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Growth disparity of motherless children might be attributed to a deficient intake of high-quality nutrients

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ABSTRACT

We hypothesized that single-parent children (SPC) are retarded in growth compared with both-parent children (BPC), and that motherless children (MC) are affected differently from fatherless children. Moreover, the growth disparity between SPC and BPC might be attributed to a deficient nutrient intake. Data from 2967 children between the ages of 2 and 18 years were extracted from 4 recent waves (2004, 2006, 2009, and 2011) of the China Health and Nutrition Survey to compare the growth status of SPC and BPC and to investigate the association between growth indicators and nutrition status. Anthropometric measures and 24-hour recall of 3 consecutive days of dietary intake were collected. The discrepancy of growth status and nutrition between BPC and SPC was analyzed by multivariable regression models with adjustments for socioeconomic status. Results indicated that MC were significantly lighter in weight than BPC ($P = .03$); the same trend was observed for height ($P = .08$). This might be attributed to the lower intake of animal-source protein ($P = .02$), such as meat ($P = .04$) and fish ($P = .04$). Further analysis showed that intake of animal-source iron and zinc was also significantly lower in MC compared with BPC ($P = .01$, $P = .03$). No difference was detected in fatherless children in comparison with BPC. Our study indicated that the loss of the mother adversely affected children's growth status and that a lower intake of animal-source protein, iron, and zinc might be a reason for the retarded growth status of MC.

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Abbreviations: BMI, body mass index; BPC, both-parent children; CHNS, China Health and Nutrition Survey; FC, fatherless children; GLS, generalized least square regression; LM, Lagrange multiplier; MC, motherless children; SPC, single-parent children.

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1. Introduction

Rapid socioeconomic development in the past 3 decades has greatly reshaped various aspects of China's society. The improved economic status shifted the traditional Chinese dietary style toward a Western diet, but although undernutrition was reduced, there was an increase in indicators of overnutrition, such as overweight and obesity [1]. At the same time, attitudes to marriage appear to have changed significantly. For instance, the Ministry of Civil Affairs claimed that 3.5 million pairs divorced in 2013, representing an increase in the crude divorce rate of 12.8% in comparison with the previous year [2]. Moreover, the unmarried birth rate has also increased in recent years. The sixth national population census data (2010) showed that single-parent families accounted for 5.25% and 6.28% in urban and rural areas, respectively, with the number of single-parent children (SPC) exceeding 20 million [3].

Families in which one or both parents are absent are associated with disadvantages in relation to children's health, education, and psychosocial development [4-9]. Published studies have mainly focused on the psychological and mental health of SPC, only a few shed light on the nutritional status of children from one-parent families [10,11]. Malnutrition in early childhood is one major reason for growth failure and it is connected with adverse consequences, such as retarded growth, negatively affected neurologic development, lower education, and failure in the marriage market [12]. However, few studies have compared the nutritional status of children from different family structures and further link dietary intake to stunted physical growth. Moreover, SPC in China were unfortunately overlooked in current studies. In light of the great improvement China achieved in eliminating undernutrition and promoting physical growth in recent decades, it is particularly important to reveal whether SPC benefited equally from this progress compared with both-parent children (BPC). In addition, whether children from families with a single mother might be affected differently from their counterparts from families with a single father should be investigated.

Thus, the aim of our study was to test the following hypotheses: (1) SPC are shorter and lighter than their BPC counterparts; (2) height, weight, and nutritional status are different between motherless children (MC) and fatherless children (FC); and (3) retarded growth might be associated with relatively poor dietary intake. To test these hypotheses, data from 2967 children aged 2 to 18 years were extracted from the China Health and Nutrition Survey (CHNS), which was conducted between 2004 and 2011. The children were divided into 2 major groups: BPC and SPC; furthermore, the SPC group was subdivided into motherless and fatherless groups. Data from anthropometric measures and 24-hour recall of 3 consecutive days of dietary intake were collected. We specifically investigated 2 research objectives: first, to compare the growth indicators and nutritional status of children from various family structures (MC, FC, and BPC), and second, to analyze the relationship between lower weight and dietary intake for SPC. Both mean comparison tests (t tests) and parametric and semiparametric multivariable regression models were adopted in our analysis.

