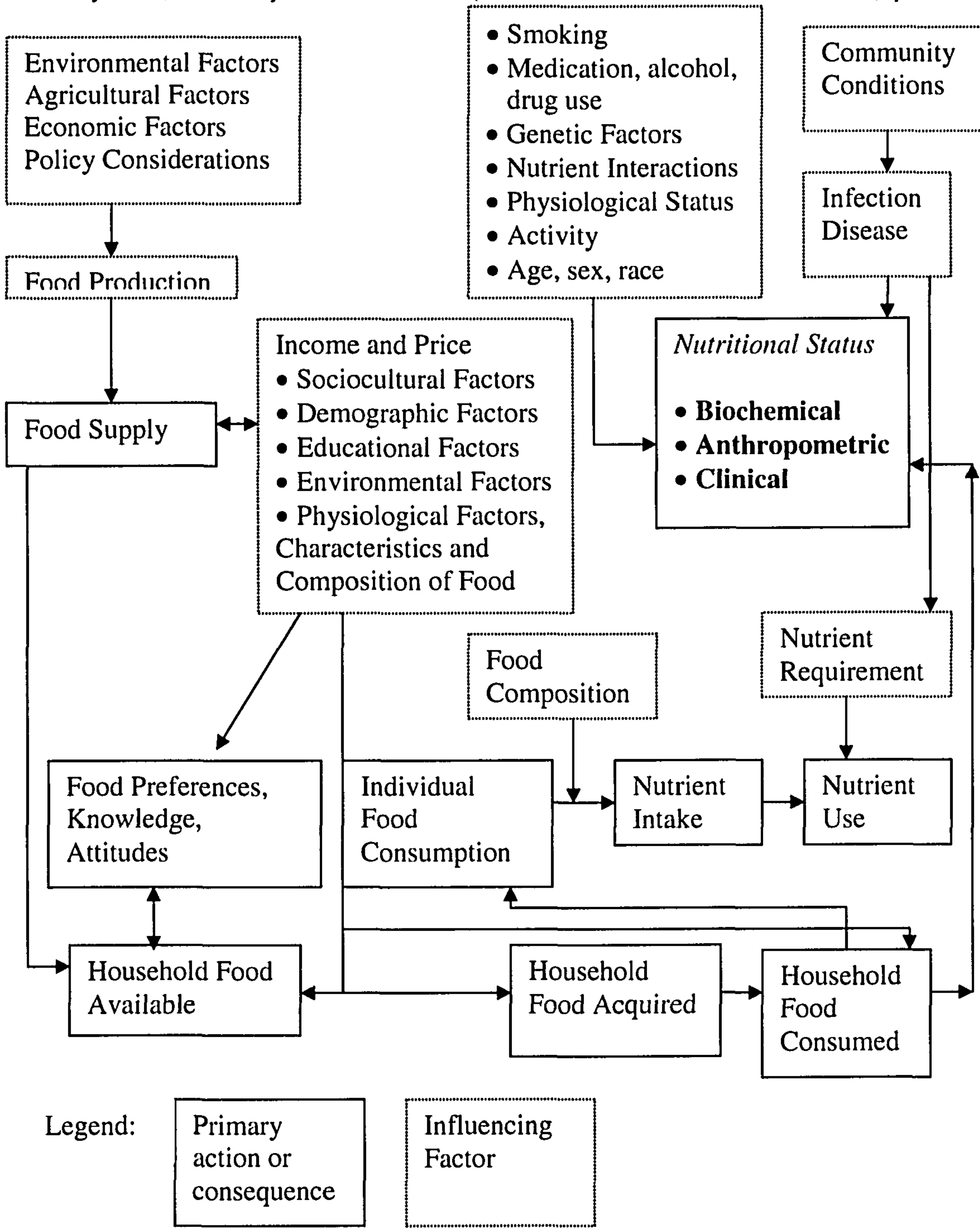
Charles Olweny, 1994

Cross-cultural research encompasses many types of research, but is commonly defined as when a researcher from a developed country undertakes research in a developing country (Olweny, 1994). The research enables researchers to test hypotheses that cannot be tested in one culture but can be tested elsewhere; for instance, the occurrence of essential fatty acid deficiency in malnourished populations is rare in North America. In certain areas of the world, particular diseases are prevalent, and research related to those diseases consequently must take place where the diseases occur. Cross-cultural research can therefore help to advance not only the health of the population, but health science as well.

i. Preparing for a Nutritional Assessment in Cross-Cultural Research

To determine the needs of a community and whether a nutritional investigation is warranted, one must first investigate what is known of the population. The factors that impact nutritional health include lifestyle, diet and environmental influences, are outlined in **Figure II-1**. These factors are interrelated, as depicted by the arrows connecting boxes containing types of factors. Whether the factor is a primary action or consequence (solid line) or an influencing factor (dotted line), it is obvious that all factors eventually impact nutritional status, and it is therefore necessary to consider all contributing factors when assessing community nutritional health. Without this background knowledge, it is ineffectual to enter a community for a nutritional assessment. In a developing country, obtaining such information can be difficult.

Figure II-1. Relationships between Food Acquisition, Diet and Nutritional Status. Adapted from: Boyle MA, *Community Nutrition in Action* (Belmont CA.: Thomson Wadsworth, 2003), p443.



The project was initially to assess the impact of agricultural development on the nutritional status of preschool children in rural Yunnan Province, China. Knowledge of Yunnan was limited to the information below, and as such, generalizations from national data were made in order to prepare for the study. Yunnan is in the southwest corner of China, south of Tibet and north of Vietnam. Yunnan's topography ranges from tropical rainforests to mountainous regions, with varying temperatures and climates. Many of the communities are found in remote areas of the mountains. The province is China's most ethnically diverse, with 25 different minority groups, resulting in a diverse and colourful array of traditions, customs, dialects and diets. The core industries are tobacco, machinery, metallurgy, agricultural products, chemicals and building materials. Agriculture is the base of the provincial economy: major crops are rice, maize, wheat, tuber crops, peas and beans, rape seed, peanuts, tobacco, tea, cotton, sugar-cane, and fruits (Yunnan Provincial Statistics Bureau, 2005).

Yunnan is one of China's undeveloped provinces with more poverty-stricken counties than most other provinces (China Development Gateway, 2004). In 1994, 7 million people lived below the poverty line (less than an annual average income of 300 Yuan) throughout the province's 73 counties. Many communities live in remote mountain villages to which there remains poor road access and scarce fertile land. In China, the national prevalence of stunting in 2000 was 20.0% (moderate) and 5.9% (severe); wasting was 13.8% (moderate) and 1.7% (severe) (WHO, 2002). In Yunnan, the rates were considerably higher in 1992, the most recent data available: 51.5% were -2SD below the 50th percentile for stunting and 28.3% were wasted. Those villages located in remote mountainous regions are likely at highest risk for malnutrition, owing to poor water availability, reduced access to markets and comparatively poor soil quality. There are however, many communities living in fertile valleys that provide excellent growing conditions for broad beans, rice, and canola.

Yunnan has recently adopted a poverty alleviation plan. It includes several large projects aimed at improving infrastructure facilities. They involve soil improvement and water conservation, electric power, roads and "green belt" building. Upon the completion of the projects, the province hopes to address the problems of grain, water, and electric power shortages, and to improve roads and ecological conditions. Foreign and domestic investors are working with local groups to improve farming practices and reduce environmental degradation. A researcher at the University of Alberta, Dr Larry Wang, has coordinated efforts in Heqing County, northern Yunnan to reduce topsoil erosion by planting mulberry trees. A food source for silkworms, the silkworms are then harvested and sold for cash income. Planting the mulberry trees replaces rice and cornfields, yet provides economic income for the farmers—and has proven successful. In 2001, 1000 mu of mulberry trees were planted. By 2003, 30 000-40 000 mu of mulberry trees were planted throughout the county.

China is changing quickly to an industrialized society. As such, China is in a nutritional transition from diets at risk of deficiencies to diets that include higher intakes of animal products high in saturated fats, which are linked to chronic disease in industrialized nations. The project was initiated to provide detailed nutrition information about an unstudied, remote, rural Chinese population. Based on increases in economic income due to the agricultural project, the hypothesis was that improved economic status has resulted in improved dietary intake and nutritional status of children. The objectives of the research project were:

1. To compare two communities (one taking part in agricultural development and one that has not) to assess if an agricultural project has positively changed diets or improved nutritional deficiencies, which can both contribute to chronic disease
2. To identify relationships between dietary nutrients (essential fatty acids, iron, zinc, protein), nutritional status and socio-economic status
3. To identify culturally acceptable foods and provide nutrition education to alleviate potential deficiencies identified in both communities, thereby reducing risk of chronic disease as related to present deficiencies and future intakes.

