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# Monetary diet cost is positively associated with diet quality and obesity: an analysis of school-aged children in Southwest China

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## ABSTRACT

**Background** Little is known about the relationships between diet cost, dietary intake and obesity in Chinese populations. This study explored how diet cost was related to diet quality and obesity among school-aged children in Southwest China.

**Methods** Data from a cross-sectional study was analysed. Diet cost was estimated based on dietary intake assessed with 24-h dietary recalls and retail food prices. Diet quality was measured using the Chinese Children Dietary Index. Body height, weight, waist circumference and skinfold thicknesses were measured, and their body mass index standard deviation score (BMISDS), waist-to-height ratio (WHtR), fat mass index (FMI) and fat-free mass index (FFMI) were calculated. Multivariate regression models were used to explore the relevance of diet cost to diet quality and obesity.

**Results** After adjustment for potential confounders, a positive association was observed between diet quality and energy-adjusted diet cost ($\beta = 0.143$, 95% confidence interval, CI: 0.014–0.285, $P_{for\text{-}trend} = 0.0006$). Energy-adjusted diet cost also showed a positive association with FMI ($\beta = 0.0354$, 95% CI: 0.0001–0.0709, $P_{for\text{-}trend} = 0.01$), BMISDS ($\beta = 0.0200$, 95% CI: 0.0006–0.0394, $P_{for\text{-}trend} = 0.002$) and WHtR ($\beta = 0.0010$, 95% CI: 0.0003–0.0017, $P_{for\text{-}trend} = 0.02$).

**Conclusions** Energy-adjusted diet cost was independently and positively associated with diet quality and obesity among Chinese school-aged children.

**Keywords** Chinese children dietary index, diet cost, diet quality, obesity

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## Introduction

Childhood obesity is becoming an increasing public health challenge worldwide. China is also facing this epidemic, with the prevalence of obesity in Chinese adolescents increasing from 0.13% in 1985 to 4.95% in 2010,[1] with some longitudinal studies showing even higher rates.[2] Not only has childhood obesity been reported to induce multiple developmental problems, including poor cognitive function[3] and altered pubertal progression,[4] it has also been shown to be a risk factor for adult diabetes mellitus,[5] hypertension[6] and mortality.[7] Therefore, many studies have focused on elucidating the factors associated with childhood obesity.[8–11]

Increasing evidence has suggested that a healthy diet with high food quality may play a critical role in preventing childhood obesity.[12,13] Choosing healthy foods and the implementation of a healthy diet are usually influenced by the cost of the food,[14] where a positive correlation between diet cost and quality has been established in several observational studies.[15–20] However, the direct association between diet cost and obesity and the potential mediating role of diet quality has yet to be elucidated. To date, only a limited number of studies, which were conducted in Spain[21,22] and Japan,[23,24] have evaluated the relationship between diet cost and adulthood obesity. However, studies examining this association in children are still missing. Moreover, all of the existing studies were conducted in developed countries. Given that diet cost may influence children differently than adults and food prices and dietary habits are vastly different between developed and developing countries, a study examining the effects of diet cost on diet quality and childhood obesity in developing countries is urgently needed to promote healthy food consumption and prevent childhood obesity worldwide.

This study aimed to (i) investigate whether freely chosen diet costs were related to diet quality and obesity in a group of school-aged children and (ii) to examine whether diet quality was a possible mediator between diet cost and obesity.

## Methods

### Study design and population

This study was based on a cross-sectional dietary survey conducted in Southwest China, namely The Dietary Quality During Childhood (DQDC) study, in which 2 043 children aged 7–15 years were recruited in 2013 and information was collected on anthropometrics, diets and lifestyles. Details of the DQDC survey can be found elsewhere.[25] Among the recruited children, 268 had incomplete dietary data. Exclusions were made when basic sociodemographic information or outcome variables were missing ($n$ = 105), dietary data were incomplete ($n$ = 268), or energy intakes were implausible ($n$ = 65).[26] As a result, 1605 participants qualified for and were included in these analyses. The study was approved by the Ethics Committee of the Sichuan University on 5 March 2012 and was performed with assent from children and written informed consent from parents.

