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Public Health Nutrition: 14(5), 896–903 doi:10.1017/S1368980010002971

Lack of dietary diversity and dyslipidaemia among stunted overweight children: the 2002 China National Nutrition and Health Survey

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Submitted 14 March 2010: Accepted 28 September 2010: First published online 10 February 2011

Abstract

Objective: Both stunting and overweight are present in children across China. Seemingly paradoxical, these two conditions can also coexist in the same child. The aim was to examine the associations between dietary food/nutrient intake and plasma lipid profiles related to stunting and overweight status.

Design: The 2002 China National Nutrition and Health Survey was a family-based nationally representative cross-sectional study.

Setting: Thirty-one provinces, autonomous regions and municipalities.

Subjects: The study included 13 770 children aged 2–17 years. The sample size for the four exposure groups was 10 814 for children of normal height and weight, 2128 for stunted, 729 for overweight and 99 for stunted overweight.

Results: Compared with children of normal height and weight, stunted and stunted overweight children consumed more high-energy-dense foods with a lower dietary diversity score, less protein, polyunsaturated fat and Fe, and a higher molar ratio of phytate to Ca. On the contrary, overweight children tended to consume significantly less carbohydrates and more protein and fat. Overall, stunted overweight children consumed lower amounts of vegetables, fruit, white meat (poultry and fish) and more milk. The OR for prevalent dyslipidaemia were 1·32 (95 % CI 1·13, 1·53), 1·76 (95 % CI 1·48, 2·09) and 2·59 (95 % CI 1·65, 4·07) among stunted, overweight and stunted overweight children, respectively, compared with children of normal height and weight. In addition, being overweight was significantly associated with high glucose concentrations, whereas stunting was significantly associated with having anaemia.

Conclusions: Limited dietary diversity and intake of high-energy-dense foods were notably observed among stunted overweight children. Furthermore, being stunted and/or overweight was associated with an increased likelihood of unhealthy lipid profiles.

Keywords
Double burden
Stunting
Overweight

The concurrence of under- and overnutrition in children has been reported in many developing countries, especially in countries experiencing economic and nutrition transitions[1,2]. In rural areas, stunting remains a major problem, whereas in metropolitan environs, changes in income and eating practices may lead to obesity[3,4]. Despite this geographic contrast, stunting and overweight can coexist in the same family[2], and in the same child[5]. In China, 2·8 million children were stunted and overweight in 2002. In poor rural areas, stunting was found in approximately half of the overweight children younger than 5 years and in one out of every four overweight children aged 5–19 years[5].

Childhood stunting is strongly associated with the following events in adulthood: shorter height, less education, reduced economic productivity, increased risk of death and disability-adjusted life-years[6–8]. Many studies have shown that obese children are more likely to become overweight or obese adults, and to be at increased risk for developing psychological disorders, asthma, certain

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cancers, CVD, type 2 diabetes and death in adulthood[9–12]. Stunting, together with obesity in the same child, may increase the risk of not only stunting-related diseases but also obesity-related comorbidities.

Impaired fat metabolism among stunted children has been suggested as a potential mechanism that may increase the risk of obesity and other related metabolic disorders in this group[13–15]. Energy intake per kilogram body weight[14] and fasting respiratory quotient[16] measurements were significantly higher in stunted children, whereas resting metabolic rate[13] and fasting fat oxidation[16] measurements were significantly lower. These factors may contribute to obesity in stunted children.

A paucity of data for food and nutrient intake among stunted overweight children in China has been reported to date. Thus, using data from the 2002 China National Nutrition and Health Survey (CNNHS), our first research objective was to investigate the associations of dietary intake among four mutually exclusive groups of children: normal height and weight, stunted, overweight and stunted overweight. In addition, we sought to determine whether dietary patterns of stunted overweight children differed from those of only stunted or overweight children. Moreover, we compared the prevalence of dyslipidaemia, high blood glucose and anaemia among the four groups of children. The final aim of our study was to offer suggestions for informing and guiding public health initiatives to ameliorate stunting and overweight among Chinese children, as well as among children in other developing countries with similar phenomena.

Methods

Sampling

The study included 13 770 children aged 2–17 years with data from the cross-sectional 2002 CNNHS, which encompassed thirty-one provinces, autonomous regions and municipalities directly affiliated with the Central Chinese Government (Hong Kong, Macao and Taiwan were not included). A multi-step cluster sampling method was used. Detailed information about sampling has been described previously[17].