The Heqing County Health Bureau (HHB) was keen to coordinate the necessary interviewers and lab tests, to inform the participants and register subjects, and to allow access to the villages to conduct the study. HHB officials would coordinate all necessary people and places to make the study successful. In a 2002 survey of child health in the county, the HHB reported a high prevalence of anaemia. They requested an investigation of diet in relation to iron status, as well as overall nutritional status, in the area of the agricultural development. To assess the impact of the development, a control village not involved in mulberry planting was requested for comparison to the agricultural development area. Ruyi, the initial site of mulberry planting, would be the test village and comparisons would be made to Shuanlun, a village near to but not involved in the agricultural development.

Gathering data in a cross cultural research setting can be made more difficult without personnel trained in the areas of nutritional status assessment (Olweny, 1994; Campbell et al 1994). Interviewers should be familiar with local food habits and customs to ensure community comfort and acceptance (Campbell et al 1994). Locally trained assistants are more likely to be aware of, sensitive to and able to give insight regarding customs and relationships; they can communicate fluently with the population and they are less socially distant than the foreign researchers (Olweny, 1994). These positive attributes will slightly lessen the impact of foreign presence in the area, and make data gathering less invasive for the participant. It was therefore confirmed that only health care workers familiar with the subjects would be involved in the measurements and data collection to reduce feelings of intrusion by foreigners. It was also confirmed that the HHB would provide a translator.

After collaboration between the HHB and University of Alberta researchers was confirmed, questionnaires were created to investigate the socioeconomic status of the families, and anthropometric measurements chosen to illustrate the nutritive health of the children. Research is often done in a different language and with people for whom the research methods are unfamiliar to their way of life (Brislin, 1976). This group of Chinese people had never before been studied and available instruments with which to measure socio-economic status were inadequate. In designing instruments, researchers can take advantage of common experiences shared by people of that culture (Brislin, 1976), yet instruments have limited usefulness in another culture where people do not attach the same value to concepts used in instrument design. Questionnaires were therefore especially difficult to create; no officials from the region were available, linguistically or physically, to provide insight into living standards and agricultural practices, and templates from international agencies could not be guaranteed to be appropriate for the community that would be investigated. Information about this area of China had never been published in a foreign publication. Thus, an entirely new questionnaire with many open-ended questions loosely based on the MICAH Guide from

World Vision Canada was developed and could not be verified for utility until return to China.

A detailed handbook was written to describe how to interview participants and how to measure children. In a process known as back translation, the documents were translated from English into Mandarin by Chinese students at the University of Alberta, and then translated back to English to assess accuracy and ensure the translation into Mandarin was functionally and conceptually equivalent (Olweny, 1994; Brislin, 1976). The handbooks proved indispensable; the previously identified translator was often unavailable during the course of the study. Thus, the handbooks were used to a great extent, and direct communication between the researcher and the interviewers was a halting and laborious process.

In preliminary meetings, HHB officials had positively confirmed the requirements for the study. In particular, buccal mucosa samples were needed to determine the ratios of essential fatty acids in cell membranes. It was agreed that the samples could be taken out of China for fatty acid analysis with written consent from the county magistrate. Blood would also be drawn to obtain a complete blood cell count. However a new county magistrate did not agree with the consent and approval provided by the previous magistrate, and questioned the legality of our study under Chinese law. A law written in 1998 details the country's stance on foreign research using genetic materials. Blood and cheek cells contain genetic materials, thus the new deputy wanted to obtain federal and provincial consent for the study before it could begin. The cheek cells were allowed to be collected, but could not be taken from the county until approval was received from Beijing officials. This approval, if given, was projected to take at least six months. To overcome disallowing blood to be taken, hospital technicians and all their lab equipment were taken to the site and blood samples were analyzed there, on the same day.

Prior to study commencement, HHB officials recruited the participants. All villagers were informed of the nutritional study, and volunteers were asked to come forward. Once the necessary number of volunteers had confirmed their involvement, the recruitment ceased. Research coordinators were not involved in village or participant recruitment. Unfortunately, the chosen villages were near to each other and both villages had taken part in the agricultural development. There was also a great income difference between the two villages, due to people living in Shuanlun who were recently employed in nearby construction work. Affluent villages in the fertile valley had been chosen for the study, hindering investigation of the representative nutritional status of preschool children in the area.

ii. Impact of the study methodology

Observations revealed that the disparity between incomes in valley villages and mountain villages is extremely high, with valley communities' incomes ranging from 1000-30 000 RMB and mountain villages' incomes below the county average of 1300RMB. Neither Shuanlun nor Ruyi are representative villages of the region in terms of income. Ruyi was chosen because it was the first village to participate in the agricultural project, and according to previous records, the average income was near the county average of 1300RMB. Despite expectations that the control village should reflect this, an HHB official made the comment: 'the villages closer to the mountains are too poor and more importantly, too difficult to collect data.' In a report of the impact that agricultural development is imposing in other areas of Heqing County, results of fieldwork indicate that a disproportionate amount of land targeted for conservation was allocated to households located near main roads (Junchen, 2001). In his report, Junchen offers culturally significant insight into why affluent valley villages with good access to roads may have been chosen: the desire to impress visiting officials, greater ease of dissemination and technical support, implementing programs in remote areas is difficult due to unfavourable conditions, and sites near the main roads are easily visible during inspection visits by officials from higher levels of government. Bias given toward richer households in conversion is also evidenced by fieldwork data. Data in his report reveals that households with higher incomes converted more land than did households of lower income status. Junchen recommends addressing this bias by taking officials from Beijing who arrive in Yunnan to observe conversion work to see villages where transport is inconvenient and environmental degradation is severe. Officials should see the real situation of Yunnan to obtain realistic evidence of Yunnan's need for conversion.

Although Junchen's report pertains to the environmental conservation project that encompasses the agricultural project that had been initially proposed to investigate, this explanation clarifies some of the actions of the HHB officials. The officials had to act within the confines of the law and within their understanding of the research. I was a guest in their country, and it was their decision to determine where researchers would be allowed to work. HHB officials did not want to reveal an impoverished China, nor endanger the researcher during the process of the study. It is therefore possible that the sample studied reflects a higher socio-economic status than the county average. The children involved in the study were not likely to be representative of the nutritional situation in the reportedly impoverished, difficult-to-access areas of Heqing County.

Once the study concluded, the issue of gaining access to and transporting the tissue samples to Canada remained. Caution by the HHB officials had increased, and they felt that allowing the cells out of the county was too risky and could not be done. They also contemplated not allowing the questionnaires out of the country, reasoning that if the cells were not allowed, then the questionnaires, which were collected in conjunction with the cells, should not be allowed to leave the country. After several hours of deliberation, the HHB officials allowed the questionnaires but not the samples to be transported to Canada.

It is advisable not to make a judgement call [without] careful analysis of the issue in question...What you see is not necessarily what is happening.

Olweny 1994

Cautious action by officials, investigation of a delicate topic, and a wide chasm between cultural practices regarding the probing nature of research provides a difficult forum for study. Considering the language and cultural barriers however, it is remarkable that the study was able to proceed in the capacity that it did. The success of the project is due to the willingness of the officials, despite their caution, to perform the majority of the tasks necessary to provide a picture of child health in the region. Due to limitations of data obtained, study objectives have shifted to that of a descriptive cross-sectional analysis of the dietary intakes and nutritional status of preschool children in rural China.

C. Study Methods

Ethics approval was received from the Human Research Ethics board of the Faculty of Agriculture, Food and Home Economics, University of Alberta.

i. Subject Recruitment

Shuanlun and Ruyi are two valley villages located in Heqing County of mid-northern Yunnan, chosen for the nutritional survey by the Heqing County Health Bureau (HHB). Each village has a health clinic and is accessible by road. Villagers were informed of the study in three public forums, hosted by HHB officials and the researchers. On the basis of these forums, parents made the decision whether to consent to have their children included in the study. The focus of the study was preschool children between 1 and 5 years old. Families were accepted into the study during February 2004 with the goal of obtaining 200 children for study, based on the number of health care workers available to be hired, and given that the study was to be completed before spring harvest. Data were collected during March and April 2004.

ii. Interviewer training

Health care workers in the villages took part in a one-day training workshop, which explained data collection methods: interview techniques, a socio-economic status questionnaire, 24-hour dietary recall procedures and anthropometric measurements. The local interviewers also received a handbook of detailed instructions pertaining to study procedures, adapted from the MICAH Guide (MacDonald et al, 2002), Gibson and Ferguson's 24-hour recall procedure (1999) and Cogill's Anthropometric Indicators Measurement Guide (2003). The handbook was translated into Mandarin and then back translated to English to ascertain accuracy and meaning consistency.

iii. Dietary data

Interviewers were given a package of questionnaires and 24-hr recall forms, with measuring tools to aid in estimating portion sizes. The mother completed three 24-hr recalls on non-consecutive days and provided information regarding breast-feeding and weaning practices: type of breast feeding during the first four months of life, duration of breast milk provision beyond four months, and age at introduction of solid food. Breastfeeding was defined as breast milk or expressed breast milk from the mother or a wet nurse (WHO, 1996). Exclusively breastfed children received no solids or other liquids with the exception of drops or syrups consisting of vitamins. Predominantly breastfed children received no solids but did receive water and water-based drinks such as juice. Complementary breastfed children had received formula and/or solid or semi-solid food. Bottle-feeding was defined as no breast milk from any source at any time. Duration of breastfeeding was defined as when the child no longer received any amount of breast milk from any source.

