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Risk factors for obesity and overweight in Chinese children: a nationwide survey

JingNan Chen[1] | **Lu Jin**[1] | **FengLei Wang**[2] | **Ke Huang**[1] | **Wei Wu**[1] |
RuiMin Chen[3] | **Mireguli Maimaiti**[4] | **ShaoKe Chen**[5] | **BingYan Cao**[6] |
Min Zhu[7] | **ChunLin Wang**[8] | **Zhe Su**[9] | **Yan Liang**[10] | **Hui Yao**[11] |
HaiYan Wei[12] | **RongXiu Zheng**[13] | **HongWei Du**[14] | **FeiHong Luo**[15] | **Pin Li**[16] |
YunXian Yu[17] | **Ergang Wang**[18] | **Robert M. Dorazio**[1] | **Junfen Fu**[1]

[1]Department of Endocrinology, The Children's Hospital, Zhejiang University School of Medicine, National Clinical Research Center for Child Health, Hangzhou, China

[2]Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, USA

[3]Department of Endocrinology, Genetics and Metabolism, Fuzhou Children's Hospital, Fuzhou, China

[4]Department of Endocrinology, Genetics and Metabolism, The First Affiliated Hospital of Xinjiang Medical University, Urumqi, China

[5]Department of Pediatrics, Nanning Women and Children's Hospital, Nanning, China

[6]Department of Endocrinology, Beijing Children's Hospital, Capital Medical University, Beijing, China

[7]Department of Endocrinology, The Children's Hospital of Chongqing Medical University, Chongqing, China

[8]Department of Pediatrics, The First Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, China

[9]Department of Endocrinology, Shenzhen Children's Hospital, Shenzhen, China

[10]Department of Pediatrics, Tongji Medical College of Huazhong University of Science and Technology, Wuhan, China

[11]Department of Endocrinology, Wuhan Women and Children's Health Care Center, Wuhan, China

[12]Department of Endocrinology, Genetics and Metabolism, Zhengzhou Children's Hospital, Zhengzhou, China

[13]Department of Pediatrics, Tianjin Medical University General Hospital, Tianjin, China

[14]Department of Pediatrics, The First Bethune Hospital of Jilin University, Jilin, China

[15]Department of Endocrinology, Genetics and Metabolism, Children's Hospital of Fudan University, Shanghai, China

[16]Department of Endocrinology, Children's Hospital of Shanghai, Shanghai, China

[17]School of Public Health, Zhejiang University, Hangzhou, China

[18]Department of Biomedical Engineering, Duke University, Durham, North Carolina, USA

Correspondence

Junfen Fu, The Children's Hospital, Zhejiang University School of Medicine, 3333 Binsheng Rd., Hangzhou, 310052, China.
Email: fjf68@zju.edu.cn

Abstract

Objective: This study aimed to analyze a comprehensive set of potential risk factors for obesity and overweight among Chinese children with a full range of ages and with wide geographical coverage.

Methods: In the Prevalence and Risk Factors for Obesity and Diabetes in Youth (PRODY) study (2017-2019), the authors analyzed 193,997 children aged 3 to 18 years from 11 provinces, autonomous regions, and municipalities that are

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geographically representative of China. All participants underwent physical examinations, and their caregivers completed questionnaires including dietary, lifestyle, familial, and perinatal information of participants. A multilevel multinomial logistic regression model was used to evaluate the potential risk factors.

Results: Among the actionable risk factors that were measured, higher consumption frequencies of animal offal (odds ratios [OR] for an additional time/day = 0.91, 95% CI: 0.88-0.95, same unit for OR below unless specified otherwise), dairy products (0.91, 95% CI: 0.88-0.94), freshwater products (0.94, 95% CI: 0.91-0.96), staple foods (0.94, 95% CI: 0.92-0.96), and coarse food grain (OR for every day vs. rarely = 0.92, 95% CI: 0.86-0.98) were associated with lower relative risk of obesity. However, higher restaurant-eating frequency (OR for >4 times/month vs. rarely = 1.21, 95% CI: 1.15-1.29) and longer screen-viewing duration (OR for >2 hours vs. <30 minutes = 1.16, 95% CI: 1.10-1.22) were associated with higher relative risk of obesity. Increased exercise frequency was associated with the lowest relative risk of obesity (OR for every day vs. rarely = 0.72, 95% CI: 0.68-0.77).