Anthropometry

Participants went to the study sites to have their anthropometric measurements taken. In the morning, body weight was measured to the nearest 0·1 kg using a balance-beam scale (Liaoning, China). Height was measured to the nearest 0·1 cm by a free-standing stadiometer mounted on a rigid tripod. All trained investigators followed standard protocols. The scale and stadiometer were calibrated at least twice daily (once before the survey and other calibrations during the conduct of the survey). In order to estimate reproducibility, body weight of 2396 participants and height of 2418 participants (randomly selected from different study sites) of CNNHS 2002 were measured twice by different investigators. The duplicate measurements in subgroups showed very high reproducibility (correlation coefficients of duplicate measurements were 0·98 for weight and 0·99 for height).

BMI was calculated as the participant's weight in kilograms divided by the square of their height in metres and expressed as kg/m^2. The height and BMI *Z*-scores, based on age and sex, were calculated according to the method recommended by WHO[18], using the WHO child growth standards for children aged 2–5 years[19] and the WHO growth reference for children aged 5–17 years[20].

Assessment of nutrient, food and dietary diversity

Trained interviewers visited the participants' homes daily for three consecutive days (two weekdays and one weekend day) and interviewed them in person about food intake in the last 24 h using the dietary recall method. The interviewers weighed the cooking oil and condiment consumption of all family members during the 3 d. The child and their main caregiver were interviewed together to recall the food consumed in the last 24 h. The percentage of oil and condiments that the child consumed was calculated as the ratio of the child's energy intake divided by the energy intake of all family members. The energy and nutrient intakes were calculated using data from the China Food Composition Table[21]. The energy density of the diet (kJ/g) was calculated as the average energy intake (kJ) divided by the average food weight (g) per day; all beverages except water were included in the food weight calculation[22]. Owing to the lack of data on phytate in the China Food Composition Table[21], we measured the phytate content of food samples in our laboratory[23]. A validation study indicated that the correlation coefficients of food intakes between the weighed food method and the 3 d dietary history method ranged from 0·58 to 0·88. The relative differences in food intakes investigated by the weighed food method and the 3 d dietary history method were <10 % for most food items[24].

Using a method developed for Chinese populations by Stookey *et al.*[25], a dietary diversity score was calculated for thirteen sub-categories derived from the four main food groups (i.e. cereals and tubers; animal foods; beans and dairy products; and vegetables and fruit). For each sub-category, points were allocated for at least 25 g of consumption of the particular food[26,27]. The thirteen sub-categories included the following: four categories of 'cereals and tubers' (rice and products (0·5), wheat and products (0·5), corn, coarse grains and products (0·5) and starchy roots and products (0·5)); four categories of 'animal foods' (red meat and products (0·5), poultry and game (0·5), egg (0·5) and fish and shellfish (0·5)); two categories of 'beans and dairy products' (legumes and products (1·0) and milk and dairy products (1·0)); and three categories of 'vegetables and fruit' (dark-coloured vegetables (1·5), light-coloured vegetables (1·0) and fruit

(1·5))[25,26]. The numbers in brackets indicate point allocation for the corresponding category[26]. The total dietary diversity score was calculated by summing points across all categories with values ranging from 0 to 10 (the highest dietary diversity).

We used an isoenergetic substitution model[28] to frame the findings of the study in the context of public health recommendations for designing prevention strategies of stunting and overweight among children. Given the daily energy requirements, total energy intake was held constant and various macronutrients were substituted for others (e.g. replacing 5 % of carbohydrate intake with 5 % protein).

The present study was approved by the Ethics Committee of the National Institute for Nutrition and Food Safety within the Chinese Center for Disease Control and Prevention. Signed consent forms were obtained from both parents or guardians, and from the children themselves if they could write.

Blood sample measurements

Plasma glucose levels were measured using a spectrophotometer within 4 h after a night's fasting blood sample was drawn. Plasma total cholesterol (TC), TAG and HDL cholesterol (HDL-C) were measured enzymatically with the Hitachi 7060, 7180 autoanalyser (Hitachi, Tokyo, Japan). LDL cholesterol (LDL-C) was calculated by means of standard methods. Plasma Hb was determined by the cyanmethaemoglobin method.