2. Methods and materials

2.1. *Study participants*

In this study, SPC were defined as "children under the age of 18 years, where only the maternal mother or paternal father lived in the home." We adopted the CHNS data (from 2004, 2006, 2009, and 2011). This survey was approved by the institutional review board of the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Food Safety, China Center for Disease Control and Prevention. All participants provided written, informed consent. Additional details about the CHNS data are provided elsewhere [13]. Single-parent children were defined by 2 questions that inquired whether the children's father or mother was still a member of the family: (1) "Does your father live in this household" and (2) "Does your mother live in this household?" If children responded to 1 of these 2 questions with "no," they were classified as SPC. Children with no parents (orphans) were not included in our analysis. The data set contained 3015 children who have both parents and 528 children with a single parent.

2.2. *Study design*

We extracted data from 4 survey years (2004, 2006, 2009, and 2011) of the CHNS data set. The sample consisted of data obtained from more than 4000 households in each survey year through the use of a multistage, random-cluster strategy for 9 provinces (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong) and 3 municipalities (Beijing, Chongqing, and Shanghai). Only children between 2 and 18 years of age with complete anthropometric and dietary data for at least 1 wave were included in our analysis (n = 3253). In addition, to avoid the distortion due to outliers, we excluded observations with values of energy intake greater than mean + 3 SD. Observations with daily energy intake less than 2146.6 KJ (the minimum energy required for an infant to survive) were also excluded. In addition, one improbable weight value of 521.2 kg was excluded. Thus, in total, 286 children with improbable energy and food intake values were excluded; 2967 children remained in our analysis. Furthermore, because children without fathers might differ from those without mothers, we divided children into 3 groups: both-parents (2510), fatherless (318), and motherless (139).

2.3. *Assessment of anthropometric data*

The weight and height of each child were measured by trained health workers, using regularly calibrated equipment and according to the manufacturer's instructions (SECA880 scales and SECA 206 wall-mounted metal tapes). Body mass index (BMI) was calculated by dividing the weight (in kg) by the square of the height (in m^2). Because these indicators were strongly correlated with age and sex, we used the Chinese Children Growth Standards, a growth reference for various ages and sexes proposed by Li et al [14] that is based on a 9-city pilot study to remove the impact of age and sex.

The Chinese growth standards, rather than World Health Organization (WHO) standards, were adopted here because Chinese children were not included in the growth studies that are the basis of the WHO standards, and the growth curve of Chinese adolescents is quite different from that of other countries. After standardization, these values can be compared directly.

2.4. *Dietary assessment and food grouping*

The CHNS developed 2 parallel approaches to measure food consumption: the household food inventory change and the individual 24-hour recall data. The former was measured by calculating changes in the home food inventory for 3 consecutive days, randomly allocated from Monday to Sunday. All foods and condiments were carefully recorded and measured at the beginning and end of the 3-day survey period, no matter if they were purchased from markets or picked from the participants' own gardens. Meanwhile, individual food consumption for the same 3 days was also recorded for all household members by trained field interviewers. Interviewers recorded the type and amount of food consumed, the type of meal (breakfast, lunch, or supper), and the place of consumption of all food items during the 24-hour period of the previous day with the help of food models and picture aids. Food consumption of children younger than 12 years was measured by asking the mother or a mother substitute who prepared the food in the household. The amount of individual food intake was estimated by the proportion each person consumed of the total amount prepared. This was used to adjust the individual food consumption estimated from the household food inventory change. More details about dietary data measurement can be found elsewhere [1].

