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PEDIATRIC ORIGINAL ARTICLE

Association between increased BMI and severe school absenteeism among US children and adolescents: findings from a national survey, 2005–2008

Y Li[1], S Raychowdhury[2], SH Tedders[3], R Lyn[4], A Lòpez-De Fede[5] and J Zhang[3]

OBJECTIVE: School absenteeism may be an underlying cause of poor school performance among overweight and obese children. We examined the associations between school absenteeism and body mass index (BMI) in a nationally representative sample.

DESIGN AND SUBJECTS: We analyzed the data of 1387 children (6–11 years) and 2185 adolescents (12–18 years), who completed an interview and anthropometric measurement as a part of the National Health and Nutrition Examination Survey, 2005–2008. The CDC 2000 growth chart was used to categorize BMI status, and the number of school days missed during the past 12 months was assessed by asking the proxies or interviewees.

RESULTS: The prevalence of obesity and overweight were 18.96 ± 1.44% (s.e.) and 16.41 ± 0.78%, respectively, among study populations. The means of school days missed in the last 12 months were not statistically different between the normal-weight, overweight and obese groups, 3.79 ± 0.56, 3.86 ± 0.38 and 4.31 ± 0.01 days, respectively. However, when >2 days missed per school month was defined as severe absence, the prevalence of severe absence were 1.57%, 2.99% and 4.94% respectively, among 6–11-year-old children with normal, overweight and obese. The adjusted odds of severe school absence were 2.27 (95% confidence interval = 0.64–8.03) and 3.93 (1.55–9.95), respectively, among overweight and obese children compared with normal-weight peers (*P* for trend test <0.01). No significant association was found among adolescents.

CONCLUSION: Increased body weight is independently associated with severe school absenteeism in children but not adolescents. Future research is needed to determine the nature, and academic and social significance of this association.

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INTRODUCTION

The prevalence and severity of overweight is increasing markedly in children and adolescents worldwide. Over 30% of children in the United States are overweight with >16% being obese.[1] Up to 10% of 290 million Chinese children are overweight or obese, and the percentage is expected to double a decade from now.[2] A large array of adverse health-related outcomes related with obesity raise the level of importance of understanding obesity as a major public health concern for children and adolescents. Among Chinese elementary school children, severely obese children had a significantly lower intelligence quotient than the controls.[3] Non-overweight students demonstrated better grades relative to their overweight peers among sixth and seventh graders of Americans.[4] Similarly, Mo-suwan *et al*.[5] found that an association between overweight status and poor school performance existed among Thai children from grades 7–9. Mond *et al*.[6] observed that the prevalence of impairment in gross motor skills was higher among obese than normal-weight boys, whereas the prevalence of impairment in the ability to focus attention was higher among the obese compared with normal-weight girls after controlling for age and other potential covariates among pre-school Germany children. A significant relationship between children's weight category and their reading/language arts, and mathematics test scores was revealed among 968 fifth grade students even after adjustment for a proxy of socioeconomic status.[7] After controlling for school level differences in socioeconomic status, minority population and school size, positive associations between academics-based rank of a school and its percentage of students achieving body mass index (BMI) Healthy Fitness Zone were also observed among 6222 schools in TX, USA.[8] Using a nationally representative sample, we previously reported a dose–response association between the percentile of BMI and general mental ability in a large sample of school-age children.[9]

Although, the conclusions from previous studies consistently highlighted an unfortunate outcome in school performance of children who were overweight or obese,[10,11] the mechanism(s) that drive the association between overweight and obesity and poor academic performance has not yet been established. A precise explanation for the impaired cognitive functions and poor academic performance among overweight or obese children remains unclear. It was hypothesized that excess body weight may be associated with poor school performance through the pathway of increased school absences.[12] We undertook a cross-sectional analysis to examine the associations between school absenteeism