Conclusions: Changes in lifestyle and diet of Chinese children may help relieve their obesity burden.

INTRODUCTION

Obesity is emerging as a major health threat among children and adolescents worldwide, with considerable consequences of medical, psychological, and social comorbidities and with serious sequelae in adulthood [1]. Approximately 39 million children under 5 years of age worldwide had overweight or obesity in 2020, and more than 340 million children aged 5 to 19 years had overweight or obesity in 2016 [2]. Substantial increases in obesity prevalence have been observed in developed countries since the 1980s (from 15% to 35%); in recent decades the increases in many developing countries have also been alarming [3]. For example, the prevalence of obesity and overweight in Chinese children aged 6 to 17 years increased from 2.4% and 4.3% in 1991 to 12.7% and 11.7% in 2015, respectively [4]. However, obesity risk factor data in developing countries are still limited, and prevention strategies have been less publicized [5].

A wide spectrum of risk factors have been considered to be associated with childhood obesity. These factors include sex, age, perinatal factors (e.g., child feeding practice, birth weight, gestational age), lifestyle factors (e.g., screen-viewing duration, sleep duration, physical/sedentary activity), parental factors (e.g., parent body weight, income, and perception of child's weight), and dietary factors (e.g., Western-style fast food, ultraprocessed foods, soft drinks, dietary pattern, frequency of away-from-home eating) [4, 6–9]. However, previous findings of risk factors for obesity among Chinese children have some limitations, including small sample sizes, incomplete regional coverage, confined age range of participants, and a narrow spectrum of

[Correction added on 12 August 2022, after first online publication: Funding information has been corrected.]

Study Importance

What Is already known?

- A wide spectrum of risk factors has been considered to be associated with childhood obesity, including lifestyle, dietary, perinatal, and parental factors.
- Previous findings of risk factors for obesity among Chinese children have had some limitations, including small sample sizes, incomplete regional coverage, a confined age range of participants, and a narrow spectrum of risk factors.

What does this study add?

- In this large-scale nationwide study that included 193,997 children aged 3 to 18 years, we found that lower relative risk of obesity was associated with some actionable risk factors, including exercise frequency and consumption frequencies of coarse food grain, animal offal, freshwater products, dairy products, and staple foods, whereas higher relative risk of obesity was associated with long screen-viewing duration and restaurant-eating frequency.

How might these results change the direction of research or the focus of clinical practice?

- Our findings emphasize that the burden of childhood obesity in China may be reduced using changes in lifestyle and diet.

risk factors [10–13]. In addition, the regional prevalences of obesity estimated by our group [14] and Bekelman et al. [15] highlight the heterogeneity of the obesity epidemic among children. To mitigate the obesity burden in a large country with diverse geographies (such as China), it is essential to consider region as a potential confounder when evaluating potential risk factors.

Therefore, using data collected in a large-scale, cross-sectional survey (Prevalence and Risk Factors for Obesity and Diabetes in Youth [PRODY]), we aimed to examine a comprehensive set of potential risk factors among Chinese children with a full range of ages and wide geographical coverage.

METHODS

Study design and participants

The details of our cross-sectional survey (PRODY, from January 1, 2017, to December 31, 2019) were described previously [14]. Briefly, using a multistage, stratified, cluster-sampling design, a sample of Chinese children and adolescents was collected from 11 provinces, autonomous regions, and municipalities, which had different levels of urbanization and economic development [16, 17] and which were representative of western, southern, eastern, northern, and central China. The study protocol was approved by the ethics review committee of the Children's Hospital of the Zhejiang University (Approval Number: 2016-JRB-018) and the cooperating institutions. Written informed consent from participants and their guardians was obtained (children under 5 years old were allowed to draw symbols instead of a signature).

Data collection

Demographic information (e.g., name, sex, school grade, date of birth) and medical history of participants were collected through interviews, and anthropometric information of participants (weight and height)

was measured by physicians, as described previously [14]. BMI of participants was calculated as weight (kilograms) divided by height (meters squared). Overweight and obesity in children and adolescents were defined using age-specific BMI cutoff values according to the Chinese criterion (Supporting Information Table S1) [18]. Height and weight outliers were defined as measurements that fell outside the mean ± fourfold SD according to growth standards for Chinese children [19]. A small proportion (2.9%) of the study population were underweight, with a BMI z score lower than −2. Therefore, underweight or normal weight children and adolescents were assigned to a single weight-status category, as with other publications [20, 21].

