



The impact of peer effect on students' consumption of sugar-sweetened beverages- instrumental variable evidence from north China

Ying Zhang^a, Ruotong Li^a, Qiran Zhao^{b,*}, Shenggen Fan^b

^a College of Economics and Management, China Agricultural University, China

^b Academy of Global Food Economics and Policy, College of Economics and Management, China Agricultural University, China

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ABSTRACT

Sugar intake is approaching problematic levels among Chinese children and adolescents. Chinese governments have issued and supervised the implementation of relevant administrative regulations, which have not achieved good results. Peers are the most important social factors influencing children and adolescents' behavior and decision-making besides family members. This study examines how the peer effect impacts SSB consumption. To clarify this relationship, we use the nutritional cognition of peers' parents as an instrumental variable to resolve the endogeneity problem and employ the two-stage least squares estimation method to investigate the data of 4,118 students in north China. The results show a significant positive correlation between sugar intake among peers, indicating that individuals are more likely to consume excessive amounts of sugar when their peers also engage in this behavior. We find that the peer effect is enhanced with increased popularity among one's peers and gradually decreases as the distance within the social network increases. It is also more significant in short-term friendships than in long-term friendships. Our findings provide a basis for school-level intervention programs from the perspective of social interaction to regulate healthy eating behaviors and nutritional perceptions among children and adolescents through peer relationships. It also confirms the feasibility of reducing individual sugar intake by increasing nutritional awareness among adolescents and parents.

1. Introduction

Evidence continues to show that the excessive intake of added sugar and sugar-sweetened beverages (SSBs) is linked with adverse health impacts, including increased risks of overweightness/obesity, insulin resistance, dental caries, cell dysfunction, and type 2 diabetes (Hu and Malik, 2010; Malik et al., 2013; Papier et al., 2017; Richelsen, 2013; Te Morenga et al., 2014; Yon and Johnson, 2014). Especially for children and adolescents, the excessive consumption of SSBs can also cause attention-deficit/hyperactivity disorder (ADHD), depression, and other mental illnesses (Hu et al., 2019; Yu et al., 2016). Despite these concerns, the practice of obtaining extra calories from SSBs has become the norm (Popkin, 2012). Although data from some countries show that SSBs consumption has decreased among adults and adolescents, both the consumption and intake proportion remain high in this latter group (Koma et al., 2020; Mesriow and Welsh, 2015; Stern et al., 2014). For example, the National Health and Nutrition Examination Survey conducted in the United States indicates that SSBs contributed to 9.3 % and

9.7 % of the total daily calories consumed by boys and girls aged 12 to 19 years, respectively (Rosinger et al., 2017). These numbers alone are very close to the WHO dietary recommendation of the consumption of not exceeding 10 % of all energy from added sugars (WHO, 2015). At the same time, more than half of the teenage populations in many low- and middle-income countries drink carbonated beverages at least once per day (Yang et al., 2017).

Although SSBs intake in East Asia is significantly lower than in the United States and Europe (Singh et al., 2019), official statistics suggest that the Chinese public health department should monitor consumption levels in children and adolescents. A nationally representative study shows that 66.6 % of Chinese children and adolescents consumed SSBs each week, with a weekly per capita consumption of 0.41 servings at 250 ml per serving (Gui et al., 2017). A cross-sectional study among 2,032 individuals in southern China aged 7 to 18 years reports that 21.6 % consumed more than 120 ml of SSBs each day (He et al., 2018). According to the China Nutrition and Health Survey (CHNS), 54.1 % of school-aged children consumed more than 150 g of SSBs per day from

* Corresponding author at: College of Economics and Management, China Agricultural University, No.17, Qinghua East Road, Haidian District 100083, Beijing, China.

E-mail addresses: zhangyingcau@126.com (Y. Zhang), liruotong_cau@163.com (R. Li), zhaqiran@cau.edu.cn (Q. Zhao), s.fan@cau.edu.cn (S. Fan).

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2010 to 2013. It is also critical to examine demographic variations, as children in urban areas tend to consume more SSBs than those in rural areas (Gan et al., 2021).

Various countries adopt national measures to reduce intake among adolescents and adults to recognize the hazards associated with excessive SSB consumption. For example, many countries have implemented intervention policies such as consumption tax to reduce SSB consumption. (Colchero et al., 2015; Jou and Techakehakij, 2012; Saxena et al., 2019). Researchers confirm that this approach can significantly reduce purchasing behaviors (Andreyeva et al., 2011; Cawley et al., 2019; Powell and Leider, 2020) especially in middle-income families (Finkelstein et al., 2010). However, there is also evidence that regular SSB consumers are unlikely to reduce their consumption due to extra tax burdens (Richardson et al., 2019). Moreover, some consumers may buy cheaper SSBs to avoid these additional costs (Alvarado et al., 2019).

For non-price methods, informational interventions have also gained widespread attention (Avery et al., 2015). A specific example is the health risk information with a warning function, referring to provisions that transmit facts about the hazards of excessive SSB intake to consumers in the form of media advertisements or warning labels, thus improving awareness and reducing purchasing behaviors (Farley et al., 2017; Roberto et al., 2016). Another example is the identification information without any warning function, referring to specific images that contain easy-to-understand caloric information or show physical forms of sugar contents on outer product packaging, thus implying that consumers should reduce their SSB consumption (Adams et al., 2014; Bleich et al., 2012). However, many behavioral change theories only consider initial behavioral changes and do not address the issue of maintenance. Long-term behavioral changes are rarely achieved (Laiou et al., 2021).