To calculate nutrient intake, the China Food Composition second edition [15] was adopted to convert the detailed food consumption data into intake of carbohydrate, protein, fat, iron, calcium, zinc, and manganese [16]. Moreover, the edible proportion of each food item was also used in the conversion to ensure that the calculated nutrient intake was the actual level of nutrition consumed, not the nutrient availability. Meanwhile, the intakes of energy, protein, fat, carbohydrate, iron, calcium, zinc, and manganese were normalized using the referenced nutrient intake or average intake proposed by the *Chinese Dietary Reference Intake Handbook*. After normalization, these indicators could be directly compared, regardless of age and sex. We further summed the nutrient intake from all consumed food products to generate the individual nutrient intake per day. Individual dietary variables were categorized into several food groups, according to the China Food Composition second edition [12]. Further description of the food group classification is presented in Supplemental Table S1.

2.5. *Statistical analyses*

We set children with both parents as the reference group for statistical comparison. Descriptive statistics were presented for the continuous data as means ± SD and categorical variables as percentages. To compare the growth status and nutritional indicators of SPC and BPC, *t* tests were applied for continuous variables and χ^2 tests were applied for categorical variables. In addition, the Holm-Bonferroni correction of the *P* values was applied when multiple comparisons (MC or FC) were made against the BPC.

Because social demographic factors can also influence children's growth and nutrition intake, we controlled for the household head's education (years), family income (renminbi/year), number of siblings, year of survey, and region (place of residence) in regression models. Well-educated people might care more mindful their children's nutrition and health, whereas more siblings could mean fierce competition for family resources, and higher income can relax the budget constraints of the family. Because some children were surveyed more than once during the 4 waves, panel data models such as a random-effects generalized least-square regression (GLS) model and a fixed-effects model should be adopted to estimate if unobserved time-invariant individual effects exist [17]. However, because more than two-thirds of the children (2186) were only surveyed once, the fixed-effects model was not appropriate because it only used within-group variation. Therefore, both the pooled regression model and random-effects model were adopted in our estimations. If the unobserved time-invariant individual effects were detected by the Lagrange multiplier (LM) test, the random-effects model was preferred; otherwise, the pooled regression model was chosen [17]. Only the results from the preferred model determined by the LM test were displayed. The Free Statistics Calculator (version 4.0) was adopted to conduct the power analysis and determine sample size. Using medium effect size (0.15), the desired statistical power level was 0.8 and the probability level was .05. The minimum required sample size was 187, which is much smaller than our sample size.

To test the robustness of the findings, a more flexible semiparametric model was also adopted to test whether the growth status and nutrition indicators of SPC were significantly different from those of BPC. Both nonparametric and semiparametric models were used to investigate the relationship between growth status and nutritional factors. Compared with the parametric model, these models were more flexible and robust because they have no assumptions about functional form of some variables [18-20]. In this study, we adopted the widely used kernel density estimation and the partial linear model. All statistical analyses were conducted using Stata version 12 (StataCorp, College Station, TX, USA), and the statistical significance level was set at $P < .05$ (2-sided).

3. Results

3.1. *Characteristics of the participant groups*

The descriptive statistics of the raw growth indicators between BPC and SPC are displayed in the upper part of Table 1, and the normalized values with standard deviation are presented beneath the original values in Table 1. Single-parent children were significantly shorter and lighter than BPC ($P < .05$) at the absolute values. After normalization, the

Table 1 – Characteristics of the study participants

		Both parents	Single-parent	Fatherless	Motherless
Original values	No. of participants	2510	457	318	139
	Age (y)	11.7 ± 3.5	11.4 ± 3.2	11.3 ± 3.2 [b]	11.8 ± 3.3
	Male (%)	52.0	48.4	45.6	54.7
	Height (cm)	146.1 ± 18.3	143.8 ± 17.2 [a]	144.0 ± 17.3	143.3 ± 17.1
	Weight (kg)	39.9 ± 14.5	37.6 ± 13.3 [a]	37.8 ± 13.5 [b]	37.3 ± 12.9 [b]
Standardized values by age and sex	BMI (kg/m^2)	18.1 ± 3.5	17.6 ± 3.42	17.6 ± 3.3	17.7 ± 3.6
	Height	1.03 ± 0.07 [c]	1.02 ± 0.07 [a, c]	1.02 ± 0.07 [c]	1.00 ± 0.07 [b]
	Weight	1.00 ± 0.23	0.97 ± 0.20 [a, c]	0.99 ± 0.20	0.93 ± 0.18 [b,c]
	BMI (kg/m^2)	1.02 ± 0.18 [c]	1.01 ± 0.18	1.02 ± 0.17	1.00 ± 0.20

Values are expressed as means ± SD. The Chinese children growth standards at each age-sex cohort are used to standardize growth indicators for all children.