The parents or caregivers of participants were asked to complete an online self-administered questionnaire (Supporting Information Table S2). Using this questionnaire, we collected parental demographics (e.g., age, education level, annual household income), anthropometrics (e.g., height, weight), and medical history (e.g., diabetes, gestational diabetes). In addition, the questionnaire included the perinatal information of participants (e.g., birth weight, gestational age, breastfeeding duration) and participants' lifestyles (e.g., daily screen-viewing duration, weekly exercise frequency, weekly mean exercise duration). Overweight in parents was defined as their BMI equal to or higher than 24 kg/m^2. Preterm birth in participants was defined as delivery at less than 37 weeks' pregnancy [22]. The birth weight of participants between 2.5 kg and 4.0 kg was considered to be normal; otherwise, it was considered as lower birth weight or macrosomia [23, 24]. Mother's age at delivery was calculated by subtracting child's age from mother's age. Screen viewing included reading books on smartphones, watching TV, playing computer games, etc. Exercise included jogging, dancing, ball games, skipping rope, etc. (walking not included).

We collected participants' dietary information using the same online questionnaire, asking the monthly restaurant-eating frequency, monthly junk food frequency, weekly coarse food grain frequency, and food categories consumed in each meal in the recent month. Coarse food grain included legumes (e.g., soybean, mung bean, pea), tubers (e.g., sweet potatoes, potatoes, Chinese yam), and grains (e.g., oat, corn, millet, barley). Junk food included pizza, hamburgers, chips, and other fried foods. Food categories included staple foods, red

TABLE 1 Population characteristics in PRODY study (2017-2019)

	Region					Total
	Southern	Northern	Eastern	Central	Western	
Total	31,782	28,270	99,384	29,633	4,928	193,997
Male	16,224 (51.0)[a]	14,532 (51.4)[a]	53,619 (54.0)[b]	15,324 (51.7)[a]	2,479 (50.3)[a]	102,178 (52.7)
Age (y)	10.13 (3.51)[a]	8.53 (3.67)[b]	10 (4.03)[c]	9.89 (3.37)[d]	11.35 (3.73)[e]	9.82 (3.84)
Obesity status	[a]	[b]	[c]	[d]	[e]	
Overweight	4,288 (13.5)	5,204 (18.4)	15,495 (15.6)	4,879 (16.5)	708 (14.4)	30,574 (15.8)
Obesity	2,340 (7.4)	4,237 (15.0)	7,661 (7.7)	2,684 (9.1)	295 (6.0)	17,217 (8.9)

Note: Continuous variables were expressed as mean (SD), and categorial variables were expressed as count (percentage). Values superscripted by different letters (a-e) were significantly different at the 5% probability level. χ^2 pairwise tests with Bonferroni method were used to compute the adjusted p values for categorial variables. Fisher least significant difference test was used to compute the adjusted p values for continuous variables.
Abbreviation: PRODY, Prevalence and Risk Factors for Obesity and Diabetes in Youth.

TABLE 2 Characteristics of potential risk factors in the PRODY study (2017-2019)

