Longitudinal associations of away-from-home eating, snacking, screen time, and physical activity behaviors with cardiometabolic risk factors among Chinese children and their parents

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ABSTRACT

Background: Little is known about intergenerational differences in associations of urbanization-related lifestyle behaviors with cardiometabolic risk factors in children and their parents in rapidly urbanizing China.

Objective: We tested the intergenerational differences in longitudinal associations of away-from-home eating, snacking, screen time, and leisure-time sports with high waist-to-height ratio (WHtR), elevated blood pressure (BP), elevated glycated hemoglobin (HbA1c), and elevated C-reactive protein (CRP) among Chinese children and their parents.

Design: We studied children enrolled in the longitudinal China Health and Nutrition Survey (1991–2009, 7 surveys) aged 7–17 y in ≥2 surveys (average follow-up: 2.3 surveys out of a possible 4 surveys with the age restriction; *n* = 3875, including 1175 siblings) and their parents (2947 mothers, 2632 fathers) living in the same household. We used 3 consecutive interviewer-administered 24-h dietary recalls to derive a 3-d average for away-from-home eating (nonconsumer, >0 and <1 meal/d, or ≥1 meals/d) and consumption of fruit or vegetable snacks (any or none) and other snacks (any or none) and a self-reported 7-d physical activity recall for screen time (≤1, >1 and ≤2, or >2 h/d) and leisure-time sports (any or none). Random-effects logistic regression was used to examine the associations of lagged (average: 3 y) behaviors with cardiometabolic risk factors (WHtR, BP, HbA1c, and CRP).

Results: We detected intergenerational differences in associations between lagged behaviors and risk factors (*P*-interaction < 0.1). Generation-specific models showed that lagged away-from-home eating of ≥1 meal/d (compared with none) was negatively associated with parents' high WHtR (OR: 0.68; 95% CI: 0.53, 0.88) but positively associated with children's high WHtR (OR: 1.46; 95% CI: 1.01, 2.12). Lagged fruit and vegetable snack consumption was negatively related to parents' (OR: 0.76; 95% CI: 0.59, 0.97) and children's (OR: 0.58; 95% CI: 0.33, 1.00) high WHtR. Lagged screen time (>2 compared with ≤1 h/d) was positively associated with parents' (OR: 2.58; 95% CI: 1.56, 4.28) and children's high WHtR (OR: 2.26; 95% CI: 1.06, 4.83).

Conclusion: Parent-offspring differences in associations between lifestyle behaviors and cardiometabolic risk factors provide insight into intergenerational differences in cardiometabolic risk with urbanization. *Am J Clin Nutr* 2017;106:168–78.

Keywords: away-from-home eating, snacking, leisure-time sports, waist-to-height ratio, blood pressure, hemoglobin A1c, C-reactive protein, urbanization, households, intergenerational difference

INTRODUCTION

China has the world's highest prevalence of diabetes (1), which, along with obesity, hypertension, and inflammation, has continued to grow in the past 2 decades (2). Although cardiometabolic disease (CMD) and its associated risk factors have been increasing in both adults and children, previous research has documented a faster increase in overweight in children compared with adults in China (3). Thus, it is important to characterize intergenerational differences in lifestyle behaviors that accompany urbanization and their associations with cardiometabolic risk factors in Chinese youth and parents. However, to our knowledge, no such study has examined the generational differences in CMD risk in urbanizing China.

Dietary and physical activity (PA) behaviors are important contributors to CMD risk factors (4, 5). Studies have shown that

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Supplemental Figure 1 and Supplemental Table 1 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://ajcn.nutrition.org.

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Abbreviations used: BP, blood pressure; CHNS, China Health and Nutrition Survey; CMD, cardiometabolic disease; CRP, C-reactive protein; DBP, diastolic blood pressure; HbA1c, glycated hemoglobin; PA, physical activity; SBP, systolic blood pressure; WHtR, waist-to-height ratio.

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westernized diets are associated with a higher risk of obesity (6, 7). China is not only experiencing a transition from traditional to westernized diets but is also experiencing a dramatic change in eating behaviors, such as increased away-from-home eating and snacking (8, 9). Away-from-home eating has been positively associated with overweight in the United States (10). The consumption of snacks in Western populations, mostly candy, sweetened beverages, and salty snacks (11, 12), has also been associated with weight gain (13, 14).

Another possible driver of the increasing CMD risk factors is the large decline in PA and increases in sedentary behaviors over the past 20 y in China (15, 16). Several studies have found positive associations of sedentary behavior with CMD risk factors, such as obesity, type 2 diabetes, and hypertension (17–19).

Although many studies examined the associations of health behaviors with CMD risk factors, the majority were cross-sectional, and few studies examined differences in behavior-risk associations across generations (10). Studying this question in a longitudinal setting allows temporality between behaviors and risk factors. It will provide a better understanding of the associations of behaviors in earlier years with risk factors in later years and whether the associations vary in children compared with adults.

We aimed to determine the longitudinal associations of away-from-home eating, snacking, screen time, and leisure-time sports with increasingly prevalent CMD risk factors, including high waist-to-height ratio (WHtR), elevated blood pressure (BP), elevated glycated hemoglobin (HbA1c), and high C-reactive protein (CRP) in Chinese children aged 7–17 y and their parents. We also tested whether the associations between these behaviors and CMD risk factors differed in children relative to their parents by using the longitudinal China Health and Nutrition Survey (CHNS; 1991–2009 across 7 surveys).

METHODS

CHNS

The CHNS is a household-based longitudinal cohort study with ongoing data collection in 9 provinces across China (north: Heilongjiang, Liaoning; central: Shandong, Henan, Jiangsu; south: Hunan, Hubei, Guangxi, Guizhou) in 9 survey rounds from 1989 to 2011. With a multistage, random-cluster design, we used a stratified probability sample to select counties and cities stratified by income levels with the use of State Statistical Office definitions (20). We then selected communities and households from these strata. The CHNS cohort initially mirrored national age-sex-education profiles (21), and the provinces in the CHNS sample constituted 44% of China's population in 2009 (according to the 2009 census). More details on survey procedures are described elsewhere (22). The study was approved by the Institutional Review Board at the University of North Carolina at Chapel Hill, the China-Japan Friendship Hospital, the Ministry of Health, and the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention. Participants gave informed consent for participation.