[1]Northrop Grumman Information Systems, Atlanta, GA, USA; [2]Department of Applied Health Sciences, School of Nursing Health and Human Services, Indiana State University, IN, USA; [3]Department of Epidemiology, Jiann-Ping Hsu College of Public Health, Georgia Southern University, Statesboro, GA, USA; [4]Institute of Public Health, Georgia State University, Atlanta, GA, USA and [5]Institute for Families in Society, University of South Carolina, Columbia, SC, USA. Correspondence: Dr J Zhang, Jiann-Ping Hsu College of Public Health, Georgia Southern University, Statesboro, GA 30460-8015, USA.
E-mail: Jianzhang@georgiasouthern.edu
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and increased BMI among school-aged children enrolled in National Health and Nutrition Examination Survey (NHANES), 2005–2008.

SUBJECTS, MATERIALS AND METHODS

Study population

The NHANES is an ongoing stratified, multistage probability sample of the US non-institutionalized population designed to represent the health and nutritional status of general populations. A unique feature of NHANES is that the sampling approaches, interviews and examination methods are standardized across surveys, and the exact methods have been published extensively elsewhere.[13] The data from two cycles of the surveys, 2005–2006 and 2007–2008 were used for this report. Survey participants completed extensive questionnaires in the household and a comprehensive physical examination, including anthropometries, at specially equipped mobile examination centers. Questionnaires for participants younger than 17 years were completed by a knowledgeable proxy. A total of 4933 participants aged 6–18 years, who were attending school when the survey was conducted, were interviewed. Among them, 4803 had completed information on the number of days missed during the last 12 months. As the primary goal of this study was to examine excessively increased body weight, we excluded 170 underweight children (BMI <5 percentile). A total of 243 children who were from races/ethnicities other than whites, blacks and Hispanic Americans were excluded due to relative small sample sizes. Additional study participants were excluded because of missing information pertaining to confounders or mediating factors, including family income ($n=242$), mothers' education ($n=477$) and family head's marital status ($n=99$). After exclusions, a total of 1387 participants aged 6–11 years (children) and 2185 participants aged 12–18 years (adolescents) remained for primary analyses.

Measurements and variable definitions

School absenteeism. The medical conditions section (muiltiple choice questions) of the NHANES survey provides self-reported personal interview data on a broad range of health conditions for both children and adolescents. The muiltiple choice questionnaire segment is generally modeled on the 'Medical Conditions' questionnaire section of the US National Health Interview Survey. The original question appearing in the muiltiple choice questionnaire was worded as 'During the past 12 months, that is, since (current month) of (last year), about how many days did (you/survey participant) miss school because of an illness or injury'? Although those aged 12–18 followed the adult self-report protocol, interviews for children between 6 and 11 years of age were conducted with proxies, but the children must be present to assist the proxies during the interviews. The preferred proxy/assistant was the person most knowledgeable about the children's daily routine, most likely, mothers. The distributions of days missed during the last 12 months were positively skewed, and comparison of the means is considered problematic, and we therefore, also dichotomized study population into either 'severely' or 'not severely' missing school. In the preliminary analyses, we observed that missed days <10 as the cutoff was not sufficient to identify distinct levels of severity of school absenteeism and provide adequate statistical power. Finally, the participants who reported 18 or more school days missed during last 12 months or 2 days per school month were categorized as 'severe absence', otherwise as 'not severe absence'. Sensitivity analyses using cutoff $\geqslant 12$ days were also performed to assess the impact of selecting cutoffs.

Overweight and obesity. NHANES participants had their anthropometries measured following a standard protocol, and body weight was determined to the nearest 0.05 kg (Toledo 2181 Scale, Columbus, OH, USA), and height was measured to the nearest 0.1 cm with standardized measuring equipment (Holtain Height Stadiometer, Holtain, Crymych, UK). BMI was calculated in $kg\,m^{-2}$ and then converted to a sex- and age-specific BMI percentile value using a computerized formula derived from the Centers for Disease Control and Prevention 2000 Growth Charts.[14] In accordance with recommendations of the American Academy of Pediatrics expert panel on childhood obesity[15] and the Institute of Medicine,[16] we assigned each participant to an obese stratum (BMI 95th percentile), an overweight stratum (85th percentile to 94th percentile) or a normal-weight stratum ($<$ 85th percentile).