Peer relationships significantly influence individual personality traits, physical characteristics, and behavioral tendencies (Fitzgerald et al., 2012; Hutchinson and Rapee, 2007). There is increasing evidence that the eating habits of children and adolescents are affected by peer examples (Baker et al., 2003; Feunekes et al., 1998; Lau et al., 1990). In this context, peers are broadly defined as children in the same age groups who attend the same schools. Research shows that children develop healthier eating habits when their peers have healthy diets (Bruening et al., 2012). By contrast, children tend to develop unhealthy eating habits when their peers eat unhealthy food. For example, there is a positive correlation between individual snack consumption and peer snack consumption (Daboné et al., 2013). Another study among girls aged 8 to 12 shows that participants eat more biscuits when their peers have higher consumption rates. (Romero et al., 2009). In addition to personal and family factors, there is also evidence that daily SSB consumption among teenagers is related to peer habits (Watts et al., 2018). Still, there is a lack of evidence on this issue among younger groups, highlighting the need to explore whether and how the peer effect influences SSB consumption in children and adolescents.

There are some difficulties in the identification of peer effect analysis, among which the wrong or misleading attribution of causality is very extensive (Manski, 1993). More specifically, the individual consumption of SSBs may be associated with unobservable characteristics. For instance, a student's follower-ship may have an effect on whether he emulates his peers' SSBs consumption. On the other hand, students' sensitivity to the price of SSBs may also have an impact on their consumption. In addition, the school food environment, such as school rules prohibiting students from drinking SSBs at school and the number of stores selling SSBs around school, may also influence students' SSBs consumption. The existing literature lacks evidence on SSB consumption among Chinese children, especially those from rural China. This study contributes to the literature in three ways. First, we offer the first empirical evidence showing the impacts of peer effects on SSB consumption among Chinese children and adolescents. Second, we used parental nutritional cognition of peers as an instrumental variable (IV) to identify a peer effect, thus solving the problem of endogeneity to a

certain extent. Third, we analyzed a dataset containing a rich set of relationship variables between children and adolescents; moreover, two rounds of data collection enabled us to estimate the short- and long-term peer effects. Specifically, we examine the differences after changes in friendship associations over the study period, focusing on "mutual" and "ego-perceived" friendship.

The remainder of this paper is organized as follows. Section two discusses the sample and data collection process. Section three outlines the method used to estimate peer effects on individual SSB consumption. Section four presents the results and discusses the findings. Finally, Section five offers a general conclusion.

2. Data

2.1. Sampling

This study used the data of Health and Nutrition Panel survey (HNPS) conducted in Jining District, Ulanqab City, Inner Mongolia Autonomous Region in northern China from 2019 to 2020. Statistics show that the per capita added sugar consumption of residents in Inner Mongolia has ranged from 1.3 kg to 1.5 kg in the past five years, slightly higher than the national average (National Bureau of Statistics, 2022). The Scientific Research Report on Chinese Dietary Guidelines (2021) also points out that SSBs have become the main source of added sugar for people (Chinese Nutrition Society, 2021). Based on these features, it is necessary and feasible to investigate the consumption of SSBs among students in the survey area.

The project team used stratified random sampling to investigate students from 36 schools in Jining District, including 25 primary schools and 11 junior high schools. Considering the follow-up investigation in the later period, the project team randomly selected two fourth-grade classes, one fifth-grade class, two seventh-grade classes, and one eighth-grade class for investigation in these primary and junior high schools, respectively. All students in the selected classes were survey targets.

The baseline and follow-up surveys were conducted in December 2019 and December 2020, with respective totals of 4,123 and 4,308 participants. Each student was asked to complete two types of questionnaires, including one on their basic personal situation and one on their basic family situation. The personal questionnaire was completed in class with the assistance of project team members and teachers. In contrast, the family questionnaire was taken home and completed by the participant's parents or other caregivers. Completed questionnaires were collected by the headteacher. The information submitted by these participants constitutes a database for conducting statistical and regression analyses. We have 4,118 respondents after removing outliers and invalid questionnaires.

2.2. Data collection

The project team collected data on the personal characteristics of participants (gender, age, boarding situation), their SSB consumption behaviors, and information about their three good friends in the class (list the names in order of the degree of intimacy). We also collected data on the essential characteristics of their parents (age, education level, nutritional cognition, and household assets).

To investigate SSB consumption behaviors, each participant needs to report the number (serving units of 350 ml) and frequency of SSBs they drank over the previous week. In this context, they answered how many servings of various SSBs they consumed over that timeframe. Since Inner Mongolia is the primary milk-producing area in China, local residents consume high amounts of yogurt, in which case yogurt was added to the beverage list. To help participants understand the various types and the package size, team members provided images and unmarked beverage bottles of different sizes as references during the survey. Answers were given based on three levels of consumption: (i) one serving per week, (ii)

two to three servings per week, and (iii) four or more servings per week (specify the quantity). To estimate added sugars in SSBs, we used a formula similar to that proposed by Louie et al. (2015); here, we calculated the sugar intake of SSBs as equal to the number of bottles of SSBs consumed multiplied by the volume of each bottle, then multiplied the corresponding proportion of added sugar per unit volume of each type of beverage. The proportion of added sugar in SSBs was estimated using the China Food Industry Yearbook, in which the proportions of added sugar per unit weight of carbonated beverages, juice beverages, and yogurt were 12 %, 8.5 %, and 3 %, respectively. The density of carbonated beverages, juice beverages and yogurt are approximately equal to 1 g per milliliter, so the weight of added sugar in each 100 ml of carbonated beverages, juice beverages and yogurt is 12 g, 8.5 g and 3 g respectively.

