# A dietary and nutritional status survey among young children in five big cities of China

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**Running title:** Dietary survey of young children in urban China

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## ABSTRACT

**Background and Objectives:** To investigate the dietary patterns and nutritional status of young children living in urban environments in China. **Methods and Study Design:** A cross-sectional study was conducted of 750 children aged 6 - 35 months living in 5 large cities in China. The survey methodology included a physical examination, blood hemoglobin measurements and a 24 hour dietary recall questionnaire. **Results:** The educational level of participant mothers was high (79% had attended college or university or higher), which may not be fully representative across all areas of urban China. Overall anthropometric nutritional status indicators were within acceptable ranges based on national recommendations, and there was no evidence of severe micronutrient deficiencies. However, we identified three significant nutritional issues that warrant attention: 1.) Later than optimal introduction and low-intake of animal-based iron-containing foods into the diet, and a need for greater inclusion of vitamin B-1 rich foods among 12-35 month old children. 2.) Presence of significant rates of anemia in 6 - 11 and 12 - 23 month old children. 3.) An increased risk of overweight/obesity. **Conclusions:** Since food availability and affordability are no longer major issues in the well developed parts of urban China, achieving further improvements in the diet and nutrition of young children in these environments is likely require more specific education to parents and other significant carers such as grandparents. The relatively high educational level and socio-economic status of the population group is likely to facilitate the uptake of such measures in this population group.


**Key Words: nutrition, complementary foods, breastfeeding, dietary recall, China**



## INTRODUCTION

The 2012 National Report of China on the nutritional status of children aged 0-6 years concluded that alongside economic and social development and improvements to the legal system, there had also been improvements in the growth and physical development of Chinese children living in urban areas.[1] In addition, as living standards have improved, families and the wider society are paying more attention to improving the cognitive, motor, and socio-emotional development of children rather than just focusing on growth measures such as height and weight. The first few years after birth represent a crucial period for human development and nutrition is one of the leading factors known to affect development in early childhood. Dietary surveys combined with anthropometrics and biochemical marker analysis are important epidemiological tools by which the nutritional status of selected populations can be assessed.[2] Many dietary surveys have been conducted previously in China among children older than 3 years,[3-5] or among those living in rural areas,[6-8] but to date only a single study[9,10] has been published on infants and young children living in urban environments in China. Against this background, the present study aimed to investigate the dietary patterns and nutritional status of young children aged between 6 and 35 months living in five large cities of China.

## MATERIALS AND METHODS

### *Study areas and subjects*

The study was conducted between June and July 2012 as a clinical-based cross-sectional study. Five Chinese cities were surveyed in the study: Beijing, Shanghai, Shenzhen, Chengdu and Nanjing. Within each of these five cities, one maternal and child care service center or hospital was selected as the survey site. Children aged between 6-35 months and their caregivers (parent(s), grandparent(s) or other(s)) were invited to participate in the survey whilst the children were visiting for a routine a physical examination, and were accepted on to the study if they met the inclusion criteria.

Based on the Pan American Health Organization's process for the promotion of child feeding, which suggests that approximately 40 children in each of two age groups (6-11 and 12-23 months) should be interviewed in every research site,[11] we chose a sample size of 50 subjects for each age group per site. In addition, we added in a 24-35 month old age group with the same sample size. The caregiver(s) of all participating children gave written informed consent for their child's participation prior to the outset of the study. Subject anonymity was preserved by allocating identifier numbers to subjects which were used in all study documents except for the contact documentation file which was kept confidential by the primary field worker at each study site.

The following inclusion and exclusion criteria were applied:

Inclusion criteria:

1. Healthy children aged 6 to 35 months, not yet attending nursery.
2. Born at full-term (gestational age equal to or greater than 37 weeks, but less than 42 weeks) with birth weight equal to or greater than 2.5 kg but less than 4 kg.
3. Caregiver(s) are familiar with the processes adopted for preparation of food for the child and must have been the one(s) who fed the infant during the preceding 24 hours.
4. Caregiver(s) agree to participation in the dietary survey.

Exclusion criteria:

1. A history of food allergies or intolerances self-reproted.
2. Have previously or are currently suffering from cardiovascular, respiratory, endocrine, blood system, gastrointestinal tract or other systemic diseases.
3. Obvious gastrointestinal abnormalities that affect food absorption.

***Questionnaire***

The questionnaire used in this study contained two parts. Part 1 recorded basic study information: survey date, child's name, gender, date of birth and basic information about the caregiver (family economic conditions, highest education level of the mother and father). Part 2 recorded the details of a 24 h dietary recall, including the number of meals, name, texture and amount of food consumed by the child on the previous day (within 24 h), such as breast milk, staple foods, vegetables, legumes, fruit, meat and fish, eggs and dairy, etc.. The 24-hour period of dietary recall was defined as the period from the moment the infant woke up the previous morning until the moment the infant woke up on the day of survey. The 24-hour dietary recall was conducted via interview by expert care physicians or doctors using the questionnaires as a basis.