Covariates. For most analyses, we stratified participants into two strata: 6–11 years (children) and 12–18 years (adolescents), and results were presented separately for children and adolescents. Determined by self-report on the questionnaire, the race/ethnicity of the participants was classified as 'non-Hispanic white', 'non-Hispanic black' or 'Mexican American', with 'other' excluded. A poverty income ratio (PIR) is the ratio of income to the family's appropriate poverty threshold defined by the US Census Bureau, and was used to assess family income. Specifically, respondents were asked to select a range of income categories for the previous calendar year. The midpoint of the selected range value was then compared with the appropriate poverty threshold based on size and composition of the family. If a family's total income was less than the appropriate threshold income value, then that family, and every individual in it, was considered poor. Thresholds are updated annually for inflation with the Consumer Price Index.[17] PIR values <1.00 were categorized as below the official poverty threshold. For this study, four categories of PIR were considered and they include 'poor' (PIR <1.0), 'near poor' ($1\leqslant$PIR <2), middle-income ($2\leqslant$PIR <4) and high-income (PIR$\geqslant 4$).[18] Socio-demographic status of the family heads was used to characterize the households where children and adolescent resided. Family head is the first household member 18 years of age or older listed on the household member roster, which owned or rented the residence where members of the household resided. The demographics file includes information on the family head's gender, age, education level and marital status. Marital status was collapsed into two categories: single (included widowed, divorced, separated or never married and the individuals who were married but their spouse was not living in the household) vs cohabiting (including individuals being married with their spouse living in the household). Additionally, information on the education level of the female proxies (mostly the mothers of the children) was also included as the covariates regardless of proxies' age. The educational attainment was categorized as less than a high school graduate, high school graduate, some college or associates degree, and college graduate or higher. Additionally, exposure to cigarette smoking was also included as a major confounder as there is evidence indicating that children in a household with smokers are more likely to absentees due to various health problems, including asthma. We used serum cotinine (low, middle and high quarter among study children and adolescents), a major metabolite of nicotine, as the measure of exposure to tobacco. However, there were 450 study participants with a missing value of serum cotinine; we included serum cotinine as a major confounder in the supplementary analyses to assess its impact while keeping the study participants with missing cotinine in the main analyses.

Statistical methods

As recommended by the National Center of Health Statistics, we used the SAS procedures for survey (SAS, Research Triangle Park, NC, USA) with appropriate weighting and nesting variables to produce accurate national estimates adjusting for the over-sampling of specific populations. Owing to the positively skewed distributions of the number of school days missed, logistic regression models were used as the primary adjustment tool to estimate the adjusted odds of severe school absence for each level of BMI, as well as to compare the odds from overweight children to normal-weight children, from obese children to normal-weight children. Odds ratios (OR) and the corresponding 95% confidence intervals (95% CI) were calculated to estimate the associations. As supplementary steps, we conducted sensitivity analyses using '>12 days during the last 12 months' as the cutoff to redefine the definition of severe absence, and ran regression with serum cotinine included ($N=3122$) to assess the direction and magnitude of the potentially confounding effects from the exposure to cigarette smoking. We also repeated all the regressions described above on all subjects ($N=5572$) who had valid data on school absence to examine potential biases caused by exclusion of a large portion of the subjects due to various reasons. For all multivariable adjusted

regressions, fully saturated models were retained, including all the covariates described in above sections.