### Dietary assessment

Data on dietary intake were collected using a validated 24-h dietary recall survey[27] conducted three times on days that were randomly selected from within a 10-day period by trained investigators. Each participant performed the dietary recall surveys on 2 weekdays and 1 weekend day. For the dietary recall, participants were asked to report types, brands and amounts of all foods and beverages consumed in the preceding 24 h. Information on food consumption was provided by parents for children younger than 9 years of age but provided by the children themselves for those children older than 8 years of age. Standard serving bowls, plates and glasses were used to assist participants with estimating portion-sizes. Additionally, participants were provided with an album containing photos of commonly consumed snacks and beverages. Data on dietary intake from the 24-h recalls were converted to nutrient intakes using the China Food Composition Table derived from the NCCW software (version 11.0, 2014).[28]

Trained investigators also conducted face-to-face interviews to collect information on eating behaviours using a validated questionnaire that included whether participants frequently consumed breakfast (at least 5 days a week) and regularly had dinner with their parents (at least 5 days a week).

### Other variables

Sedentary time (h/day) was calculated from the participants' self-reported data on time spent doing sedentary activities (i.e. doing homework, using a computer, watching television) for weekdays and weekends. Physical activity was computed as the average metabolic equivalent-hours per day (MET-h/day), based on participants' self-reported information about the frequency and duration of different activities they performed (i.e. walking, doing housework, sports) over the previous year.[29]

A questionnaire was given to parents to obtain birth characteristics and sociodemographic data about the children, including information on birth weight, family location, household income, parental education level, and parental height and weight.

### Measurement of diet quality

The Chinese Children's Dietary Index (CCDI) was used to measure the diet quality of participants. The CCDI follows the Chinese dietary intake recommendations and incorporates 16 components including grains, vegetables, fruits, dairy and dairy products, soybeans and soy products, meat, fish and shrimp, eggs, drinking water, sugar-sweetened beverages, vitamin A, fatty acids, fibre, dietary variety, regularly having breakfast or dinner with parents, and energy balance. Each component contributed 0–10 points to the total CCDI score. Children who consumed appropriate types and amounts of foods or nutrients and engaged in health-promoting behaviours received full points for each component (i.e. 160 points). Therefore, the range of CCDI scores was 0–160, with a higher score indicating better diet quality. The development and calculation of the CCDI have been described in detail previously.[25]

### Diet cost calculation

The cost of each food was determined by multiplying the average amount of food consumed per day (g/day) with the unit price. The diet cost was calculated by summing the cost of each food.

All foods reported in the dietary recall surveys were converted into purchasable forms. Mixed dishes were divided according to their ingredients and converted into purchasable forms. For example, a serving of tomato omelette was broken down into two separate ingredients: tomato and egg. For some processed foods (i.e. Chinese Tangyuan), ingredients were analysed from the food package labels. Ultimately, ~605 food and beverage items were analysed.

The price of each food item was initially obtained from the Chengdu Municipal Development and Reform Commission website.[30] This website lists the prices of routine foods every month from each district in Chengdu. The mean unit prices for 66 of the items (10.9% of the total) were calculated by averaging the monthly prices from different districts over the past 12 months. For 349 (57.7%) food items that lacked officially announced prices, the unit price was obtained from two supermarkets and three farmers' markets in Chengdu selected through random sampling. The price survey was conducted in each quarter of the year, and the average annual unit price for each item was calculated by averaging the prices of the four quarters. For 155 (25.6%) packaged foods, the median package size was typically selected and unit prices were collected from the aforementioned supermarkets. Unit prices of 16 (2.7%) fast food items were taken from fast food restaurants (Kentucky Fried Chicken, McDonalds and DICOS in Chengdu, Southwest China). Alcoholic beverages and drinking water were excluded from the calculation. Discounted prices were not used to determine the food costs. For 19 (3.1%) food items that did not have obtainable prices, substitutions were made for similar food items. For example, the price of turkey was substituted with the price of chicken.