Anaemia was defined by the Hb cut-off points recommended in 2001 by WHO and the UNICEF. The cut-off points (g/l) were 110, 115, 120, 120 and 130 for children aged <5, 5–11, 12–14, ≥15 years (boys) and ≥15 years (girls), respectively.

On the basis of age and sex, values for TAG, TC, LDL-C and glucose above the 90th percentile[29] of the present sample were considered as abnormally high, whereas values for HDL-C below the 10th percentile[29] were considered as abnormally low. Dyslipidaemia was defined as having at least one abnormal TC, TAG or HDL-C value.

Statistical methods

On the basis of height and BMI *Z*-scores, children were classified into four groups: (i) normal height and weight, height *Z*-score ≥ -2 SD and BMI *Z*-score ≤ 1 SD; (ii) stunted, height *Z*-score < -2 SD and BMI *Z*-score ≤ 1 SD; (iii) overweight, height *Z*-score ≥ -2 SD and BMI *Z*-score >1 SD; (iv) stunted overweight, height *Z*-score < -2 SD and BMI *Z*-score >1 SD.

Means and standard errors for energy, nutrient and food intakes consumed by the four groups of children were computed using a generalized linear model adjusting for age category (≤5, 6–12 and 13–19 years), sex and urban *v.* rural. For these cross-sectional data, OR for prevalent dyslipidaemia, high glucose and anaemia among stunted and/or overweight children compared with children of normal height and weight were analysed using multivariate logistic regression. Statistical interactions between stunting and weight status for dyslipidaemia, high glucose and anaemia were conducted using likelihood ratio tests. A sensitivity analysis was performed using the 95th percentiles of TAG and TC, and 5th percentile of HDL-C, to indicate dyslipidaemia.

Using isoenergetic substitution models, the odds of replacing one dietary macronutrient with another for the same amount of energy contribution were estimated[28]. Polychotomous logistic regression was used to calculate the odds of stunting, overweight and stunted overweight, with normal height and weight as the reference category.

Among the 13 770 participants, 63 % had complete data for the height measurements of both parents. A sensitivity analysis using this subset was performed to examine whether the association of dyslipidaemia with stunting and overweight was explained by the potential effect of parents' height. As socio-economic status was associated not only with lipid metabolism, stunting and overweight but also with food and nutrient consumption, we performed an additional sensitivity adjusting for socio-economic status as determined by family income and mother's educational level. Statistical significance was defined at an α level of 0·05. The SAS statistical software package version 9·2 (SAS Institute Inc., Cary, NC, USA) was used for all statistical analyses.

Results

The proportion of children who were of normal height and weight, as well as stunted, overweight and stunted overweight, was 78·5, 15·5, 5·3 and 0·7 %, respectively (Table 1). Among rural areas, the prevalence of being stunted was significantly higher, whereas in urban areas the prevalence of being overweight was significantly higher ($\chi^2 = 397·02$, $P < 0·0001$).

Compared with children of normal height and weight, energy intake was significantly lower among stunted children and significantly higher among overweight children. The energy intake of stunted overweight children was significantly lower than that of overweight children, but not different from that of normal or stunted children (Table 1). After further adjustment for socio-economic status, only overweight children were found to consume significantly higher dietary energy. Overall, stunted and stunted overweight children consumed significantly less protein, polyunsaturated fat, Fe and Se, and their diet had a significantly higher energy density (kJ/g) and higher molar ratio of phytate to Ca (Table 2). On the contrary, overweight children tended to consume significantly less carbohydrates and more protein and fat.

Table 3 shows the results by group for consumption of various foods. Overall, stunted overweight children tended to consume lower amounts of vegetables, fruit, white

Table 1 Characteristics of the study population: China National Nutrition and Health Survey 2002

	Normal height and weight		Stunted		Overweight		Stunted overweight	
	n	%	*n*	%	*n*	%	*n*	%
Total	10 814	78·5	2128	15·5	729	5·3	99	0·7
Age (years)								
2–6	2799	78·0	611	17·0	134	3·7	44	1·2
7–12	4791	75·9	1103	17·5	385	6·1	37	0·6
13–19	3224	83·4	414	10·7	210	5·4	18	0·5
Sex								
Boys	5802	78·6	1086	14·7	430	5·8	61	0·8
Girls	5012	78·4	1042	16·3	299	4·7	38	0·6
City								
Urban	2272	83·0	161	5·9	291	10·6	14	0·5
Rural	8542	77·4	1967	17·8	438	4·0	85	0·8