In the survey, participants were asked the following: “Who is your best friend in the class?” The “peer” of each student was determined based on matching answers. Parental nutritional cognition included dietary and nutritional knowledge. The questions were taken from the nutritional health status survey of the Nutrition Improvement Program for the Rural Compulsory Education Students, which was compiled by the Nutrition and Health Institute of the Chinese Center for Disease Control and Prevention. The questionnaire listed 7 points of view (e.g., “What do you think is the best food source of vitamins and minerals?” Table A2 for a specific list). Total nutrition cognition scores were calculated based on parental judgments of each point of view, with one point awarded for each correct answer.

Reliable measurement of nutritional cognition is challenging. While some studies have used the correctly answered number of questions to characterize individual nutritional cognition, this approach may produce biased results because it ignores differences between test items on difficulties and the ability to distinguish knowledgeable respondents. To more intuitively reflect differences in project difficulty and distinguish between different levels of nutritional cognition, this study used nutrition cognition scores obtained from item response theory (IRT). We used two-parameter logistic model (2pl model) to estimate parents’ nutrition cognition. The IRT model gives the probability that a person with a certain level of nutrition cognition can correctly answer each question. People with lower ability have less chance to answer the right questions, while people with higher ability can answer more accurately (DeMars, 2010). The probability of parents j with nutritional cognitive ability θ_j correctly answering question i can be expressed as:

$$P_r(Y_{ij} = 1|\theta_j) = \frac{\exp[a_i(\theta_j - b_i)]}{1 + \exp[a_i(\theta_j - b_i)]} \theta_j N(0, 1)$$

where Y_{ij} is the answer of parents j to question i . If the answer is correct, then $Y_{ij} = 1$; or the answer is wrong, $Y_{ij} = 0$. a_i represents the discrimination of question i . A larger a_i indicates that question is better at distinguishing the respondent’s ability. b_i represents the difficulty of question i . A larger b_i indicates that the higher cognitive ability required for the respondent to answer question i correctly. The irt 2pl command of Stata16 software was used to fit the IRT model to obtain the parameters Y_{ij} .

2.3. Descriptive statistics

Table 1a lists weekly sugar intake data for the study sample and summarizes parental nutrition cognition. As shown, the average weekly sugar intake was 107.10 g. Chinese Dietary Guidelines provide that daily sugar intake should be limited to 50 g (preferably under 25 g, or 175 g per week). In this study, the sample reached 61.2 % of the total weekly sugar intake from SSBs, which is a high proportion. Further, the statistics on different beverage types showed that participants consumed the most sugar from carbonated beverages each week, at an average of 49.5 g, or about half the total intake. In comparison, sugar intake from fruit juice beverages and yogurt averaged 41.91 g and 15.81 g, respectively. This

Table 1a

Summary statistics on sugar intake and parental nutrition cognition (data collected during the 2020 survey).

Variable	Definition	Obs.	Mean	SD
Sugar intake	Sugar intake per week(g)	4118	107.10	63.32
Peer’s sugar intake	Peer’s sugar intake per week(g)	4118	106.50	61.03
Sugar intake from carbonated beverages	Sugar intake from carbonated beverages per week(g)	4118	49.50	41.46
Sugar intake from juice beverages	Sugar intake from juice beverages per week(g)	4118	41.91	32.74
Sugar intake from yogurt	Sugar intake from yogurt per week(g)	4118	15.81	12.01
Parents’ nutrition cognition	Parents’ nutrition cognition score per week (g)	4118	4.42	1.55
IRT parents’ nutrition cognition	Parents’ nutrition cognition score using IRT models	4118	-0.01	0.69
Peer parents’ nutrition cognition	Peer parents’ nutrition cognition score	4118	4.42	1.54
IRT peer parents’ nutrition cognition	Peer parents’ nutrition cognition score using IRT models	4118	-0.01	0.69

situation also exists in other countries. For example, Hafekost et al. (2011) investigated a sample of students aged 14 to 16 years, finding that 41.7 % of the total sugar intake from SSBs was derived from carbonated beverages, with 20.9 % from juice and 21.2 % from flavored milk. While individual and national preferences may differ, this generally shows high sugar intake from SSBs. As for the average score of parents’ nutrition cognition was 4.42 on a scale of 0–7.

Table 1b lists the personal and family characteristics of the participants. As shown, there was a balanced gender ratio across the sample, with approximately 30 % classified as boarding students and only about 6 % classified as left behind (with either parent migrant). It shows that most students lived with their parents. Still, nearly half of the sample had their own pocket money, which could be used to buy their preferred drinks and food.

3. Estimation framework

3.1. Statistical relationship of interest

This study estimated how the peer effect impacted SSB consumption among a sample of children and adolescents in China. We examined whether consumption behaviors among peers influenced personal SSB

Table 1b

Variable summary statistics for participants, parents, and households (data collected during the 2020 survey).