All food prices were adjusted for food preparation and waste (i.e. peeling of vegetables and fruits, removal of bones from pork ribs) using the China Food Composition database.[28] Prices were expressed in Chinese Yuan (CNY, ¥) (1 CNY = 0.138 Euros = 0.145 US dollars on 2 March 2017) per 100 g. Since monetary diet cost was observed to be strongly associated with energy intake ($\gamma = 0.69$), diet cost per 1000 kcal of energy intake per day (hereinafter, energy-adjusted diet cost) was calculated by dividing the daily diet cost (CNY/day) by the energy intake per day (kcal/day) and multiplying by 1000.

### Anthropometrics

Anthropometric measurements were performed by trained investigators according to standard procedures.[31] To obtain comparable measurements, children were required to remove their shoes and undress down to their underwear. Girls were also asked to take their hair down. Standing height and weight were measured in duplicate to the nearest 0.1 cm and 0.1 kg using an Ultrasonic Height and Weight Instrument (DHM-30; Dingheng Ltd.). Waist circumference at the umbilicus[32] was measured in duplicate to the nearest 0.1 cm using a measuring tape. Skinfold thickness was measured on the right side of the body at the tricep and subscapular sites to the nearest 0.1 mm using Holtain calipers (Holtain Ltd., Crymych, UK). All instruments were calibrated regularly, and the investigators conducting the anthropometric measurements were subject to regular quality controls checks.

For the anthropometric analyses, body mass index (BMI) was calculated as weight (kg) divided by the square of height ($m^2$). An age- and gender-specific BMI standard deviation score (BMISDS) was calculated based on Chinese reference curves.[33] Percentage body fat (%BF) was calculated using the Slaughter equations[34] and was used to derive the fat mass index [FMI; (weight × %BF)/height$^2$] and fat-free mass index [FFMI; weight-(weight × %BF)/height$^2$].[35] Additionally, the waist-to-height ratio (WHtR) was estimated by dividing waist circumference (cm) by height (cm).

### Statistical analysis

All statistical analyses were carried out using SAS software (versions 9.3, 2011). Mean energy-adjusted diet costs and CCDI scores in population sub-groups were calculated.

Analyses used *t*-tests for normally distributed continuous variables, Wilcoxon rank sum tests for non-normally distributed continuous variables, and chi-square tests for categorical variables. All calculated *P*-values were two-tailed and were considered statistically significant at <0.05 for single variables and <0.1 for interaction terms.

The relationship between the energy-adjusted diet cost and CCDI score was investigated first. Multivariate linear models were used to provide covariate-adjusted means of energy-adjusted diet costs among strata of the CCDI score. Covariates included age (years), gender (male or female), family location (urban or rural), parental education level (≥12 or <12 years) and family income level (low or high). Family income level was considered high when the annual income was above ¥35 000 per person according to the National Bureau of Statistics of China.[36] Due to an age-differentiated association between the energy-adjusted diet cost and CCDI score ($P = 0.04$), the interaction of age and CCDI score was also included in the adjusted model.

The association between energy-adjusted diet cost and body composition was also evaluated. Energy-adjusted diet cost was used as an independent variable while FMI, FFMI, BMISDS and WHtR were used as dependent variables. Multivariate regression models were used and the results were adjusted for age (years), gender (male or female), energy (kcal/day), physical activity (MET-h/day), birth weight (kg), family location (urban or rural), parental education level (≥12 or <12 years), parental BMI (kg/m$^2$) and family income level (low or high).[36]

Since dietary quality was shown to be associated with both diet cost[15,17,21,37] and obesity,[25,38–40] a mediation model adjusted for dietary quality (measured by CCDI score) was utilized to determine whether dietary quality was a possible mediator in the relationship between energy-adjusted diet cost and obesity.

