The effect of poverty on the relationship between household education levels and obesity in U.S. children and adolescents: an observational study

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Summary

Background Although ample evidence has shown the link between childhood obesity and socioeconomic status including family income and household education levels, the mediating role of poverty in the association between household education levels and childhood obesity is unclear. This study aimed to quantify the extent to which family poverty levels contribute to the association between household education levels and obesity among US children and adolescents.

Methods This cohort study used the nationally representative data of 21,754 US children and adolescents aged 6–17 years (National Health and Nutrition Examination Survey 1999–2018). We applied mediation analysis of the association between household education levels (less than high school, high school, and college or above) and obesity mediated through poverty (≤138% vs. >138% federal poverty level), adjusting for demographic characteristics of household head and their offspring. Obesity was defined as age- and sex-specific body mass index in the 95th percentile or greater using the 2000 Centers for Disease Control and Prevention growth charts.

Findings Among 21,754 children and adolescents (weighted N = 43,544,684; mean age, 11.6 years; female, 49%), 9720 (weighted percentage, 33.0%) were classified as living in poverty and 4671 (weighted percentage, 19.1%) met the criteria for obesity. Low household education level (less than high school) showed increased risks of poverty (adjusted relative risk [95% CI], 5.82 [4.90–6.91]) and obesity (adjusted relative risk [95% CI], 1.94 [1.68–2.25]) compared to high household education level (college or above). We also quantified that poverty mediated 18.9% of the association between household education levels and obesity among children and adolescents. The mediation effect was consistently observed across age, gender, and race/ethnicity.

Interpretation Poverty mediated the association between the low educational status of household heads and their offspring's obesity. Our findings highlight the importance of reducing obesity risk among the low-income population to minimize the burden of intergenerational health disparities due to socioeconomic status.

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Keywords: Childhood obesity; Parental education; Poverty; Intergenerational social disparity; Mediation analysis

Introduction

Obesity among school-aged children and adolescents is a major public health concern. In the United States, nearly 20% of the US population is obese, including almost 14.7 million children and adolescents.[1,2] Childhood obesity is influenced by a myriad of factors, such as diet, physical activity, sociocultural elements, familial factors, environment, and psychological aspects.[3] This condition can significantly impact a child's physical health, social and emotional well-being, and

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Research in context

Evidence before this study

Childhood obesity is one of the major public health issues, which stems from a confluence of social, environmental, and genetic factors. Particularly, socioeconomic factors, such as parental education and income levels, are associated with childhood obesity and social disparities over the past two decades. On April 10, 2023, we searched PubMed for childhood obesity and parental or household socioeconomic status using terms ('obesity' OR 'obese') AND ('children' OR 'childhood' OR 'adolescent*' OR 'offspring*') AND ('parent*' OR 'household*' OR 'intergenerational') AND ('education status' OR 'educational status' OR 'education level*' OR 'educational level*'). Although several studies have shown the relationship between parental educational status and childhood obesity, the evidence is limited about the potential mechanisms of intergenerational health disparities among children and adolescents. In particular, no studies so far have quantified the extent to which the current poverty mediates the relationship between parental educational status and childhood obesity.

Added value of this study

Using nationally representative data for US children and adolescents, we found that poverty mediated around 20% of the association between low household education levels (less than high school) and obesity among children and adolescents. The mediating role of poverty was consistently observed regardless of age, gender, and race/ethnicity. Given the widening disparity of childhood obesity by parental education over the past two decades, our results of the mediation analysis provide practical insights into the effective strategies alleviating situations caused by the current poverty levels (e.g., tax relief, cash transfers, ensuring access to affordable healthcare access, etc) to reduce the intergenerational social disparity for childhood obesity.

Implications of all the available evidence

Our findings indicate that childhood health disparities could be induced by household socioeconomic status mediated through current poverty, highlighting the need to develop better policies and programs to support the health and well-being of children living in low-income families. Because the findings were consistently observed in subgroup analyses, aggressive policies to reduce socioeconomic disparities are imperative to minimize the burden of intergenerational health disparities across all age, gender, and race/ethnicity groups. Nonetheless, we could not establish the causal link between household education status, current poverty levels, and childhood obesity. Further studies are required to assess the intergenerational social disparities involving child health.

self-esteem, while also being linked to poor academic performance and a diminished quality of life.[3] Furthermore, childhood obesity is associated with an elevated risk of developing early-onset chronic conditions, such as asthma and slipped capital femoral epiphysis.[4–6] It also has a high risk to persist until adulthood, thereby increasing the likelihood that affected children will develop metabolic syndrome and cardiovascular disease later in life.[7–10]

Household education and income levels are strong predictors of childhood obesity,[11–13] perhaps because children from families with lower education and income levels are more likely to have limited access to healthy diets, be less physically active, and spend more time using recreational screen media.[12–15] Since poverty may affect a family for generations, limited opportunities and unhealthy lifestyles may increase the chance that children of each generation will develop obesity. Moreover, given the widening disparity of childhood obesity by household education over the past two decades,[11] it is critical to disentangle the pathway from parental education to childhood obesity, and consider the effective strategies to reduce such intergenerational social disparity.