[a] t Test was used to compare the difference between BPC (n = 2510) and SPC groups (n = 457). Statistically significant difference ($P < .05$) was detected.

[b] t Test was used to compare the difference between fatherless (n = 318)/motherless (n = 139) and both-parent group, individually. Statistically significant difference was detected. The P value was corrected by Holm-Bonferroni correction; $P_1 < .025/P_2 < .05$ was considered statistically significant.

[c] Statistically significant difference ($P < .05$) between these values and 1 was detected using t test.

differences in growth status remained. In addition, MC were even shorter and lighter in comparison with BPC. Meanwhile, a simple comparison between standardized value and 1 shows that the heights of BPC and FC were significantly higher than 1 (all $P < .05$), whereas the weights of SPC were significantly lower than 1 (all $P < .05$). The frequency distribution of height and weight is demonstrated in Supplemental Fig. S1 using a probability density curve. We found a similar shape of the density curve for the groups, whereas the motherless group was concentrated to the left (the proportions of children with normalized height values greater than mean + 2 SD were 2.87% for BPC and 1.44% for MC, and the proportions of weight were 4.54% for BPC and 1.44% for MC, indicating that the difference was due the entire shifting of all groups.

3.2. *Intake levels of macronutrients and micronutrients of the participants*

The comparison of nutrient indicators between BPC and SPC are presented in the first 2 columns of Table 2, and the normalized values with standard deviation are presented beneath the original values in Table 2. Intake of protein and fat was much less in SPC in comparison with BPC; however, after removing the effect of age and sex, the differences were diminished. It should be noted that the normalized protein intake of MC remained significantly lower than that of BPC (0.82 ± 0.31 vs 0.89 ± 0.31, $P < .05$). Results also showed that all children, whether SPC or BPC, had significantly lower intakes of energy, protein, fat, iron, calcium, and zinc (all $P < .05$) and a significantly higher intake of carbohydrate and manganese (all $P < .05$) than the referenced intake.

3.3. *Association of standardized height, weight, BMI, macronutrients, and micronutrients with socioeconomic variables in the study participants*

The aforementioned results might be biased by socioeconomic status. To address this, the data were adjusted to account for socioeconomic variables such as the household head's education, the number of siblings, and household income. Table 3 only presents the results of the appropriate parametric model according to the LM test (Supplemental Table S2). After this adjustment, the motherless status of children was still a significant predictor of growth status (Table 3). Motherless children tended to be shorter ($\beta = -0.010$, $P = .08$) and lighter ($\beta = -0.032$, $P = .03$) than their counterparts in both-parent families. The comparison of nutrient intake was similarly conducted by controlling for socioeconomic factors, and in this case, all of the associations were attenuated. Protein intake was lower compared with BPC ($\beta = -0.050$, $P = .08$), but this difference did not reach statistical significance. However, no difference was detected between the FC and BPC.

3.4. *Association of fish, meat, egg, dairy, animal- or vegetable-source protein, iron, and zinc with socioeconomic variables in the study participants*

We further distinguished animal-source protein from vegetable-source protein because the former was usually termed as "high-quality" protein and important for the children's growth [21]. Moreover, the bioavailability of zinc and iron is much higher in animal-source foods, and thus, the animal and vegetable sources of protein, iron, and zinc were further analyzed (Table 4). As expected, the intakes of animal-source protein, iron, and zinc were significantly lower in MC in comparison with BPC ($P = .02$, $P = .01$, and $P = .03$, respectively). However, no difference was detected between these 2 groups for vegetable-source foods. In addition, no difference was detected between FC and BPC.