Table 2 Comparison of energy and nutrient intakes: China National Nutrition and Health Survey 2002

	Normal height and weight (*n* 10 814)		Stunted (*n* 2128)		Overweight (*n* 729)		Stunted overweight (*n* 99)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Energy intake (MJ)*	7·5[b]	0·02	7·4[c]	0·1	8·0[a]	0·09	7·3[bc]	0·2
Energy density of diet (kJ/g food)†	9·2[b]	0·02	9·4[a]	0·04	9·0[c]	0·07	9·7[a]	0·2
Carbohydrate (% energy)*	58·7[b]	0·1	60·9[c]	0·2	56·5[a]	0·4	60·2[bc]	1·1
Protein (g/d)†	52·1[c]	0·1	50·5[b]	0·3	54·9[a]	0·5	50·8[bc]	1·3
Protein (% energy)*	11·8[b]	0·03	11·4[c]	0·1	12·2[a]	0·1	11·4[bc]	0·3
Protein (% energy <10 %)‡	25·9[b]		33·9[a]		16·5[c]		35·4[a]	
Fat (% energy)*	29·6[b]	0·1	27·8[c]	0·3	31·3[a]	0·4	28·4[bc]	1·1
Saturated fat*	6·4	0·03	6·5	0·1	6·6	0·1	6·6	0·3
Monounsaturated fat*	10·0[b]	0·04	9·7[c]	0·1	10·4[a]	0·2	9·7[abc]	0·5
Polyunsaturated fat*	6·6[b]	0·03	5·3[c]	0·3	7·5[a]	0·1	5·8[c]	0·3
Fibre (g/d)†	9·4	0·1	9·5	0·1	9·1	0·2	9·4	0·6
Fe (mg/4·2 MJ)*	10·3[a]	0·03	10·0[b]	0·1	10·3[a]	0·1	9·9[ab]	0·3
Se (μg/4·2 MJ)*	18·4[b]	0·1	16·8[c]	0·2	19·8[a]	0·4	15·6[c]	1·0
Zn (mg/4·2 MJ)	5·0	0·01	5·1	0·03	5·0	0·05	4·9	0·1
Ca (mg/4·2 MJ)	173·8	1·0	168·4	2·2	182·8	3·7	165·8	10·0
Molar ratio of phytate to Ca ≥0·24 (%)‡	47·9[c]		58·8[b]		37·6[d]		68·1[a]	

a,b,c,dMean values within a row with unlike superscript letters were significantly different ($P<0·05$).
*Means and SE from generalized linear models adjusted for age category, sex and urban/rural.
†Daily energy adjusted.
‡Logistic regression model, adjusted for age category, sex and urban/rural.

meat (poultry and fish) and more milk, but these associations did not reach statistical significance. The dietary diversity scores for stunted and stunted overweight children were significantly lower than the scores for normal and overweight children. Specifically, the dietary diversity scores for vegetables/fruit and animal food groups for stunted and stunted overweight children were significantly lower than those for normal and overweight children; the cereal and tubers consumed by stunted overweight children had a significantly higher dietary variety score than those consumed by stunted children. Further adjustment for socio-economic status did not significantly attenuate the associations.

Using an isoenergetic substitution model[24], we observed in rural areas that for each 5 % energy from carbohydrates substituted by protein, the odds of being stunted and stunted overweight decreased by 32 % (OR = 0·68, 95 % CI 0·46, 0·99) and 19 % (11–25 %), respectively, whereas the odds of being overweight increased by 29 % (10–52 %). When 2 % of energy from carbohydrates was substituted by polyunsaturated fat, the odds of being stunted overweight decreased by 34 % (30–37 %), whereas the odds of being overweight increased by 24 % (15–23 %). However, in urban areas, when 5 % of energy from fats was substituted by carbohydrates, the odds of being overweight decreased by 12 % (6–18 %).