Risk factor	Normal weight children Exposure	Children with overweight Exposure	p value	Children with obesity Exposure	p value
Dietary					
Animal offal (times/d)	0.22 (0.55)	0.20 (0.53)	<0.001	0.18 (0.50)	<0.001
Freshwater products (times/d)	0.79 (0.85)	0.77 (0.85)	0.002	0.73 (0.83)	<0.001
Dairy products (times/d)	0.64 (0.59)	0.65 (0.58)	0.120	0.62 (0.57)	<0.001
Staple foods (times/d)	2.77 (0.74)	2.76 (0.75)	0.210	2.76 (0.74)	0.240
Seafoods (times/d)	0.38 (0.69)	0.38 (0.68)	1.000	0.35 (0.67)	<0.001
White meat (times/d)	0.90 (0.87)	0.89 (0.87)	0.030	0.86 (0.87)	<0.001
Red meat (times/d)	1.38 (0.80)	1.40 (0.79)	<0.001	1.37 (0.80)	1.000
Eggs (times/d)	1.59 (1.13)	1.63 (1.11)	<0.001	1.62 (1.12)	<0.001
Dark-colored vegetables (times/d)	1.33 (0.84)	1.35 (0.83)	<0.001	1.34 (0.83)	0.034
Light-colored vegetables (times/d)	1.04 (0.88)	1.03 (0.89)	0.301	1.01 (0.89)	<0.001
Fruit (times/d)	0.26 (0.47)	0.27 (0.47)	0.026	0.27 (0.47)	0.640
Legumes (times/d)	0.80 (0.87)	0.83 (0.88)	<0.001	0.82 (0.88)	0.086
Algae/mushrooms (times/d)	0.66 (0.84)	0.67 (0.85)	0.380	0.65 (0.84)	0.610
Coarse food grain frequency			<0.001		<0.001
Rarely	24,690 (16.9)	5,509 (18.0)		3,418 (19.9)	
1-2 times/wk	80,758 (55.2)	16,671 (54.5)		9,359 (54.4)	
3-4 times/wk	25,726 (17.6)	5,385 (17.6)		2,932 (17.0)	
Daily	15,032 (10.3)	3,009 (9.8)		1,508 (8.8)	
Junk food frequency			<0.001		<0.001
Rarely	75,165 (51.4)	14,724 (48.2)		7,922 (46.0)	
1-2 times/mo	58,425 (40.0)	12,980 (42.5)		7,630 (44.3)	
3-4 times/mo	9,210 (6.3)	2,127 (7.0)		1,195 (6.9)	
>4 times/mo	3,406 (2.3)	743 (2.4)		470 (2.7)	
Restaurant-eating frequency			<0.001		<0.001
Rarely	39,384 (26.9)	7,640 (25.0)		3,993 (23.2)	
1-2 times/mo	54,096 (37.0)	11,396 (37.3)		6,470 (37.6)	
3-4 times/mo	30,805 (21.1)	6,632 (21.7)		3,795 (22.0)	
>4 times/mo	21,921 (15.0)	4,906 (16.0)		2,959 (17.2)	
Lifestyle					
Screen-viewing duration			0.561		0.801
<30 minutes	70,800 (48.4)	14,980 (49.0)		8,225 (47.8)	
1-2 hours	52,471 (35.9)	10,836 (35.4)		6,263 (36.4)	
>2 hours	22,935 (15.7)	4,758 (15.6)		2,729 (15.9)	
Exercise frequency			< 0.001		<0.001
Rarely	21,733 (14.9)	4,474 (14.6)		2,839 (16.5)	
1-3 times/wk	71,647 (49.0)	15,441 (50.5)		8,980 (52.2)	
4-6 times/wk	23,948 (16.4)	4,909 (16.1)		2,577 (15.0)	
Daily	28,878 (19.8)	5,750 (18.8)		2,821 (16.4)	
Exercise duration (min)			1.000		0.017
<90	60,001 (41.0)	12,489 (40.8)		7,285 (42.3)	
90-120	41,218 (28.2)	8,623 (28.2)		4,747 (27.6)	
>120	44,987 (30.8)	9,462 (30.9)		5,185 (30.1)	

(Continues)

TABLE 2 (Continued)

Risk factor	Normal weight children Exposure	Children with overweight Exposure	p value	Children with obesity Exposure	p value
Family					
Mother's age at delivery (y)	27.03 (4.47)	26.99 (4.41)	0.420	27.05 (4.46)	1.000
Household income (yuan)			<0.001		0.012
<100,000	72,374 (49.5)	14,533 (47.5)		8,370 (48.6)	
100,000-200,000	46,438 (31.8)	10,106 (33.1)		5,683 (33.0)	
>200,000	27,394 (18.7)	5,935 (19.4)		3,164 (18.4)	
Having a father with overweight			<0.001		<0.001
Yes	12,991 (4.4)	4,018 (6.6)		3,194 (9.3)	
Having a mother with overweight			<0.001		<0.001
Yes	4,785 (1.6)	1,550 (2.5)		1,239 (3.6)	
Father's education level			<0.001		<0.001
Lower than high school	48,091 (32.9)	9,652 (31.6)		5,281 (30.7)	
High school	41,400 (28.3)	8,686 (28.4)		5,006 (29.1)	
Higher than high school	56,715 (38.8)	12,236 (40)		6,930 (40.3)	
Perinatal					
Preterm			1.000		0.102
Yes	7,337 (5.0)	1,504 (4.9)		929 (5.4)	
Breastfeeding duration			<0.001		<0.001
Never breastfed	45,504 (31.1)	9,087 (29.7)		4,805 (27.9)	
<6 months	39,411 (27.0)	8,176 (26.7)		4,615 (26.8)	
6-10 months	15,941 (10.9)	3,054 (10.0)		1,550 (9.0)	
>10 months	45,350 (31.0)	10,257 (33.5)		6,247 (36.3)	
Birth weight (kg)			<0.001		<0.001
Normal	129,224 (88.4)	26,187 (85.7)		14,564 (84.6)	
Lower	4,719 (3.2)	785 (2.6)		435 (2.5)	
Macrosomia	12,263 (8.4)	3,602 (11.8)		2,218 (12.9)	