RESULTS

The study participants were evenly distributed between boys and girls for both children and adolescents (Table 1). On average, the children missed 3.72 ± 0.28 (s.e.) days in the last 12 months, lower than the average of adolescents, 4.01 ± 0.19 days. The prevalence of severe absenteeism was higher among adolescents than children, 3.86 ± 0.79% vs 2.46 ± 0.52%, respectively. However, neither mean number of days missed nor prevalence of severe absenteeism differed significantly between children and adolescents. Corresponding to the mean difference of age between children and adolescents, there was 4 years of age difference between proxies (mostly mothers) for children and adolescents, 39.77 ± 0.31 vs 43.87 ± 0.32 years. A significantly higher percentage of children lived in 'poor' or 'near poor' family compared with adolescents. More adolescents (25.35%) lived with single parents currently compared with children (21.70%).

Overall, the number of days missed during the last 12 months was lower among children and adolescents with normal-weight compared their overweight or obese peers. The means of missed days were 3.86 ± 0.51, 3.80 ± 0.60 and 4.70 ± 0.01 for normal, overweight and obese adolescents with medians of 1.85 ± 0.13, 1.50 ± 0.24 and 2.11 ± 0.18, respectively (Table 2). No significant differences of mean number of days missed were observed between study participants with different levels of BMI percentiles, either among children or adolescents. However, when the numbers of days missed were dichotomized, the proportions of severe absence were significantly higher among obese and overweight children compared with normal-weight children. A dose–response association was identified, the prevalence of severe absence were 1.57%, 2.99% and 4.94%, respectively, among normal-weight, overweight and obese children (Table 3). The prevalence of severe absenteeism was more than doubled (OR = 2.27, 95% CI = 064–8.03) among overweight children and nearly quadrupled (OR = 3.93, 95% CI = 1.55–9.95) among obese children compared with their normal-weight peers (Table 4). These estimates were obtained after adjustment for all potential confounders selected.

Using the cutoff >12 days per school year to dichotomize the children, we obtained ORs of 1.00 (reference), 1.61(0.52–4.97) and 2.14 (1.01–4.55), respectively, for normal-weight, overweight and obese children, demonstrating that the nature of the association is independent of the cutoffs selected. The ORs estimated from sensitivity analyses including the categorized serum cotinine ($N = 3122$) were 1.00 (reference), 2.88 (0.82–10.17) and 4.94 (1.42–17.15), stronger than those estimated from main analyses but with wider CIs due to a reduced size of study population, indicating that controlling for exposure to cigarette smoking may make the association stronger rather weaker. Supplementary analyses on all children ($N = 2441$) who had valid data of school days missed showed that the estimates,

Table 1. Selected characteristics of weighted study population estimated from a sample of 3572 Children aged 6–18, NHANES 2005–2008

Characteristic[a]	*Level*	*Age 6–11* (N = *1387*)		*Age 12–18* (N = *2185*)		P[b]
		Sample size	*% ± s.e.*	*Sample size*	*% ± s.e.*	
Age at interview	Mean	1387	9.13 ± 0.05	2185	15.06 ± 0.06	<0.001
Age of family head	Mean	1387	39.77 ± 0.31	2185	43.87 ± 0.32	0.24
School days missed	Mean	1367	3.72 ± 0.28	2151	4.01 ± 0.19	0.73
Severe absentee[c]	Yes	31	2.46 ± 0.52	72	3.86 ± 0.79	<0.001
BMI level	Obese	308	19.57 ± 1.35	488	18.92 ± 1.58	0.95
	Overweight	240	15.94 ± 1.46	368	16.16 ± 1.02	
	Normal weight	839	64.49 ± 2.41	1329	64.91 ± 1.49	
Gender	Boys	666	50.33 ± 1.76	1070	50.28 ± 1.29	0.98
	Girls	721	49.67 ± 1.76	1115	49.72 ± 1.29	
Race/ethnicity	Non-Hispanic Black	416	15.87 ± 1.96	742	15.67 ± 1.99	0.07
	Non-Hispanic White	427	63.68 ± 3.40	667	67.53 ± 2.64	
	Mexican/other Hispanics	544	20.45 ± 2.51	776	16.80 ± 1.63	
Family income[d]	Poor	440	22.35 ± 2.04	584	17.19 ± 1.27	<0.001
	Near poor	366	22.08 ± 2.08	553	19.69 ± 1.40	
	Middle income	352	30.44 ± 1.39	615	31.52 ± 1.68	
	High income	229	25.13 ± 2.76	433	31.59 ± 2.38	
Marital status of family header[e]	Single	405	21.70 ± 1.68	741	25.35 ± 1.71	0.07
	Cohabiting	982	78.301 ± 1.68	1444	74.65 ± 1.71	
Mother's Education	Below high school	408	18.51 ± 1.58	620	16.15 ± 1.58	0.50
	High School/Equivalent	316	22.59 ± 1.88	489	24.20 ± 1.46	
	Some College years	413	34.16 ± 2.08	694	33.58 ± 1.59	
	College Graduate or above	250	24.73 ± 2.53	382	26.07 ± 2.48	