We thus applied causal mediation analysis to explore the contribution of family poverty levels to the association between household education levels and obesity among children and adolescents in the US general population, analyzing data from the National Health and Nutrition Examination Survey (NHANES). We also assessed the mediating role of poverty by individuals's age, gender, and race/ethnicity. Quantifying the mediating role of poverty in the association between parental education and childhood obesity will help public health professionals design effective interventions to improve situations caused by the current poverty levels (e.g., tax relief,[16] cash transfers,[17] ensuring access to affordable healthcare access,[18] etc) and mitigate childhood health disparities created by differential household educational status.

Methods

Data sources and study population

We used data from the NHANES—a stratified, multistage probability sample of individuals selected at random from the US general population through a complex statistical process.[19] Data are collected continuously and released in two-year cycles. The present study includes data from ten cycles of the continuous NHANES cohort (1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, 2011–2012, 2013–2014, 2015–2016, and 2017–2018). The average response rates of the household interview and examinations for children or adolescents were 80% and 78%, respectively.[20] The study protocol was approved by the

Research Ethics Review Board of the National Center for Health Statistics.[21]

There were 25,361 children and adolescents aged 6–17 years at survey enrollment. We excluded participants who lacked data for education levels of household reference persons (n = 1036), income levels (n = 1702), or body mass index (n = 869). The final analytical cohort of 21,754 (weighted: 43,544,684) children and adolescents. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.[22]

Exposure ascertainment: household education levels

Household education levels were defined using the education levels of the household reference person (i.e., the first household member aged ≥18 years listed on the household member roster, who owns or rents the residence where members of the household reside), and were categorized as less than high school, high school or general educational development (GED), and college or above.

Mediator ascertainment: poverty

Household poverty was defined based on family poverty income ratios (PIR). In the NHANES, PIR was calculated by dividing the family's income by the U.S. Census Bureau's poverty threshold, which accounted for household size, the number of related children, and inflation in the survey year.[23] Participants were stratified by their family PIR (i.e., ≤1.38 vs. >1.38 federal poverty level).[24]

Outcome ascertainment: obesity

The primary outcome was obesity, and the secondary outcome was the body mass index (BMI) z-score. In the NHANES, BMI was calculated as weight in kilograms divided by height in meters squared, rounded to 1 decimal place. Obesity among children and adolescents was defined as age- and sex-specific BMI in the 95th percentile or greater based on the 2000 Centers for Disease Control and Prevention growth charts.[2]

Other covariates

Demographic characteristics included age, gender (women, men), and race/ethnicity (Hispanic, non-Hispanic Black, non-Hispanic White, or others) of children and adolescents. Age (<40 years, 40–<60 years, or ≥60 years) and gender (women, men) of their household reference person were also reported.

Statistical analyses

After we described the demographic characteristics of children or adolescents and their household reference person, we employed modified Poisson regression models (i.e., Poisson regression models with a robust error variance[25]) adjusting for these demographic characteristics to estimate adjusted relative risks (RRs) of poverty and obesity for each household education level (i.e., less than high school and high school or GED; reference group was college or above). For the continuous BMI z-score (the secondary outcome), we applied ordinary least square (OLS) regression models. In all models, we first adjusted for the NHANES survey year (Model 1). We further adjusted for age (continuous and square transformed), gender, race/ethnicity, and height of survey participants aged 6–17 years (Model 2). In our main analysis (Model 3), we adjusted for age and gender of the household reference person in addition to covariates in Model 2.