Staple foods such as meat, vegetables and fruits etc., were listed directly by name in the questionnaire. For preparations comprising a mixture of ingredients not accounted for in the Food Composition tables, information was recorded about the nature of the ingredients and their proportions (in weight or volume), which enabled us to calculate the nutritional composition of the dish. Additionally, we provided participants with standard quantitative measures (including standard measuring utensils (bowl 250 ml, spoon 10 ml), life-sized food models and an atlas of food pictures[12]) to help caregivers to recall and accurately measure the weight of foods and liquids consumed by the children during the previous 24 hours. For manufactured ready-to-eat foods, participants recorded the full specification, such as brand name, company, volume, net weight etc. For infant formula, the brand and target developmental stage of the product were recorded. If caregivers were unable to recall the brand, volume and weight of manufactured foods, a "common" product was used as a substitute. Because most of the children were fed breast milk directly, it was not possible to estimate the volumes of breast milk consumed. As a alternative, we estimated breast milk intake using published data from developing countries from a WHO review.[13] The figures used were: 674 g, 616 g and 549 g breast milk consumed by breast-fed children aged 6-8 months, 9-11 months and 12-23 months, respectively.

***Measurements***

Experienced staff were recruited to the 5 participating study centers to conduct the hemoglobin testing, perform anthropometrics measurements and complete the study questionnaires. These staff received training from the study team prior to the commencement of the study. Child body length/height and weight measurements were performed in accordance with the WHO Training Course on Child Growth Assessment (WHO).[14] Length/height was measured to the nearest 0.1 cm. Children were partially undressed before measuring their weight, which was measured to the nearest 0.1 kg. Blood hemoglobin concentrations were measured on site using the Hemocue Hb 201+ system (HemoCue company, Sweden), after obtaining a blood sample by the finger prick method.

***Evaluating indicators of undernutrition, overweight/obesity and anemia***

The 2006 WHO standards were used to calculate Z-scores of height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) as indicators of child nutritional status. In accordance with the aforementioned WHO Training Course on Child Growth Assessment, stunting was defined as HAZ <-2, underweight as WAZ <-2 and wasting as WHZ <-2. Undernutrition was defined as any of the z-scores (HAZ, WAZ or WHZ) being below -2. The ranges assigned to being at risk of overweight, overweight and obese were set as $1 < WHZ \leq 2$, $2 < WHZ \leq 3$ and WHZ >3, respectively.[14] Anemia in children aged 6-59 months was defined as having a hemoglobin concentration of <110 g/l, according to the WHO standard.[15] Because all study sites were located at an altitude of between 0 and 1000 meters above sea level, there was no need for altitude correction.

***Statistical analysis***

Study data were entered into a database using Epidata version 3.1 (Epidata Association, Denmark). Anthro version 3.2.2 software (WHO, Geneva, Switzerland) was used to calculate Z-scores of HAZ, WAZ and WHZ. SAS version 9.1 (SAS Institute Inc., Cary, NC, USA) was used for all statistical analyses and $p < 0.05$ was considered as statistically significant. Energy and nutrient intakes were calculated using data from the China Food Composition Tables.[16,17]

***Ethical approval***

The study and accompanying protocols were approved by the Capital Institute of Pediatrics Ethics Committee, Beijing, China. The work conformed to the 1995 Declaration of Helsinki as revised in Edinburgh in 2000.

## RESULTS

### *Demographics*

Boys constituted 52.3% of the total study population (n=750 children). There were no differences in the average ages of boys and girls within each age group. The average age of participating mothers was 30.6±3.6 years (min 19, max 43). Of these, 7.4% stated that their highest educational level was middle school or lower, 14.0% stated that they attended high school, 69.2% reported college or university as their highest educational level, and 9.4% of the mothers were classified as graduates or higher. Further details on the study participants, occupation of the father and family income are given in Table 1.

### *Growth status and prevalence of anemia*

In accordance with the WHO Growth Standards, a very low prevalence of undernutrition indicators (stunting, underweight or wasting) was found within all three age groups of the study population, as shown in Table 2. The overall prevalence of overweight/obesity (WHZ >+2) was 5.1%, and there was no statistically significant difference among age groups ($p$=0.38) or between the sexes ($p$ = 0.96). The prevalence of being at risk of overweight (+1< WHZ ≤+2) was 22.0% for the total study population. Seventy three children were defined as anemic, representing 9.7% of the total study population. The prevalence of anemia decreased and the average blood hemoglobin concentration increased with increasing age ($p$<0.05 for comparisons between the three age groups).There were no differences between boys and girls in the prevalence of anemia or the blood hemoglobin concentration ($p$>0.05 in both cases). Comparisons among age groups are presented in Table 2.

### *Continued breastfeeding, consumption of infant formula and the introduction of complementary foods*

During infancy, the rate of continued breastfeeding was found to drop sharply; from 58.5% (38 out of 65 infants) at 6 months of age, then to 44.8% (26 out of 58 infants) at 7-8 months of age, and to 31.5% (40 out of 127 infants) at 9-11 months of age. Of the participating children in the 12-23 month old age group, 12.0% (30 out of 250) were still being breast fed, and in the 24-35 month old age group, this figure dropped to 1.6% (Figure 1). The reported average breastfeeding duration was 6.7±4.9 months among the total study population. Infant formula was consumed by 66% of 6-8 month old infants and by more than 80% of children aged 9-35 months. Figure 2 shows the distribution of infant formula consumption among children who had be introduced to formula and were not/no longer receiving breastmilk (n=526). Among children aged 6-11 months and 12-23 months, respectively, 11 and 29 were fed neither breastmilk nor formula. Complementary foods (including home prepared and/or manufactured complementary foods such as fruit puree, vegetable puree and rice flour), had been consumed by all participating 6-8 month old children during the previous 24 hours before the survey. In addition, more than 50% of these children had been introduced to grains, fruit and eggs. By 9-11 months of age, vegetables, meat, fish and poultry had been introduced to more than 50% of the infants. Milk and dairy products (aside from infant formula) had been introduced to more than 50% of the infants by age 24-35 months. Further details are given in Table 3.