Analysis sample

We used longitudinal data from 1991, 1993, 1997, 2000, 2004, 2006, and 2009 when diet, PA, BP, and anthropometric data on parents and children aged 7–17 y in ≥2 visits were collected. Fasting blood samples were first collected in 2009. Participants were eligible if they were parents with children aged 7–17 y who participated in ≥2 surveys over this period (4744 children, 3497 mothers, and 3346 fathers). Children aged into, and out of, the analytic sample with the age restriction. We excluded participants if they were missing all risk factor measures (n = 745) or if they were diagnosed with hypertension or diabetes (n = 164). We further excluded those who were missing covariates (n = 1194). For CRP, we excluded participants who had CRP concentrations >10 mg/L (n = 50), because this indicates current infection (23). Our final analytic sample included 3875 children aged 7–17 y in ≥2 visits, 2947 mothers, and 2632 fathers (**Supplemental Figure 1**), with an average of 2.3 visits for diet and PA behaviors out of a maximum of 4 visits given the age restriction of 7–17 y in the period between 1991 and 2009. The included participants were slightly more likely to have a higher household income and to live in more urbanized areas than the eligible but excluded participants; children were younger and parents were older than those who were excluded. There was no significant difference in the prevalence of the CMD risk factors between included and excluded individuals.

Diet

We used 3 consecutive 24-h dietary recalls at the individual level and a food inventory at the household level during the same 3-d period to collect dietary data, randomly starting from Monday to Sunday. For 24-h recalls, trained interviewers recorded types and amounts of foods, types of meals, and places of food preparation of all food items consumed by each household member. For children <10 y old, mothers or a mother substitute recalled the children's dietary intake, including during school hours. All foods available in the household were measured daily for the food inventory. We used a Chinese food-composition table to estimate nutrient intake (24). This dietary assessment has been validated relative to doubly labeled water (r^2 = 0.56 for men; r = 0.60 for women) for energy (25) and urine for sodium (r^2 = 0.58), potassium (r^2 = 0.59), and monosodium glutamate (r^2 = 0.82) (26). In this study, we focused on away-from-home eating and snacking. We defined away-from-home eating as the consumption of foods prepared away from home (no matter if they were consumed at or away from home) during the 3-d period, which was categorized into nonconsumer, >0 and <1 meal/d, and ≥1 meals/d. Snacks were reported as foods consumed outside of the 3 main meals (breakfast, lunch, and dinner). The most frequent snack food in China is fruit (27). Due to the potential health benefits of fruit consumption and the adverse effects of high-fat or high-sugar snacks on cardiometabolic health, we further separated snacks into fruit and vegetable snacks and other snacks, and categorized them into any compared with no consumption for both types.

PA

Our PA data were derived from self-reported 7-d PA recalls across a variety of domains. Children and parents were asked about their participation and time spent in different types of sedentary behaviors and PA. We calculated PA by using hours spent in each activity multiplied by metabolic equivalents for that activity and defined total PA as the sum of metabolic equivalent hours for all activities (28, 29). Parents or primary caregivers completed the surveys for children aged <10 y. In this study, we examined screen time and discretionary leisure-time sports participation outside of school. Screen time referred to time spent watching television or videotapes, playing video games, and using a computer at home. We categorized individuals into ≤1, >1 and ≤2, and >2 h/d. Leisure-time sports included gymnastics, dancing, track-and-field sports, swimming, ball sports (e.g. basketball, tennis), and other sports (e.g., martial arts, tai chi). Due to the low participation rate in leisure-time sports, we dichotomized the variable into any compared with none. Because data on screen hours in adults were first collected in 2004 and the leisure-time sports survey changed in 2004, we restricted our screen time and PA analyses to 2004, 2006, and 2009 only.

Anthropometric measures

At each survey from 1991 to 2009, trained staff measured height (without shoes) and waist circumference (midway between the lower rib margin and the iliac crest; first collected in 1993). WHtR is calculated as waist circumference (centimeters) divided by height (centimeters). We classified high WHtR by using WHtR ≥0.5 (30).

BP

Trained physicians measured BP in triplicate at each visit from 1991 to 2009, and these values were averaged. Children's systolic BP (SBP) and diastolic BP (DBP) z scores were calculated on the basis of the age-, sex-, and height-specific BP percentile algorithm for children by using the US CDC 2000 growth curve reference (31). We defined elevated BP in children as an SBP z score or a DBP z score ≥90th percentile or an SBP ≥120 mm Hg or a DBP ≥80 mm Hg, as recommended by the NIH for prehypertension and hypertension in children (32). We combined prehypertension and hypertension as elevated BP because hypertension (SBP z score or DBP z score ≥95th percentile of the algorithm) is uncommon in children and adolescents (7% in our study sample). We defined parental elevated BP as prehypertension and hypertension by using the same cutoff (SBP ≥120 mm Hg or DBP ≥80 mm Hg) for consistency on the basis of recommendations from the American Heart Association (33) and the NIH (34).

Biomarkers

Blood samples were collected by venipuncture after overnight fasting in 2009. Laboratory analysis methods are described in detail elsewhere (2). We defined elevated HbA1c by using HbA1c ≥5.7% (as recommended by the American Diabetes Association for prediabetes and diabetes) (35). We combined prediabetes and diabetes as elevated HbA1c because diabetes (HbA1c ≥6.5%) is rare in children and adolescents (1% in our study sample). We defined parental HbA1c status by using the same cutoff for consistency. We measured high-sensitivity CRP via the immunoturbidimetric method and defined elevated CRP as CRP of 1–10 mg/L in children and 3–10 mg/L in adults (23, 36).