In mediation analyses, we aimed to quantify the degree to which poverty mediated the association between household education levels and obesity among children and adolescents adjusting for potential confounders included in Model 3 (Supplementary Figure S1). We employed a marginal structural approach within the counterfactual framework.[26,27] The proportion mediated was computed as the log of the natural indirect effect divided by the log of the total effect. Bias-corrected 95% confidence intervals (CIs) were estimated by repeating the analysis on 20,000 bootstrapped samples. Subgroup analyses were conducted to investigate the mediating role of poverty in the association between household education levels and obesity stratified by age (6–11 years, 12–17 years), gender (women, men), and race/ethnicity (Hispanic, non-Hispanic Black, non-Hispanic White, or others) of children and adolescents. As a sensitivity analysis, we computed the E-value to quantify the minimum strength of the association of an unmeasured confounder with both the mediator (poverty) and the outcome (childhood obesity), which could explain the estimated indirect effect.[28]

Statistical analyses were conducted using Stata 17 (StataCorp, College Station, Texas, US). For all analyses, we selected appropriate sample weights to account for unequal probabilities of selecting NHANES participants, as well as nonresponse of those eligible and approached.[29]

Role of the funding source

The funders have no role in study design, data collection, data analysis, interpretation, or writing of the report.

Results

The mean age (standard deviation) of participants was 11.6 (3.4) years, and 49.1% were women. Children and adolescents with lower household education levels were more likely to be Hispanic or Non-Hispanic Black compared to those with higher household education levels (Table 1). Household reference persons with lower household education levels were more likely to be

Characteristics	Less than high school	High school or GED	College or above
Unweighted number	6545	11,115	4094
Weighted number	8,635,727	23,391,325	11,517,632
Participants			
Age, mean (SD), years	11.5 (3.4)	11.6 (3.4)	11.5 (3.4)
Aged 6–11 years, %	49.2	47.9	50.4
Aged 12–17 years, %	50.8	52.1	49.6
Gender, %			
Women	51.1	47.8	50.4
Men	48.9	52.2	49.6
Race/ethnicity, %			
Hispanic	44.1	16.6	8.0
Non-Hispanic Black	18.5	15.8	7.8
Non-Hispanic White	31.5	60.7	72.9
Non-Hispanic other	5.9	6.9	11.3
Height, mean (SD), cm	148.7 (18.0)	150.5 (18.8)	150.6 (19.1)
Weight, mean (SD), kg	50.0 (21.8)	50.2 (22.0)	47.0 (19.9)
BMI, mean (SD), Z-score	0.71 (1.16)	0.61 (1.15)	0.33 (1.07)
Participants' household reference person			
Age, %			
<40 years	52.5	49.9	24.5
40–<60 years	39.4	46.8	73.0
≥60 years	8.1	3.3	2.5
Gender, %			
Women	49.6	51.2	45.1
Men	50.4	48.8	54.9
Poverty income ratio (PIR), mean (SD)	1.35 (1.10)	2.33 (1.44)	3.80 (1.39)
PIR <1.38	65.7	32.9	8.5
PIR ≥1.38	34.3	67.1	91.5
Survey years, %			
1999–2002	22.5	18.6	17.4
2003–2006	19.5	22.9	16.8
2007–2010	20.1	19.5	20.7
2011–2014	20.0	19.3	22.9
2015–2018	17.9	19.7	22.2

Abbreviations: GED, general educational development; BMI, body mass index. [a]Household education level was defined as the education levels of household reference person.

Table 1: **Demographic characteristics by household education levels.**[a]

<40 years or ≥60 years compared to those with higher household education levels.

Household education levels and poverty

Across a total of 21,754 children and adolescents, 9720 (weighted percentage, 33.0%) were classified as living in poverty. After adjusting for demographic characteristics of participants and their household reference person in Model 3, lower household education levels were associated with increased risk of poverty compared to college or above household education (less than high school, adjusted RR [95% CI] = 5.82 [4.90–6.91]; high school or GED, adjusted RR [95% CI] = 3.36 [2.85–3.95]; p-value for trend <0.001; Table 2). The association and the dose-response relationship were consistently observed when we stratified the population into children (aged 6–11 years), adolescents (aged 12–17 years), women, and men. They were also observed across all race/ethnicity groups with larger estimates for non-Hispanic White compared to Hispanic (less than high school, adjusted RR = 6.53 vs. 4.30, p-for-interaction = 0.05; high school or GED, adjusted RR = 3.44 vs. 2.41, p-for-interaction = 0.03).