## Results

There were no significant differences in the distributions of gender, age, family location or family income level between the children who excluded due to missing data and the children used in the study (data not shown).

The general characteristics of the children included in the study are presented in Table 1. Approximately half of the children were female. The average age of the children was 9.9 years old. The mean CCDI score of the subjects was 88.9 ± 15.1 and the mean energy-adjusted diet cost was ¥11.00 per 1000 kcal.

**Table 1** General characteristics of 1 605 participants aged 7–15 years in the Diet Quality During Childhood Study, 2013[a]

| *Characteristics* | *Values* |
|---|---|
| Female, % | 48.4 |
| Age, y, medians (P25, P75) | 9.9 (8.4, 11.6) |
| Urban, % | 69.1 |
| Time spend in sedentary behaviours, h/day, medians (P25, P75) | 2.7 (1.7, 4.1) |
| Father educated at least 12 y, % | 25.7 |
| Mother educated at least 12 y, % | 20.1 |
| Family income per person > ¥35 000 per year, % | 24.8 |
| CCDI, means ± standard deviation | 88.9 ± 15.1 |
| Dietary cost, CNY /1000 kcal[b], medians (P25, P75) | 11.00 (9.20,13.40) |
| Overweight/obesity[c], % | 16.9 |

P25–P75, 25th–75th percentile; CCDI, Chinese Children Dietary Index Score.

[a]Values are means ± standard deviation, medians (P25, P75) or frequency.

[b]Calculated by dividing the estimated daily diet costs (CNY/day) by the energy intake per day (kcal/day) and multiplying by 1000. 1 CNY = 0.138 Euros = 0.145 US dollars on 2 March 2017.

[c]Defined according to the Working Group on Obesity in China (WGOC) criteria.

The energy-adjusted diet costs and CCDI scores were calculated for each population strata (Table 2). In general, boys had lower diet costs ($P = 0.0001$) and CCDI scores ($P < 0.0001$) than girls. Children in urban areas had higher diet costs ($P < 0.0001$) and CCDI scores ($P < 0.0001$) relative to their rural counterparts. Both energy-adjusted diet costs ($P = 0.0003$) and CCDI scores ($P = 0.0006$) increased with paternal education level. Children whose mothers had a higher education level had higher CCDI scores ($P = 0.02$).

A significant, positive association was observed in the multivariate models ($\beta = 0.143$, $P_{\text{for-trend}} = 0.0006$) (Table 3). The energy-adjusted diet cost for children in the highest CCDI tertile was ¥12.35 per 1000 kcal, which was ¥1.19 higher than those in the lowest CCDI tertile after adjusting for potential confounding factors. With each 1-point increase in CCDI score, the diet cost increased ¥0.14 per 1000 kcal.

Associations between the energy-adjusted diet cost, body composition and obesity were examined (Table 4). After adjusting for age, gender, energy, physical activity, birth weight, family location, parental education level, parental BMI, and family income level, energy-adjusted diet cost was positively associated with FMI ($\beta = 0.0354$, $P_{\text{for-trend}} = 0.01$), BMISDS ($\beta = 0.0200$, $P_{\text{for-trend}} = 0.002$), and WHtR ($\beta = 0.0010$, $P_{\text{for-trend}} = 0.02$). These associations remained