To find out which nutrients contributed to the disparity of animal-source foods, we further investigated the difference in intake of major animal-source foods, including fish, meat (including poultry), eggs, and dairy products. The results showed that MC had significantly lower consumption of fish ($\beta = -6.640$, $P = .04$) and meat ($\beta = -10.619$, $P = .04$) than their BPC counterparts, after adjustment for all other socioeconomic variables. Here, fish refers to all fish and its associated foods, such as shellfish and mollusks. Intriguingly, we also found significantly higher intake of eggs ($\beta =$

Table 2 – Intake levels of macronutrients and micronutrients in the study participants

		Both parents	Single-parent	Fatherless	Motherless
Original values	No. of participants	2510	457	318	139
	Energy (KJ/d)	5285.5 ± 2037.1	5280.6 ± 2126.1	5225.4 ± 2147.0	5407.3 ± 2079.3
	Protein (g/d)	45.8 ± 18.0	43.7 ± 17.6 [a]	43.9 ± 18.2	43.0 ± 16.3
	Fat (%E)	27.8	25.6 [a]	25.3 [b]	26.3
	Carbohydrate (g/d)	218.4 ± 95.0	220.8 ± 102.8	217.9 ± 102.8	227.3 ± 102.9
	Iron (mg/d)	13.4 ± 5.9	13.1 ± 6.0	13.1 ± 6.1	13.2 ± 5.8
	Calcium (mg/d)	250.2 ± 144.8	249.8 ± 139.5	247.2 ± 136.1	255.8 ± 147.4
	Zinc (mg/d)	7.4 ± 2.9	7.3 ± 2.8	7.3 ± 2.9	7.3 ± 2.8
	Manganese (mg/d)	4.1 ± 2.1	4.1 ± 2.0	4.1 ± 2.0	4.2 ± 2.2
Standardized values by *Chinese Dietary Reference Intake Handbook* 2013	Energy	0.60 ± 0.21 [c]	0.60 ± 0.23 [c]	0.60 ± 0.24 [c]	0.60 ± 0.21 [c]
	Protein	0.89 ± 0.34 [c]	0.86 ± 0.36 [c]	0.88 ± 0.37 [c]	0.82 ± 0.31 [b,c]
	Fat	0.42 ± 0.27 [c]	0.39 ± 0.27 [c]	0.39 ± 0.27 [c]	0.40 ± 0.27 [c]
	Carbohydrate	1.60 ± 0.67 [c]	1.61 ± 0.73 [c]	1.59 ± 0.74 [c]	1.65 ± 0.73 [c]
	Iron	0.90 ± 0.40 [c]	0.89 ± 0.41 [c]	0.89 ± 0.41 [c]	0.89 ± 0.40 [c]
	Calcium	0.25 ± 0.15 [c]	0.24 ± 0.14 [c]	0.24 ± 0.14 [c]	0.24 ± 0.14 [c]
	Zinc	0.88 ± 0.33 [c]	0.86 ± 0.33 [c]	0.87 ± 0.34 [c]	0.84 ± 0.30 [c]
	Manganese	1.12 ± 0.53 [c]	1.14 ± 0.54 [c]	1.15 ± 0.54 [c]	1.14 ± 0.55 [c]

Values are expressed as means ± SD. The Chinese reference intakes for each age-sex cohort are used to standardize nutrient intake for all children.

[a] *t* Test was used to compare the difference between BPC (n = 2510) and SPC groups (n = 457). Statistically significant difference ($P < .05$) was detected.

[b] *t* Test was used to compare the difference between fatherless (n = 318)/motherless (n = 139) and both-parent group, individually. Statistically significant difference was detected. The *P* value was corrected by Holm-Bonferroni correction; $P_1 < .025/P_2 < .05$ was considered statistically significant.

[c] Statistically significant difference ($P < .05$) between these values and 1 was detected using *t* test.

5.362, $P < .01$) in the fatherless group when compared with the both-parent group.