Note: Continuous variables were expressed as mean (SD), and categorial variables were expressed as count (percentage). χ^2 pairwise tests with Bonferroni method was used to compute the adjusted *p* values for categorial variables. Fisher least significant difference test was used to compute the adjusted *p* values for continuous variables. Birthweight between 2.5 kg and 4.0 kg was considered to be normal. Parents' overweight was defined as BMI equal to or higher than 24.
Abbreviation: PRODY, Prevalence and Risk Factors for Obesity and Diabetes in Youth.

meat, white meat, animal offal, freshwater products, seafoods, eggs, legumes, dark-colored vegetables, light-colored vegetables, and algae/mushrooms. Sample foods in these categories are shown in Supporting Information Table S3. The consumption frequency of each food category (times per day) was derived by summing the frequencies during three meals.

Statistical analysis

To summarize the characteristics of participants, we calculated percentage for categorical observations and used χ^2 tests with a *p* value adjusted by Bonferroni method to compare differences among participants in different regions. In addition, we computed mean and standard deviation (SD) for continuous variables, and we used Fisher least significant difference test for multiple comparisons.

We fitted a multinomial logistic regression of three outcomes (normal weight, overweight, and obesity) with three levels of random effects (province/municipality/autonomous region, prefecture/district, and county/county-level city) and with regressors for age group (16 groups spanning ages 3-18 years), sex (categorical), region (categorical), and their interactions [14]. Potential risk factors, which included dietary factors (junk food frequency [categorical], coarse food grain frequency [categorical], restaurant-eating frequency [categorical], and the daily consumption frequencies of food categories [continuous]), lifestyle factors (screen-viewing duration, exercise frequency, and exercise duration; all these were categorical), family factors (mother's age at delivery [continuous], annual household income [categorical], having an overweight father or mother [categorical], and father's education level [categorical]), and perinatal factors (preterm, breastfeeding duration, and birth weight; all these were categorical), were also specified as regressors. The association between each potential risk factor and the

relative risk of obesity or overweight was estimated using an odds ratio (OR) while adjusting for the effects of age group, sex, and region. Generalized variance inflation factors were computed to examine multicollinearity in regressors (Supporting Information Table S4) [25]. A two-sided p value of 0.05 was considered statistically significant. Statistical analyses were conducted using the R software program (version 4.0, R Group for Statistical Computing).

RESULTS

Our analysis included a sample of 193,997 healthy children and adolescents (102,178 boys [52.7%] and 91,819 girls [47.3%]; mean [SD] age = 9.8 [3.8] years) from eastern, southern, northern, central, and western China (Table 1). Between January 2017 and December 2019, a total of 217,127 eligible participants were initially enrolled in the PRODY study; however, we excluded 3,220 participants without consent statements and 6,216 participants diagnosed with liver or renal dysfunction, congenital metabolic diseases, heart diseases, and solid or hematologic tumors or who were undergoing treatment with drugs that affect body weight (e.g., orlistat, topiramate, liraglutide). We also excluded 2,121 participants with missing weight or height values, 4,472 participants with outlying height or weight values, and 7,101 participants with missing data on potential risk factors (Supporting Information Figure S1). The general characteristics of these risk factors in the study population are presented in Table 2.