Food variety and preparation methods in the region were limited, thus simplifying description. Interviewers measured common portion sizes three times to obtain the mean weight of food types as they were typically served to children. The child's guardian estimated portion sizes with the interviewer using bowls and utensils the child used. The interviewer then calculated the weight of the food that the child ate by multiplying the number of serving portions by the mean weight for that portion size. Recipes and serving sizes were also requested from the guardian when combination foods were eaten. The child's consumption was estimated from combination foods by determining the proportion the child ate from the total amount of the dish (Popkin et al 2002). Food

Processor SQL Edition Version 9.1.2 (ESHA Research, Salem OR) was used to analyze recipes and dietary intakes, supplemented by the 2002 Chinese Food Composition Table (Peking University Medical Press).

HHB officials and the researchers visited the interviewers each morning during the data collection period to review the previous day's responses. Families were revisited in the cases of unclear or incomplete data. For purpose of comparison, dietary intakes were compared to Chinese Recommended Nutrient Intakes (RNIs). To simplify comparisons between dietary intake and recommended intakes, children were grouped into ages 1-3 years and 4-5 years based on similar age categories for the Chinese RNIs.

iv. Markers of socio-economic status and food expenditure

The primary caregiver estimated gross annual income in 2003. Per capita income was determined by dividing annual income by the number of household occupants, including children. Food expenditure per capita was estimated by the respondent as a percentage of annual income spent on food, which was then divided by number of occupants in the household.

v. Anthropometric data

Anthropometric measurements were performed as specified by Cogill (2003). Height was measured with a portable stadiometer (Quick Medical) to the nearest 0.1 cm for children $\geq$ 24 months, and length was measured for children 12-23 months with a portable mat (Quick Medical) to the nearest 0.1 cm. Wearing light underclothing, the child was weighed to the nearest 0.1 kg on a Secca digital scale (Quick Medical). If the child could not stand, the caregiver was individually weighed then weighed again holding the child; the caregiver's weight was subtracted from the total to obtain the child's weight. Mid-upper arm circumference (MUAC) was taken on the left arm while the arm was relaxed. MUAC was measured at the midpoint between acromion process and the tip of the olecranon with flexible steel tape and recorded to the nearest 0.1 cm.

Anthropometric measures were reported as z-scores below or above the mean of international reference values. The reference population growth charts are derived from the National Centre for Health Statistics (NCHS)/ WHO Reference Data, recommended for use by the WHO. Children with z-scores greater than two and three SD below the mean are considered moderately and severely malnourished respectively. The indices used to identify the pathology of malnourishment are described in **Table I-1** (WHO, 1995). Mid-upper-arm-circumference is an additional screening tool that can be used in community-based studies of nutrition status that may be a superior predictor of childhood mortality than height- and weight-based indices (WHO, 1995).

vi. Anaemia

Children's haemoglobin values were measured using 20μL blood obtained by finger-prick. Blood was immediately analyzed using an AC900 haemoglobin auto counter (SWELAB) transported from the county hospital and calibrated on-site. Adjusted for elevation, where Heqing County's is 2200m, the haemoglobin cut-off is 117g/L for 1-5 year old children (WHO 2001; Nestel 2002).

vii. Statistical Analyses

Z-scores were calculated using the US Centers for Disease Control (CDC) anthropometric software package, Epi-Info Version 6.0. Anthropometric measurements, z-scores and results of dietary analysis were analyzed using SPSS for Windows, Version 12.0. Statistical tests included the ANOVA with Bonferroni correction and t-test for interval level data, and chi square tests for categorical data. Significant differences were considered $p<0.05$.

D. Characteristics of Subjects

i. Demographics

Dietary data were obtained for 199 children and anthropometric data were available for 196 children, representing 39.0 percent of the total preschool-aged population in the two villages. The proportion of girls and boys in the total population of preschool-aged children was 46.4 percent and 53.5 percent, respectively. The sample represented 35.2 percent of girls and 42.3 percent of boys. There was a small gender imbalance in the population, and this was represented by the proportion of boys to girls in the sample. Age and gender group sizes of the sample are detailed (**Table II-1**). The data is presented for 196 children with complete anthropometric and dietary data.

Table II-1 Total subjects by gender and age*

Age	Males	Females (Percent of total)	Age group total
1	24	16 (40)	40
2	23	17 (43)	40
3	30	16 (35)	46
4	17	17 (50)	34
5	20	16 (44)	36
Total	114	82 (42)	196

*Not significantly different proportion of males to females ($p>0.05$)

ii. Socio-economic status

The majority of households were of the Bai ethnic group (77 percent), and the remainder were of China's majority ethnicity, Han. Households were mainly composed of mother and father, the child or children, and one or two grandparents. The majority of households (69 percent) had one child and 31 percent had two children. Most mothers (91 percent) were involved in domestic work (handicrafts, house maintenance, selling goods) as their primary occupation and 6.5 percent identified agricultural work (farming, animal husbandry) as their occupation. A small majority of women (53.5 percent) had a primary school education, while 37.9 percent completed junior or senior high school, and 7.1 percent had no education. The majority of men in the households (64.3 percent) identified agricultural work while the remaining men (35.7 percent) listed labour (hourly wages) as their primary occupation. Most men obtained junior or secondary educations (55.7 percent) while 40.7 percent completed primary school and 1.0 percent had no education.

Mean annual income per capita was 2042 RMB (250 USD) (SD ±1299 RMB; range 167-7500 RMB). Gross income, income per capita and proportion of gross income spent on food were grouped for analysis into three relative income categories (low, medium and high) based on 25^{th} and 75^{th} percentiles. There were no significant differences between the three income categories for children's dietary intake, weight, height, MUAC, haemoglobin or z-score for any anthropometric index. There were no significant correlations between income (absolute or income per capita) and diet (micronutrients, macronutrients or energy) or income and anthropometrics (height, weight, MUAC or z-scores). There was a strong correlation between proportion of income spent on food and income per capita ($r = 0.734$, $p<0.001$).

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III. Dietary intakes and nutritional status of preschool-aged children in rural China

A. Results

Anthropometric data The prevalence of stunting, wasting, underweight and low muscle/fat by age groups 1-3 years and 4-5 years are presented (**Table III-1**). The majority of children who were wasted, underweight or stunted were aged 1-3 years, though the difference in prevalence between age groups did not reach significance. Of the children who were underweight, 80.5 percent were stunted. Conversely, 44.6 percent of the children who were stunted were also underweight. Younger children also had lower mean z-scores for WHZ, WAZ and HAZ, though only WAZ was significantly different between age groups (p=0.043). Gender differences at each year are also presented (**Table III-2**). The age of underweight vs. non-underweight children was not different (32.3 ± 13.6 vs. 31.6 ± 11.3 months, p=0.755) within the 1-3 year old group. Stunted children (37 ± 12.3 months) were significantly older than non-stunted children (28.4 ± 10.4 months) (p<0.001) in the 1-3 year old age group. Boys had higher anthropometric measures and z-scores than girls at age one (MAZ, weight, height and MUAC), at three years (WHZ and WAZ) and overall (MUAC and MAZ) (p<0.05).

Anaemia There were no nutrients correlated with haemoglobin concentration. The average haemoglobin values for 1-5 year old children was 111.2 ± 9.5 g/L; one third of children (34.5 percent) had haemoglobin values less than 110 g/L whereas 73.3% had values less than 117 g/L. One-year old children had the lowest haemoglobin values (107.6 ± 11.4 g/L), and anaemia was most prevalent in this group, 51.3% at 110g/L and 79.5% at 117 g/L (**Table III-3**). Girls had significantly higher haemoglobin values than boys at three years of age (109.3 ± 8.4 vs 115.3 ± 7.3 g/L, p=0.02) whereas boys had significantly higher haemoglobin values than girls at five years of age (115.4 ± 7.6 vs. 110.1 ± 10.9 g/L, p=0.029).

Breastfeeding and weaning All children had been breastfed until the age of four months; 85.2 percent were exclusively breastfed, 7.7 percent predominantly, and 7.1 percent complementarily. The average age at conclusion of breastfeeding was 12 ± 2.9 months. Introduction of solids began at greater than 6 months of age for 62.2 percent of the children, between 4 and 6 months for 31.6 percent of children, and prior to four months for 7.2 percent. The predominant weaning food was rice congee; a thin rice paste prepared with unfortified rice and boiled water.