***Nutrient and energy intakes***

Table 4 presents the calculated energy and nutrient intakes for participating children in the three age groups 6-11, 12-23 and 24-35 months. As most of the data were non-normally distributed, medians and inter quartile ranges are given. The results of the statistical analysis showed that daily protein intake increased significantly with increasing age of the children ($p<0.01$). A similar trend was found for daily intakes of energy, carbohydrate, vitamin C and vitamin E between 6-11 months and 12-23 months of age, but intakes of these nutrients did not increase further among 24-35 month old children. Although the absolute intakes of fat did not change with increasing age of the children ($p=0.10$), a decrease was found in the percentage of energy obtained from fat between 6-11 month and 12-23 month old children ($p<0.05$). Significant age-dependent changes in the daily intake of micronutrients were found for vitamin B2 (which was lower in 24-35 month old children compared with the 6-12 and 12-23 month old children, $p<0.05$) and Fe (which was increased in 24-35 month old compared with 6-11 month old children $p<0.05$). For intakes of Ca and Zn, a trend with age was also found ($p=0.04$ and $p=0.06$, respectively).

When the individual calculated daily nutrient intakes were compared with EAR (Estimated Average Requirement) or AI (Adequate Intake) values from the Chinese daily recommended intake (DRI) values (2013), it was found that more than 60% of the children were not meeting the EAR for energy. Furthermore, 40% of the 6-11 month old infants were not meeting the EAR for Fe. Calcium and Vitamin B1 intake inadequacy was evident in more than 40% of the subjects in the 12-23 and 24-35 month old age groups. The proportion of children receiving inadequate intakes of Vitamins E and C was between 26% and 44% across all age groups. Vitamin B2 and zinc intakes were inadequate in less than 20% of the children among all age groups. Finally, relatively few children were found to have protein intakes below the EAR, especially between the age of 24 and 36 months.

## DISCUSSION

Ongoing socio-demographic changes are occurring in China as a result of rapid development and high levels of migration from rural to urban environments. These changes are highly likely to have significant and variable effects on the nutritional status and nutritional exposures of young children in urban environments. Thus, whilst the study of nutritional issues amongst rural and/or poor communities is important for the improvement of nutritional status in these environments, it is also important to monitor and ascertain to what extent the recent economic and educational advances in urban areas have improved the nutrition and health status of young children. This study has provided new information on the nutritional and growth status, complementary feeding and nutrient intakes of 750 children aged 6 to 35 months living in 5 large cities in China. The mothers of these children, on average, had an education level markedly above the national average for 19 to 43 year old women as reported by the 6th national population census in 2010 (in which 32.6% of mothers had received education to college/university or a higher level vs 78.6% in the present study).[18] The study data indicated that the overall anthropometric nutritional status of the children was satisfactory and no severe micronutrient deficiencies were suggested. However, three areas of nutrition were identified as requiring attention in the population studied: the first is the timing of introduction of complementary foods and their overall nutritional quality; the second concerns the significant presence of anemia among 6-11 months old infants, and the third is an increased risk of overweight/obesity for the total study population.



### *Anemia*

A 17.2% prevalence of anemia among children from urban settings aged 6-11 months was unexpected and is indicative of a significant health issue. Whilst a peak in the prevalence of anemia is known to routinely appear around 6 months of age in infants who are ready to start consuming complementary foods, an typically declines thereafter,[19,20] the high prevalence in this age group in the present study was unexpected based on the demographics of the study population which indicated that mothers were well educated and that affordability of complementary foods was not an issue. The overall prevalence of anemia across the whole age range of the present study (6 to 35 months) (9.7%) was almost equal to that reported for (10.3%) urban children aged under 5 by the National Report on Nutritional Status of Children aged 0-6 Years in 2012 (10.30% vs 9.7% in the present study).[1] Iron deficiency has been identified as a major cause of anemia in China.[21] In the present study, manufactured complementary foods and infant formula were the main sources of iron among both anemic and non- anemic children, while the iron-contribution from animal sources – in which iron which is more bioavailable - was rather low. This is suggestive of suboptimal complementary food practices being employed and/or a lack of use or of recommendation for the use of adequate iron supplements. Similar findings were reported in 2008 in a nationally representative study in China.[21] In the present study, because the highest prevalence of anemia was observed in the 6-11 month age group, we undertook a nutrient intake comparison analysis between those infants classified as anemic and those classified as non-anemic in this age group. We also compared nutrient intakes between infants receiving continued breast feeding and those who did not. These analyses revealed that the intake of iron from animal sources was lower in the anemic infants compared to the non-anemic ones, and that continued breast feeding without optimal supplementation with complementary food or adequate iron supplements represented a risk factor for anemia in the 6-11 and 12-23 month old age groups. The details of these subgroup analyses have been published elsewhere.[22]

***Overweight/obesity, continued breastfeeding and infant formula consumption***

Our results indicate that under-nutrition is no longer a problem among the study population, which is consistent with the results of the Chinese Food and Nutrition Surveillance System (CFNSS) (2010) and with the National Report on Nutritional Status of Children Aged 0-6 Years (2012).[1,20]