Household education levels and obesity

Across a total of 21,754 children and adolescents, 4671 (weighted percentage, 19.1%) met the criteria for obesity. After adjusting for demographic characteristics of participants and their household reference person in Model 3, lower household education levels were associated with an increased risk of obesity compared to college or above household education (less than high

Population	Poverty/Total cases	Model 1[a]	Model 2[b]	Model 3[c]
		RR (95% CI)	RR (95% CI)	RR (95% CI)
A) Total population				
College or above	481/4094		Referent	
High school or GED	4634/11,115	3.92 (3.34–4.61)	3.60 (3.07–4.23)	3.36 (2.85–3.95)
Less than high school	4605/6545	7.77 (6.54–9.23)	6.20 (5.24–7.32)	5.82 (4.90–6.91)
p *for trend*		<0.001	<0.001	<0.001
B) Aged 6–11 years				
College or above	248/2103		Referent	
High school or GED	2456/5391	4.18 (3.40–5.13)	3.82 (3.11–4.70)	3.61 (2.92–4.45)
Less than high school	2184/2965	7.83 (6.33–9.7)	6.27 (5.07–7.76)	6.01 (4.83–7.48)
p *for trend*		<0.001	<0.001	<0.001
C) Aged 12–17 years				
College or above	233/1991		Referent	
High school or GED	2178/5724	3.70 (3.04–4.50)	3.36 (2.77–4.08)	3.09 (2.53–3.77)
Less than high school	2421/3580	7.73 (6.28–9.53)	6.08 (4.96–7.46)	5.57 (4.52–6.86)
p *for trend*		<0.001	<0.001	<0.001
D) Women				
College or above	256/2073		Referent	
High school or GED	2271/5395	3.79 (3.09–4.66)	3.50 (2.85–4.29)	3.20 (2.59–3.96)
Less than high school	2332/3324	7.49 (6.05–9.29)	6.00 (4.86–7.41)	5.53 (4.45–6.87)
p *for trend*		<0.001	<0.001	<0.001
E) Men				
College or above	225/2021		Referent	
High school or GED	2363/5720	4.06 (3.37–4.90)	3.72 (3.08–4.49)	3.52 (2.92–4.26)
Less than high school	2273/3221	8.07 (6.64–9.81)	6.40 (5.28–7.77)	6.13 (5.04–7.45)
p *for trend*		<0.001	<0.001	<0.001
F) Hispanic				
College or above	114/648		Referent	
High school or GED	1285/3087	2.44 (1.80–3.30)	2.47 (1.83–3.33)	2.41 (1.79–3.25)
Less than high school	2748/3794	4.29 (3.22–5.72)	4.34 (3.26–5.77)	4.30 (3.24–5.71)
p *for trend*		<0.001	<0.001	<0.001
G) Non-Hispanic Black				
College or above	124/840		Referent	
High school or GED	1858/3562	3.60 (2.78–4.66)	3.60 (2.77–4.67)	3.12 (2.42–4.04)
Less than high school	1234/1724	5.21 (4.00–6.77)	5.20 (3.99–6.76)	4.54 (3.50–5.90)
p *for trend*		<0.001	<0.001	<0.001
H) Non-Hispanic White				
College or above	174/1831		Referent	
High school or GED	1142/3557	3.75 (2.96–4.74)	3.76 (2.97–4.75)	3.44 (2.70–4.40)
Less than high school	436/750	7.12 (5.44–9.32)	7.11 (5.43–9.30)	6.53 (4.94–8.63)
p *for trend*		<0.001	<0.001	<0.001
I) Non-Hispanic others				
College or above	69/775		Referent	
High school or GED	349/909	4.02 (2.75–5.87)	4.05 (2.77–5.91)	3.79 (2.57–5.59)
Less than high school	187/277	7.89 (5.52–11.28)	8.04 (5.61–11.52)	7.41 (5.03–10.90)
p *for trend*		<0.001	<0.001	<0.001

[a]Adjusted for survey year. [b]Adjusted for age, gender, race/ethnicity, and height of survey participants (aged 6–17 years) in addition to Model 1. [c]Adjusted for age and gender of household reference person in addition to Model 2.

Table 2: **Association between household education levels and poverty.**

school, adjusted RR [95% CI] = 1.94 [1.68–2.25]; high school or GED, adjusted RR [95% CI] = 1.76 [1.55–1.99]; p-value for trend <0.001; Table 3). The association and the dose-response relationship were consistently observed when we stratified the population into children (aged 6–11 years) and adolescents (aged 12–17 years).