Variable	Definition	Obs.	Mean	SD
Boy	Dummy; 1 = boy; 0 = girl	4118	0.49	-
Age	Age measured by year	4118	11.45	1.56
Board	Dummy; 1 = board; 0 = not	4118	0.27	-
Number of siblings	The number of siblings	4118	0.81	0.73
Left-behind children	Dummy; 1 = Left-behind; 0 = not	4118	0.06	-
Pocket money	Dummy; 1 = have pocket money; 0 = not	4118	0.49	-
Father’s age	Age of father	4118	41.17	5.27
Mother’s age	Age of mother	4118	39.01	5.00
Father’s education	Educational years of father	4118	10.40	3.27
Mother’s education	Educational years of mother	4118	9.88	3.65
Household assets	Household durable asset index	4118	1.2E-08	1.31

consumption. Throughout this paper, the term peers refer to “good friends,” as reported by participants on their questionnaires. We estimated the following OLS model:

$$Sugar = \beta_0 + \beta_1 \times Sugar_{Peer} + \beta_2 \times Sugar_{Previousyear} + \beta_3 C + \beta_4 D + \beta_5 U_j + \epsilon \tag{1}$$

where *Sugar* is the standardized individual sugar intake from SSBs, while *Sugar_{Peer}* refers to the standardized sugar intake of peers. *Sugar_{Previousyear}* refers to the standardized individual sugar intake from SSBs over the last year to control for past consumption habits. *C* represents a series of characteristic variables at the individual level, including gender, age, boarding status, number of siblings, and pocket money indicators. *D* represents a series of characteristic variables at the household level, including parents’ age, parents’ education level, parents’ nutritional cognition, and household assets. School fixed effects *U_j* control for invariant factors that differ between schools.

3.2. Validity of the IV

Due to the potential mutual influence between peers and individual participants in sugar intake (i.e., simultaneity), OLS estimates will be biased. This study used “nutritional cognition of peers’ parents” as an IV to solve endogeneity problems. There were two potential concerns regarding the validity of this IV. First, parents may work in other places and usually do not eat or live with students. We asked the guardians who cooked for the participants on weekdays to complete the family situation questionnaires, thus ensuring that the measured parental nutritional cognition levels were comparable. Second, there were concerns over the relationship between individual food consumption habits and parental nutritional cognition. Here, research has shown that improving the nutritional awareness of parents improves the health of students (Zhao and Yu, 2020).

Moreover, parents hold the central food purchasing powers for the family, meaning that individual choices and selections (including SSBs) are directly affected by these purchasing habits, which are in turn affected by nutritional awareness. More importantly, the level of parental nutritional cognition in one family does not affect how and whether peers from other families make choices regarding SSBs consumption or sugar intake. Therefore, the IV variables selected were exogenous and effective. In addition, two students may become friends because they have similar preexisting behaviors and not because they influence one another after becoming friends, which may lead to self-selection problems. We included the following item in the questionnaire to solve this problem: “Why did he/she become your best friend?” The results showed that 71 % of participants chose to make friends with their peers because of their “good personality,” Only three participants (0.07 %) said they chose friends based on having the same eating habits. Therefore, we could ignore the endogeneity self-selection problem on the peer effect of SSB intake. We established the following equation:

$$Sugar = \beta_0 + \beta_1 \times Sugar_{Peer} + \beta_2 \times Sugar_{Previousyear} + \beta_3 C + \beta_4 D + \beta_5 U_j + \epsilon \tag{2}$$

$$Sugar_{Peer} = \gamma_0 + \gamma_1 \times NC_score + \gamma_2 \times Sugar_{Previousyear} + \gamma_3 C + \gamma_4 D + \gamma_5 U_j + \nu \tag{3}$$

$$Sugar_{Peer} = \gamma_0 + \gamma_1 \times NC_score + \gamma_2 \times Edu_parents + \gamma_3 \times Sugar_{Previousyear} + \gamma_4 C + \gamma_5 D + \gamma_6 U_j + \nu \tag{4}$$

Equation (2) is the 2SLS model. In equation (3), we used the nutritional cognition of peers’ parents as the IV. To meet the assumption that all instrumental variables were exogenous (Guevara, 2018), we used the nutritional cognition of peers’ parents and the average educational years of peers’ parents as IVs to carry out the over-identification test (equation

(4)), where *Sugar_{Peer}* is the standardized peer sugar intake, *NC_score* is the standardized nutrition cognition of peers’ parents, and *Edu_parents* is the average educational years of peers’ parents. *C* represents a series of characteristic variables at the participants’ level (gender, age, boarding status, number of siblings, and pocket money indicators). *D* represents a series of characteristic variables at the family level (parents’ age, parents’ education level, parents’ nutritional cognition, and household assets). School fixed effects *U_j* controls for invariant factors that differ between schools.

4. Results and discussion

4.1. The peer effect of sugar intake on individual SSB consumption

In Table 2, column (1) lists the estimation results of the OLS regression on the impact of standardized peer sugar intake on individual standardized sugar intake. The results showed that peer SSB sugar intake had a positive and significant effect on individual sugar intake. One standard deviation increases in peer SSB sugar intake increased individual sugar intake by 0.098 standard deviation. There may also be measurement error here because students’ SSBs consumption is self-reported and recalls the previous week’s consumption. Considering the possible endogenous problems, we used IV to estimate the impact of the peer effect. In Table 2, column (2) shows the results of the two-stage least squares estimation (2SLS) regression using “parental nutritional cognition” as the IV. We constructed two instrumental variables to ensure the exclusion restriction. Column (3) lists the 2SLS regression results using both “average educational years of peer’s parents” and “nutritional cognition of peer’s parents” as IVs.