The emerging nutritional problem among the study population appeared to be overweight/obesity. The recorded prevalence of overweight/obesity in our study population (4.4-6.4%), is twice as high as that which would be expected from a Gaussian distribution based on the WHO growth charts.[23] These findings were supported by a prevalence of 22% of children being at potential risk of overweight (+1<WHZ≤+2), compared with an expected figure of 13.5%, according to the WHO growth charts.[23] A similar finding was reported in 2012 in a cohort study of 180 children in Shanghai in which the overweight/obesity rates were 6%, 5% and 5% in children aged 6 months, 12 months and 18 months, respectively.[24] In

recent decades the prevalence of child overweight and obesity have risen rapidly in most parts of the world.[25,26] A meta-analysis conducted using data on Chinese children has shown that the prevalence of overweight/obesity among infants increased from 13.0% in 1996-2000 to 25.7% in 2006-2010, and from 5.6% to 22.1% among toddlers, and that the rates were even higher in urban areas.[27] The 2012 National Report on Nutritional Status of Children Aged 0-6 Years reported that 8.5% of children under 5 years of age living in large cities were overweight or obese in 2010.[1] In 2013, Zhang et al. reported a figure of 14% overweight and 10% obesity in 2 year old children in a similar urban population in China.[28] However, the ability to reliably compare the obesity and overweight figures amongst the various studies is limited by the use of different definitions and cut-off values for these outcome measures.[29] Zhang et al. used the 85th-95th percentile and higher than the 95th percentile of the BMI distribution, respectively, as cut-off points for overweight and obesity.[28] In a normal Gaussian distribution, the 85th percentile is 1.04 times the standard deviation above the median, and thus the figure of 24% (14%+10%) for overweight/obesity given by Zhang et al, can be compared with our figure of 27% (22%+5%) for possible risk of overweight and overweight/obesity, which indicates a fair degree of agreement. Thus, although in the present study we have used the more conservative WHO method to define overweight and obesity, the prevalence figures derived from our data should be of concern to parents, caregivers and health workers.

Feeding infant formula, particularly during the first 6 months of life and possibly also in the second half of infancy, is known to make children inclined to more rapid weight gain and to result in an increased risk of developing overweight, due to many factors.[30-32] Theoretically, greater promotion of breastfeeding would be an effective prevention method because of the known beneficial effects on breastfed infants such as lower serum insulin levels, lower IGF-1 levels, lower protein levels and lower levels of other serum biomolecular markers with specific effects on obesity like leptin, adiponectin and ghrelin.[33-37]

In the present study, the breast feeding rate was 52% for 6-8 month old infants and 31.5% for 9-11 month old infants. These figures are nearly identical to those obtained in 2005 from a study of the breast feeding practices in nine cities in China, in which breast feeding rates of 47-58% and 34.6% were reported for 6-9 month old and 10-12 month old infants, respectively.[38] The proportion of children in the present study still being breastfed at age 12-15 months (14.5%) is lower than that reported for 12 months old children in 1998 in Beijing by Li (25%),[39] but higher than that reported by Ma et al for 12 month old children in Shanghai (6.7%).[24] Furthermore, the prevalence of breastfeeding among children aged 2 years (20-24 months) in the present study (3.2%) compares favorably to that reported by Ma et al for 18 month old children (1.7%), although the number of participants in the latter study was low. Based on the Chinese national target to bring the level of exclusive breastfeeding at 6 months of age to 50%,[40] it is also reasonable to expect that the level of continued breastfeeding in the second half of infancy and into the second year of life could be similarly increased, to levels that are desirable according to the WHO standard.

There are many reasons why infant formula may be introduced during early infancy, such as poor insistence of breastfeeding, cesarean delivery,[41-44] parental and grandmother educational levels, mothers' professional occupational status,[45] living in a city,[46-48] and social and cultural factors.[49-52] In the present study, 17% of participant caregivers were the children's grandparent(s), indicating that a significant proportion of parents living in cities in China could not take care of their children by themselves, presumably due to being busy with work. A meta-analysis of observational studies found that breastfeeding could only reduce 15-25% of the risk of obesity at school age, compared to formula feeding,[53-55] and that ending childhood obesity is clearly a multidimensional challenge.[56] Both under- and over-nutrition in early life can affect developmental and epigenetic pathways leading to obesity,[57] and it has been established that epigenetic gene promotor methylation at birth is associated with a child's later adiposity, thus providing evidence that the prenatal phase is also important in influencing the risk of later obesity.[58]

According to the Chinese Residents Food Guideline (Chinese Nutrition Society, Maternal and child nutrition branch, 2007), 600-800 ml breastmilk or formula (equivalent to approximately 100-130 g of formula powder per day) is required by infants aged 6-11 months, and 80-100 g of formula powder is required by children aged 12-35 months.[59] On this basis, in our analysis of the distribution of infant formula consumption (Figure 2) we classified daily formula powder consumption into 4 levels: less than 80 g, 80-100 g, 100-130 g and more than 130 g. We found that 62%, 61% and 83% of the 6-11, 12-23 and 24-35 month old formula fed children in our study were fed lower than these recommended amounts, and only 18%, 20% and 9%, respectively, of the children in these age groups consumed more than these recommended values. On the basis of these results, our study does not give rise for significant concern regarding the over consumption of milk or of infant formula, as was recently reported for Malaysian young children.[60] On the other hand, it is also not of major concern that the majority of the children in the present study had a lower level of consumption of formula compared to the 2007 guideline. Most children in study population consume 50-80 g of formula or approximately 300-500 ml/day. A daily amount of 200-400 ml of "young child formula" has recently been recommended as optimal by an international expert group for children aged 12-36 months,[61] and a daily amount of 300-500 ml of milk was recommended by a WHO working group for non-breast children aged 6-24 months.[62]

***Dietary intakes***

Information about the dietary intakes of 6-35 month old children in urban China is currently limited. Furthermore, existing information is incomplete and likely to be outdated because of the current rapid development occurring in urban China. The current policy focus on promoting exclusive breastfeeding during the first 6 months of life and advising against the introduction of complementary foods before this time may have prompted researchers to study dietary intakes beyond 6 months of age, but there is now growing recognition that the promotion of breast feeding and of adequate weaning practices should go hand in hand,[62] therefore there is a need for research studies to incorporate both of these aspects.