**Tables 2** Energy-adjusted diet cost and the Chinese Children Dietary Index by demographic and sociodemographic strata among school-aged children in Southwest China

| | *Energy-adjusted diet cost (CNY/1 000 kcal)*[a] | | | *CCDI score* | | |
|---|---|---|---|---|---|---|
| | *Medians* | *P25–P75* | P *value* | *Mean* | *SD* | P *value* |
| Gender | | | | | | |
| Boys | 10.74 | 8.87–13.10 | 0.0001 | 86.0 | 14.7 | <0.0001 |
| Girls | 11.17 | 9.48–13.81 | | 91.9 | 14.9 | |
| Age groups | | | | | | |
| 7–10 y | 11.08 | 9.25–13.42 | 0.2 | 88.5 | 15.3 | 0.3 |
| 11–15 y | 10.85 | 9.10–13.32 | | 89.4 | 14.9 | |
| Family location | | | | | | |
| Urban | 11.17 | 9.46–13.59 | <0.0001 | 90.0 | 15.1 | <0.0001 |
| Rural | 10.46 | 8.63–12.98 | | 86.7 | 14.8 | |
| Paternal education level | | | | | | |
| <12 years | 10.89 | 9.02–13.28 | 0.0003 | 88.5 | 15.2 | 0.0006 |
| ≥12 years | 11.34 | 9.84–14.18 | | 91.6 | 15.0 | |
| Maternal education level | | | | | | |
| <12 years | 11.00 | 9.17–13.33 | 0.07 | 88.9 | 14.9 | 0.02 |
| ≥12 years | 11.22 | 9.67–13.79 | | 91.3 | 15.3 | |
| Family income level | | | | | | |
| ≤ ¥35 000/year/person | 11.08 | 9.21–13.42 | 0.5 | 89.5 | 14.7 | 0.7 |
| > ¥35 000/year/person | 10.96 | 9.43–13.45 | | 89.1 | 15.5 | |

CCDI, Chinese Children Dietary Index Score; P25–P75, 25th–75th percentile; SD, standard deviation.

[a]Calculated by dividing the estimated daily diet costs (CNY/day) by the energy intake per day (kcal/day) and multiplying by 1 000. 1 CNY = 0.138 Euros = 0.145 US dollars on 2 March 2017.

**Table 3** Multiple linear regression least-squares means and 95% confidence interval for the association of the Chinese Children Dietary Index scores with daily energy-adjusted diet costs (*n* = 1605)[a]

| | *Tertiles of scores on the Chinese Children Dietary Index* | | | β | $P_{for\text{-}trend}$[c] |
|---|---|---|---|---|---|
| | *T1* (n = 535) | *T2* (n = 535) | *T3* (n = 535) | | |
| Energy-adjusted diet costs[b] | | | | | |
| Unadjusted model | 10.86 (10.51, 11.21) | 11.58 (11.23, 11.93) | 12.51 (12.16, 12.87) | 0.007 (0.001, 0.054) | <0.0001 |
| Adjusted model[d] | 11.16 (10.47, 11.85) | 11.62 (11.22, 12.03) | 12.35 (11.70, 13.00) | 0.143 (0.014, 0.285) | 0.0006 |

[a]Values are model-adjusted least-squares means; 95% CIs in parentheses.

[b]Calculated by dividing the estimated daily diet costs (CNY/day) by the energy intake per day (kcal/day) and multiplying by 1 000. 1 CNY = 0.138 Euros = 0.145 US dollars on 2 March 2017.

[c]Linear trends ($P_{\text{for-trend}}$) were obtained with ordinal median energy-adjusted diet costs for each tertile as continuous variables.

[d]Adjusted for age (years), gender (boy or girl), family location (urban or rural), parental education level (≥12 or <12 years), family income level (low or high) and interaction of age and CCDI score.

significant when the potential mediator of diet quality was included [FMI ($\beta = 0.0352$, $P_{\text{for-trend}} = 0.01$), BMISDS ($\beta = 0.0190$, $P_{\text{for-trend}} = 0.01$) and WHtR ($\beta = 0.0007$, $P_{\text{for-trend}} = 0.03$)]. Neither the adjusted model nor the mediation model showed a significant association between the energy-adjusted diet cost and FFMI.