Population	Obesity/Total cases	Model 1[a]	Model 2[a]	Model 3[c]
		RR (95% CI)	RR (95% CI)	RR (95% CI)
A) Total population				
College or above	575/4094		Referent	
High school or GED	2479/11,115	1.78 (1.57–2.02)	1.76 (1.56–1.99)	1.76 (1.55–1.99)
Less than high school	1617/6545	2.07 (1.81–2.37)	1.95 (1.69–2.25)	1.94 (1.68–2.25)
p *for trend*		<0.001	<0.001	<0.001
B) Aged 6–11 years				
College or above	291/2103		Referent	
High school or GED	1189/5391	1.66 (1.39–1.98)	1.63 (1.38–1.93)	1.64 (1.38–1.94)
Less than high school	731/2965	1.98 (1.66–2.37)	1.79 (1.49–2.15)	1.78 (1.49–2.13)
p *for trend*		<0.001	<0.001	<0.001
C) Aged 12–17 years				
College or above	284/1991		Referent	
High school or GED	1290/5724	1.90 (1.61–2.24)	1.89 (1.60–2.23)	1.86 (1.57–2.20)
Less than high school	886/3580	2.16 (1.78–2.62)	2.08 (1.69–2.56)	2.05 (1.66–2.53)
p *for trend*		<0.001	<0.001	<0.001
D) Women				
College or above	253/2073		Referent	
High school or GED	1195/5395	2.06 (1.70–2.49)	2.03 (1.67–2.46)	1.99 (1.63–2.43)
Less than high school	794/3324	2.41 (1.98–2.93)	2.30 (1.87–2.84)	2.26 (1.82–2.81)
p *for trend*		<0.001	<0.001	<0.001
E) Men				
College or above	322/2021		Referent	
High school or GED	1284/5720	1.57 (1.36–1.82)	1.58 (1.37–1.82)	1.60 (1.38–1.85)
Less than high school	823/3221	1.82 (1.55–2.14)	1.71 (1.44–2.03)	1.72 (1.45–2.05)
p *for trend*		<0.001	<0.001	<0.001
F) Hispanic				
College or above	123/648		Referent	
High school or GED	749/3087	1.37 (1.05–1.79)	1.46 (1.13–1.89)	1.48 (1.15–1.91)
Less than high school	1006/3794	1.50 (1.14–1.99)	1.67 (1.27–2.19)	1.68 (1.28–2.21)
p *for trend*		<0.001	<0.001	<0.001
G) Non-Hispanic Black				
College or above	169/840		Referent	
High school or GED	837/3562	1.20 (1.01–1.41)	1.23 (1.04–1.46)	1.23 (1.04–1.46)
Less than high school	393/1724	1.21 (0.99–1.48)	1.27 (1.04–1.55)	1.25 (1.02–1.53)
p *for trend*		0.10	0.03	0.05
H) Non-Hispanic White				
College or above	196/1831		Referent	
High school or GED	689/3557	1.82 (1.52–2.18)	1.92 (1.61–2.30)	1.91 (1.60–2.29)
Less than high school	165/750	2.02 (1.59–2.57)	2.29 (1.82–2.89)	2.27 (1.78–2.89)
p *for trend*		<0.001	<0.001	<0.001
I) Non-Hispanic others				
College or above	87/775		Referent	
High school or GED	204/909	2.10 (1.54–2.86)	1.99 (1.49–2.65)	1.87 (1.36–2.56)
Less than high school	53/277	1.87 (1.27–2.75)	1.82 (1.29–2.57)	1.71 (1.18–2.48)
p *for trend*		<0.001	<0.001	<0.001

[a]Adjusted for survey year. [b]Adjusted for age, gender, race/ethnicity, and height of survey participants (aged 6–17 years) in addition to Model 1. [c]Adjusted for age and gender of household reference person in addition to Model 2.

Table 3: **Association between household education levels and obesity.**

Women showed larger estimates compared to men (less than high school, adjusted RR = 2.26 vs. 1.72, p-for-interaction = 0.02; high school or GED, adjusted RR = 1.99 vs. 1.60, p-for-interaction = 0.02). Non-Hispanic White also tended to show a larger risk of obesity compared to Hispanic when their household

education levels were low (less than high school, adjusted RR = 2.27 vs. 1.68, p-for-interaction = 0.10; high school or GED, adjusted RR = 1.91 vs. 1.48, p-for-interaction = 0.09).