Abbreviations: BMI, body mass index; NHANES, National Health Examination and Nutrition Survey; PIR, poverty index ratio. [a]Presented as percentage (s.e.) unless otherwise specified. [b]Test for the difference of the variables (characteristics, listed in the first column of the table) between two age groups, namely, children (6–11 years old) and adolescents (12–18 years old). *P*-values were from *t*-tests (unequal variances) for continuous variables or χ^2-tests for categorical variables. [c]The severe absenteeism was defined as 'missing 2 days or more per school month' or '18 days or more per school year'. The number of missed school days was measured by asking the question, 'During the past 12 months, about how many days did you (or selected kids) miss school because of an illness or injury?' While those aged 12–18 followed the adult self-report protocol, interviews for children between 6 and 11 years of age were conducted with proxies and the child was requested to be present to assist the proxy during the interview. The preferred proxy/assistant was the person most knowledgeable about the children's daily routine, most likely, mothers. [d]Family income level was measured by a PIR, calculated by comparing the midpoint for the family income category and the family size with the federal poverty line. PIR values <1.00 were categorized as below the official poverty threshold, 1 ⩽ PIR < 2 was defined as 'near poor', 2 ⩽ PIR < 4 defined as 'middle income' and PIR ⩾ 4 as high income. [e]The single status included widowed, divorced, separated or never married and the individuals who were married but their spouse was not living in the household. The individuals being married with their spouse living in the household were classified as cohabiting.

Table 2. Mean difference of the number of missed school days by category of BMI estimated from a sample of 3572 children and adolescents aged 6–18 years, NHANES 2005–2008[a,b]

Age group (years)	*BMI level*[c]	*Sample size*	*Mean*			*Median (IR)*
			Mean ± s.e.	*Difference*	P-*value*	
6–11	Normal	829	3.67 ± 0.51	−0.05	0.93	1.80 (0.23–4.03)
	Overweight	235	3.96 ± 1.05	0.25	0.82	1.49 (0–4.30)
	Obese	303	3.71 ± 0.01	0.00	(Ref)	1.62 (0–3.75)
12–18	Normal weight	1311	3.86 ± 0.51	−0.83	0.11	1.85 (0–4.49)
	Overweight	360	3.80 ± 0.60	−0.90	0.15	1.50 (0–4.03)
	Obese	480	4.70 ± 0.01	0.00	(Ref)	2.11(0.13–4.56)