Covariates

At each survey, we collected participants' age (years), sex, household income (inflated to 2009; tertiles), geographic region (north, central, or south), year of study entry, highest parental education (none or primary, middle school, high school, or technical, college or higher), smoking (yes or no), total energy intake (kilocalories per day), total fat intake (percentage of total energy), total fruit and vegetable intake (percentage of total energy), sodium intake (milligrams per day; BP models only), and total PA (metabolic equivalent hours per week). We also used the CHNS multicomponent urbanicity scale composed of 12 urban environment domains representing infrastructure, economic, and social service. The scale has high reliability and validity (37), ranging from 0 to 120, with a higher score indicating higher urbanicity, which was categorized into year-specific tertiles.

Statistical analysis

We conducted all of the analyses by using Stata 14.0 (StataCorp), and used a P value <0.05 as our significance level. In descriptive analyses, we examined characteristics of children and their parents by away-from-home eating, snacking, screen time, and PA behavior categories and tested differences of these characteristics across behavior categories by using the chi-square test (categorical variables) and 1-factor ANOVA (continuous variables).

To establish temporality between behaviors and risk factors (i.e., latency period), we lagged behaviors by the period of time between surveys of analysis ($t - 1$). We conducted random-effects logistic regression models to examine the associations of lagged away-from-home eating, snacking, screen time, and PA with high WHtR and elevated BP at follow-up, with random intercepts for repeated measures within individuals and clustering within households. Because biomarkers were only collected in 2009, we conducted logistic regression models to examine the associations of away-from-home eating, snacking, screen time, and PA in 2006 with elevated HbA1c and elevated CRP in 2009. We additionally tested the associations of lagged behaviors with having 1 risk factor and ≥2 risk factors at follow-up. We conducted separate models for away-from-home eating, snacking, screen time, and PA. All away-from-home eating and snacking variables were included in the diet models; both screen time and leisure-time sports were included in the PA models. To test whether the associations differed between child and parent generations, we first included both generations in the same models with interaction terms between behaviors and a generation variable (children and parents). Because the interaction terms were significant ($P < 0.1$) for away-from-home eating, consumption of non–fruit or vegetable snacks, and leisure-time sports, we stratified all models by generation for consistency and conducted generation-specific analyses. We conducted 2 sets of models. The first set adjusted for covariates mentioned above, and we additionally adjusted for snacking in PA models, because evidence suggests an association between television watching and snacking (38). The second set of models additionally adjusted for WHtR in models with elevated BP, HbA1c, and CRP outcomes to test whether the behavior–risk factor associations were independent of central obesity, because previous research suggests that some behaviors, such as sedentary behavior, may have a direct influence on metabolic health in addition to the indirect effect of body weight. We present 2 sets of model results (fully adjusted models with and without WHtR adjustment). In addition, we tested whether the behavior-risk associations varied by survey year, age of children or parents, sex of children or parents, urbanicity, or year of study entry with the use of the Wald test. To test whether the censoring of our sample due to the age restriction of 7–17 y altered the associations of behaviors with risk factors, we conducted a sensitivity analysis among children who entered the CHNS at age 7 y and completed all 4 surveys before they turned 17 y (951 children with their parents: 902 mothers and 884 fathers).

RESULTS

Across all surveys, individuals who consumed away-from-home foods or any type of snacks had a higher household income and lived in more urban areas than did individuals who did not consume any away-from-home foods or snacks (**Table 1**). A greater proportion of individuals who participated in leisure-time sports lived in more urban areas. Adults who consumed any (compared with none) away-from-home foods generally had lower total energy intake and lower total PA. Those who had >2 (compared with ≤ 1) h/d of screen time and who participated in any (compared with none) leisure-time sports also had lower total PA. Children with >2 h/d screen time and who participated in leisure-time sports had higher total PA. The prevalence of CMD risk factors in parents and children from 1993 to 2009 is shown in **Supplemental Table 1**.

Associations of lagged away-from-home eating and snacking with CMD risk factors at follow-up

The associations between eating away-from-home and high WHtR, as well as between the consumption of non–fruit or vegetable snacks and elevated HbA1c differed between children and their parents (P-interaction < 0.1); thus, we conducted generation-specific models for all dietary analyses for consistency. We detected significant effect measure modification ($P < 0.1$) by parental age group (20–39 y or ≥ 40 y) for the association of lagged away-from-home eating with high WHtR at follow-up, so the results are presented separately by age groups for this association (**Table 2**). The associations of lagged away-from-home eating and snacking with CMD risk factors at follow-up did not differ by parent or child sex, survey year, or other covariates. Therefore, we did not further stratify our analyses.

Younger parents (aged 20–39 y) who had ≥ 1 (compared with no) away-from-home meals/d in the previous survey were less likely to have a high WHtR at follow-up (OR: 0.68; 95% CI: 0.53, 0.89), whereas children who had ≥ 1 (compared with no) away-from-home meals/d in the previous survey were more likely to have a high WHtR at follow-up (OR: 1.46; 95% CI: 1.01, 2.12). For both parents and children, fruit and vegetable snackers were less likely to have a high WHtR at follow-up than nonsnackers (parents—OR: 0.76; 95% CI: 0.59, 0.97; children—OR: 0.58; 95% CI: 0.33, 1.00). Parents who consumed fruit or vegetable snacks (compared with nonsnackers) in the previous survey also had lower odds of having an elevated BP at follow-up (OR: 0.73; 95% CI: 0.59, 0.89) in the fully adjusted model with WHtR adjustment. In addition, for parents, we found that fruit and vegetable snack consumption was associated with lower odds of having 1 and ≥ 2 risk factors, whereas the consumption of other snacks was associated with higher odds of having 1 risk factor.

Associations of lagged screen time and PA with CMD risk factors at follow-up

The associations of leisure-time sports with elevated HbA1c and high CRP differed between children and their parents (P-interaction < 0.1); thus, we conducted generation-specific models for all screen time and PA analyses for consistency. We found significant effect measure modification by parental age group (20–39 y or ≥ 40 y) for the association between lagged screen time and high WHtR at follow-up, so the results are presented separately by parental age group for this association (**Table 3**). The associations of lagged screen time and PA with CMD risk factors at follow-up did not differ by sex or other covariates.