Both stunted and overweight children had greater odds for having an unhealthy lipid profile, with the strongest odds being observed among stunted overweight children. Compared with children of normal height and weight, the OR for prevalent dyslipidaemia were 1·32 (95 % CI 1·13, 1·53), 1·76 (95 % CI 1·48, 2·09) and 2·59 (95 % CI 1·65, 4·07) among stunted, overweight and stunted overweight children, respectively (Fig. 1). After further adjustment for parents' height, income and educational level, the odds of dyslipidaemia among stunted overweight children were

Table 3 Comparison of food consumption: China National Nutrition and Health Survey 2002

	Normal height and weight (*n* 10 814)		Stunted (*n* 2128)		Overweight (*n* 729)		Stunted overweight (*n* 99)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Rice (g/4·2 MJ)	99·6^{b}	0·7	130·5^{a}	1·6	87·9^{c}	2·7	104·3^{b}	7·3
Wheat (g/4·2 MJ)	71·0^{b}	0·7	45·6^{c}	1·6	79·4^{a}	2·7	60·4^{b}	7·3
Vegetables (g/4·2 MJ)	117·5^{b}	0·7	123·9^{a}	1·7	111·2^{c}	2·9	107·2^{bc}	7·7
Fruit (g/4·2 MJ)	30·1^{a}	0·5	21·1^{b}	1·2	30·4^{a}	2·1	20·2^{ab}	5·7
Cooking oil (g/4·2 MJ)	17·8^{a}	0·1	16·7^{b}	0·2	18·1^{a}	0·4	17·3^{ab}	1·0
Red meat (g/4·2 MJ)	26·0	0·3	27·2	0·6	26·5	1·0	25·4	2·8
White meat (poultry and fish, g/4·2 MJ)	18·0^{b}	0·3	17·0^{b}	0·7	21·5^{a}	1·2	12·1^{b}	3·3
Egg (g/4·2 MJ)	12·4^{b}	0·2	7·3^{c}	0·4	15·9^{a}	0·7	9·3^{bc}	1·9
Milk (g/4·2 MJ)	16·5^{b}	0·5	8·3^{c}	1·2	23·1^{a}	2·1	28·1^{a}	5·6
Dietary diversity score								
All	4·18^{b}	0·01	3·77^{c}	0·03	4·53^{a}	0·05	3·75^{c}	0·14
Cereals and tubers	1·07^{a}	0·004	0·97^{b}	0·01	1·13^{a}	0·02	1·07^{a}	0·04
Vegetables and fruit	2·24^{b}	0·01	2·03^{c}	0·02	2·29^{a}	0·04	1·91^{c}	0·11
Animal foods	0·59^{b}	0·004	0·52^{c}	0·01	0·70^{a}	0·02	0·46^{c}	0·05
Beans and dairy products	0·28^{b}	0·004	0·24^{c}	0·01	0·40^{a}	0·02	0·31^{abc}	0·05

^{a,b,c,d}Mean values within a row with unlike superscript letters were significantly different ($P<0·05$).
Means and SE from generalized linear models adjusted for age category, sex and urban/rural.
Dietary diversity score was calculated using thirteen sub-categories derived from the four main food groups (details are provided in the Methods section).

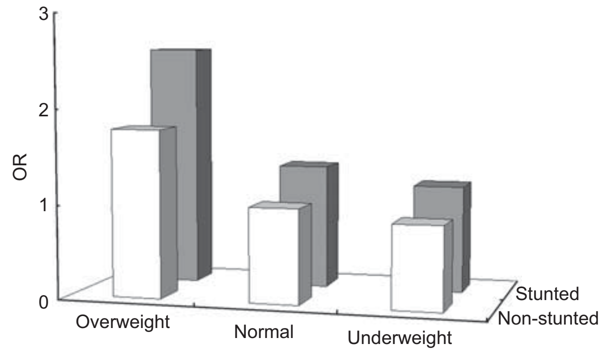

Fig. 1 OR for prevalent dyslipidaemia according to stunting and weight status: China National Nutrition and Health Survey 2002. On the basis of age and sex, values for TAG and total cholesterol above the 90th percentile were considered as abnormally high, whereas values for HDL cholesterol below the 10th percentile were considered as abnormally low. Dyslipidaemia was defined as having at least one abnormal TAG, total cholesterol or HDL cholesterol value (P trend for weight $= <0·0001$; P trend for stunting $= <0·0001$; P for interaction $= 0·9889$)