To achieve a better interpretation of the apparent positive relationship between protein intake and height and weight, a kernel density estimation and a partial linear model were conducted to verify the direct relationship between height and protein (Supplemental Fig. S2). Both estimations found an upward sloped curve between these 2 indicators, which indicates that high levels of protein intake will support a favorable growth status.

Results of a sensitivity analysis (semiparametric multivariable regression) are presented in Supplemental Table S3 and Supplemental Table S4. In general, the findings are consistent with those of parametric models, indicating that our results are robust.

Table 3 – Association of standardized height, weight, BMI, macronutrients, and micronutrients with socioeconomic variables in the study participants (n = 2932)

	Height	Weight	BMI	Energy	Protein	Fat	Carbohydrate	Iron	Calcium	Zinc	Manganese
Household head's educational level	0.001 [a] (.02) [b]	0.002 (.01)	0.001 (.34)	0.001 (.19)	0.003 (.02)	0.004 (<.01)	0.000 (.96)	0.002 (.13)	0.002 (<.01)	0.002 (.14)	−0.002 (.25)
No. of siblings	−0.008 (<.01)	−0.017 (.02)	−0.011 (.12)	−0.006 (.48)	−0.026 (.07)	−0.038 (<.01)	0.014 (.61)	−0.019 (.27)	−0.002 (.75)	−0.008 (.58)	0.021 (.33)
Family income	0.005 (<.01)	0.008 (.01)	0.003 (.40)	0.011 (.01)	0.027 (<.01)	0.026 (<.01)	0.007 (.57)	0.007 (.38)	0.010 (<.01)	0.023 (<.01)	−0.004 (.66)
Motherless	−0.010 (.08)	−0.032 (.03)	−0.006 (.67)	−0.006 (.73)	−0.050 (.08)	0.006 (.79)	0.019 (.73)	−0.007 (.83)	0.007 (.57)	−0.045 (.11)	−0.028 (.52)
Fatherless	−0.001 (.88)	−0.004 (.71)	−0.005 (.65)	0.003 (.78)	−0.003 (.89)	−0.007 (.66)	0.000 (1.00)	0.004 (.88)	−0.005 (.54)	−0.007 (.72)	0.011 (.73)
Year dummies [c]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies [c]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F test [d]	418.2 (<.01)	509.7 (<.01)	202.4 (<.01)	17.5 (<.01)	15.4 (<.01)	465.8 (<.01)	26.3 (<.01)	296.2 (<.01)	14.7 (<.01)	15.0 (<.01)	579.1 (<.01)

[a] All values are regression coefficients. Analysis was conducted using GLS or pooled regression.

[b] All values are *P* values.

[c] Year and regional dummies are used to control unobserved time-variant common factors and time-invariant factors.

[d] Significance test for the whole model.

Table 4 – Association of fish, meat, egg, dairy, animal or vegetable source protein, iron, and zinc with socioeconomic variables in the study participants

	Protein_a [a]	Protein_v [b]	Iron_a	Iron_v	Zinc_a	Zinc_v	Fish	Meat	Egg	Dairy
Age	0.324 [c]	1.102	0.039	0.440	0.038	0.203	0.484	2.043	0.185	−0.781
	(<.01) [d]	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(.01)	(<.01)	(.20)	(.02)
Sex	2.084	2.765	0.265	0.822	0.252	0.501	2.261	12.005	2.099	−0.259
	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(.09)	(<.01)	(.03)	(.91)
Household head's educational level	0.268	−0.054	0.040	−0.003	0.034	−0.010	0.154	1.335	0.491	0.659
	(<.01)	(.26)	(<.01)	(.87)	(<.01)	(.22)	(.31)	(<.01)	(<.01)	(.01)
No. of siblings	−1.676	0.596	−0.153	0.231	−0.217	0.162	−1.976	−8.305	−1.207	−5.702
	(<.01)	(.24)	(.04)	(.30)	(<.01)	(.07)	(.22)	(<.01)	(.31)	(.03)
Family income	1.385	−0.023	0.180	−0.088	0.184	0.003	1.958	6.687	1.150	5.127
	(<.01)	(.92)	(<.01)	(.37)	(<.01)	(.94)	(<.01)	(<.01)	(.02)	(<.01)
Motherless	−2.091	0.352	−0.396	0.156	−0.289	0.013	−6.640	−10.619	1.630	0.058
	(.02)	(.73)	(.01)	(.73)	(.03)	(.94)	(.04)	(.04)	(.49)	(.99)
Fatherless	−0.179	−0.280	−0.054	0.123	−0.022	0.014	−3.650	−3.469	5.362	3.128
	(.78)	(.70)	(.61)	(.70)	(.81)	(.91)	(.10)	(.33)	(<.01)	(.40)
Year dummies [e]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies [e]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F test [f]	1119.6	42.5	25.2	25.2	892.0	41.5	15.5	986.8	10.9	22.2
	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)