Mediation of poverty in the association between household education levels and obesity

We estimated that poverty mediated 18.9% of the association between household education levels (less than high school vs. college or above) and obesity among children and adolescents (Table 4). E-value for the indirect association mediated through poverty among the total population (adjusted RR [95% CI] = 1.13 [1.01–1.26]) was 1.51, indicating that the effect size for an unmeasured confounder associated with both poverty and childhood obesity would need to be moderate (i.e., risk ratios of >1.51 conditional on measured covariates) to completely explain away the observed indirect effect. The indirect association mediated through poverty (adjusted RR, 1.10–1.14) was observed across children (aged 6–11 years), adolescents (aged 12–17 years), women, and men. We observed a large proportion mediated by poverty among non-Hispanic White (34.4%) but the indirect association was not statistically significant due to insufficient statistical power (adjusted RR [95% CI] = 1.32 [0.98–1.82]). We did not find any evidence for mediation through poverty for middle household education (i.e., high school or GED vs. college or above) and obesity.

Additional analyses for BMI z-score

For the secondary outcome, lower household education levels were associated with higher BMI z-score compared to household education levels of college or above (less than high school, adjusted mean difference [95% CI] = +0.34 [0.26–0.41]; high school or GED, adjusted mean difference [95% CI] = +0.27 [0.21–0.32]; p-value for trend <0.001; Supplementary Table S1). The results of mediation analysis were also consistent when we used OLS models for BMI z-score instead of modified Poisson regression models for obesity: i.e., poverty mediated 22.8% of the association between household education levels (less than high school vs. college or above) and obesity among children and adolescents (Supplementary Table S2).

Discussion

Our study revealed that parental household income levels play a significant mediating role in the link between low parental education and offspring obesity. Using mediation analysis, we found that poverty mediated around 20% of the association between low household education levels (less than high school) and obesity among children and adolescents in the US (Fig. 1). The mediating role of poverty was consistently observed among children, adolescents, men, women, and all race/ethnicity groups. While middle household education status (high school or GED) was associated with an increased risk of poverty and obesity, we did not find evidence of mediation by poverty for this group. These findings indicate the important of developing better policies and programs, such as the Supplemental Security Income or Temporary Assistance for Needy Families, to support the health and well-being of children living in poverty.

This is the first study to estimate potential pathway from the educational status of household heads to their offspring's obesity through family poverty levels using a large nationally representative sample of the U.S. general population. The prevalence of childhood obesity in the US remained stable until the 1970s, but began to rise in the 1980s.[30] In response to this trend, various efforts have been undertaken to address the increasing prevalence of childhood obesity. In the early 2000s, public health interventions targeted at childhood obesity primarily focused on modifying individual-level behaviors, such as the promotion of physical activity and education about healthy eating.[31] For example, the Centers for Disease Control and Prevention (CDC) introduced the VERB program to increase and maintain physical activity among children aged 9–13 years.[32] Moreover, the Healthy, Hunger-Free Kids Act of 2010 was implemented to improve the nutritional quality of meals served to children through the National School Lunch and School Breakfast Programs, by increasing the availability of fruits and vegetables, reducing the amount of saturated fat and others.[33] While behavioral changes among parents and children are important in preventing childhood obesity, the choices that parents and children make are heavily influenced by the environment in which they live and the resources available to them.

Despite the complexity of childhood obesity, which stems from a confluence of social, environmental, and genetic factors,[34] socioeconomic factors (e.g., parental education and income levels) have been particularly salient, as disparities in these areas are prevalent among children with obesity.[35,36] Furthermore, recent research has revealed that these disparities have widened in the past two decades, suggesting that childhood obesity does not affect all population groups equally.[11] The potential pathway from low parental education and income levels to obesity in offspring is thought to occur through a variety of mechanisms, including limited healthcare literacy, limited access to healthier food options, a lack of safe spaces for physical activity, and reduced utilization of healthcare resources, as well as heightened levels of stress.[37–40] These factors interact in complex ways, perpetuating an intergenerational cycle of socioeconomic status and obesity that is challenging to interrupt.

Of note, we found a larger association of household education levels with poverty and childhood obesity among non-Hispanic White than among other races/