Macronutrient composition of diet Children 1-3 yrs old ate significantly less total calories (660 ± 258 vs. 817 ± 223 kcal/d), total carbohydrate (109 ± 42 vs. 140 ± 41 g/d) and total protein (18 ± 8 vs. 20 ± 6 g/d) than 4-5 year old children (**Table III-4**). Protein as percent of total energy did not significantly differ by age group, however carbohydrate as percent of total energy was less in the younger group (65 ± 8 vs. 69 ± 8 percent) (p=0.002). Younger children ate significantly more percent of total energy as fat than did older children (24 ± 7 vs. 21 ± 7 percent) (p=0.003), however there was no significant difference between the age groups in total fat intake (18 ± 10 vs. 19 ± 9 g/d) (p=0.384).

Gender differences in dietary intake Dietary intakes of macro- and micronutrients are presented according to age group and by gender (**Table III-5**). The mean intake of macro- and micronutrients was less than the Chinese RNI for all nutrients. Girls had lower intakes of almost all nutrients than did boys in both age groups. This difference reached significance only in the 1-3 year old age group for energy, protein, carbohydrates, thiamine, iron and zinc ($p<0.05$). To assess the accuracy of dietary intakes, correlations between diet and current height and weight were tested. Confirming expectation that energy, protein and fat intakes increase with age, as do anthropometrics, height and weight were significantly correlated with calorie ($r=0.43$, $p<0.001$) and protein intakes ($r=0.33$, $p<0.001$), and weakly correlated with fat intakes ($r=0.15$, $p<0.06$).

Categories of anthropometric indices were also compared to dietary intake. Comparing dietary intakes by children above and below –2SD, significant differences ($p<0.05$) were found within the WAZ and HAZ indices. Underweight children consumed significantly more energy (63.5 vs. 52.3 kcal/kg, $p<0.001$), protein (1.7 vs. 1.4 g/kg, $p<0.001$), carbohydrate (10.0 vs. 8.7 g/kg, $p=0.024$), and fat (1.9 vs. 1.3 g/kg, $p=0.007$) than children who were not underweight. Stunted children consumed significantly more energy (59.1 vs. 52.0 kcal/kg, $p=0.012$), protein (1.5 vs. 1.3 g/kg, $p=0.020$), carbohydrate (9.5 vs. 8.6 g/kg, $p=0.038$) and fat (1.6 vs. 1.3 g/kg, $p=0.026$) than children who were not stunted.

Fatty acid intake Mean intakes of fatty acids in mg/d, mg/kg body weight/d and as percent of total energy intake are presented (**Table III-6**). Of children aged 1-5 years, 89.8% had intakes of n-3 fatty acids less than the AI of 0.7g/d for 1-3 year old children, and 99.0% had intakes of n-6 fatty acids less than the AI of 7g/d for 1-3 year olds. In absolute numbers, three 4-5 year old children exceeded the AI of 0.9g/d for n-3 fatty acids, while eleven 1-3 year old children exceeded the AI of 0.7g/d for n-3 fatty acids. Two children aged 1-3 years exceeded the AI of 7g/d for n-6 fatty acids, and no children aged 4-5 years exceeded the 10g/d AI for n-6 fatty acids.

Fatty acid intakes and anthropometric indices Total n-6 fatty acid intake was significantly greater in the stunted (191±119 mg/kg/d) and underweight (208± 140 mg/kg/d) groups than in the non-stunted (160±88 mg/kg/d) (p=0.034) and non-underweight groups (162± 87 mg/kg/d) (p=0.010) (**Table III-7**). AA intake was significantly greater in the underweight (6±5 mg/kg/d) than in the non-underweight group (4± 3 mg/kg/d) (p=0.020). Energy (kcal/kg/d), protein, carbohydrates and fat intakes (g/kg/d) were significantly greater in the stunted and underweight groups (p<0.05). DHA intakes were not significantly different between underweight and non-underweight groups (4±23 vs. 2±11 mg/kg/d, p=0.376) and stunted and non-stunted groups (4±18 vs. 2±11 mg/kg/d, p=0.471).

When controlling for age, correlations between macronutrients excluding carbohydrate become non-significant. Total carbohydrate was significantly correlated with weight and MUAC (p<0.02) when age was controlled. LNA was significantly correlated with MUAC and MAZ (p=0.031) while AA was negatively correlated with MUAC and MAZ (p<0.02) after controlling for age.

B. Tables of Results

Table III-1 Prevalence of malnutrition as measured by anthropometric indices less than -2SD below the median of the National Centre for Health Statistics/World Health Organization reference population growth curve.

Age group		WHZ Wasting	WAZ Underweight	HAZ Stunting	MAZ ↓Muscle/Fat
1-3 yrs	Mean ± SD	-0.34 ± 0.83	-1.3 ± 1.0	-1.7 ± 1.3	-0.94 ± 0.65
	Percent of children below −2SD (%, no.)	75.0, n=3	80.5, n=33	40.5, n=51	46.2, n=6
	Percent of children below-2SD by gender (%, no.)	M: 66.7, n=2 F: 33.3, n=1	M: 48.5, n=16 F: 51.5, n=17	M: 54.9, n=28 F: 45.1, n=23	M: 16.7, n=1 F: 83.3, n=5†
4-5 yrs	Mean ± SD	-0.14 ± 0.75	-1.0 ± 0.9*	-1.5 ± 1.0	-1.2 ± 0.76
	Percent of children below −2SD (%, no.)	25.0, n=1	19.5, n=8	32.9, n=23	53.8, n=7
	Percent of children below-2SD by gender (%, no.)	M: 100.0, n=1 F: 0.0, n=0	M: 37.5, n=3 F: 62.5, n=5	M: 65.2, n=15 F: 34.8, n=8	M: 42.9, n=3 F: 57.1, n=4
1-5 yrs	Mean ± SD	-0.27 ± 0.81	-1.21 ± 0.98	-1.65 ± 1.21	-0.99 ± 0.68
	Percent below −2SD of all children (%, no.)	2.0, n = 4	20.9, n = 41‡	37.8, n = 74	8.3, n = 13‡
	Percent below -2SD of total children within gender (%, no.)	M: 2.6, n = 3 F: 1.2, n = 1	M: 16.7, n = 19 F: 26.8, n = 22	M: 37.7, n=43 F: 37.8, n=31	M: 4.3, n = 4 F: 14.1, n=9†

HAZ, height-for-age z-score; WAZ, weight-for-age z-score; WHZ, weight-for-height z-score; MAZ, mid-upper-arm circumference for age z-score
*Mean z-score significantly different between age groups ($p<0.05$)
†Prevalence of malnutrition significantly different between genders ($p<0.05$)
‡Prevalence of malnutrition significantly different between age groups ($p<0.05$).

Table III-2 Anthropometric indices: Comparison between genders within each age group and across all children (μ ± SD). Boys, n=114; girls, n=82 (proportion not significantly different across age groups).

	Weight (kg)		Height (cm)		MUAC (cm)		WHZ		WAZ		HAZ		MAZ	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	10.3± 1.5*	9.2± 0.8	79.7± 5.1*	76.6± 3.2	15.2± 0.9*	14.3± 0.8	-0.7± 0.8	-0.8± 0.7	-1.4± 0.8	-1.5± 1.0	-1.5± 1.1	-1.7± 1.6	-0.6± 0.6*	-1.1± 0.7
2	11.7± 1.6	10.8± 1.3	83.5± 4.9	82.2± 4.0	15.3± 0.9	14.6± 0.9	-0.2± 0.8	-0.4± 0.8	-1.3± 0.9	-1.5± 1.0	-2.0± 1.2	-1.8± 0.9	-0.8± 0.6*	-1.1± 0.7
3	14.2± 1.6*	12.5± 1.8	92.6± 4.4	90.6± 4.9	15.4± 0.8	14.9± 0.8	0.2± 0.6*	-0.6± 0.9	-0.8± 1.1*	-1.8± 1.0	-1.5± 1.6	-2.3± 1.1	-1.0± 0.6	-1.2± 0.6
4	15.2± 1.5	15.6± 1.8	98.8± 3.9	100.1± 4.8	15.3± 1.1	15.4± 1.3	-0.2± 0.7	0.1± 0.7	-1.2± 0.6	-0.7± 0.9	-1.6± 0.7	-1.2± 0.9	-1.2± 0.7	-1.1± 0.8
5	17.3± 1.9	16.9± 3.3	106.4± 4.0	105.7± 7.9	15.7± 1.0	15.3± 1.2	-0.2± 0.9	-0.2± 0.8	-1.2± 0.8	-1.0± 1.3	-1.6± 0.8	-1.4± 1.5	-	-
1-5	13.6± 1.9	13.0± 3.5	91.4± 10.5	91.0± 11.9	15.4± 0.9*	14.9± 1.1	-0.2± 0.8	-0.4± 0.8	-1.2± 0.9	-1.3± 1.1	-1.6± 1.2	-1.7± 1.3	-0.9± 0.7*	-1.1± 0.7

HAZ, height-for-age z-score; WAZ, weight-for-age z-score; WHZ, weight-for-height z-score; MUAC, mid-upper-arm circumference; MAZ, mid-upper-arm circumference-for-age z-score
*Significantly different between genders ($p<0.05$)

Table III-3 Haemoglobin values by age group in comparison to cut-offs for identification of anaemia at sea level and adjusted for elevation

Age (years)	Mean ± SD	Range	Percent below 110g/L	Percent below cut-off* adjusted for elevation (2200m)
1	107.6 ± 11.4	69 – 129	51.3	79.5
2	113.0 ± 10.2	85 – 141	40.0	70.0
3	111.4 ± 8.4	85 – 126	30.4	76.1
4	111.2 ± 8.9	94 – 130	32.4	76.5
5	113.0 ± 7.4	99 – 127	36.1	69.4
1-5	111.2 ± 9.5	69-141	35.4	73.3

*117g/L (WHO 2001; Nestel 2002; CDC 1989)

Table III-4 Comparison of macronutrient intakes between age groups depicted as total intakes (g/d) and as percent of total energy intake.