We found that for older parents (aged ≥ 40 y) and children, those who were in the highest lagged screen time category (>2 h/d) compared with the lowest (≤ 1 h/d) were more likely to have a high WHtR at follow-up (older parents—OR: 2.58; 95% CI: 1.56, 4.28; children—OR: 2.26; 95% CI: 1.06, 4.83). Children who had >2 h/d (compared with ≤ 1 h/d) of screen time in the previous survey were also more likely to have elevated BP at follow-up (OR: 1.54; 95% CI: 1.03, 2.31) in the fully adjusted model with WHtR adjustment. In addition, screen time of >2 h/d (compared with ≤ 1 h/d) was associated with higher odds of having ≥ 2 risk factors in both parents (OR: 1.61; 95% CI: 1.18, 2.20) and children (OR: 3.03; 95% CI: 1.11, 8.29). Children who participated in leisure-time sports in the previous survey, compared with those who did not, had lower odds of high CRP at follow-up (OR: 0.24; 95% CI: 0.11, 0.53). Lagged leisure-time sports participation was not associated with any of the risk factors at follow-up among parents.

Comparing models that did and did not adjust for WHtR, associations of lagged non–fruit or vegetable snack consumption with elevated HbA1c at follow-up were attenuated after adjustment for WHtR in parents. Those who consumed non–fruit or vegetable snacks in the previous survey were more likely to have elevated HbA1c at follow-up (OR: 2.63; 95% CI: 1.00, 6.88) before adjustment for WHtR. However, after WHtR adjustment, the association was no longer significant (OR: 2.41; 95% CI: 0.95, 6.14), suggesting that the association between non–fruit or vegetable snack consumption and elevated HbA1c in parents was not independent of central obesity. Our sensitivity analysis for children who entered the CHNS at age 7 y and completed all surveys before they turned 17 y showed similar results for away-from-home eating, snacking, screen time, and PA (data not shown).

DISCUSSION

Lagged away-from-home eating, fruit and vegetable snacking, screen time, and leisure-time sports were associated with CMD

TABLE 1

Characteristics of the analytic sample according to dietary, screen time, and PA behaviors (CHNS 1991–2009 for diet, CHNS 2004–2009 for screen time and PA)[1]

					Snacking												
	Away-from-home eating				FVs			Other snacks			Screen time				Leisure-time sports participation		
	Nonconsumer	>0 and <1 meal/d	≥1 meal/d	*P*	Nonsnacker	Snacker	*P*	Nonsnacker	Snacker	*P*	≤1 h/d	>1 and ≤2 h/d	>2 h/d	*P*	None	Any	*P*
Parents																	
n	3199	1122	1258		5090	479		5339	230		743	1014	1046		2762	157	
Age, y	40.3 ± 6.5[2]	39.8 ± 5.9	39.9 ± 5.9	<0.001	40.2 ± 6.3	39.7 ± 5.9	0.003	40.1 ± 6.3	40.7 ± 5.5	0.01	41.6 ± 6.8	40.3 ± 6.1	40.2 ± 5.9	<0.001	40.6 ± 6.3	40.7 ± 5.7	0.67
Sex, % male	43.4	46.5	54.3	<0.001	47.4	42.1	<0.001	46.9	46.7	0.92	45.0	45.9	49.0	0.03	46.9	56.4	<0.001
Total energy intake, kcal/d	2463 ± 689	2368 ± 649	2362 ± 660	<0.001	2437 ± 679	2268 ± 620	<0.001	2416 ± 675	2488 ± 670	0.004	2230 ± 627	2246 ± 627	2238 ± 645	0.77	2242 ± 644	2246 ± 615	0.91
Fat, % of energy	20.1 ± 10.5	26.8 ± 10.7	30.2 ± 10.9	<0.001	24.6 ± 11.1	30.1 ± 10.8)	<0.001	25.0 ± 10.2	29.0 ± 10.4	<0.001	26.6 ± 10.8	27.2 ± 10.3	29.5 ± 11.0	<0.001	27.7 ± 10.8	32.4 ± 11.2	<0.001
FVs, % of energy	2.8 ± 2.4	3.0 ± 2.7	3.0 ± 2.7	<0.001	2.6 ± 2.3	5.3 ± 3.2	<0.001	2.8 ± 2.5	3.8 ± 3.0	<0.001	3.0 ± 2.3	3.2 ± 2.7	3.3 ± 2.6	0.001	3.2 ± 2.7	3.7 ± 2.9	0.28
Total PA, MET-h/d	324 ± 224	294 ± 226	221 ± 181	<0.001	295 ± 180	260 ± 181	<0.001	292 ± 180	285 ± 180	0.37	311 ± 238	297 ± 225	241 ± 212	<0.001	280 ± 231	191 ± 151	<0.001
Household income,[3,4] 1000 yuan/y	15.1 ± 19.1	19.6 ± 17.8	24.5 ± 25.3	<0.001	16.8 ± 19.5	28.6 ± 27.1	<0.001	17.3 ± 20.1	27.1 ± 26.0	<0.001	27.5 ± 29.7	27.1 ± 28.1	27.8 ± 28.7	0.86	26.7 ± 33.0	30.0 ± 31.9	0.01
Urbanicity[3,5]	45.3 ± 15.7	54.8 ± 19.3	63.4 ± 18.3	<0.001	49.9 ± 18.1	63.3 ± 18.7	<0.001	50.6 ± 18.0	60.8 ± 19.8	<0.001	61.6 ± 20.4	60.5 ± 19.3	59.7 ± 18.6	0.11	59.5 ± 19.3	65.1 ± 19.7	<0.001
Geographic region,[3] %				<0.001			<0.001			0.03				<0.001			0.04
North	13.5	21.8	13.4		12.0	36.7		14.7	16.8		27.0	19.7	21.3		21.6	20.7	
Central	25.6	29.7	38.9		30.0	27.3		29.5	31.8		28.1	28.7	21.9		27.1	23.2	
South	60.9	48.5	47.8		58.0	36.1		55.8	51.4		44.8	51.6	56.8		51.2	56.2	
Children																	
n	2310	643	922		3541	330		3625	246		521	495	501		1039	443	
Age, y	12.2 ± 2.9	12.2 ± 2.9	12.5 ± 2.9	<0.001	12.2 ± 2.9	12.3 ± 2.9	0.48	12.3 ± 2.9	12.0 ± 2.8	0.02	13.1 ± 2.9	12.3 ± 2.9	12.7 ± 3.2	<0.001	12.1 ± 3.0	13.2 ± 2.7	<0.001
Sex, % male	52.8	52.8	52.3	0.91	52.9	50.6	0.12	52.5	53.9	0.40	46.8	51.2	61.0	<0.001	46.6	66.2	<0.001
Total energy intake, kcal/d	2007 ± 632	1966 ± 595	1995 ± 613	0.04	2000 ± 621	1985 ± 619	0.40	1993 ± 618	2053 ± 622	0.005	1873 ± 612	1811 ± 578	1865 ± 627	0.06	1762 ± 560	1974 ± 648	<0.001
Fat, % of energy	21.7 ± 9.9	26.8 ± 9.4	30.0 ± 9.8	<0.001	24.1 ± 10.2	29.8 ± 9.8	<0.001	24.3 ± 10.1	29.4 ± 11.1	<0.001	28.0 ± 11.1	28.6 ± 10.6	28.6 ± 11.0	0.41	27.9 ± 11.1	29.9 ± 10.1	<0.001
FVs, % of energy	2.9 ± 2.6	3.0 ± 3.0	3.2 ± 3.1	<0.001	2.6 ± 2.4	5.7 ± 4.0	<0.001	2.9 ± 2.7	4.0 ± 3.3	<0.001	3.3 ± 2.7	3.4 ± 2.9	3.2 ± 2.7	0.20	3.3 ± 2.9	3.4 ± 2.2	0.80
Total PA, MET-h/d	44.1 ± 66.2	43.6 ± 59.1	43.4 ± 55.8	0.92	43.1 ± 63.1	48.1 ± 55.5	0.02	43.1 ± 62.3	50.4 ± 60.0	0.003	47.1 ± 60.3	49.3 ± 51.3	66.5 ± 95.0	<0.001	28.8 ± 36.0	91.9 ± 68.6	<0.001