Abbreviations: BMI, body mass index; IR, inter-quartile range; NHANES, National Health Examination and Nutrition Survey; Ref, reference. [a]The number of missed school days was measured by asking the questions, 'During the past 12 months, about how many days did you (or selected kids) miss school because of an illness or injury'? While those aged 12–18 followed the adult self-report protocol, interviews for children between 6 and 11 years of age were conducted with proxies, but the child must be present to assist the proxy during the interview. The preferred proxy/assistant is the person most knowledgeable about the children's daily routine, most likely, mothers. [b]The sample sizes were unweighted but the medians and the means were weighted estimates for the study population. [c]BMI was calculated in $kg\,m^{-2}$ and then converted to a sex- and age-specific BMI percentile value using a computerized formula derived from the Centers for Disease Control and Prevention 2000 Growth Charts. In accordance with recommendations of the American Academy of Pediatrics expert panel on childhood obesity, and the Institute of Medicine, we assigned each participant to an obese stratum ($\geqslant$95th percentile), an overweight stratum (85th percentile to 94th percentile) or a normal stratum ($<$85th percentile).[15,16]

Table 3. Prevalence (%) of severe absenteeism by the level of co-variables estimated from a sample of 3572 children aged 6–18 years, NHANES 2005–2008[a]

Co-variants	*Level*	*Age 6–11* (N = *1387*)				*Age 12–18* (N = *2185*)			
		Sample Sizes[b]	*School absenteeism*			*Sample Sizes*[b]	*School absenteeism*		
			n[b]	%	P-*value*[c]		n[b]	%	P-*value*[c]
Gender	Boys	654	13	2.55	0.86	1058	20	1.90	$<$0.001
	Girls	713	18	2.36		1093	52	5.85	
Race/ethnicity	Non-Hispanic black	412	6	1.31	0.20	731	20	2.90	0.18
	Non-Hispanic white	422	12	2.89		663	32	4.40	
	Mexican/other Hispanics	533	13	1.97		757	20	2.56	
Family income[d]	Poor	429	15	4.32	0.25	566	27	6.92	0.16
	Near poor	362	7	2.12		540	15	3.48	
	Middle income	349	6	2.09		613	20	3.78	
	High income	227	3	1.57		432	10	2.54	
Marital status	Single	386	11	2.58	0.87	691	31	5.04	0.19
Of family head[e]	Cohabiting	950	20	2.42		1388	41	3.46	
(Grand)mom's	Below high school	397	10	2.99	0.31	601	19	4.02	0.05
education	High school/equivalent	315	6	1.03		482	23	5.44	
	Some college years	407	11	3.51		690	25	4.61	
	College graduate or above	248	4	1.92		378	5	1.31	

Abbreviations: BMI, body mass index; NHANES, National Health Examination and Nutrition Survey; PIR, poverty index ratio. [a]The severe absenteeism was defined as 'missing 2 days or more per school month'. The number of missed school days was measured by asking the question, 'During the past 12 months, about how many days did you (or selected kids) miss school because of an illness or injury'? While those aged 12–18 followed the adult self-report protocol, interviews for children between 6 –and 11 years of age were conducted with proxies and the child was requested to be present to assist the proxy during the interview. The preferred proxy/assistant was the person most knowledgeable about the children's daily routine, most likely, mothers. [b]The sample sizes were unweighted but the prevalence was weighted estimations for the study populations. [c]The *P*-values for χ^2-test. [d]Family income level was measured by a PIR, calculated by comparing the midpoint for the family income category and the family size with the federal poverty line. PIR values $<$1.00 were categorized as below the official poverty threshold, 1$\leqslant$PIR$<$2 was defined as 'near poor', 2$\leqslant$PIR $<$4 defined as 'middle income' and PIR$\geqslant$4 as high income. [e]The single status included widowed, divorced, separated or never married and the individuals who were married but their spouse was not living in the household. The individuals being married with their spouse living in the household were classified as cohabiting.

in principle, remained unchanged, ORs were 1.00 (reference), 1.57 (0.44–5.58) and 3.11 (1.46–6.63), respectively, for normal-weight, overweight and obese children (data not shown in tables), indicating that the associations described above were not sensitive to exclusion of a large portion of the subjects due to various reasons.