The relatively low average daily energy intake that transpired from the 24 h dietary questionnaires combined with the food pictures atlas to facilitate portion size quantification, was unexpected. The finding that 62-78% of the study population (young children) were not meeting the EAR for energy could not be explained on the basis of the favorable and very low prevalences of underweight, stunting or wasting. We therefore reassessed the adequacy of our dietary assessment tool and concluded that its failure to capture use of cooking oil for preparing homemade complementary foods (which was largely due to difficulties in measuring the the amounts of oil used) represents one plausible reason that could explain the underestimation of energy intake. According to the Chinese Residents Food Guideline,[59] between 5-10 and 20-25 g of cooking oil are recommended for children aged 6-11 months and 12-36 months, respectively. If it is thus assumed that, respectively, 7.5 g and 22.5 g of cooking oil could reasonably have been added to home-prepared foods consumed by children in these two age groups in the present study, the median energy intake values would become approximately 731 kcal (79 kcal/kg), 942 kcal and 960 kcal for children aged 6-11 months, 12-23 months, and 24-35 months, which are closer to the China EAR levels (of 80 kcal/kg, 800-900 kcal and 1000-1100 kcal for children aged 6-11 months, 12-23 months and 24-35 months, respectively). Whilst this hypothesis was not tested, it provides a plausible explanation as to the low energy intake values observed in the present study, which otherwise contradict the results relating to overall nutritional status. The EAR for energy which has recently been updated for Chinese children, is now similar to the values recommended by other countries and organizations, such as EFSA (2013) which recommends energy intakes of

75-79, 712-1028 and 946-1174 kcal, respectively, for each age group,[63] and FAO/WHO/UNU (2001) which recommends intakes of 79-81, 865-948 and 1047-1129 kcal, respectively.[64]

The median intakes of protein provide evidence of an increasing trend in the age groups studied, and were higher than the EAR for protein in all three age groups. In this respect it should be noted that although the Chinese EAR for protein has recently been adjusted downwards, the recommended value is still markedly higher compared to that of other countries.[63,65] Moreover, excessive protein intake (2-3 times the EAR or higher) in early life has been associated with a higher risk of obesity.[66] Our findings regarding high daily protein intakes in young children are in agreement with those from another recent study in urban China, in which median intakes of 34 g/day and 40 g/day were reported in 12-23 and 24-36 month old children, respectively.[9] On this basis, it is recommended that the Chinese EAR for protein should be regularly reviewed and, if needed, further adjusted. The percentage of energy derived from fat in the present study was below the AMDR (Acceptable Macronutrient Distribution Ranges) for fat, which might suggest a low fat intake. However, based on our hypothesis that the omission of cooking oil from the 24 hr recall assessment could have contributed significantly to an underestimate of energy intake, it is likely that the actual fat intake was probably higher which might have moved the energy contribution from fat into the adequate range.

Based on the findings of our study, there is potential concern regarding the adequacy of intake of certain vitamins and minerals in particular age groups. For example, the proportions of participant children not meeting the EAR for vitamin A (36.8%) and Fe (40%) were highest in the 6-11 month age group, and Ca deficiency (41.6-52.8%) was highest in older children (12-35 months). Vitamin B1 deficiency, which has been reported previously from rural dietary surveys,[67-69] was also evident in our survey, especially among children aged 12-35 months, and may be a cause for concern. It may be the case that more vitamin B1 rich foods (e.g. whole grains, nuts and lean meat), or supplements, are needed by these older children to support optimal growth and nutrition, even in big cities. Although fruit had already been introduced in more than 60% of children in the present study by 6-8 months of age, the diets of about 1/3 of the participants were deficient in vitamin C. This may be a reflection of both the amount of fruit consumed and also its vitamin C content. The intake of Zn and vitamin B2 in young children seems to be adequate in our study population. For vitamin E, taking account of the aforementioned omission of cooking oil consumption from the 24 h recall, adjusted median averages for each age group were calculated that reduced the prevalence of vitamin E inadequacy to 15.2% for 6-11 month old infants, and that raised the average intake of Vitamin E among 12-35 month old children above the acceptable level.

Apart from highlighting the low dietary intake of certain nutrients in one or more of the studied age groups, the study has also identified some suboptimal food choices behaviors. According to the Chinese Residents Food Guideline,[59] non-modified dairy products should not be introduced before the age of 12 months, due to their high protein and mineral content. However, in the present study 28% of the infants aged 6-11 months had already begun to consume fresh milk in their diets. The potential benefits of using age-specific infant formula for young children aged 12-35 months, versus the introduction of non-modified dairy product into the diet, is a topic of current scientific debate. A recent international expert group has concluded that formula represents one of several options that can contribute to improving nutrient supply to young children up to the age of 3 years, and reduce the prevalence of micronutrient deficiencies.[61] Moreover, they state that formula milks aimed at young children are not an exclusive source of nutrients but should be fed along with appropriate meals, and at times also along with partial breastfeeding.[61] In order to explore this issue further, it is our future intention to use the present study data to conduct a simulation analysis to illustrate the nutritional effects of substituting infant formula with fresh milk in children aged 12-23 and 24-35 months old.