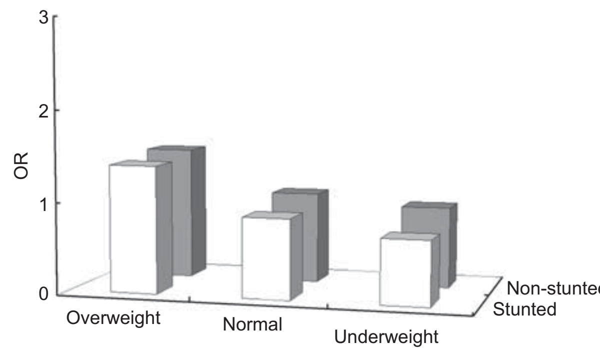

Fig. 2 OR for prevalent high glucose concentrations according to stunting and weight status: China National Nutrition and Health Survey 2002. High glucose was defined as having a fasting plasma glucose value above the age- and sex-specific 90th percentile (P trend for weight $= <0·0009$; P trend for stunting $= 0·1824$; P for interaction $= 0·6219$)

3·6 (95 % CI 2·0, 6·6). Applying a more conservative definition of dyslipidaemia (i.e. serum lipid concentrations above the 95th percentile for TAG and TC or below the 5th percentile for HDL-C as abnormal), the odds of dyslipidaemia among stunted overweight children were higher (4·2, 95 % CI 2·1, 8·2). Being overweight was significantly associated with a greater odds of having an abnormally high glucose level (Fig. 2), whereas being stunted was significantly associated with being anaemic (Fig. 3). We did not find evidence of significant interactions between stunting and body weight for dyslipidaemia, high glucose or anaemia.

Discussion

Findings from the present study suggest that a lack of dietary diversity and high-energy-dense diets may be

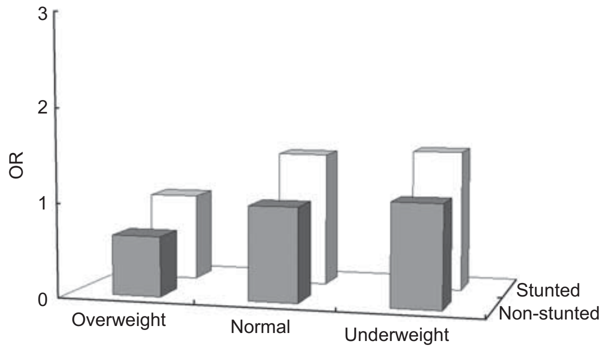

Fig. 3 OR for prevalent anaemia according to stunting and weight status: China National Nutrition and Health Survey 2002. Anaemia was defined by the Hb cut-off points recommended in 2001 by WHO and UNICEF. The cut-off points (g/l) were 110, 115, 120, 120 and 130 for children aged <5, 5–11, 12–14, ≥15 years (boys) and ≥15 years (girls), respectively (*P* trend for weight = 0·0049; *P* trend for stunting = <0·0001; *P* for interaction = 0·6512)

related to a child being both stunted and overweight. Stunted overweight children consumed less protein, polyunsaturated fat, Fe, Se and bioavailable Ca. Both stunted and overweight children had greater odds of having dyslipidaemia than children of normal height and weight.

In developing countries, there were 559 million children younger than 5 years; among them, 156 million were stunted[30]. Protein and energy deficiency were initially evaluated as major causes of stunting. However, with improved socio-economic development and continued food supply abundance, stunting rather than underweight remained the most prevalent problem[31,32]. At the end of the last century, among children younger than 5 years in China, Egypt and Mexico, the prevalence of underweight was 10·0, 4·0 and 7·5 %, respectively, whereas the prevalence of stunting was 14·2, 18·7 and 17·7 %, respectively[32]. The present study suggests that, in addition to lower protein intake, stunted and stunted overweight children also consume less polyunsaturated fat, Se, Fe and bioavailable Ca. Inadequate intake of these nutrients may compromise optimal linear growth. These observations are consistent with previous observational and intervention studies[33–35]. Nutritional interventions, based on energy – protein supplements to ameliorate stunting in thirty-six countries, reduced the prevalence of stunting at 36 months by only 0·3 %, whereas the micronutrient interventions reduced stunting by 17·4 %[34].