Table 2
Estimated effects of peer sugar intake on individual standardized sugar intake from SSBs.

Variable	OLS	2SLS	2SLS
Standardized peer’s sugar intake	0.098*** (0.033)	0.349*** (0.121)	0.315** (0.128)
Standardized sugar intake in the previous year	0.235*** (0.026)	0.229*** (0.025)	0.229*** (0.026)
Boy	0.113*** (0.033)	0.058* (0.032)	0.065* (0.034)
Age	-0.041** (0.020)	-0.032** (0.014)	-0.034** (0.015)
Board	-0.035 (0.055)	-0.012 (0.048)	-0.015 (0.048)
Number of siblings	0.006 (0.020)	0.023 (0.023)	0.021 (0.022)
Left-behind children	0.179*** (0.061)	0.166** (0.066)	0.168** (0.065)
Parents’ nutritional cognition	-0.127*** (0.033)	-0.111*** (0.035)	-0.113*** (0.035)
Father’s education	-0.015** (0.006)	-0.017** (0.007)	-0.017** (0.007)
Mother’s education	0.007 (0.006)	0.010 (0.006)	0.010 (0.006)
Father’s age	-0.006 (0.005)	-0.006 (0.005)	-0.006 (0.005)
Mother’s age	0.001 (0.005)	0.000 (0.005)	0.000 (0.005)
Household assets	0.034** (0.015)	0.032** (0.014)	0.032** (0.014)
Pocket money	0.117*** (0.034)	0.107*** (0.033)	0.108*** (0.034)
Constant	0.665** (0.250)	0.573*** (0.207)	0.585*** (0.212)
School fixed effects	Yes	Yes	Yes
Observations	4118	4118	4118
Cragg-Donald Wald F statistic		50.832	27.193
Hansen J statistic			0.990

Note: Robust standard errors in parentheses. The definitions for each of the variables are available in Table 1a and 1b. *** p < 0.01, ** p < 0.05, * p < 0.1.

According to the regression results from the first stage (Table A1), we found that the F statistic did not exceed 10 ($F(15, 4102) = 6.05$). Thus, we retained “nutritional cognition of peer’s parents” as the IV and focused on the results in column 2. Before interpreting the main results, we performed a weak identification test for the instruments. The Cragg-Donald Wald F statistic of the weak instrument test reached 50.832, much larger than 16.38 (10 % maximal IV size), indicating that the IV was valid. The IV estimation results showed that one standard deviation increase in peer SSB sugar intake was associated with 0.349 standard deviation increase in individual SSB sugar intake. It suggests that the eating habits of children and adolescents are influenced by the eating habits of their peers, which is consistent with previous findings (Baker et al., 2003; Romero et al., 2009).

We also found significant differences in sugar intake between students of different ages. For example, younger students had significantly higher sugar intake than older students. It may be because younger children have lower cognitive abilities and are more susceptible to unhealthy eating habits (Triches and Giugliani, 2005). In addition, children classified as left behind had higher sugar intake from SSBs than those not classified as such. It may be because children who are left behind lack parental care and daily life guidance while their parents are out to work, thus causing them to eat more unhealthy food (Gao et al., 2010). Moreover, the father’s education level negatively affected individual sugar intake from beverages. Here, one standard deviation increases in the father’s education lowered individual sugar intake by 0.017 standard deviation. It is consistent with previous studies showing that lower parental education levels may lead children to eat unhealthy foods and consume more drinks (Hafekost et al., 2011; Lopez et al., 2012). There is also evidence that children with pocket money tend to buy more snacks or sugary drinks (Li et al., 2017).

Considering the different added sugar amounts between SSB types, we estimated the specific peer effects on individual sugar intake for carbonated beverages and juice beverages, thus finding similar effects. As shown in Table 3, individual sugar intake from carbonated beverages increased by 0.415 standard deviation when peer sugar intake from carbonated beverages increased by one standard deviation. Meanwhile, individual sugar intake from juice beverages increased by 0.378 standard deviation when peer sugar intake from carbonated beverages increased by one standard deviation. By contrast, individual sugar intake from yogurt was unrelated to peer consumption behaviors. It may be because parents believe that yogurt is healthier than carbonated beverages and juice beverages. Thus, the individual consumption of yogurt is thus more determined by parental influence, and the participants were not susceptible to the same type of peer effect for this item.

4.2. Mechanism and effect analysis

(1) Intimacy effects.

Considering that the connection between items weakens as their distance in the social network increases (Boguñá et al., 2004), we tested for different peer effects on individual SSB sugar intake by categorizing peers as more intimate and distant. It was possible by using the results for the following questionnaire item: “Please list your three best friends and rank them according to their closeness.” Table 4 lists the sugar intake effects imposed by the second intimate peer (column 1) and third intimate peer (column 2). The second intimate peer had a significant impact on individual sugar intake, but the third intimate peer did not; further, the second intimate peer had less influence than the first intimate peer (0.224 SD vs 0.378 SD). It confirms that the peer effect decreases toward zero with lower-ranking friendships (more distant relationships).

(2) Popularity effects.

Existing research shows that more popular individuals tend to hold more influence (Dijkstra et al., 2013). In the current sample, we identified a subset of individuals who were more popular than others (that is, more than three students in the class agreed that the student is their best

Table 3
Estimated effects of peer sugar intake on individual standardized sugar intake for different types of SSBs.