## Discussion

### Main findings of this study

Our study found that the energy-adjusted diet cost had an independent and positive association with both diet quality and obesity among school-aged children in Southwest

**Table 4** Association of energy-adjusted diet costs with FMI, FFMI, BMISDS and WHtR ($n = 1605$)

| | *Regression coefficient* | *95% Confidence intervals* | $P_{for\text{-}trend}$ |
|---|---|---|---|
| FMI | | | |
| Crude model | 0.0405 | 0.0004, 0.0810 | 0.0007 |
| Adjusted model[a] | 0.0354 | 0.0001, 0.0709 | 0.01 |
| Mediation model[b] | 0.0352 | 0.0002, 0.0704 | 0.01 |
| FFMI | | | |
| Crude model | −0.0057 | −0.0114, −0.0002 | 0.5 |
| Adjusted model[a] | 0.0090 | 0.0000, 0.0180 | 0.2 |
| Mediation model[b] | 0.0084 | −0.0001, 0.0168 | 0.2 |
| BMISDS | | | |
| Crude model | 0.0210 | 0.0001, 0.0420 | 0.0002 |
| Adjusted model[a] | 0.0200 | 0.0006, 0.0394 | 0.002 |
| Mediation model[b] | 0.0190 | 0.0002, 0.0381 | 0.01 |
| WHtR | | | |
| Crude model | 0.0006 | 0.0001, 0.0013 | 0.003 |
| Adjusted model[a] | 0.0010 | 0.0003, 0.0017 | 0.02 |
| Mediation model[b] | 0.0007 | 0.0002, 0.0014 | 0.03 |

FMI, fat mass index; FFMI, fat-free mass index; BMISDS, body mass index standard deviation score; WHtR, waist-to-height ratio.

[a]Adjusted for age (years), gender (boy or girl), energy (kcal/day), physical activity time (MET-h/day), birth weight (kg), family location (urban or rural), parental education level (≥12 or <12 years), parental BMI (kg/m$^2$) and family income level (low or high).

[b]Additionally adjusted for Chinese Children Dietary Index score.

China. Children with higher diet costs had a higher CCDI score as well as higher values of FMI, BMISDS and WHtR, independent of diet quality.

The findings from our study indicate that consumers with limited financial resources might choose foods that are relatively less healthy. This finding highlights the importance of developing a strategy to lower the price of healthy foods, especially for low-income families. These results support the promotion of healthy food consumption and obesity prevention among school-aged children in Southwest China.

## What is already known on this topic

Dietary quality can be influenced by diet cost. The positive association between diet quality and monetary diet cost among children has been observed in several developed countries.[15,16,41] In these studies, diet quality was evaluated using various indicators including dietary indices and dietary patterns. Although diet quality is an important risk factor for obesity and diet quality is related to diet cost, the association between diet cost and obesity is still unclear. To our knowledge, there have only been a small number of studies on this topic, and these studies were conducted in Spain[21,22] and Japan.[23,24] These studies reported an inverse association between diet cost and BMI. However, these previous studies were all conducted in adults, and studies focusing on the association between diet cost and obesity among children are missing.

## What this study adds

Our study adds several aspects to the existing knowledge. First, it assessed the diet quality of school-aged children using a newly developed dietary index—the Chinese Children Dietary Index, which follows current Chinese dietary intake recommendations and may reflect the diet quality of Chinese children more accurately than other foreign indices. The results imply that the diet quality of children in Southwest China is moderate and need to be improved.

Second, this study was the first to investigate the relationship between diet cost and quality among Chinese school-aged children. The positive relationship found in our study is consistent with several observational studies conducted in other countries, suggesting that for children, a healthier diet is more expensive. A German study on children and adolescents[16] found that diet cost was significantly and positively associated with diet quality. In Swedish children, a higher total score on a healthy eating index was related to a more expensive diet.[15] In Denmark, low-fat diets for children were associated with higher diet costs.[41] The reason why healthier diets cost more is likely because energy-dense foods are usually cheaper, when measured by cost per kilojoule,[42] and healthier diets often involve a consuming a greater variety of food.[43]

Arguably, not all healthier diets are necessarily associated with higher costs. It has been reported that healthy diets can be obtained at different cost levels.[20,44] Mexican–Americans were found to consume higher-quality diets with lower costs than other populations,[45] suggesting that high-quality diets can be achieved without major increases in cost. To date, several studies have aimed to develop foods that are both nutritionally and economically efficient. A study from the USA[20] reported that purchasing more nuts, soy and bean products, and whole grains, while spending less on red meats, processed meats and high-fat dairy products might be a worthwhile investment for healthy diets. These studies highlight the need to identify dietary patterns that are both healthy and affordable for Chinese populations.