[a] a means animal source. There are 2932 measurements.
[b] v means vegetable source.
[c] All values are regression coefficients. Analysis was conducted using GLS or pooled regression.
[d] All values are *P* values.
[e] Year and regional dummies are used to control unobserved time-variant common factors and time-invariant factors.
[f] Significance test for the whole model.

4. Discussion

Chinese children growth standards, rather than WHO growth standards, were adopted in this study to normalize growth indicators of children from different family structures, because the growth curve of Chinese adolescents is different from the one presented by WHO. In particular, the Chinese growth curve has a higher height standard than the WHO one for girls younger than 13 years and boys younger than 15 years, whereas it has a lower height standard for older children. After normalization, the height of BPC and FC was slightly and significantly higher than 1, whereas the weight of SPC was slightly and significantly lower than 1, indicating that the children are on average taller but lighter than their counterparts at the same age and with the same sex. However, normalized nutrient intake was significantly smaller than 1 except for carbohydrate and manganese, which might be attributed to measurement error in calculating individual food consumption and nutrient intake. More importantly, we detected a particularly stunted growth status in MC in China compared with children with 2 parents, after standardization. A plausible reason for the retarded growth status of MC might be the lower intake of protein, iron, and zinc from animal-source foods, which were significantly lower in the motherless group in comparison with BPC. However, no significant difference of growth status between FC and BPC was detected.

Various socioeconomic factors, such as income, the number of siblings, the educational levels of parents, and regional and time variations, might also influence children's height [12,22,23]. Furthermore, several previous studies showed that birth weight and parents' height (especially the mother's height) affect children's height as well [11,23]. In the present study, we also found that family income, the household head's educational level, the number of siblings, and time and regional variations are key determinants of children's height. After controlling for these socioeconomic factors, MC still had a deficient growth status compared with BPC in the present study. Therefore, the first hypothesis was confirmed but applied only to MC. Meanwhile, our results are also in line with the second hypothesis which states that MC are affected differently from FC. The possible reason for the different impact of the absence of the mother and father might be that the mother dominates the kitchen and prepares food for the whole family in a traditional Chinese family; thus, the loss of a mother has a significant impact on children's nutrition and growth [24]. In addition, some studies also highlight that breast-feeding and complementary feeding in the first 2 years play an important role in children's growth [25], whereas others show that adverse emotion decelerates the growth status of children as well [26]. However, this survey did not study these relevant factors. Therefore, we believe that there are still some unmeasured factors that may also contribute to the lower growth status of MC observed in this study.

In this study, we documented a plausible reason for growth failure in MC in terms of nutrition. The current literature supports that one of the major determinants of children's growth is protein intake, particularly high-quality protein such as meat, fish, eggs, and their related products [22,27]. Our results are consistent with the findings from previous studies in Korea [28] and Guatemala [29,30]. As mentioned, in a traditional Chinese family, the mother dominates the kitchen and prepares food for the whole family [24]. Conversely, in a motherless family, the children's diet is usually prepared by their fathers or grandparents and are less likely to cook dishes such as meat and fish for children. Interestingly, in our present study, we found that intake of eggs in children of the fatherless group was significantly higher than that of the BPC, indicating that single mothers used eggs to compensate for the lower intake of fish.