Variable	Carbonated beverages	Juice beverages	Yogurt
Standardized peer’s sugar intake	0.415*** (0.117)	0.378* (0.221)	−0.413 (0.593)
Standardized sugar intake in the previous year	0.207*** (0.027)	0.153*** (0.021)	0.217*** (0.027)
Boy	0.092*** (0.035)	0.019 (0.043)	−0.200** (0.079)
Age	−0.025* (0.013)	−0.029 (0.018)	−0.012 (0.020)
Board	0.028 (0.045)	−0.096* (0.055)	0.325* (0.179)
Number of siblings	0.005 (0.026)	0.027 (0.025)	−0.005 (0.040)
Left-behind children	0.143* (0.081)	0.105 (0.077)	−0.019 (0.100)
Parents’ nutritional cognition	−0.100*** (0.032)	−0.088** (0.036)	−0.007 (0.022)
Father’s education	−0.012* (0.007)	−0.021** (0.008)	−0.001 (0.007)
Mother’s education	0.008 (0.006)	0.008 (0.008)	0.011 (0.008)
Father’s age	−0.004 (0.005)	−0.004 (0.004)	−0.005 (0.006)
Mother’s age	0.003 (0.006)	−0.007* (0.004)	0.008* (0.005)
Household assets	0.030** (0.014)	0.018 (0.014)	0.021 (0.014)
Pocket money	0.071** (0.036)	0.115*** (0.035)	0.066** (0.033)
Constant	0.258 (0.230)	0.844*** (0.270)	−0.107 (0.228)
School effects	Yes	Yes	Yes
Observations	4118	4118	4118
Cragg-Donald Wald F statistic	39.051	26.706	2.888

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 4
Estimated effect of peer sugar intake on individual standardized sugar intake for second intimacy friend and third intimacy friend.

Variable	Second Intimacy Friend	Third Intimacy Friend
Standardized peer’s sugar intake	0.224* (0.116)	0.272 (0.219)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	4118	4118
Cragg-Donald Wald F statistic	91.702	38.323

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

friend). We labeled these individuals as “star peers” and estimated their peer effect on sugar intake. As shown in Table 5, star peers had more significant effects on individual sugar intake, with even more pronounced effects on carbonated beverage consumption. A possible reason is that star peers had more substantial demonstration effects. In this case, individuals who exhibit the herd mentality are more likely to maintain the same hobbies as their peers to strengthen those relationships.

(3) Short-term effects.

Since our sample was investigated over two periods of data collection, we considered the possibility that good friend status would change. Indeed, this was the case for some participants. We therefore divided the sample into two groups, including one comprised of individuals for whom peers did not change over the survey period, and one comprised

Table 5

Estimates of the peer’s sugar intake on student’s standardized sugar intake from the more popular peer sample from all types of SSBs and carbonated beverages.

	Sugar Intake from all types of SSBs	Sugar Intake from Carbonated beverages
Standardized peer’s sugar intake	0.578** (0.260)	0.695*** (0.253)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	2346	2346
Cragg-Donald Wald F statistic	23.627	17.839

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

of individuals for whom peers did change. We used the groups without and with peer changes to estimate the effects of long-term and short-term friendship on individual sugar intake, respectively. The results are listed in Table 6. As shown, the peer effect on sugar intake was greater for participants with peer changes than for those without change. It is consistent with previous reports that friendships among teenagers that have lasted one year or less entail more similar behaviors between friends than found in long-term friendships (Brendgen et al., 2000).

(4) Self-selection effects.

Friendship identifications are directional, so we separated two different types of friendships. In our sample, 47.2 % of participants reciprocally considered each other as best friends and were thus placed into the “mutual friendship” group. Meanwhile, the remaining 52.8 % of good friend relationships were unilaterally identified; in such an arrangement, only one of two given participants regarded the other as their best friend and were thus placed into the “ego-perceived friendship” group.¹ As shown in Table 7, the peer effect of an “ego-perceived friendship” was slightly higher than that of a “mutual friendship.” Column (1) shows that individual sugar intake in the “mutual friendship” group increased by 0.321 standard deviation when the peer’s sugar intake increased by one standard deviation. The “ego-perceived friendship” group increased by 0.354 standard deviation when the peer’s sugar intake increased by one standard deviation. While there was not a significant difference in peer influence on individual sugar intake between relationship types, a possible reason is that mutual friendships entail greater feelings of stability than those found in ego-perceived friendships. Therefore, one party makes targeted efforts to gain more trust and favor from the other party, which may lead to higher rates of imitation and obedience.

Table 6

Estimated effect of peer sugar intake on individual standardized sugar intake for the same peer sample and different peer sample.

Variable	Long-term friendships	Short-term friendship
Standardized peer’s sugar intake	0.293* (0.161)	0.404** (0.202)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	2333	1785
Cragg-Donald Wald F statistic	28.220	22.826

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 7

Estimated effect of peer sugar intake on individual standardized sugar intake for ego-perceived friendship and mutual friendship.