The results of our analysis of potential risk factors for obesity and overweight are summarized in Figure 1 and Supporting Information Figure S2, respectively. We mainly describe the results for risk factors of obesity because the results for overweight were similar. We observed significant associations of eating habits and food consumption frequencies with relative risk of obesity (Figure 1). Daily consumption frequencies of animal offal, dairy products, staple foods, and freshwater products were associated with lower relative risk of obesity. The OR for an additional time per day was 0.91 (95% CI: 0.88-0.95) for animal offal, 0.91 (95% CI: 0.88-0.94) for dairy products, 0.94 (95% CI: 0.92-0.96) for staple foods, and 0.94 (95% CI: 0.91-0.96) for freshwater products. In contrast, daily consumption frequencies of algae/mushrooms and legumes were only borderline associated with relative risk of obesity (OR = 1.03 [95% CI: 1.00-1.05] for algae/mushrooms; 1.04 [95% CI: 1.02-1.06] for legumes). Compared with rarely consumed, having coarse food grain more than once a month was negatively associated with relative risk of obesity, with OR ranging from 0.89 (95% CI: 0.85-0.93) for one to two times per week to 0.92 (95% CI: 0.86-0.98) for every day. Higher restaurant-eating frequency was associated with higher relative risk of obesity (compared with rarely, OR ranged from 1.09 [95% CI: 1.04-1.14] for 1-2 times/mo to 1.21 [95% CI: 1.15-1.29] for >4 times/mo).

Several lifestyle factors were also associated with relative risk of obesity of Chinese children (Figure 1). Longer screen-viewing duration was associated with higher relative risk (compared with <30 minutes, OR for 1-2 hours = 1.07 [95% CI: 1.03-1.11] and for >2 hours 1.16 [95% CI: 1.09-1.22]). More frequent exercise was
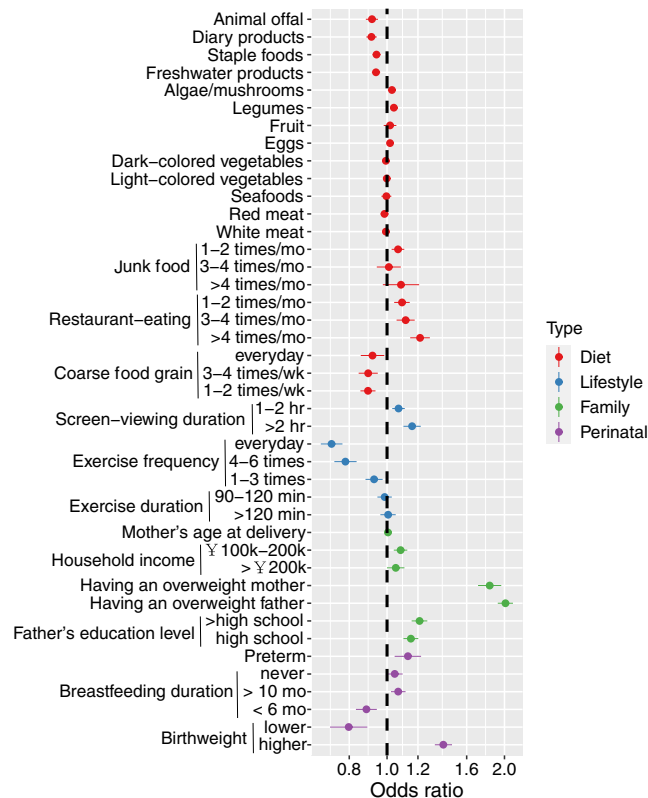

FIGURE 1 OR for relative risk of obesity in the PRODY study (2017-2019). Error bars indicate 95% CI. A multilevel multinomial logistic regression model was used to estimate OR. Regressors included age group (3-18 years), sex (male or female), region (east, south, north, central, or west), age-sex interaction, age-region interaction, sex-region interaction, term of birth (full-term or preterm), birth weight (normal, lower, or macrosomia), breastfeeding duration (6-10 months, never breastfed, <6 months, or >10 months), annual household income (<¥100,000, ¥100,000-¥200,000, or >¥200,000), father's education level (lower than high school [primary or middle school], high school, or higher than high school [undergraduate or graduate school]), having a mother or father with overweight, daily screen-viewing duration (<30 minutes, 1-2 hours, or >2 hours), weekly exercise frequency (rarely, 1-3 times, 4-6 times, or daily), weekly mean exercise duration (<90 minutes, 90-120 minutes, or >120 minutes), mother's age at delivery (years), monthly restaurant-eating frequency (rarely, 1-2 times, 3-4 times, or >4 times), monthly junk food frequency (rarely, 1-2 times, 3-4 times, or >4 times), weekly coarse food grain frequency (rarely, 1-2 times, 3-4 times, or daily), and food categories (algae/mushrooms, eggs, fruit, legumes, seafoods, white meat, red meat, dark-colored vegetables, light-colored vegetables, staple foods, freshwater products, animal offal, and dairy products collected as the daily consumption frequencies). Peterm birth in participants was defined as delivery at less than 37 weeks' pregnancy. Birth weight between 2.5 kg and 4.0 kg was considered to be normal. Parents' overweight was defined as BMI equal to or higher than 24. k, thousands; OR, odds ratio; PRODY, Prevalence and Risk Factors for Obesity and Diabetes in Youth [Color figure can be viewed at wileyonlinelibrary.com]