	Total Calories (Kcal/d)	Carbohydrate (g/d)	Carbohydrate (Percent of energy)	Protein (g/d)	Protein (Percent of energy)	Fat (g/d)	Fat (Percent of energy)
1-3 yrs n=126	660 ± 258	109 ± 42	65 ± 8	18 ± 8	11 ± 3	18 ± 10	24 ± 7
4-5 yrs n=70	817 ± 223*	140 ± 41*	69 ± 8*	20 ± 6*	10 ± 2	19 ± 9	21 ± 7*
p	0.000	0.000	0.002	0.008	0.075	0.384	0.003

*P<0.01

Table III-5 Dietary intake comparison between genders within age groups (μ ± SD). Data in brackets are the mean as percent of Chinese RNIs.

		1-3 yrs n=77 boys, 49 girls	Percent of RNI	4-5 yrs n= 37 boys, 33 girls	Percent of RNI
Macronutrients					
Energy (kcal)	Male	712 ± 286	61	849 ± 215	57
	Female	580 ± 180*	49	782 ± 230	52
	Total	660 ± 258	56	817± 23‡	54
Protein (g/d)	Male	19 ± 8	48	22 ± 6	42
	Female	16 ± 6*	40	19 ± 6	37
	Total	18 ± 8	44	20 ± 6‡	38
Carbohydrates (g/d)	Male	115 ± 46	-	147 ± 39	-
	Female	94 ± 31*	-	133 ± 42	-
	Total	107± 42	-	140± 41‡	-
Fat-Total (g/d)	Male	20 ± 11	-	20 ± 9	-
	Female	16 ± 7*	-	20 ± 9	-
	Total	18 ± 10	-	19 ± 9	-
Percent of total energy					
Fat	Male	24 ± 7	-	20 ± 6	62
	Female	24 ± 8	-	22 ±7	69
	Total	24 ± 7	75	21 ± 7‡	66
Micronutrients					
Vitamin A (RE) †	Male	304 ± 458	61	358 ± 410	60
	Female	297 ± 444	59	228 ± 186	38
	Total	301 ± 451	60	296 ± 329	49
Thiamin (mg)	Male	0.3 ± 0.1	50	0.3 ± 0.1	43
	Female	0.2 ± 0.1*	33	0.3 ± 0.1	43
	Total	0.2 ± 0.1	35	0.3 ± 0.1	43
Riboflavin (mg)	Male	0.3 ± 0.2	50	0.3 ± 0.1	43
	Female	0.3 ± 0.1	50	0.3 ± 0.1	43
	Total	0.3 ± 0.2	50	0.3 ± 0.1	43
Vitamin C (mg)	Male	31 ± 18	52	40 ± 30	57
	Female	30 ± 21	50	33 ± 16	47
	Total	31 ± 19	52	37 ± 25	53
Calcium (mg)	Male	144 ± 126	24	123 ± 69	15
	Female	118 ± 81	20	114 ± 58	14
	Total	134 ± 111	22	119 ± 63	15
Iron (mg)	Male	3.2 ± 1.8	27	3.9 ± 2.2	32
	Female	2.3 ± 1.3*	19	3.5 ± 1.3	29
	Total	2.8 ± 1.7	23	3.7 ± 1.9‡	31
Zinc (mg)	Male	2.1 ± 0.8	23	2.4 ± 0.6	20
	Female	1.8 ± 0.6*	20	2.2 ± 0.7	18
	Total	1.9 ± 0.7	21	2.3 ± 0.6‡	19

*Significantly different between gender, $p<0.05$ ‡Significantly different between age groups, $p<0.05$ † Log10 computed, significance remained. Mean presented, though not normally distributed

Table III-6 Intake of individual fatty acids obtained by three 24-hr dietary recalls for 1-3 year old (n=126), 4-5 year old (n=70) and total (n=196) children.

Fatty Acid		mg/d*	mg/kg/d	P**	Percent of total energy	P**
Total n-3[1]	1-3 years	346 ± 343 AI[2]=700	30 ± 23	NS	0.5 ± 0.4	NS
	4-5 years	376 ± 319 AI[2]=900	23 ± 21		0.4 ± 0.3	
	Total	351 ± 335	27 ± 31		0.5 ± 0.4	
Total n-6	1-3 years	2 142 ± 1 238 AI[2]=7 000	186 ± 110	0.006	23.0 ± 1.3	0.015
	4-5 years	2 323 ± 1 242 AI[2]=10 000	145 ± 79		2.5 ± 1.1	
	Total	2207 ± 1239	172 ± 102		2.8 ± 1.2	
LA	1-3 years	2 082 ± 1 169	18 ± 100	0.005	2.9 ± 1.2	0.019
	4-5 years	2 272 ± 1 221	142 ± 78		2.5 ± 1.1	
	Total	2105 ± 1189	167 ± 95		2.7 ± 1.1	
LNA[1]	1-3 years	278 ± 229	24 ± 19	NS	0.4 ± 0.3	NS
	4-5 years	335 ± 232	21 ± 16		0.4 ± 0.3	
	Total	299 ± 239	23 ± 18		0.4 ± 0.3	
AA	1-3 years	55 ± 42	5 ± 4	0.001	0.08 ± 0.06	0.004
	4-5 years	50 ± 31	3 ± 2		0.06 ± 0.04	
	Total	54 ± 38	4.3 ± 3.6		0.07 ± 0.05	
DHA[1]	1-3 years	34 ± 148	3 ± 2	NS	0.05 ± 0.2	NS
	4-5 years	23 ± 87	2 ± 6		0.02 ± 0.07	
	Total	30 ± 129	2.7 ± 14.2		0.04 ± 0.2	

AA, arachidonic acid; AI, Adequate Intake; DHA, docosahexaenoic acid; LNA, α-linolenic acid; LA, linoleic acid

*Intakes (mg/d) are not significantly different between age groups.

**P-values represent differences in intakes between age groups, student's t-test.

[1]Not normally distributed; log10 computed, significance remained therefore mean presented as non-log10 value.

[2]FNB/IOM 2002

Table III-7 Difference in dietary intakes (μ ± SD) of macronutrients and individual fatty acids compared between anthropometric indices greater or less than -2SD[1]

	Underweight	Not underweight	P	Stunted	Not stunted	P
Female (%)	53.7	38.7	0.102	41.9	41.8	1.000
Age (mo)	38.2 ± 17.3	43.2 ± 17.5	0.102	43.7 ± 15.2	41.2 ± 18.9	0.333
Macronutrients						
Energy, kcal/kg/d	63.5 ± 20.4	52.3 ± 17.1	0.000	59.1 ± 20.3	52.0 ± 16.5	0.012
Protein, g/kg/d	1.7 ± 0.6	1.4 ± 0.5	0.000	1.5 ± 0.6	1.4 ± 0.5	0.020
Carbohydrate, g/kg/d	10.0 ± 2.8	8.7 ± 2.9	0.014	9.5 ± 3.0	8.7 ± 2.8	0.038
Fat, g/kg/d	1.9 ± 1.2	1.3 ± 0.7	0.007	1.6 ± 1.0	1.3 ± 0.7	0.026
Fatty acids, mg/kg/d						
LA	192 ± 113	160 ± 88	NS	181 ± 102	158 ± 89	NS
LNA[2]	23 ± 16	23 ± 18	NS	23 ± 19	23 ± 17	NS
AA[2]	6 ± 5	4 ± 3	0.020	5 ± 4	4 ± 3	NS
DHA[2]	4 ± 23	2 ± 11	NS	4 ± 18	2 ± 11	NS
n-6	208 ± 140	162 ± 87	0.010	191 ± 119	160 ± 88	0.034
n-3[2]	31 ± 43	26 ± 27	NS	30 ± 38	26 ± 26	NS

AA, arachidonic acid; DHA, docosahexaenoic acid; LNA, □-linolenic acid; LA, linoleic acid

[1]National Centre for Health Statistics/World Health Organization international growth reference charts; where scores below -2SD indicate poor nutritional status

[2]Not normally distributed; log10 computed, mean presented as non-log10 value

C. Discussion

Nutritional status This study describes differences in dietary intake and in growth between preschool-aged boys and girls in a predominantly ethnic minority rural southwestern Chinese population. The overall prevalence of stunting and underweight were high: 37.8% and 20.9%, respectively. Although both genders had poor growth, girls predominantly had lower anthropometric scores and lower dietary intakes than did boys. Girls had significantly lower MAZ scores and tended to have lower WAZ scores than boys. Boys consumed significantly more energy, protein, fat, iron and zinc than did girls. Preschool aged children in rural southwestern China may not have adequate intakes of macronutrients, several vitamins and minerals and essential fatty acids.