[1] Chi-square test was used for categorical variables and 1-factor ANOVA was used for continuous variables. CHNS, China Health and Nutrition Survey; FV, fruit and vegetable; MET-h, metabolic equivalent hours; PA, physical activity.

[2] Mean ± SD (all such values).

[3] These are household-level variables that are identical for parents and children so are not repeated below for children.

[4] Total household income inflated to 2009.

[5] Urbanicity defined by a multicomponent urbanicity scale ranging from 0 to 120 (37).

TABLE 2
ORs (95% CIs) of cardiometabolic risk factors among parents and children according to categories of away-from-home eating and snacking in the previous survey year: CHNS 1991–2009[1]

	Away-from-home eating					Snacking: Fruit and vegetables			Snacking: Other snacks		
		>0 and <1 meal/d vs. none (ref)		≥1 meal/d vs. none (ref)			Snacker vs. nonsnacker (ref)			Snacker vs. nonsnacker (ref)	
	None	OR (95% CI)	*P*	OR (95% CI)	*P*	Nonsnacker	OR (95% CI)	*P*	Nonsnacker	OR (95% CI)	*P*
Parents											
High WHtR (n = 5579)											
Fully adjusted model[2]						Ref	0.76 (0.59, 0.97)	0.03	Ref	0.70 (0.49, 1.01)	0.06
Age 20–39 y	Ref	0.81 (0.62, 1.06)	0.12	0.68 (0.53, 0.88)	0.004						
Age ≥40 y	Ref	1.20 (0.96, 1.50)	0.11	0.91 (0.73, 1.15)	0.44						
Elevated BP (n = 5577)											
Fully adjusted model without WHtR[2]	Ref	1.08 (0.94, 1.23)	0.29	0.90 (0.78, 1.03)	0.12	Ref	0.72 (0.59, 0.87)	0.001	Ref	1.06 (0.81, 1.39)	0.67
Fully adjusted model with WHtR[3]	Ref	1.07 (0.93, 1.23)	0.33	0.95 (0.82, 1.09)	0.44	Ref	0.73 (0.59, 0.89)	0.002	Ref	1.09 (0.82, 1.43)	0.57
Elevated HbA1c (n = 942)											
Fully adjusted model without WHtR[2]	Ref	0.76 (0.43, 1.37)	0.36	1.12 (0.67, 1.85)	0.67	Ref	1.00 (0.58, 1.73)	0.99	Ref	2.63 (1.00, 6.88)	0.049
Fully adjusted model with WHtR[3]	Ref	0.71 (0.41, 1.26)	0.25	1.09 (0.67, 1.78)	0.74	Ref	1.13 (0.67, 1.90)	0.66	Ref	2.41 (0.95, 6.14)	0.06
High CRP (n = 925)											
Fully adjusted model without WHtR[2]	Ref	1.16 (0.70, 1.91)	0.57	0.94 (0.59, 1.50)	0.81	Ref	1.04 (0.65, 1.68)	0.86	Ref	0.98 (0.38, 2.52)	0.97
Fully adjusted model with WHtR[3]	Ref	0.94 (0.56, 1.59)	0.82	0.87 (0.55, 1.40)	0.58	Ref	1.23 (0.75, 2.02)	0.41	Ref	0.88 (0.31, 2.46)	0.80
One risk factor (n = 5579)											
Fully adjusted model without WHtR[2]	Ref	0.91 (0.81, 1.03)	0.13	0.95 (0.85, 1.07)	0.42	Ref	0.79 (0.66, 0.94)	0.01	Ref	1.13 (1.06, 1.70)	0.01
Two or more risk factors (n = 5630)											
Fully adjusted model without WHtR[2]	Ref	1.12 (0.95, 1.33)	0.18	0.86 (0.72, 1.02)	0.09	Ref	0.76 (0.60, 0.97)	0.03	Ref	0.70 (0.48, 1.00)	0.05
Children											
High WHtR (n = 3875)											
Fully adjusted model[2]	Ref	1.11 (0.74, 1.66)	0.61	1.46 (1.01, 2.12)	0.04	Ref	0.58 (0.33, 1.00)	0.05	Ref	1.20 (0.68, 2.11)	0.52
Elevated BP (n = 3451)											
Fully adjusted model without WHtR[2]	Ref	1.11 (0.87, 1.40)	0.41	0.98 (0.77, 1.24)	0.86	Ref	1.04 (0.76, 1.42)	0.81	Ref	1.01 (0.71, 1.44)	0.94
Fully adjusted model with WHtR[3]	Ref	1.05 (0.85, 1.31)	0.64	1.04 (0.84, 1.30)	0.72	Ref	1.13 (0.86, 1.49)	0.39	Ref	1.06 (0.78, 1.45)	0.70
Elevated HbA1c (n = 264)											
Fully adjusted model without WHtR[2]	Ref	0.80 (0.26, 2.40)	0.69	1.27 (0.45, 3.58)	0.66	Ref	1.78 (0.62, 5.13)	0.29	Ref	0.74 (0.27, 2.05)	0.57