associated with significantly lower relative risk (OR ranging from 0.93 [95% CI: 0.88-0.97] for 1-3 times/wk to 0.72 [95% CI: 0.68-0.77] for every day, compared with rarely exercise).

Among the familial risk factors, higher annual household income (> ¥100,000) had a borderline positive association with relative risk of obesity compared with the lowest tertile (<¥100,000; OR = 1.08 [95% CI: 1.04-1.13] for ¥100,000-¥200,000; OR = 1.05 [95% CI: 1.00-1.11] for >¥200,000; Figure 1). Having a father or mother with overweight was the most significant risk factor (OR for father = 2.01 [95% CI: 1.92-2.10]; OR for mother = 1.83 [95% CI: 1.71-1.96]). Interestingly, having a better-educated father was associated with higher relative risk of obesity (OR comparing > high school to < high school = 1.21 [95% CI: 1.16-1.27]; Figure 1).

Among the perinatal risk factors, being born preterm was associated with higher relative risk of obesity (OR = 1.13, 95% CI: 1.04-1.22; Figure 1). Children breastfed longer (>10 mo) were borderline associated with relative risk compared with those with proper breastfed duration (6-10 mo; OR = 1.07, 95% CI: 1.02-1.12). Macrosomia also was positively associated with relative risk (OR = 1.39, 95% CI: 1.33-1.47).

DISCUSSION

In the present study we analyzed data collected in a large-scale nationwide survey to evaluate potential risk factors of overweight and obesity among Chinese children and adolescents. Although risk factors for childhood obesity have been established [6–9], the wide range of ages and the broad geographic coverage of our survey allowed us to examine these risk factors in the context of differences in obesity among the heterogeneous population. Furthermore, by including explorative risk factors (such as food categories) in the spectrum of potential risk factors, we were able to compare a comprehensive set of risk factors at the same scale.

As expected from previous studies [26], we found that having parents with overweight was the most significant risk factor for overweight and obesity in children. This was likely due to both genetic susceptibility [4] and unhealthy home environment factors [6]. Therefore, combating the obesity epidemic is not only the responsibility of children; parents should be role models for their offspring to help them lose weight. The second conspicuous risk factor of obesity was birthweight, and its positive association has been indicated in previous studies of limited sample size [27–29]. Therefore, we suggest that parents pay special attention to children born with macrosomia. Interestingly, having a better-educated father and a higher annual household income were also associated with higher relative risk of obesity. Given that previous studies have either supported [16, 30] or contradicted [27, 31] our findings, we speculate that these discrepancies might be attributed to differences in the variables included in the statistical models. We did not include mother's education level in our analyses because this risk factor was colinear with father's education level. Consistent with a previous national study using three consecutive interviewer-administered 24-hour dietary recalls [32], we also found that higher restaurant-eating frequency was significantly associated with higher relative risk of obesity. A possible reason for this result is that food sold in restaurants is usually rich in fat and sugar to strengthen flavor, which potentially can increase the relative risk of obesity. Our findings also corroborated the positive associations between relative risk of obesity and long screen-viewing time (>2 hours), which have been inferred in previous studies [27]. Mechanistically, long screen-viewing time is probably associated with long sedentary duration and habits of eating snacks. In addition, we also observed that being born preterm and breastfed longer (>10 mo) were associated with higher relative risk of obesity. These findings are consistent with those of previous regional studies including the perinatal risk factors [33, 34]. Because we failed to distinguish mixed feeding from pure breastfeeding in our questionnaire, the association that we estimated between breastfeeding duration and offspring's risk of childhood obesity should be interpreted carefully. Mixed feeding may have had adverse effects on childhood obesity because the delivery amount could have exceeded an infant's need.