Third, this study examined the association between diet cost and obesity and explored the possible mediating role of diet quality. In contrast, with some previous studies in Spain[21,22] and Japan,[23,24] our study observed that energy-adjusted diet cost was positively associated with BMISDS. This study also found, for the first time, that there was a positive association between energy-adjusted diet cost and FMI or WHtR. However, these positive relationships are not explained by diet quality, which indicated a direct relationship between of energy-adjusted diet cost and obesity, even after adjusting for diet quality. The reason for this independent association is currently unclear. It is possible that diet cost is a proxy for socioeconomic factors, which may play an important role in the development of obesity. Many previous studies have confirmed that distribution of childhood obesity is associated with socioeconomic status (SES) and that the patterns vary depending on the economic development of a country.[46] Studies from developed countries showed that high-SES children are less likely to be obese than their lower-SES counterparts.[47] In contrast, in developing countries such as China, high-SES children are more likely to be obese.[48] This difference in the associations between socioeconomic factors and obesity in developing and developed countries may explain the inconsistency between the results of our study and those conducted in developed countries.

### Limitations of this study

This study has some limitations. First, the use of a non-representative study sample may reduce the generalizability of the results to the general Chinese population. However, there were few or no differences in sociodemographic characteristics between the subjects in our study and those in national surveys for social class and eating behaviours.[49] Second, %BF was estimated from skinfold thickness measurements, which are more susceptible to measurement error than specialized research-based techniques and may underestimate body fat.[50] However, intra- and inter-observer variability can be reduced notably when measurements are conducted in duplicate by a trained investigator, as was done in the present study. Third, seasonal and regional variations of food prices might introduce a potential bias for the assessment of the diet cost. However, the annual average price across multiple regions was used in this study, which may reduce this bias. Additionally, this study had acceptable minor bias even after strict quality control. Furthermore, our data were cross-sectional in nature, and therefore, possible causal pathways indicated by the mediation analyses cannot be confirmed. Future studies are necessary to further investigate this issue using a prospective study design.

It is worth mentioning that appropriate data were lacking when assessing actual price expenditures on foods because the dietary intake and health surveys were conducted at the individual level while the food expenditure surveys were usually conducted at a household level. The calculation of diet costs based on the retail prices do not necessarily represent the actual prices paid by study participants, and therefore, the results should be interpreted with caution. However, a similar method was used in previous observational studies,[15,16,23,37] and no study has collected dietary consumption and food expenditure data simultaneously on an individual level. Furthermore, Monsivais *et al.*[51] concluded that merging food retail prices with standard dietary assessment tools could provide estimates of individual diet costs that were closely associated with the food consumed. Thus, the estimated diet cost calculated in this study was considered reliable. Our study was also limited by the assumption that all foods consumed were purchased and prepared at home. Therefore, the findings in this study might not be appropriate for children who frequently eat away from home. For future studies, a more precise evaluation on diet cost for children with multiple dining locations should be considered. The association among diet cost, diet quality and obesity might also be moderated by the neighborhood food environment, which is expected to be captured by modern technologies.[8,52]

## Conclusion

The current study found that Chinese children with higher diet quality had higher diet costs, and children spending more money on food had higher FMI, BMISDS and WHtR values, independent of diet quality. These findings indicated that current and future attempts to promote healthy food consumption and prevent childhood obesity should take economic issues into account.

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