Population	Total effect[a]	Direct effect[a]	Indirect effect[a]	% Mediated[b]
	RR (95% CI)	RR (95% CI)	RR (95% CI)	
A) Total population				
College or above		Referent		
High school or GED	1.73 (1.51–2.00)	1.71 (1.47–2.00)	1.01 (0.95–1.07)	2.4
Less than high school	1.89 (1.64–2.21)	1.68 (1.39–2.04)	1.13 (1.01–1.26)	18.9
B) Aged 6–11 years				
College or above		Referent		
High school or GED	1.62 (1.35–1.97)	1.59 (1.31–1.97)	1.02 (0.94–1.11)	3.6
Less than high school	1.76 (1.45–2.15)	1.55 (1.21–2.01)	1.13 (0.98–1.33)	22.2
C) Aged 12–17 years				
College or above		Referent		
High school or GED	1.83 (1.48–2.27)	1.82 (1.45–2.29)	1.01 (0.93–1.09)	1.4
Less than high school	1.99 (1.60–2.51)	1.79 (1.37–2.38)	1.11 (0.96–1.30)	15.5
D) Women				
College or above		Referent		
High school or GED	1.96 (1.59–2.47)	1.95 (1.56–2.51)	1.01 (0.92–1.10)	0.9
Less than high school	2.22 (1.78–2.84)	2.01 (1.52–2.71)	1.10 (0.95–1.29)	12.3
E) Men				
College or above		Referent		
High school or GED	1.57 (1.31–1.89)	1.54 (1.26–1.89)	1.02 (0.94–1.10)	4.2
Less than high school	1.66 (1.38–2.03)	1.45 (1.13–1.86)	1.14 (0.99–1.34)	26.2
F) Hispanic				
College or above		Referent		
High school or GED	1.48 (1.13–1.99)	1.46 (1.09–1.99)	1.02 (0.93–1.12)	3.8
Less than high school	1.68 (1.28–2.25)	1.57 (1.16–2.15)	1.07 (0.95–1.22)	13.4
G) Non-Hispanic Black				
College or above		Referent		
High school or GED	1.25 (1.03–1.57)	1.29 (1.04–1.64)	0.97 (0.89–1.06)	NA
Less than high school	1.28 (1.05–1.64)	1.23 (0.92–1.66)	1.04 (0.86–1.28)	16.5
H) Non-Hispanic White				
College or above		Referent		
High school or GED	1.89 (1.54–2.32)	1.86 (1.48–2.33)	1.02 (0.92–1.11)	2.4
Less than high school	2.23 (1.76–2.81)	1.69 (1.12–2.47)	1.32 (0.98–1.82)	34.4
I) Non-Hispanic others				
College or above		Referent		
High school or GED	1.82 (1.29–2.65)	1.68 (1.11–2.58)	1.09 (0.89–1.35)	14.0
Less than high school	1.65 (1.05–2.54)	1.44 (0.59–3.01)	1.14 (0.63–2.33)	26.8

[a]Adjusted for age, gender, race/ethnicity, and height of survey participants (aged 6–17 years), age and gender of household reference person, and survey year. Bootstrapping was performed to estimate 95% confidence interval. [b]% Mediated was calculated by indirect effect/total effect, and therefore, depends on both total and indirect effect.

Table 4: **Association between household education levels and obesity mediated through poverty.**

ethnicities. In the US, the poverty rate varies greatly by race/ethnicity: i.e., the rates for Hispanic and non-Hispanic Black (17.1–19.5%) are more than double that of non-Hispanic White (8.1%) in 2021.[41] Moreover, according to the CDC report, the prevalence of childhood obesity in the US from 2017–2020 was 26.2% among Hispanic and 24.8% among non-Hispanic Black, while that among non-Hispanic White was 16.6%.[2] Although there is no doubt that we need to build an effective strategy to mitigate such racial disparities, our findings indicate that, even among non-Hispanic White, the low household education status—another key social determinant of child health—may largely contribute to the increased risk of poverty and childhood obesity. In this context, policies to reduce obesity risk among the low-income population needs to be further accelerated to minimize the burden of intergenerational health disparities across all race/ethnicity groups.

Strengths and limitations

Although this is one of the largest study which included the 10-cycle NHANES survey over 20 years and scrutinized the relationship according to age, gender, and race/ethnicity, our study has several