No significant associations between the levels of BMI and absenteeism were observed among adolescents from either main analyses ($n = 2185$) or supplemental analyses ($n = 3131$). The prevalence of severe absence were 3.38%, 4.91% and 4.61%, and the corresponding adjusted ORs equaled to 1.00 (reference), 1.33 (0.68–2.59) and 1.26(0.48–3.23), respectively, for normal-weight, overweight and obese children. When the cutoff of $>$12 days was used, the ORs were 1.00 (reference), 0.93 (0.54–1.62) and 1.05 (0.47–2.35) for normal-weight, overweight and obese children (data not shown in tables).

Table 4. Adjusted odds ratio of severe absenteeism by the level of BMI estimated from a sample of 3572 children aged 6–18 years, NHANES 2005–2008, USA[a,b]

Age (years)	*BMI level*[c]	*Sample size*	n	*%*	*Odds ratio (95% CI)*
6–11	Normal weight	829	15	1.57	1.00 (reference)
	Overweight	303	5	2.99	2.27 (0.64 – 8.03)
	Obese	235	11	4.94	3.93 (1.55–9.95)
	P for trend test				0.04
12–18	Normal	1311	36	3.38	1.00 (reference)
	Overweight	360	15	4.91	1.33 (0.68–2.59)
	Obese	480	21	4.61	1.26 (0.48–3.23)
	P for trend test				0.24

Abbreviations: BMI, body mass index; CI, confidence interval; NHANES, National Health and Nutrition Examination Survey. [a]The variables adjusted included age (year), race (four categories), gender, family income (four levels), marital status of family head (currently, previously and never married) and life time history of receiving special education services. [b]The severe absenteeism was defined as 'missing 2 days or more per school month' or '18 days or more per school year'. The number of missed school days was measured by asking the question, 'During the past 12 months, about how many days did you (or selected kids) miss school because of an illness or injury'? While those aged 12–18 followed the adult self-report protocol, interviews for children between 6 and 11 years of age were conducted with proxies and the child was requested to be present to assist the proxy during the interview. The preferred proxy/assistant was the person most knowledgeable about the children's daily routine, most likely, mothers. [c]BMI was calculated in kg m^{-2} and then converted to a sex- and age-specific BMI percentile value using a computerized formula derived from the Centers for Disease Control and Prevention 2000 Growth Charts. In accordance with recommendations of the American Academy of Pediatrics expert panel on childhood obesity, and the Institute of Medicine, we assigned each participant to an obese stratum ($\geqslant$95th percentile), an overweight stratum (85th percentile to 94th percentile) or a normal stratum ($<$85th percentile).[15,16]

DISCUSSION

Using a nationally representative sample, we documented an association between BMI percentile category and school absenteeism in a large study population of school-age children. This association remained robust even after adjusting for parental and familial socioeconomic status and other potential confounders, and in various sensitivity analyses. We identified a 'dose–response' effect of excessive body weight on school absenteeism, and the effect was stronger in children compared with adolescents. The odds of missing school 2 days or more per school month were doubled and quadrupled, respectively, among overweight and obese children compared with their normal-weight peers.

An increasing number of studies have demonstrated that excessive body weight is associated with poor academic achievement and school performance. Magnetic source imaging suggested a link between increased body weight and pathological alteration in cortical communication processes in the central nervous system among adolescents.[19] White matter lesions in the brain of children younger than 10 years with early onset obesity but not sibling controls was also demonstrated.[20] It is postulated that early exposure to pathological changes in the brain, including alterations in levels of adipokines, hormones or neurotransmitters, may have detrimental effects on the rapid growth of the central nervous system during childhood when the brain is known to be more susceptible to adverse factors.[21] Increased school absenteeism among overweight and obese children observed by this study, as well as others,[8,22] might be an additional explanation of the association between poor school performance and elevated body size. It has long been recognized that chronic absenteeism and school truancy are significant problems with highly visible negative consequences, including poor academic performance.