Other micronutrients, such as calcium, iron, zinc, and manganese, might also affect children's height [16,31-33]. No discrepancy was detected for total iron and zinc between the groups of children. The possible reason for the lack of a positive association between total iron or zinc and parental status might be that iron and zinc exist in many other foods, such as staple foods (i.e., rice, flour, and vegetables) in addition to animal-source foods, and vegetable foods are the main source of iron and zinc in Chinese residents [34]. Thus, no differences in iron and zinc amounts consumed were detected among total-source foods. To further elucidate this issue, protein, iron, and zinc from animal- or vegetable-source foods were analyzed as well. We did find that the intake of protein from animal-source foods was significantly lower in MC in comparison with that of BPC. Meanwhile, iron and zinc from animal sources were significantly lower in the motherless group compared with the BPC group, which is in line with the observed lower intake of meat and fish. These findings also confirmed the third hypothesis that the growth disparity between SPC and BPC might be attributed to the deficient nutrient intake. These animal-source foods are known to contain high-quality protein and highly bioavailable micronutrients, including these so-called problem nutrients, such as iron and zinc. In addition, the average intake of calcium was significantly lower than the Chinese referenced nutrient intake level in all groups. This might be attributed to the low consumption of dairy products, such as cheese and milk, which are the main sources of calcium in the typical Chinese diet. Nonetheless, all individual nutrient intakes were calculated using the same food-nutrient conversion table, which assumes an identical absorbance rate of nutrients for all children. However, the absorbance rates of iron could be affected by other nutrients, such as calcium [35], polyphones [36], ascorbic acid [37], and muscle tissue [38,39]. In addition, the absorbance of iron is influenced by other host factors, such as inflammation and obesity [40-42]. Hence, to understand this dynamic, further research that uses tools such as biomarker analyses (serum ferritin) needs to be performed.

Our study has several limitations. First, although other factors such as the length of being parentless, the reason for becoming parentless, the principal caregiver, the weight at birth of the child, and the mother's height might also affect children's growth status, these factors were not investigated in the survey. Future research should be designed to collect such data to deepen our understanding of the impact of parentless on children's growth. Second, we ignored the heterogeneity in the absorbance rate of nutrients across individuals. Therefore, the detected difference for macronutrients and micronutrients refers to different intake levels rather than absorbed levels. To further elucidate the "real" impact of nutrition on growth status, biomarker analyses such as blood tests for iron or ferritin need to be performed. Third, our study is a cross-sectional study. We did not get the period of the parent's absence; hence, we cannot draw a causal relationship between protein intake and growth status. Fourth, although the total number of families included in the analysis was more than 3000, the number of MC was quite small at only 139, and this would have reduced the power of the analysis.

Despite these limitations, our study still has several strengths. To our knowledge, this was the first study on micronutrients and the growth status of SPC in China. In addition, we separated MC from FC and compared their growth and nutrition status with BPC separately. Moreover, we used a combination of stringent statistical methods to investigate the association between nutrient intakes and growth status for children in different parental groups.

Our study highlights that the growth status of children is positively correlated with protein intake, especially high-quality protein intake. Although the prevalence of malnutrition in children declined significantly along with the successful economic development of China over recent years [43,44], children in single-parent families still need special attention. To help children in remote areas access basic nutrition, the Chinese government implemented school meal programs in 2011. Future research should try to estimate the role of these programs in eliminating undernutrition and the effect they have on improving the nutritional status of vulnerable groups such as SPC.

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Zhibin Hu conceptualized and designed the study, revising it critically for important intellectual content. Xu Tian and Shaowei Wu coordinated and supervised data collection, carried out the initial analyses, and reviewed and revised the manuscript. Hui Wang corrected the data analyses, drafted the manuscript, and critically reviewed the manuscript. All authors read and approved the final manuscript. No author declared a conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.nutres.2016.11.005.

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