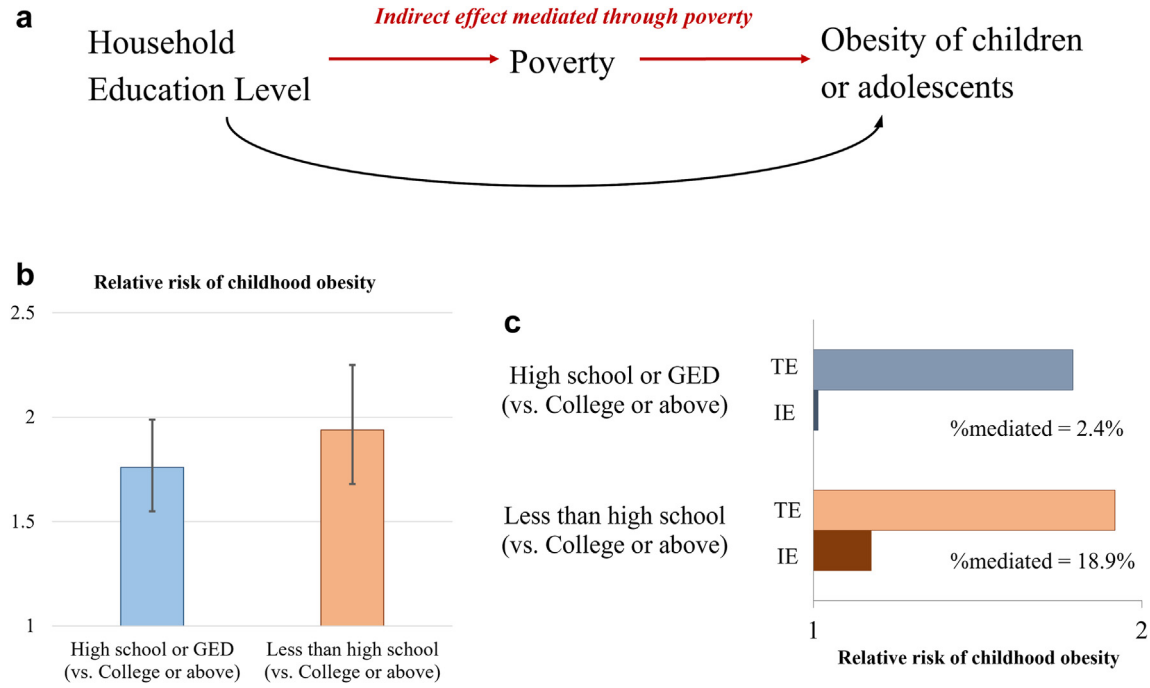

Fig. 1: An overview of the study. GED, general educational development; TE, total effect; IE, indirect effect. a) Using a nationally representative sample of US children and adolescents, causal mediation was applied to quantify the extent to which poverty mediates the relationship between household education levels and childhood obesity. b) Lower household education levels were associated with an increased risk of obesity compared to college or above household education (high school or GED, adjusted RR [95% CI] = 1.76 [1.55–1.99]; less than high school, adjusted RR [95% CI] = 1.94 [1.68–2.25]; p-value for trend <0.001). c) Poverty mediated 18.9% of the association between household education levels (less than high school vs. college or above) and obesity among children and adolescents. Although "total effect" and "indirect effect" are common terminologies in mediation analysis, our estimates based on observational study represent the association rather than the effect.

limitations. First, due to the lack of detailed information on household reference persons in the NHANEs, our results might suffer from uncontrolled confounding. In mediation analysis, we need to assume there is no uncontrolled confounding in exposure-outcome, exposure-mediator, and mediator-outcome associations. We also assumed that there was no (measured or unmeasured) confounding between the mediator and outcome affected by exposure when we computed the proportion mediated.[42] However, it is possible the unmeasured health status of household reference persons might be a confounder between current income levels and the obesity of offspring, and their health status was also affected by the parent's own educational status. Second, we used the cross-sectional data of the NHANES in our mediation analysis. Meanwhile given that family poverty levels and childhood obesity could reasonably be assumed to occur after parental education, we assumed that the temporality between exposure, mediator and outcome was less likely to be violated. Lastly, because participants self-reported their household education levels, we cannot rule out the possibility of exposure misclassification. For example, parents of children with obesity may attribute their child's weight status to their socioeconomic status and thus may misreport their own education levels. This could result in an overestimation of the association between parental education and childhood obesity.

Conclusions and public health implications

Poverty mediated the association between low educational status of household heads and their offspring's obesity regardless of age, gender, and race/ethnicity of children and adolescents in the US. Our findings indicate that some childhood health disparities could be induced by household socioeconomic status, highlighting the need to reduce obesity risk among low-income families to minimize the burden of intergenerational health disparities. Further longitudinal investigations, incorporating extensive data on reference household individuals and resident children, are paramount to validate our findings, establish the causality between parental education and childhood obesity, and disentangle the underlying mechanisms of this relationship.

Contributors

Dr. Inoue and Dr. Okubo had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. Dr. Inoue has final responsibility for the decision to submit the study for publication.

Concept and design: Inoue, Seeman, Nianogo, Okubo.

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Statistical analysis: Inoue, Seeman, Nianogo, Okubo.

Data sharing statement

The data is publicly available from the National Center for Health Statistics of the Center for Disease Control and Prevention through https://www.cdc.gov/nchs/nhanes/index.htm.

Declaration of interests

The authors have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lana.2023.100565.

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