(Continued)

TABLE 2 (*Continued*)

	Away-from-home eating					Snacking					
						Fruit and vegetables			Other snacks		
		>0 and <1 meal/d vs. none (ref)		≥1 meal/d vs. none (ref)			Snacker vs. nonsnacker (ref)			Snacker vs. nonsnacker (ref)	
	None	OR (95% CI)	*P*	OR (95% CI)	*P*	Nonsnacker	OR (95% CI)	*P*	Nonsnacker	OR (95% CI)	*P*
Fully adjusted model with WHtR[3]	Ref	0.89 (0.29, 2.70)	0.84	1.27 (0.44, 3.62)	0.66	Ref	1.76 (0.60, 5.12)	0.30	Ref	0.72 (0.25, 2.03)	0.53
High CRP (n = 236)											
Fully adjusted model without WHtR[2]	Ref	0.66 (0.29, 1.49)	0.32	0.49 (0.23, 1.06)	0.07	Ref	0.85 (0.41, 1.77)	0.66	Ref	0.91 (0.40, 2.06)	0.82
Fully adjusted model with WHtR[3]	Ref	0.52 (0.21, 1.32)	0.17	0.48 (0.21, 1.10)	0.08	Ref	0.96 (0.44, 2.09)	0.92	Ref	1.04 (0.43, 2.55)	0.93
One risk factor (n = 2621)											
Fully adjusted model without WHtR[2]	Ref	1.29 (1.02, 1.63)	0.04	1.05 (0.83, 1.32)	0.70	Ref	0.89 (0.66, 1.20)	0.44	Ref	1.00 (0.71, 1.42)	0.98
Two or more risk factors (n = 2684)											
Fully adjusted model without WHtR[2]	Ref	0.78 (0.46, 1.35)	0.38	0.83 (0.49, 1.41)	0.50	Ref	1.51 (0.85, 2.69)	0.16	Ref	1.06 (0.55, 2.07)	0.86

[1] We conducted separate random-effects logistic models for parents and children, with random intercept for individuals and households. The total sample with ≥1 risk factor included n = 3875 children and their parents (2947 mothers, 2632 fathers); the models differed slightly in sample size due to missingness of some outcome measures. HbA1c and CRP were only measured in 2009. High WHtR: WHtR ≥0.5; Elevated BP: systolic BP or diastolic BP z scores ≥90th percentile of the age-, sex-, and height-specific BP percentile or BP ≥120/80 mm Hg for children using the US CDC 2000 growth curve reference; BP ≥120/80 mm Hg for adults; Elevated HbA1c: HbA1c ≥5.7%; Elevated CRP: 1–10 mg/L for children and 3–10 mg/L for adults. BP, blood pressure; CHNS, China Health and Nutrition Survey; CRP, C-reactive protein; HbA1c, glycated hemoglobin; ref, reference; WHtR, waist-to-height ratio.

[2] Models adjusted for baseline age (years), sex, household income (tertiles), geographic region (north, central, or south), survey year, year of study entry, highest parental education (none or primary, middle school, high school or technical, college or higher), smoking (yes or no), total energy intake (kilocalories per day; quartiles), total fat intake (percentage of total energy; quartiles), total fruit and vegetable intake (percentage of total energy; quartiles), sodium intake (milligrams per day; quartiles; BP models only), and total PA (metabolic equivalent hours per week; quartiles).

[3] Models additionally adjusted for WHtR.

TABLE 3

ORs (95% CIs) of cardiometabolic risk factors among parents and children according to categories of screen time and leisure-time sports participation in the previous survey year: CHNS 2004–2009[1]