One potential mechanism may involve impaired fat metabolism among stunted overweight children. After measuring the energy metabolism of stunted children, Grillol and Hoffman found that the resting metabolic rate[13] and fasting fat oxidation[16] were significantly lower. In the follow-up period, these stunted children had a higher rate of weight gain concurrent with decreased lean mass[13]. Severe childhood stunting was also found to be associated with greater central adiposity in Guatemalan adults[36]. In the present study, stunted children had higher levels of TAG, TC and LDL-C and lower levels of HDL-C. Unfavourable lipid profiles among stunted children could be a potential mechanism underlying the increased risk of CVD in shorter men and women[37]. Childhood obesity has been noted as a major determinant of adverse plasma lipids in childhood, and also as a predictor of CVD, certain cancers, type 2 diabetes, asthma and death in adulthood[9–12]. Research has seldom studied the simultaneous effects of both stunting and overweight on the health of the same child. Barker *et al.*[7,37] reported that not only shorter childhood height but also accelerated childhood weight gain was associated with an increased risk of CVD in adulthood. Consistently, we observed that the strongest significant association for dyslipidaemia was among stunted overweight children.

In the present study, stunted and stunted overweight children had less dietary diversity overall, especially among vegetables/fruit and animal food groups. Stunted overweight children consumed significantly more wheat flour products and milk than stunted children. In China, reduced-fat milk is scarce and relatively expensive compared with full-fat milk. It is plausible that additional energy intake from full-fat dairy and refined wheat flour products, and lower consumption of a variety of vegetables and fruits, may contribute to the existence of stunting and overweight in the same child. As Chinese diets are still based on plant foods, the energy density of these diets depends relatively more on cereals, which contribute to 40 % of total foods and 50 % of energy[38]. In this large nationally representative study population, stunted children consumed more vegetables, but along with a high consumption of rice and rice products and low consumption of fruit. Substituting energy from carbohydrates with protein in poor rural areas should be considered for prevention of stunting, whereas substituting energy from fat with carbohydrates, especially replacing saturated fat with carbohydrates with low glycaemic index[39], should be considered for prevention of obesity in urban areas.

The strengths of our study include the large sample size, which facilitated the comparison between the four groups of children, as well as detailed information from 3 d dietary recall. An additional strength is the availability of biological data for this large sample of participants. Both dietary data and blood samples are generally difficult to obtain from children and adolescents.

One primary limitation of the present study is the cross-sectional design that disallows a sequence of temporality to be established for stunted overweight and dietary patterns or prevalent dyslipidaemia. For example, reverse causation may be present whereby stunted overweight children may have changed their dietary patterns in an attempt to control body weight or stimulate height development when assessed at the time of the 2002

CNNHS. Future prospective investigations are warranted to clarify the findings herein. Another limitation is that we had no documentation on infectious diseases, which may be related to both stunting and micronutrient deficiency. Safe food and drinking water, micronutrient supplementation and food fortification were other potential confounding factors that should be considered in future research.

Preventing both stunting and overweight simultaneously in the same population will be a remarkable public health challenge, as providing adequate food to prevent stunting may in turn enable an obesogenic environment[31]. Similarly challenging, obesity prevention programmes should not lose sight of efforts to combat malnourishment. In a concerted effort to promote optimal growth in all children, malnutrition and obesity prevention programmes should collaborate with each other in countries where under- and overnutrition coexist. Monitoring height-for-age and weight-for-height is necessary for both programmes to identify stunted overweight children[31]. Considering the long-term health burden of childhood stunting and overweight, the earlier and more effectively these conditions are treated, the greater the opportunity for recovery, or, at a minimum, the attenuation of future health consequences.

Acknowledgements

The 2002 China National Nutrition and Health Survey was supported by the Ministry of Health and the Ministry of Science and Technology in China (Grant no. 2001DEA30035 and 2003DIA6N008). The authors declare that they have no conflict of interest. Y.L. was also a Takemi fellow in the Department of Global Health and Population at Harvard School of Public Health. All authors contributed to the discussion and interpretation of the data and to the writing of the manuscript. X.Y., C.C. and G.M. were the main investigators of the 2002 CNNHS. The analyses were performed primarily by Y.L. and N.M.W. The present study was initiated by C.C., and later conceptualized and supervised by F.B.H. The authors graciously thank all team members and participants from the thirty-one provinces. They appreciate the support of UNICEF, WHO, Unilever and the Danone Nutrition Institute, China.

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