Overall, dietary intakes in China have been reported to be low in several studies (Ge and Chang, 2001; Chen 1996; Chen et al, 1992). Some, but not all, studies in China report gender and urban/rural differences in dietary intake and anthropometric indices in children. A survey of rural Chinese found male or female children less than 6 years of age to have similar dietary intakes and anthropometric indices (Ying et al, 1994). However, the 1992 national survey reveals a smaller percentage of girls than boys had intakes of calcium or vitamin A greater than 50 percent of the RDA (Ge and Chang, 2001). A larger percentage of girls also had intakes below 50 percent of the RDA for zinc and selenium. Leung et al (2000) reported that macronutrient intakes by boys aged 0-7 years in Hong Kong were significantly greater than by girls at 6, 36, 60 and 84 months. Correspondingly, boys grew significantly more than girls until two years of age, after which the difference remained, though insignificant (Leung et al, 2000). In contrast, girls in four prefectures of Gansu province were taller and heavier than boys ($p>0.05$) among preschool aged children (Hu et al, 2001). In Yunnan, boys were more likely to be underweight and stunted than girls ($p<0.01$) yet a higher percentage of girls were severely wasted ($p > 0.05$) (Yan et al, 1999). In the current study, girls had lesser growth and significantly inferior dietary intakes as compared with boys, especially between 1 and 3 years of age. Although inconsistent, there is evidence to suggest that girls fare nutritionally worse than boys in several areas of China.

Income is a determinant of food intake and food intake is a major factor in determining nutritional status (Mason, 2002). Accordingly, there are many studies linking income changes with nutritional status indicators, but malnutrition is both a cause and a result of poverty (Gillespie, 1997). Despite strong evidence that per capita income is often related to child growth or diet, SES indicators used in this study did not correlate with anthropometric or dietary intake data. Income per capita was strongly correlated with proportion of income spent on food in this study, but it is possible that recent increases in income have not yet translated into changes in growth. Heqing County is undergoing drastic transportation and tourism industry changes. Many of the men and women were obtaining income from these industries only in recent months. Another reason increased income spent on food is not evidenced in child growth in this population is that parents were possibly not educated in nutritional feeding practices for their children, and increases in the proportion of income spent on food may not have been distributed to the children. Income cannot independently improve nutrition; more food may not be what is purchased with money, environmental hygiene and health care may not be available to improve health status, and intra-household distribution of food and other resources may not benefit nutritional status indicators (Gillespie and Haddad, 2001).

Estimating dietary intake is difficult; methods are controversial and the potential for error is great. For the current study, three days of recall were used rather than a single 24hr recalls to improve data accuracy and to better characterize an individual's intake (Kigutha, 1997; Stein et al, 1994; Cresanta et al, 1988; Persson et al, 1984;). Three-day dietary intakes were chosen because estimates based on three days are more stable than those based on one day, and three days provides a reasonably accurate estimate of usual intake for population studies (Biro et al 2002). To reduce errors in data collection, all interviewers received standardized training and were provided with a detailed handbook of procedures. Food recalls were also frequently reviewed in detail. Dietary intake data are difficult to obtain in China owing to the practice of eating from common dishes (Popkin et al 2002), however careful attention was given to obtaining recipes and proportion of the total recipe served to the child. The use of oil also varies from family to family and can contribute a significant amount of variation in calories (Popkin et al 2002), thus collection of recipes and proportion eaten by the child was an important aspect of this research.

To the authors' knowledge, there are no descriptions available in the literature of fatty acid intakes in specific relation to anthropometric indices of preschool-aged children in developing countries. A small number of studies examining plasma and erythrocyte lipids of infants and young toddlers with kwashiorkor and/or marasmus discussed ratios and proportions of LCPUFAs, but did not list dietary intake (Leichsenring et al, 1995; Vajreswari et al, 1990; Koletzko et al, 1986a; Koletzko et al, 1986b; Holman et al, 1981).

Dietary intakes of PUFAs have not been specifically related to growth and nutritional status of preschool-aged children in rural China, as in the current study.

The results of the current dietary intake study suggest AA may be inversely related to growth. After controlling for age, AA was negatively associated with muscle/fat, as measured by MAZ ($r=-0.198$, $p=0.13$) and MUAC ($r=-0.187$, $p=0.019$). Correspondingly, AA and total n-6 fatty acids were also the only fatty acids to show significant difference between malnourished and nourished groups, suggesting children with z-scores less than –2SD below the median of the reference population consume less AA than do children above –2SD. To investigate why this may be the case in lieu of the fact that more children who had z-scores below –2SD were 1-3 years old vs. 4-5 years old, mean age of stunted/non-stunted and underweight/non-underweight were calculated within each age group. The age of underweight vs. non-underweight children was not significantly different within the 1-3 year old group. Stunted children were significantly older than non-stunted children in the 1-3 year old age group. Age could therefore be driving the significant difference between intakes in the stunted/non-stunted groups, but not in the underweight/non-underweight groups. It is also possible however, that parents of stunted or underweight children were aware of their child's nutritional state, and were compensating by increasing the child's dietary intake of pork and eggs, which were the major sources of n-6 fatty acids in this population.

Walker et al (1990) reported 24-hr dietary recall data in comparison to anthropometrics. Stunted children 9-24 months old in Jamaica met protein intake requirements but both stunted and non-stunted groups consumed fewer calories than recommended, as was the case in this population. Energy ($p<0.001$) and protein

($p<0.005$) intakes per kg were significantly higher in stunted children, as in the present study. Walker et al explained the malnourished group could have been subjected to increased morbidity due to a combination of nutritional and environmental effects, which may explain why intakes by malnourished children were higher in the malnourished children and not reflected in their growth (Krahenbuhl et al, 1998; Walker et al, 1990). However, it is possible that parents were aware of their child's malnourishment and were compensating by providing higher intakes during the study course.

In addition, the only significant correlations remaining in this population after controlling for age were total carbohydrate, LNA and LA (negatively) with arm circumference. A low arm circumference may signal loss of muscle mass due to protein-energy malnutrition (Cogill, 2003; WHO, 1995). MUAC is proposed as an alternative index of nutritional status, comparable to weight-for-height measures. Weight-for-height is an estimate of acute nutritional or environmental impact on body size and the positive correlation between arm circumference and dietary carbohydrate could reveal that carbohydrates, comprising the major energy source in the Chinese diet, were more strongly related to muscle and protein stores than were other macronutrients.

Malnourished children consuming more than nourished children may also be explained by other pathological factors such as a range of dietary inadequacies or altered nutrient metabolism during growth in a malnourished state (Rump et al, 2001). In malnutrition, metabolism of EFA is altered even with sufficient EFA intakes due to the contribution of protein, zinc and other minerals in the metabolism of fatty acids that may also be low in the diet (Desci et al, 1998). Although EFA intakes by the malnourished children may be greater than by the better nourished population, EFA conversion to

LCPUFA is likely compromised, indicating that fatty acid intakes and subsequent bioconversion is altered in malnutrition (Desci et al, 1998; Leichsenring et al, 1995; Koletzko et al, 1986; Holman et al, 1981). It is therefore unlikely that EFA deficiency can be separated in its effects on growth in the presence of other nutrient inadequacies that also occur in this population. Indeed, few children had sufficient intake compared to the DRIs for n-3 or n-6 fatty acids.