Variable	Mutual Friendship	Ego-perceived Friendship
Standardized peer’s sugar intake	0.321** (0.160)	0.354* (0.188)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	1944	2174
Cragg-Donald Wald F statistic	25.705	23.782

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

4.3. Heterogeneity analysis results

Increasingly, peer effects may vary according to school grade and age (Asirvatham et al., 2014; Lynch and Cicchetti, 1997). Indeed, significant changes may occur in areas of cognitive development as children age. This section discusses the potential heterogeneous peer effects of individual SSB sugar intake based on different grade levels. First, we divided the sample into primary and junior middle school groups. In Table 8, columns (1) and (2) show that both groups were significantly and positively affected by the sugar intake of their peers. The junior middle school group was less affected than the primary school group in this regard, although the difference was slight. This result is contrary to previous research (Lynch and Cicchetti, 1997). It may be that younger students are more susceptible to peer behavior due to their lack of nutrition cognition and weaker self-control. Motivated by this result, nutritional interventions for younger children are more necessary. Research also shows that investing in early childhood can lead to greater benefits (Doyle et al., 2009).

Pocket money is another important factor that influences individual purchasing power. Here, students with more pocket money tend to buy more unhealthy food (including sugary drinks and snacks) and are more likely to be overweight or obese (Li et al., 2017). To investigate this issue in light of the peer effect on sugar intake, we divided the sample into groups of “with pocket money” and “without pocket money.” In Table 9, columns (1) and (2) show that participants with pocket money were significantly and positively affected by the sugar intake of their peers, while those without pocket money were not. It may be because students with pocket money have more significant financial autonomy for imitating their peers’ behavior in purchasing SSB. Our data also showed that students with pocket money consumed about 12 % more sugar per week from SSB than students without pocket money. The finding reminds us that pocket money may be a risk factor for many unhealthy lifestyles. Therefore, it is necessary to emphasize the use of children’s pocket money when carrying out nutritional cognitive interventions for parents.

In rural China, the number of children classified as left behind has dramatically increased in recent years. They constitute a unique group in which grandparents are the most common caregivers in their life, and diet matters. Left-behind children are more at risk of malnutrition as grandparents lack nutritional cognition and healthy eating habits

Table 8

Estimated effect of peer sugar intake on individual standardized sugar intake for the primary school sample and junior middle school sample.

Variable	Primary School	Junior Middle School
Standardized peer’s sugar intake	0.307* (0.164)	0.303** (0.139)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	2573	1545
Cragg-Donald Wald F statistic	26.717	24.379

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

¹ The definition of two groups is followed (Christakis and Fowler, 2007).

Table 9

Estimated effect of peer sugar intake on individual standardized sugar intake for the sample with pocket money and sample without pocket money.

Variable	Have pocket money	Have no pocket money
Standardized peer's sugar intake	0.493** (0.237)	0.212 (0.177)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	2016	2102
Cragg-Donald Wald F statistic	22.433	27.615

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

(Zhang et al., 2018). Many studies have shown that parental migration has significant impacts on dietary diversity and cognitive development for left-behind children (Yue et al., 2020; Zhang et al., 2016). At the same time, parents' migration indirectly increases the opportunities for left-behind children to interact with their peers, which makes it easier for left-behind children to engage in the same activities or behaviors with their peers (Chen, 2017). We divided the sample into groups classified as "left-behind children" and "non-left-behind children" to examine this condition about the peer effect on sugar intake. In Table 10, columns (1) and (2) show that SSB sugar intake was significantly and positively affected by peers for participants who were not left behind, but this was not the case for those left behind. This result may be related to the small number of children classified as left behind within the total sample (4 %), in which case the first stage of the equation failed. Nonetheless, our data show that left-behind children consume approximately 14 % more sugar than non-left-behind children, so it is crucial to help them shape healthy eating behaviors.

Previous studies have shown some notable differences in the influence of fathers' education level on children's eating habits (Khandpur et al., 2016; Rahill et al., 2020). We divided our sample into two groups, one in which the children's fathers with a high school level education and higher, and the other in which the children's fathers with less than a high school education. In Table 11, columns (1) and (2) show that students with lower father's education level are more influenced by their peers. In contrast, students with higher father's education level are less affected by their peers (the significance level of this coefficient is exactly 10 %). One possible reason is that fathers with a high school level education are usually more concerned about their children's eating habits and limit children's consumption of unhealthy foods such as SSBs, resulting in children being less influenced by their peers.

5. Discussion and policy implications

The excessive intake of added sugars negatively affects human capital accumulation in children and adolescents. There is increasing evidence that sugar intake is approaching problematic levels among Chinese children and adolescents (Gan et al., 2021; Gui et al., 2017; He et al., 2018). China has begun to explore SSB consumption interventions

Table 10

Estimated effect of peer sugar intake on individual standardized sugar intake for participants classified as left behind and not left behind.

Variable	Left-behind Children	Non-left-behind Children
Standardized peer's sugar intake	1.138 (1.002)	0.316*** (0.109)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	237	3881
Cragg-Donald Wald F statistic	1.775	47.707

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 11

Estimated effect of peer sugar intake on individual standardized sugar intake for participants with higher or lower father's education level.

Variable	higher father's education level	lower father's education level
Standardized peer's sugar intake	0.226 (0.137)	0.453** (0.181)
Control variables	Yes	Yes
School effects	Yes	Yes
Observations	1633	2485
Cragg-Donald Wald F statistic	20.195	29.290

Note: Robust standard errors in parentheses. The results reported are the results of the 2SLS model. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A1

The first stage regression results of two IVs.