All children in the present study were introduced to complementary food after 6 months of age. However, the quality of the complementary food may have initially been suboptimal, as vegetable, meat, fish and poultry were not introduced until 9-11 months of age in the majority of the children. The data also revealed a discrepancy between recommendations and actual feeding practices regarding the introduction and role of beans in complementary feeding;[59] only 9.5% of children aged 9-11 months had started to consume beans. Whilst animal derived protein has a higher bioavailability than plant protein, and is to be preferred in situations of food shortage, the current concern is more to do with excessive protein intake. Thus, the introduction of a strategy to shift consumption patterns back in favor of (more sustainable) plant based protein sources, may be a sensible strategy to improve the balance of nutrition in young children.

Overall, the study data indicate that the current dietary intake among urban young children is in China general agreement with broader Chinese dietary habits and recommendations, and nutrient intakes in the population studies are generally consistent with the Chinese DRIs. Our major recommendation to address the identified relatively high prevalence of anemia in 6-11 month old infants would be to advocate earlier introduction of complementary foods rich in animal-based iron, such as meat, fish, poultry and eggs. This recommendation is particularly relevant for those mothers who choose to breastfeed their child during the full period of infancy and beyond. Based on the study findings, we also recommend that vitamin B-1 rich foods such as whole grains, nuts and lean meat should be highlighted more prominently as being important in the diet of young children in urban China. Finally, our data suggest that an increase in the consumption of fresh fruit and/or of a greater variety of fruits that are rich in vitamin C, should be recommended.

***Strengths and limitations***

The main strength of our study is that it incorporated large numbers of children from 5 big cities across China and thus should be fairly representative of the wider population from which the study participants were drawn. The high level of education of the majority of mothers who participated in the study was not envisaged at the study's outset, and could be seen as a selection bias. However, it may also be interpreted as a strength of the study. This is because it is indicative of a high level of general education and socio-economic status among the participating families, which may as a result be more likely to be receptive to and adopt any new advice to improve the diet and nutrition of children in this population than groups with lower educational and/or socio-economic status backgrounds.

There are several limitations to our study: The cross-sectional design which was chosen prevents the ability to draw conclusions about longitudinal changes in dietary habits with increasing age. However, by comparing the data obtained from the specific age groups studied with the national recommended intake levels, we were able to produce draw reasonable conclusions about the adequacy of nutritional intake and dietary practices within and across the different age groups. For practical reasons we were only able to include a one-day dietary recall rather than the more comprehensive three-day approach. It is also possible that the calculations of nutrient intake from the 24-h recall records supplied by parents (that were based on a food pictures atlas to decide on quantities), could have produced less accurate results than asking participants to actually weigh and measure all the foods consumed. Whilst the approach we adopted has been validated for adults, this may not be fully adequate for complementary foods. As indicated above, we did not take into account the amount of cooking oil used by study participants to prepare homemade complementary foods. Had we done so, this would probably have led to higher values for energy intakes which would likely have led to the conclusion that energy intakes in the study population were adequate, consistent with the anthropometric nutritional statement parameters. Finally, as in most dietary assessments in young children, the amount of breastmilk consumed could not be quantitatively assessed. Thus, we assigned an average amount based on what has been assumed from the available published literature, and combined this with the known average composition of breast milk from the Chinese Food tables.

### *Conclusion*

This study is one of few dietary surveys of diet and nutritional intake among urban young children in China. Whilst the study findings may not be truly representative of all urban areas in China, the data produced highlighted three significant nutritional issues in the population: 1.) Later than optimal introduction and low-intake of animal-based iron-containing foods into the diet, and a need for greater inclusion of vitamin B-1 rich foods among toddlers (12-35 month old children). 2.) Presence of significant rates of anemia in 6-11 and 12-23 month old children. 3.) An increased risk of overweight/obesity. The factors contributing to these problems are complex. These findings indicate that specific education initiatives aimed at parents are warranted and more general education of other significant carers such as grandparents in order to improve these issues. The relatively high educational level and socio-economic status of the population group is likely to facilitate the uptake of such measures.

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## FUNDING DISCLOSURE AND CONFLICT OF INTEREST

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**Table 1.** Characteristics of the study participants (n = 750)

| Characteristics | Age (months) | | |
|---|---|---|---|
| | 6-11 | 12-23 | 24-35 |
| N | 250 | 250 | 250 |
| Gender (boys, %) | 52.4 | 50.8 | 53.6 |
| Average age (X±S) | 8.46±1.92 | 15.31±3.33 | 27.73±3.76 |
| Respondents (main caregivers, %) | | | |
| Mother | 81.2 | 74.9 | 72.5 |
| Father | 5.7 | 5.4 | 7.4 |
| Grand Mother/Father | 12.7 | 19.4 | 18.9 |
| Others | 0.4 | 0.4 | 1.2 |
| Father's job (%) | | | |
| Governmental staff | 14.8 | 17.6 | 18.6 |
| Professionals & technical | 52.0 | 43.6 | 44.2 |
| Business services | 16.4 | 17.2 | 21.9 |
| Farmer | 0.8 | 0.8 | 0.8 |
| Worker | 2.5 | 2.4 | 2.4 |
| Soldier | 0.8 | 2 | 1.2 |
| Rural migrant worker | 0.8 | 0.4 | 0.8 |
| Other | 11.9 | 16 | 10.1 |
| Family incomes [median (Q1, Q3), 10 thousand/per year ] | 15 (10, 20) | 16.5 (10, 20) | 15 (10, 25) |