Children 1-3 years old consumed approximately half of the AI (0.7g/d) for n-3 fatty acids. Older children consumed slightly more n-3 fatty acids yet still less than the AI of 0.9g/d for 4-8 year old children. Young children consumed less than a third of the 7g/d n-6 fatty acid AI for 1-3 year olds, and 4-5 year old children consumed less than a quarter of the 10g/d AI. Using three-day food records, Lien et al (2005) reported 4-7 year old children in Canada consumed 7.4±3.3 g/d LA and 0.71±0.5 g/d LNA, approximately triple the intake by Chinese children in the present study. Meyer et al (2003) reported a similar result: 7.5 g/d LA and 0.81 g/d LNA. However, intakes of AA and DHA were similar to Chinese children's intakes in the Lien et al and Meyer et al studies: 57±35 and 37±63 mg/d (Lien et al, 2005) and 47 and 22 mg/d (Meyer et al, 2003), AA and DHA respectively. Despite low absolute intake of LNA and LA, intakes as percent of total energy were comparable to other dietary intake studies (Innis et al, 2004; Meyer et al, 2003). Intakes in this population were approximately 3.0-3.5 percent of total energy. PUFA intakes estimated with FFQs in 1.5-5 year old children in Canada were 4.5±0.2 percent (Innis et al, 2004). Using diet records, British children were estimated to consume 3.7-4.3 percent of total energy as PUFAs (Meyer et al, 2003). Though methods of collecting dietary intake data in these studies differ, children's dietary intake of PUFAs tends to be around 4 percent of total energy despite differences in total gram per day intakes.

Yet another consideration is that the North American DRIs are not appropriate for this population, regardless of percent of total fat being somewhat close to other nations' intake data. Almost none of the children met the AI for n-3 or n-6 fatty acids. The Chinese Recommended Nutrient Intakes (Chinese Nutrition Society, 2005) do not specify n-3 or n-6 fatty acids specifically, though the recommendation for fat intake is 30-35% or total energy, and the children in this population do not meet the Chinese RNI for fat intake. Fat intake by this population is inadequate compared to Chinese or North American recommendations.

If the AI is used as a measure of adequate intake, comparisons between intakes less than or greater than the AI and the subsequent growth impact in this population are limited, as few children met or exceeded the AI. The relationship between individual fatty acid intakes and growth measurements in caloric inadequacy has been investigated (Leichsenring et al, 1995; Vajreswari et al, 1990; Koletzko et al, 1986a; Koletzko et al, 1986b; Holman et al, 1981). It remains unclear if fatty acids, alone or in combination, play a specific role in growth beyond or in addition to the impact of inadequate vitamin, mineral or caloric intake for development after infancy (WHO, 1995; Beaton et al, 1990).

Complete randomization of town selection and child participants was not possible; HHB officials stated that mountain villages in the county were simply 'too poor' to be studied, they were difficult to access, and contained no health clinics for measuring children. Thus, by HHB request, only villages in the comparatively affluent valley participated. For this reason, subjects may not represent an unbiased sample and those children who were not involved in the study could be of poorer nutritional status than the study reveals. Also, because a convenience sample was used, rather than a random sample, a proportion of the population may not be adequately represented. It is probable the results provide an underestimation of dietary inadequacies and prevalence of malnutrition in a rural ethnic minority population of China.

We conclude that fatty acid intake may have a relationship with growth and stature in children 1-5 years old, although it is difficult to ascertain the impact of fatty acid on growth separately from other nutrients in the presence of inadequate intakes of other nutrients. Intakes of LNA and LA appear low compared to available data (Lien et al, 2005) however DHA and AA intakes are somewhat comparable. The impact of individual fatty acids on growth in later childhood should be further investigated in randomized, controlled studies to determine if n-6 fatty acids specifically impact growth. China may want to consider setting DRIs for EFA intake by children, as North American standards may not be accurate for the Chinese population.

Based on anthropometric data, malnutrition was prevalent in preschool children from Heqing County in Yunnan Province, a rural area of China. An early presentation of significant growth disparity between genders as in the current study may indicate different feeding practices for girls than for boys; in fact, there is evidence for this as illustrated by dietary intakes herein described. Considering China's one-child policy and the possibility that male children may be favoured under this regime, it would be meaningful to further investigate nutritional status of boys and girls separately to identify if female children would benefit from nutritional intervention in rural areas of China.

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IV. General Discussion and Conclusion

Despite national economic improvements, a significant proportion of preschool-aged children in a rural area of China have suboptimal dietary intakes and poor nutritional status. Intakes of almost all nutrients, but especially iron, zinc, essential fatty acids, calcium, carbohydrate and total energy are suboptimal in comparison to the DRIs and the Chinese RNIs. The multiplicity of inadequate nutrient intakes contributes to the nutritional status of children in Yunnan province. The prevalence of both stunting and underweight are high, indicative of chronically poor nutritional intake and/or repeated infection. Anaemia affects a large proportion of the children in Heqing County. Low dietary iron intake is likely a significant contributing factor. Essential fatty acid intakes are low in comparison the DRIs; it may be beneficial for China to investigate levels of intake in their nation in recommending adequate intakes for their population.

Hypotheses summary

The primary hypothesis, that there will be a high prevalence (>30.0%) of stunting in rural mid-northern Yunnan province was correct. The related hypotheses however, that there will be a relationship between measures of economic status (income per capita) and nutritional status (HAZ or WHZ) was inaccurate. This is likely due to rapid change occurring in Heqing County, and possibly due to increases in income not translating to changes in diet. It is possible that extra income is being spent on items other than food.

There was a high prevalence of anaemia, measured by haemoglobin status, and as expected, dietary intakes of iron were also low. Dietary intake of iron was not correlated with any measure of nutritional status, possibly due to interrelated mechanisms of micronutrients that contribute to haemoglobin status and could not be captured using the methodology of this study. It is also possible there is a threshold effect whereby the majority of children had insufficient iron for haemoglobin production.

Growth was related to essential fatty acid intakes where undernourished children had higher consumption of n-6 fatty acids than did better nourished children. A possible explanation for this is that parents may have been aware of their children's nutritional status. They may have been consciously adding more dietary sources of eggs and meat, high sources of n-6 fatty acids. Dietary intakes of essential fatty acids were low, regardless of measurement as percent of total fat, total energy, grams per day or mg per kg of body weight.

The results of this study may be biased. It is possible the nutritional status and dietary intakes of the volunteers from villages chosen by health bureau officials are greater than those of people not involved in the study, who live in more remote and less affluent areas of the region. Without permission to investigate the remote areas, foreign researchers can only develop conclusions on a limited and perhaps unrepresentative proportion of the population. It is prudent however, that Chinese officials work in both the affluent and remote areas to improve nutritional status of preschool aged children.

Recommendation

Essential fatty acids are vital for health, and fat is an essential nutrient of a young child's diet. In light of the role of fat in growth and development, it may be prudent for officials to educate rural Chinese people of the importance of including n-3 and n-6 fatty acids in the child's diet. Chinese people may also benefit from investigating nutritional status and diet of people living in remote regions of Yunnan province, with special consideration of the female population. Girls may be at particular risk for nutritional deficiencies. Finally, nutritional education for child caretakers on the importance of energy intake for adequate growth would likely benefit the population.

V. Appendix: Forms

INFORMATION SHEET

The Nutritional Impact of Agricultural Development

Purpose:

This research project aims to define if and how agricultural development impacts nutritional status.

Methods:

You are being asked to talk to the researcher about agricultural production, income, education and what you feed your child/children. Please answer the researcher's questions in your own words. There are no right or wrong answers. We will interview you three times. The first interview will last about 1 hour. The next two interviews will last about 30 minutes each. You will also be asked to attend a meeting at the school where your child's temperature, height, weight and arm circumference will be measured, and a swab of his/her inner cheek will be taken. These measurements are completely painless. You will also be asked to take you child to the health unit where a small amount of blood will be drawn from his or her arm.

Confidentiality:

Your name and your child's name not be given to anyone outside the study. We will use a number instead of your name to protect your privacy. This number will be given to you at the first interview. This number will be used on all documents, instead of your name, so that you cannot be identified.

People at the school who are also taking part in the study will know that you took part in this research study. However, everything you say in the interview and the results of the measurements will not be shared with any other participant in the study. Only the interviewer and the researcher will have access to that information.

Benefits:

The researcher wants to learn about your child's daily food intake, and whether this is meeting his/her needs for growth. This will benefit you because with the information you give the researcher, she will be able to tell you what foods may be missing from your child's diet that would help him/her to be healthy. You will learn about healthy eating.

Risks:

This study is not expected to harm you or your child. Your child may feel some discomfort when the blood sample is taken, but this will only last a few seconds.