Variable	Peer's standardized sugar intake
Peer parents' nutrition cognition	-0.152*** (0.04)
The average educational years of the peers' parents	-0.010* (0.01)
Standardized sugar intake in the previous year	0.022* (0.01)
Boy	0.222*** (0.05)
Age	-0.039 (0.02)
Board	-0.082 (0.08)
Number of siblings	-0.073*** (0.03)
Left-behind children	0.043 (0.06)
Parents' nutritional cognition	-0.054*** (0.02)
Father's education	0.012* (0.01)
Mother's education	-0.010* (0.01)
Father's age	-0.003 (0.00)
Mother's age	0.004 (0.00)
Household assets	0.014 (0.01)
Pocket money	0.034 (0.02)
Constant	0.471 (0.29)
School fixed effects	Yes
F-statistic	6.05
Observations	4118

Note: The value of robust standard errors is reported in parentheses.

*** Indicate significance level of 1%.

** Indicate significance level of 5%.

* Indicate significance level of 10%.

targeting children and adolescents in school food environment. In 2019, National Health Commission promulgated the "National Oral Healthy Campaign (2019–2025)", which required the canteens of primary and secondary schools and kindergartens to reduce the supply of SSBs and other high-sugar foods. Some local governments have also issued regulations that do not allow shops inside the school to sell SSBs, especially carbonated beverages. For example, Beijing issued the "Notice on Setting up Normative Diet Environment in Primary and Secondary Schools" in 2013; Shanghai launched the "Initiative to Improve Health (2019–2030)" in 2019; In 2017, Jiangsu Province issued a "Notice on

Table A2

The questionnaire list of nutritional cognition.

Question	Options
1. Which of the following states do you consider to be healthy?	[1] Physical disease [2] good physical performance [3] physical strength [4] Not only the absence of disease, but also good psychological and social adaptability [5] other
2. What is the best food source of vitamins and minerals?	[1] legumes, dairy [2] grains [3] fresh vegetables and fruits [4] meat, eggs [5] unknown
3. What is the foods with the highest protein content?	[1] Dairy [2] grains [3] vegetables and fruits [4] meat and eggs [5] do not know
4. Which of the following foods are the best sources of calcium?	[1] beans, milk [2] grains [3] vegetables and fruits [4] meat, eggs [5] do not know
5. Which do you think will help growing taller?	[1] Drink more milk [2] exercise more [3] proper sun [4] eat more carrots [5] do not know
6. How to prevent iron deficiency anemia through diet?	[1] eat meat and fresh vegetables and fruits [2] drink milk more [3] eat light food [4] do not know
7. What disease does salty food often cause easily?	[1] Diabetes [2] hypertension [3] gastritis [4] do not know

Reducing Students' Sugar Intake in Primary and Secondary School in Qidong"; Hebei Province released "Program for Improving Oral Health (2019–2025)" in 2019. Although regulations or restrictions have been issued in some places, we still find that the consumption of SSB by children and adolescents increases (Xu et al., 2021).

Interactions between different levels of social systems and individuals can influence a person's developmental process (Bronfenbrenner and Morris, 2006). Besides family members, one of the most important social factors influencing children and adolescents' behavior and decision-making are peers (van Ansem et al., 2015; Wouters et al., 2010). We used data from northern China to investigate how peer effects affect SSB consumption. We addressed the endogeneity problem to some extent by examining the data collected in both survey waves and implementing IVs in our analysis. Our findings suggest that peers' SSB consumption behavior may be an essential factor influencing sugar intake in children and adolescents.

Our results support the idea that star peers had more substantial demonstration effects. It shows that children and adolescents imitate more of their popular peers when they shape eating behaviors or norms. It has necessary guidance and reference value for implementing the intervention plan in the school. We should use "stars" to guide and deliver correct behavior and information. We can promote students with healthy diets and active lifestyles as "peer leaders," voted on by their classmates or directly nominated by the teachers.

Reduce students' unhealthy food consumption behavior by setting peer leaders as role models or peer leader supervision. Peer imitation provides a relatively stable social environment and long-term intervention than other school-level interventions. The characteristics of this intervention can be in two ways. First, peer imitation is more precise. Adolescents in the same social network will be intervened; Second, peer imitation behavior can occur naturally. Students are subtly affected by "peer leaders" with the high frequency of daily exposure at school.

Therefore, it is very effective to standardize healthy eating behavior and nutrition cognition through peer relationships.

Our findings further suggest that interventions based on peer effects start better in lower-grade students. Younger students may have poor self-control and a lack of knowledge about nutrition and health; thus, they are more easily to be influenced unhealthy behaviors. Therefore, it is necessary to set up a correct peer leader model or implement the intervention of nutrition and health subjects in primary schools, especially in lower- grade.

In addition, the findings confirm the feasibility of home-based cognitive interventions. Parents can provide students with the skills and opportunities to adopt healthy eating behaviors by guiding and regulating their nutritional cognition. For example, explain to students the hazards of excessive consumption of SSBs. It is also important to note that parents should be informed and educated of the potential adverse health impacts of student's pocket money and empowered to help children develop healthy consumption behaviors.

CRedit authorship contribution statement

Ying Zhang: Conceptualization, Methodology, Software, Writing – original draft, Writing – review & editing. **Ruotong Li:** Data curation, Software, Writing – original draft. **Qiran Zhao:** Conceptualization, Methodology, Resources, Supervision, Funding acquisition, Writing – original draft, Writing – review & editing. **Shenggen Fan:** Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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