In a study to examine the relationship between BMI and academic achievement in a group of $>$5,000 Icelandic children, a significantly negative correlation between school absenteeism and academic achievement was observed. It has been speculated that school absence might be the surrogate reflecting the negative impact of physical health problems on academic achievement. However, Moonie *et al*.[23] reported that asthma status had no impact on academic achievement; instead, school absenteeism itself had negative impact on performance. In a study among an inner city community with predominately African American residents, a higher rate of school absence was associated with a lower cumulative grade point average.[24] Two studies failed to obtain a relationship between poor school performance and school absence were also reported.[25,26] However, both were conducted among underachieving students with relatively small sample sizes, one among 42 school-aged children with sickle cell disease[27] and another among 66 boys with hemophilia.[28]

Owing to its cross-sectional nature, this study was not able to assess the temporality of the association. Psychosocial factors within the family may have a role in both the origins of obesity and chronic absenteeism, and it is possible that the elevated prevalence of severe absence present in overweight and obese children may reflect parental psychopathology or socioeconomic status rather than solely problems that result from the children's increased BMI percentiles. Although, this study demonstrated that controlling for parental socioeconomic status strengthened, rather diminished, the association between increased BMI percentiles and severe absence, the residual confounding from parental psychopathology remained a concern. Perhaps the greatest limitation of this study was that the major variable of interest, namely, school days missed in the past 12 months, was measured by either self-reported or proxy respondent questionnaire without being validated by reviewing school report cards. Studies have found that the reliability of items varies by the relationship of the proxy to the children.[29–32] Grandparents and other non-parental guardians are a less reliable source of information compared with parents. They may be more common among poor children, who are also at high risk of both excessive body weight and school absenteeism. At present, the direction of possible bias due to proxy responses is unclear. On the other hand, compared with adolescents, children are more likely to be observed by their parents, who are generally able to adequately report health and schooling problems in younger children in comparison with adolescents,[33] whose daily life is more likely beyond their parents' observation. This may contribute, at least in part, to not detecting a significant association between increased BMI percentiles and school absence among adolescents in spite of the fact that more adolescents were included and a similar trend was observed.

School absenteeism reflects general life stressors associated with both physical and mental health issues. Owing to the relatively straightforwardness of the question used to measure the number of missing school days, this study was not able to address several key issues for a better understanding of the association investigated. For instance, was increased absence due to elevated

risk of being bullied as observed by others[34-36] or teased among school children with high BMI percentiles as observed by others? Were obese or overweight children more likely to be embarrassed to participate in physical activities and miss the school day to avoid physical education sessions? There might be co-morbidity with physical conditions, such as asthma, the largest medical contributor to school absenteeism,[37-40] or obstructive sleep apnea,[41] responsible for missed school days. This study is not able to differentiate how many days missed by children with elevated BMI percentiles were due to school refusal behavior or pure absenteeism. The implication of the striking findings that the relationship was more salient among children compared with adolescents remains to be explored.

Yet, even with these limitations, this study is robust enough to inform educators, policymakers and researchers concerned with early school success. Despite the current lack of a precise explanation for the poor school performance associated with increased body weight status among children and adolescents, the fact that there is an association is adequate to trigger important questions–chief among them being whether the pathological learning trajectories in early school years reflected by missed school ultimately lead to lessened odds of success in later school years, and decreased social functioning as adults? Seeking answers to these questions invites further detailed and sustained investigations in large prospective settings.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

Dr Zhang had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Zhang, Raychowdhury, Lyn, Tedders and Lopez-De Fede. Acquisition of data: Li and Zhang. Analysis and interpretation of data: Li, Lyn and Zhang. Drafting of the manuscript: Li and Zhang. Critical revision of the manuscript for important intellectual content: Zhang, Raychowdhury, Lyn, Tedders and Lopez-De Fede. Statistical analysis: Li and Zhang. Obtained funding: Zhang.

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