**Table 2.** Growth status and anemia prevalence of study participants (n = 750)

| Characteristics | Age (months) | | |
|---|---|---|---|
| | 6-11 | 12-23 | 24-35 |
| N | 250 | 250 | 250 |
| WAZ (X±S) | 0.85±1.22 | 0.75±1.35 | 0.60±1.01 |
| HAZ (X±S) | 1.12±1.56 | 1.03±1.57 | 0.83±1.07 |
| WHZ (X±S) | 0.48±1.22 | 0.38±1.33 | 0.19±1.05 |
| Underweight† (%) | 0 | 0.8 | 0 |
| Stunting‡ (%) | 1.2 | 1.6 | 1.2 |
| Wasting§ (%) | 0 | 0.4 | 0.8 |
| Possible risk of overweight¶ (%) | 25.2 | 22.8 | 18 |
| Overweight/obesity†† (%) | 6.4 | 4.4 | 4.4 |
| Hemoglobin (g/L, X±S) | 119±11 | 123±10 | 125±8 |
| Anemia (%) | 17.2 | 8 | 4 |

WAZ: Z-scores of weight-for-age; HAZ: Z-scores of height-for-age; WHZ: Z-scores of weight-for-height.
†Underweight: WAZ <-2. ‡Stunting: HAZ<-2; §Wasting: WHZ<-2; ¶Possible risk of overweight: 1＜WHZ≤2; ††Overweight/obesity: WHZ >+2.

**Table 3.** Proportion of children who consumed specific complementary foods, formula and breastmilk in the last 24 hours (assessed by 24 hr dietary recall), by age (%)

| | Age (months) | | | |
|---|---|---|---|---|
| | 6-8 | 9-11 | 12-23 | 24-35 |
| Any complementary food | 100 | 100 | 100 | 100 |
| Grains, tuber and crops | 78.1 | 96.1 | 96 | 98.8 |
| Vegetables | 40.7 | 69.3 | 74.8 | 86 |
| Fruits | 61.7 | 68.5 | 73.6 | 77.6 |
| Beans | 8.9 | 9.5 | 15.2 | 25.6 |
| Meat, fish and poultry | 35 | 65.4 | 69.6 | 83.2 |
| Eggs | 57.7 | 75.6 | 71.2 | 78.4 |
| Milk and dairy products† | 26.8 | 29.9 | 38 | 54.4 |
| Manufactured complementary foods | 35.8 | 30.7 | 13.6 | 3.2 |
| Formula | 65.9 | 81.1 | 83.6 | 80.4 |
| Breastmilk | 52 | 31.5 | 12 | 1.6 |

†Milk and dairy products didn't include formula.

**Table 4.** Energy and nutrient intakes for children by age

| Nutrients | Median (Q1, Q3) of actual intake$^{\dagger}$ | | | *p* value for ANOVA of rank among different groups |
|---|---|---|---|---|
| | 6-11 months | 12-23 months | 24-35 months | |
| Energy (kcal/kg) | 71.0 (59.8,87.7) | - | - | - |
| Energy (kcal) | 664$^{\ddagger}$ (540,818)$^{a}$ | 739$^{\ddagger}$ (571,951)$^{b}$ | 758$^{*}$ (562,996)$^{b}$ | 0.0023 |
| Protein (g/kg) | 2.1 (1.5,2.9) | - | - | - |
| Protein (g) | 20.0 (13.7,26.9)$^{a}$ | 26.5 (20.3,33.2)$^{b}$ | 30.0 (21.5,39.2)$^{c}$ | <0.01 |
| Fat (g) | 26.6 (22.9,32.5) | 24.7 (18.6,31.7) | 25.9 (17.7,33.4) | 0.10 |
| Fat (% E$^{**}$) | 37.4 (30.6,43.3)$^{a}$ | 31.9 (25.2,37.5)$^{b}$ | 30.9 (23.2,36.1)$^{b}$ | <0.01 |
| Carbohydrate (g) | 85.1(64.9,112.5)$^{a}$ | 97.4 (72.5,126.6)$^{b}$ | 98.1 (69.8,135.7)$^{b}$ | 0.01 |
| Carbohydrate (% E$^{\S}$) | 50 (46, 56)$^{a}$ | 54 (47,62)$^{b}$ | 54 (46,61)$^{b}$ | <0.01 |
| Vitamin A (RE, μg) | 506.7 (206.2,872.6) | 538.0 (334.0,881.0) | 456.2 (288.9,752.9) | 0.10 |
| Vitamin B-1 (mg) | 0.45 (0.21,0.75) | 0.42 (0.31,0.67) | 0.42 (0.30,0.57) | 0.44 |
| Vitamin B-2 (mg) | 1.0 (0.6,1.7)$^{a}$ | 1.0 (0.7, 1.4)$^{a}$ | 0.9 (0.6,1.2)$^{b}$ | 0.01 |
| Vitamin C (mg) | 49.2 (34.1,78.7)$^{a}$ | 58.9 (33.0, 85.6)$^{b}$ | 49.1 (28.0,81.6)$^{a}$ | 0.02 |
| Vitamin E | 5.1 (1.8, 9.0)$^{a}$ | 6.5 (3.9, 9.6)$^{b}$ | 6.5 (4.6, 9.8)$^{b}$ | <0.01 |
| Ca (mg) | 550.0 (329.7,844.1)$^{a}$ | 545.2 (372.0,736.8)$^{a}$ | 492.2 (354.0,678.0)$^{a}$ | 0.04 |
| Fe (mg) | 8.2 (4.3,13.9)$^{a}$ | 8.6 (6.6, 12.4)$^{a,b}$ | 9.2 (6.9,13.6)$^{b}$ | 0.01 |
| Zn (mg) | 4.8 (3.4,6.8) | 5.3 (4.0,6.8) | 5.5 (4.1,7.3) | 0.06 |