Our analysis also identified several protective factors that are important for obesity control. First, increased weekly exercise frequency brought profound benefits compared with weekly exercise duration. Given that physical activity has been negatively [35] or nonsignificantly [36] associated with overweight and obesity among Chinese children in previous regional studies, we speculate that our ability to detect an association between physical activity and obesity risk was facilitated by the large sample size and wide geographical coverage. Second, higher consumption frequency of coarse food grain was associated with lower relative risk of obesity. To our knowledge, evidence of an association between coarse food grain intake and obesity among Chinese children is scarce. Findings from several cross-sectional studies conducted in Western countries have demonstrated a negative association between whole-grain intake and obesity among children and adolescents [37–39]. However, these studies mainly included whole grains typically consumed in the form of whole-grain breads or breakfast cereals, whereas the most frequently consumed sources of coarse food grains in traditional Chinese diets are millet, corn, oats, adlay, and buckwheat rather than rice and wheat products [40, 41]. Coarse food grains are minimally processed and are rich in fiber, B vitamins, and some trace minerals [40]; therefore, we recommend that intake of coarse food grains be encouraged to combat obesity. In addition, our analysis of dietary risk factors revealed some new findings about the beneficial effects of increased consumption frequencies of animal offal, freshwater products, dairy products, and staple foods for Chinese children. The association between dairy products and lower relative risk of obesity was consistent with meta-analyses of cross-sectional studies and with prospective cohort studies, but not with a meta-analysis of intervention studies [42]. This benefit might be associated with the increased fecal fat excretion and insulin secretion mediated by dietary calcium and proteins, respectively [42]. However, explanations for the associations between other food categories and obesity are unclear and warrant further investigation. We speculate that they may be related to food diversity, which has been reported to be inversely associated with body adiposity indicators by modulating hormonal pathways involved in fat deposition [43].

Prevention and intervention of childhood obesity should be public health priorities to prevent children and adolescents from suffering multiple obesity-related comorbidities. Our analysis identified significant family, perinatal, lifestyle, and dietary risk factors for overweight

and obesity to help develop intervention strategies that may relieve the obesity burden of children in China.

Strengths

The strengths of our study included its large sample size and the breadth of information on demographic, anthropometric, lifestyle, dietary, perinatal, and parental characteristics. By including a comprehensive set of well-known and explorative risk factors, we were able to assess their contributions to obesity and overweight. In addition, we evaluated these risk factors while considering regional differences in age and sex as confounders of obesity and overweight prevalence [14]. Moreover, the PRODY survey included body weights and heights measured by physicians that provided more accurate estimates of BMI than self-reported or parent-reported weights and heights.

Limitations

Our study had several limitations. First, given the inherent limitations of cross-sectional survey data, we could not test causal relationships. Second, we did not include some confusing food categories such as sweetened beverages and desserts. By omitting these obviously adverse food items, we also intended to collect less-biased answers from those parents who insisted on the healthy dietary habits of their children. Third, the dietary information in our survey is qualitative. As a compromise between the precision and user-friendliness of the online questionnaire, we decided to simplify the food-frequency questionnaire and to explore the preliminary associations between food categories and relative risk of obesity. Therefore, hypotheses can be derived from our study, but not definitive answers. Fourth, the parental-reported dietary information may not be completely accurate, although it is common in surveys for parents to estimate the dietary intake of their child as a proxy, especially in surveys on children with a full range of ages [44]. Recall bias of parents filling in perinatal information also existed. Fifth, our results may have been affected by residual confounding, including participants' ages, sleep duration, and so on. Finally, our sampling was restricted to suburban and urban areas (91% of schools are surveyed from urban areas) because access to the population in rural areas was challenging. Therefore, future efforts should attempt to improve sampling of the rural population.

CONCLUSION

In summary, we found that higher relative risk of obesity was associated with some actionable risk factors, including long screen-viewing duration and frequent eating in restaurants. Lower relative risk of obesity was associated with more frequent exercise and consumption of coarse food grain, animal offal, dairy products, freshwater products, and staple foods. Our findings emphasize the need for using these risk factors to help develop effective strategies for reducing the childhood obesity burden in China.**O**

ORCID

JingNan Chen https://orcid.org/0000-0003-2391-8028
Junfen Fu https://orcid.org/0000-0001-6405-1251

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.