	Screen time					Leisure-time sports participation		
		>1 and ≤2 h/d vs. ≤1 h/d (ref)		>2 h/d vs. ≤1 h/d (ref)			Any vs. none (ref)	
	≤1 h/d	OR (95% CI)	*P*	OR (95% CI)	*P*	None	OR (95% CI)	*P*
Parents								
High WHtR (*n* = 1900)								
Fully adjusted model[2]						Ref	1.62 (0.86, 3.07)	0.14
Age 20–39 y	Ref	1.10 (0.65, 1.87)	0.71	1.05 (0.62, 1.80)	0.85			
Age ≥40 y	Ref	2.12 (1.32, 3.40)	0.002	2.58 (1.56, 4.28)	<0.001			
Elevated BP (*n* = 1899)								
Fully adjusted model without WHtR[2]	Ref	1.21 (0.94, 1.57)	0.14	1.20 (0.91, 1.56)	0.19	Ref	0.91 (0.58, 1.42)	0.67
Fully adjusted model with WHtR[3]	Ref	1.17 (0.90, 1.51)	0.24	1.14 (0.87, 1.49)	0.34	Ref	0.82 (0.52, 1.30)	0.34
Elevated HbA1c (*n* = 898)								
Fully adjusted model without WHtR[2]	Ref	0.82 (0.49, 1.36)	0.44	0.99 (0.58, 1.70)	0.98	Ref	1.16 (0.49, 2.71)	0.74
Fully adjusted model with WHtR[3]	Ref	0.81 (0.49, 1.34)	0.41	1.00 (0.59, 1.68)	0.99	Ref	1.19 (0.51, 2.79)	0.69
High CRP (*n* = 881)								
Fully adjusted model without WHtR[2]	Ref	1.52 (0.94, 2.46)	0.09	1.03 (0.61, 1.75)	0.91	Ref	1.38 (0.67, 2.83)	0.38
Fully adjusted model with WHtR[3]	Ref	1.45 (0.89, 2.38)	0.14	1.05 (0.61, 1.81)	0.85	Ref	1.50 (0.70, 3.19)	0.30
1 risk factor (*n* = 1867)								
Fully adjusted model without WHtR[2]	Ref	0.81 (0.65, 1.03)	0.08	0.83 (0.65, 1.05)	0.13	Ref	1.04 (0.69, 1.58)	0.84
≥2 risk factors (*n* = 1878)								
Fully adjusted model without WHtR[2]	Ref	1.63 (1.21, 2.19)	0.001	1.61 (1.18, 2.20)	0.003	Ref	1.31 (0.79, 2.17)	0.29
Children								
High WHtR (*n* = 1321)								
Fully adjusted model[2]	Ref	2.08 (1.06, 4.09)	0.03	2.26 (1.06, 4.83)	0.03	Ref	1.45 (0.84, 2.51)	0.18
Elevated BP (*n* = 1154)								
Fully adjusted model without WHtR[2]	Ref	1.07 (0.75, 1.52)	0.73	1.59 (1.06, 2.38)	0.03	Ref	0.98 (0.71, 1.36)	0.92
Fully adjusted model with WHtR[3]	Ref	1.00 (0.70, 1.42)	0.98	1.54 (1.03, 2.31)	0.04	Ref	1.01 (0.73, 1.39)	0.95
Elevated HbA1c (*n* = 234)								
Fully adjusted model without WHtR[2]	Ref	1.34 (0.47, 3.81)	0.58	1.47 (0.47, 4.57)	0.51	Ref	0.67 (0.25, 1.80)	0.43
Fully adjusted model with WHtR[3]	Ref	1.10 (0.37, 3.20)	0.87	1.29 (0.41, 4.02)	0.66	Ref	0.71 (0.26, 1.92)	0.50
High CRP (*n* = 210)								
Fully adjusted model without WHtR[2]	Ref	2.56 (1.07, 6.15)	0.04	1.76 (0.70, 4.41)	0.23	Ref	0.33 (0.16, 0.69)	0.003
Fully adjusted model with WHtR[3]	Ref	3.44 (1.32, 8.99)	0.01	2.15 (0.76, 6.06)	0.15	Ref	0.24 (0.11, 0.53)	<0.001
1 risk factor (*n* = 1229)								
Fully adjusted model without WHtR[2]	Ref	1.21 (0.90, 1.63)	0.21	1.19 (0.83, 1.70)	0.34	Ref	0.98 (0.73, 1.30)	0.91
≥2 risk factors (*n* = 1246)								
Fully adjusted model without WHtR[2]	Ref	2.02 (0.81, 5.01)	0.13	3.03 (1.11, 8.29)	0.03	Ref	1.09 (0.54, 2.20)	0.82

[1] We conducted separate random-effects logistic models for parents and children, with a random intercept for individuals and households. Models differed slightly in sample size due to missingness of some outcome measures. HbA1c and CRP were only measured in 2009. High WHtR: WHtR ≥0.5; Elevated BP: systolic BP or diastolic BP *z* scores ≥90th percentile of the age-, sex-, and height-specific BP percentile or BP ≥120/80 mm Hg for children using the US CDC 2000 growth curve reference; BP ≥120/80 mm Hg for adults; Elevated HbA1c: HbA1c ≥5.7%; Elevated CRP: 1–10 mg/L for children and 3–10 mg/L for adults. BP, blood pressure; CHNS, China Health and Nutrition Survey; CRP, C-reactive protein; HbA1c, glycataed hemoglobin; ref, reference; WHtR, waist-to-height ratio.

[2] Models adjusted for baseline age (years), sex, household income (tertiles), geographic region (north, central, or south), survey year, year of study entry, highest parental education (none or primary, middle school, high school or technical, college or higher), smoking (yes or no), total energy intake (kilocalories per day; quartiles), total fat intake (percentage of total energy; quartiles), total fruit and vegetable intake (percentage of total energy; quartiles), sodium intake (milligrams per day; quartiles; BP models only), total PA (metabolic equivalent hours per week; quartiles), and snacking (yes or no).

[3] Models additionally adjusted for WHtR.

risk factors at follow-up in Chinese children and their parents. The direction and magnitude of associations varied by behaviors and by risk factors, and differed between children and their parents. CMD risk factors were negatively associated with intakes of fruit and vegetable snacks and positively related to screen time in both generations. The association of away-from-home eating with high WHtR was negative in parents but positive in children.

Lagged away-from-home eating and snacking with CMD risk factors at follow-up

Our findings suggest a positive association between the frequency of eating away-from-home and obesity among Chinese children, which is consistent with findings from a previous study in US adolescents (10). Foods prepared away from home are generally high in saturated fat, sugar, and sodium (39), which have been associated with adverse health outcomes in both children (10) and adults (40) in the United States and Spain. In our study, lagged away-from-home eating was inversely associated with WHtR in parents but positively related to WHtR in children. This inconsistency is possibly due to different away-from-home food choices or overall differences in diet choices between 2 generations. One study in China suggested a higher processed-food intake in children compared with adults and a positive association of processed-food intake with overweight in children but not adults, which suggests less-healthy food choices in children (41). Differences in food choices between children and adults may reflect generational disparities in response to urbanization.