WAZ: Z-scores of weight-for-age; HAZ: Z-scores of height-for-age; WHZ: Z-scores of weight-for-height.
$^{\dagger}$Values in the same row with different superscript letters are significantly different ($p<0.05$).
$^{\ddagger}$Energy intake may be underestimated (eg. cooking oil for frying was not accounted for).
$^{\S}$% E means percentage in total energy

**Table 5.** Proportion of study participants with nutritional intake below the EAR or AI$^{\dagger\ddagger}$, %

| Nutrition | Age (months) | | |
|---|---|---|---|
| | 6-11 | 12-23 | 24-35 |
| Energy | 61.6 | 66.4$^{a}$ | 78.4$^{b}$ |
| Protein | 30.4$^{a}$ | 23.6$^{a}$ | 20.4$^{a}$ |
| Vitamin A (RE) | 36.8$^{a}$ | 15.6$^{b}$ | 16.0$^{b}$ |
| Vitamin B-1 | 34.4$^{a}$ | 57.6$^{b}$ | 65.2$^{b}$ |
| Vitamin B$_{-2}$ | 16.8$^{a}$ | 11.2$^{a}$ | 13.6$^{a}$ |
| Vitamin C | 39.2$^{a}$ | 26.8$^{b}$ | 34.4$^{b}$ |
| Vitamin E | 42.4$^{a}$ | 46.0$^{a}$ | 44.4$^{a}$ |
| Ca | 15.2$^{a}$ | 41.6$^{b}$ | 52.8$^{c}$ |
| Fe | 40.0$^{a}$ | 20.8$^{b}$ | 21.6$^{b}$ |
| Zn | 16.0$^{a}$ | 15.2$^{a}$ | 15.2$^{a}$ |

$^{\dagger}$Values in the same row with different superscript letters are significantly different ($p<0.05$).
$^{\ddagger}$EAR (Estimated Average Requirement) or AI (Adequate Intake).

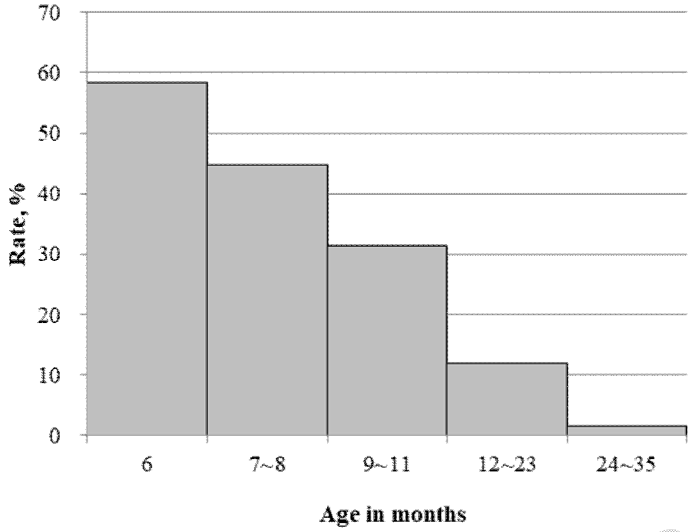


**Figure 1.** Continued Breastfeeding Rates

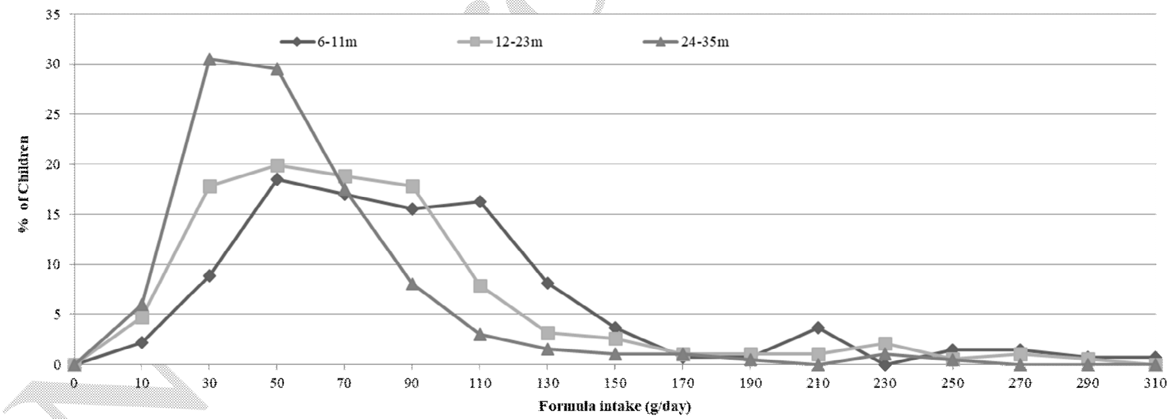


**Figure 2.** Distribution of formula consumption (g powder/day) among children who were exclusively formula fed. (age 6-11 months, n=116; age 12-23 months, n=209; age 24-35 months, n=201).