Withdrawal from the Study:

Declaration of Consent

Title of Research Project: The Nutritional Impact of Agricultural Development

Investigator: Bobbi Barbarich RD MSc (Candidate)
Community Nutrition, University of Alberta
Residence: Tien Heng Hotel

Consent (please check yes or no):
1. Do you understand the research procedures described on the Information Sheet?
Yes __ No __

2. Have all your questions been answered? Yes __ No __

3. Do you know that you may contact the person designated on this form if you have further questions? Yes __ No __

4. Do you understand the possible benefits of joining the research study, as well as the possible risks and discomforts? Yes __ No __

5. Have you been assured that personal records relating to this study will be kept confidential and you consent to the use of the data outlined on the information sheet?
Yes __ No __

6. Do you understand that you are free to withdraw from the study at any time without jeopardy to yourself or your child/children? Yes __ No __

7. Do you understand that the data collected may be used in scientific publications but you will not be identified? Yes __ No __

8. Do you understand that if any knowledge is gained from the study that could influence your decision to continue participating, you will be promptly informed? Yes __ No __

9. Do you understand that this data may be used to initiate projects in the future, but you or your child will not be identified? Yes __ No __

Signature:______________________________ Date:_____________
Print Name:______________________________

Signature of Witness:____________________ Date:_____________

Print Name:______________________________

Signature of Investigator:____________________ Date:_____________

Print Name:______________________________

24hr Recall Form

Subject ID:	Circle Number of interview: **1 2 3**
Subject Name:	Location:
Date of birth (yr/mo/day): ___/___/___	Interviewer:
Circle who is providing information: Mother OR Caretaker	Date of interview (yr/mo/day): ___/___/___

Time	**Place eaten**	**Food or Drink, description and cooking method**	**Amount eaten (House-hold measure)**	**Weight equivalent (Bobbi)**

Was food intake today unusual? (**1** Yes **0** No **99** No answer) _____

If yes, describe why (illness, special occasion, unknown, etc).

List any supplements (minerals, vitamins, herbs) or medications given to the child today.

Did the respondent provide any recipes? (**1** Yes **0** No) _____ If yes, attach recipes to this form.

Anthropometric Data Form

Subject ID:	Gender (circle): **M** **F**
Subject Name:	Village:
Date of birth (yr/mo/day): ___/___/___	Date of interview (yr/mo/day): ___/___/___
Age: _____ (months)	

HEIGHT/LENGTH

1. If the child is **=>24 months old**, record height: __ __ . ___cm

   If the child is **12-23 months old**, record length: __ __ . __ cm

WEIGHT

2. If the child can stand still, record child's weight: __ __ . __ kg

Only if the child cannot stand still, record the following:

i. Mother/caretaker's weight: __ __ . __ kg

ii. Mother/caretaker's weight with child: __ __ . __ kg

MID UPPER ARM CIRCUMFERENCE

3. Mid Upper Arm Circumference (use the left arm): __ __ . __cm

TEMPERATURE

4. Temperature:____.__ ^{0}C

PREVALENCE OF INFECTION

5. Diarrhea is 3 or more loose, watery stools or any stool containing blood in the past 24hrs (WHO, 2000). Does this child have diarrhea?

   i. Yes
   ii. No
   iii. Don't know
   iv. No answer

SOCIOECONOMIC QUESTIONNAIRE

IDENTIFICATION SECTION--INTERVIEWER: Begin by introducing yourself - for example, *"I am from Heqing County, working with a researcher from Canada. With permission from the Director of the Bureau of Health of Heqing County and the county magistrate, we are conducting a survey of child health in Heqing County. Are there any children in this house between the ages of 1 and 5 years?"* If there are **no children**, thank the individual and continue to the next house. **If there are children in the household between the ages of 1 and 5 years**, continue with the following: *"The questions will take a short time. I would like to speak with the mother, the person in charge of household finances, or primary caretaker of the child or children."*

When the respondent is brought to the door or you are invited in, continue: *"The health bureau of Heqing County is working with a researcher from Canada, and we are collecting information about agriculture, food and child health. These types of surveys are common in the Western culture, and allow them to learn about child health to improve child health for future generations. This type of study has never been done in Heqing County, and we respectfully request your participation. With the knowledge we gain from this survey, we will be able to learn about and possibly improve the health of our children. We will be collecting information about what Heqing children eat. Everyone with a preschool aged child will be visited three times to discuss children's dietary intake to get a detailed picture of what the children in Heqing County are fed. After that, we would also like to measure the children's size and their blood strength, and then take a swab of their mouths to measure the fats in their diets, to learn how our children are growing. None of this information will be given to other people, and it will only serve to help our children's health."*

Give the respondent the information and consent forms. Read them to him/her if he/she cannot read. Have him/her sign the forms, you sign in the witness space, and begin the interview. It is preferable that the mother or member of the household that manages the finances answers the socioeconomic questionnaire. The mother or primary caregiver can provide the answers for the breast feeding module and the 24hr recall.
For multiple choice questions, **read all possible responses to the question, and have the respondent pick one of them,** then circle the appropriate option in the list or write the number from the option list into the blank. Follow the instructions on the questionnaire for where to check mark, circle or write the answers. For questions that ask for descriptions, list in the space provided exactly what the respondent says.

Village: __________
Call-back necessary? Yes/No
Time to revisit (day/mo/yr): ___/___/___
Interviewer: __________
Name of Respondent: __________
Supervisor: Bobbi Barbarich RD
Checked by supervisor?
(signature) ________________

Date of interview (day/mo/yr): ___/___/___
Questionnaire complete? Yes/No
If no, why? ________________

Date ___/___/___

Adapted from the MICAH guide, World Vision Canada, 2003

HOUSEHOLD CHARACTERISTICS (Section A)

Interviewer: Complete the Household Member Listing Table (Table 1). Use the list of options from Table 2 to fill in columns A, B, C, D and E. Write the appropriate number in each column. Sections A and B should be answered by the mother or person in charge of household finances. Please state to the respondent: *"I am first going to ask you who all lives here. You do not need to tell me about family members who do not live here."* List the child(ren) first, followed by the mother, father, grandparents, and other relatives. For houses where more than one family lives, list the members of each family (child, mother, father, grandparents) together, followed by the next family (child, mother, father, grandparents). In the age category, write "00" if the child is less than 1 year old.

Table 1--Household Member Listing Table

House hold member No.	**Name of household member**	Sex **Male=1 Female=2**	Age **(years)**	(A) Family status in relation to child	(B) Marital status	(C) Work status	(D) Highest level of education	(E) Able to read/write?
Example	Hongyu	1	2	1	1	7	0	4
Example	Ding Yun	2	27	2	2	4	4	3
01								
02								
03								
04								
05								
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12								
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15								

Table 2--Options

(A)	(B)	(C)	(D)	(E)
1 Child	1 Single	1 Farmer	0 None	1 Read
2 Mother	2 Married	2 Hourly wage earner	1 Primary school	2 Write
3 Father	3 Divorced/separated	3 Business/trade	2 Junior high	3 Both
4 Grandparent	4 Widowed	4 Domestic/house work	3 Senior high	4 Neither
5 Other relative		5 Student/pupil	4 University/college	
6 No relation		6 Professional	5 Technical school	
		7 Not employed		

Socioeconomic Questionnaire and Breastfeeding and Weaning Patterns Module:
Summary of questions

1. What is your ethnicity?
2. What occupations contribute most to the household income?
3. Starting with the biggest contribution to income, list up to three occupations.
4. What was the annual income for the household in 2003?
5. What are the highest household expenditures? Starting with the highest expenditure, list up to 3 expenditures.
6. What does the household plant on the land? Starting with the greatest area of land planted, list up to 3 options.
7. Please estimate the proportion of household income spent on family meals.
8. What is the main source of drinking water for the household? For example: well, lake, indoor pipes.
9. How does the household dispose of excreta?
10. If the household grows or raises any animals, how are they used?
11. Is there electricity in the house?
12. How many rooms are in the house?

BREASTFEEDING and WEANING PATTERNS MODULE

1. What is the gender of this child?
2. What is this child's birthday? (day/mo/yr)
3. Choose which option best describes your breastfeeding practices:

Exclusive breastfeeding:

During the first 4 months of life, the child received only breast milk or expressed breast milk from the mother or a wet nurse. The child received no solids or other liquids with the exception of drops or syrups consisting of vitamins

Predominant breastfeeding:

During the first 4 months of life, the child received mostly breast milk or expressed breast milk from the mother or a wet nurse. The child received no solids. However, the infant also received water and water-based drinks such as juice.

Complementary feeding:

During the first 4 months of life, the child received mostly breast milk or expressed breast milk from the mother or a wet nurse. In addition to breast milk, the child has also received formula and/or solid or semi-solid food.

Bottle-feeding:

During the first 4 months of life, the child DID NOT receive breast milk from any source at any time.

SECTION 1—Complete if the child is or has been breastfed exclusively, predominantly or complementary.

1. Is the child still receiving breast milk?

Complete this question only if the child no longer receives any breast milk:

2. at what age did this child stop receiving breast milk?

SECTION 2—Complete if the child is/was bottle-fed, complementary fed or receives/received formula.

1. What types of formula, solid or semi-solid foods were given to the child, during the first 4 months of life, in addition to breast milk?
2. Is/was the formula fortified with iron?
3. How is/was the formula constituted?
4. What was the child given to eat and drink instead of breast milk during the first 4 months of life?

SECTION 3—Complete for all children

1. At what age did the child begin eating solid food? Please describe the types of solid foods given to the child between 4 months and 1 year of life