Current evidence for the direction of associations between snacking and health status is mixed (13, 14, 42). Higher snacking has been related to lower waist circumference in US children (42), suggesting that frequent eating without increasing total energy intake may enhance certain hormonal signals that increase satiety and suppress appetite (43, 44). In contrast, other studies reported positive relations between snacking and obesity among US children (13) and adults (14). In addition, Mekary et al. (45) found a positive association of snacking with type 2 diabetes in US men. However, these studies did not differentiate between types of snacks, which could explain the mixed evidence. Phillips et al. (46) found an association of BMI with soda intake in US adolescents, but not with total snacks. In the CHNS, fruit was the most common snack across the 18 y (27). Fruit is high in nutrients and dietary fiber, which can provide health benefits (47). On the contrary, high amounts of refined carbohydrate and sugar in other snacks may associate with CMD risk factors such as obesity (46) and type 2 diabetes (45). Due to the potential differences in the direction of association between different types of snacks with cardiometabolic health, we studied fruit and vegetable snacks and other snacks separately. We found that after adjustment for total energy, fruit and vegetable snack consumption was inversely associated with WHtR and BP in parents and with WHtR in children, whereas other snack consumption was positively associated with having 1 risk factor in parents. Despite faster increases in the consumption of other snacks compared with fruit and vegetable snacks over time (48), we did not expect to find temporal variations in the association between snacks and CMD risk factors. As expected, we did not see differences in these associations over time. In addition, concordant with a previous study that examined snacking and diabetes in US men (45), our observed association of non–fruit and vegetable snack intake with elevated HbA1c in parents was attenuated after adjustment for WHtR, which suggests a potential role of obesity in the snacking-diabetes association in adults.

Lagged screen time, PA, and CMD risk factors at follow-up

Our results are consistent with previous studies of sedentary behaviors in relation to obesity in adults (18, 49) and children (50) in various countries, such as Canada, the United States, and China. In addition, we found similar findings compared with earlier research that suggested positive associations of screen time with hypertension (51) and high CRP (52) in US children. A number of theories may explain these findings. First, television watching is often accompanied by increased food and snack intakes (38), resulting in higher caloric intake. Second, screen-based activities involve low energy expenditure, and thus reduce total energy expenditure (53). Third, sedentary behaviors may have a direct influence on metabolic health through reducing insulin sensitivity and increasing triglyceride concentrations (53, 54). Our findings suggest that increased screen time has significant associations with a wider variety of risk factors in children compared with parents.

We found that lagged leisure-time sports participation was associated with lower odds of high CRP at follow-up in children, independently of WHtR. This association is supported by a previous review (55), which suggested a "long-term anti-inflammatory" response of exercise. However, other than inflammation, participation in leisure-time sports was not associated with any other CMD risk factors in our study in either generation, which is inconsistent with previous evidence for the health benefits of moderate-intensity PA (56). This is possibly because screen time and leisure-time sports were positively correlated in our study. After mutually adjusting for these 2 behaviors in our models, screen time was positively associated with a high WHtR in parents and children, independently of leisure-time sports, whereas no association was found for leisure-time sports. This finding is supported by an earlier study that reported stronger associations of body weight with sedentary time compared with leisure-time PA in US adults (57). In particular, Bauman et al. (58) suggested that leisure-time sports alone may be not sufficient to prevent obesity in China. Focus should be placed on promoting an active lifestyle in general (58).

Our study has several limitations. First, HbA1c and CRP were only measured in 2009; thus, sample sizes for these risk factors were limited compared with the larger samples for repeated measurements of WHtR and BP. Second, we were unable to test if a child's pubertal status played a role in the associations due to the lack of pubertal markers data. However, we tested for differences in associations in younger compared with older children and found no differences. Similarly, menopausal status could have played a role in the associations in mothers, but the vast majority of mothers in our study (95%) were below the average age of menopause (49 y) in China (59). Third, compared with the excluded participants, our analytic sample had higher incomes and lived in more urbanized areas. In addition, the censoring of our sample due to age restriction reduced the full sample size, although our sensitivity test for the sample who entered at age 7 y and completed all 4 visits from 1991 to 2009 showed similar results to those of the analysis sample. Last, self-reported behavior data may be subject to recall bias, although the CHNS data are based on detailed recall methods with weighing of condiments. Previous research on selected components of the diet suggests strong validity (60), and the PA components have been highly predictive of incident obesity (61–63).

Our study also has several notable strengths, including the use of a regionally diverse sample from a national survey with highly detailed diet and PA data collected at the household level over 18 y. Furthermore, we measured each individual's risk factors and ascertained elevated risk, which is otherwise largely undiagnosed in this population. Moreover, we defined children's elevated BP on the basis of the age-, sex-, and height-specific BP percentile algorithm for children, which appropriately classified children's BP status (64). Last, with the use of lagged behaviors we were able to establish a latency period between behaviors and risk factors. Previous studies have reported longitudinal but not cross-sectional associations of sedentary time with body fat among non-Hispanic white girls (65) and with insulin resistance in white adults (66, 67). The difference in results from longitudinal compared with cross-sectional studies highlights the importance of a latency period between behaviors and risk factors when studying the behavior-risk associations.

In conclusion, CMD risk factors in children and their parents were inversely associated with fruit and vegetable snacking and positively associated with screen time. Away-from-home eating was related to a higher WHtR in children but a lower WHtR in parents, likely due to different food choices and responses to urbanization between 2 generations in China. Parent-offspring differences in associations between lifestyle behaviors and CMD risk factors provide insight into intergenerational differences in cardiometabolic risk with urbanization.

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