

Physical Activity Mediates the Association between Food Insecurity and Childhood Obesity

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Abstract

Context: Childhood obesity and food insecurity constitute a global public health concern. Food insecurity could increase the risk of obesity but the mechanisms and pathways underlying the relationship are not clear.

Objective: To explore the role of physical activity in the association between food insecurity and obesity.

Methods: Data from the National Survey of Children's Health for the years 2016-2020 were used. Only children aged 10 to 17 years were included in this analysis. Logistic regression and causal mediation analysis within the counterfactual framework were employed to explore the role of physical activity.

Results: The prevalence of obesity was 15.8% in our study sample. Children experiencing food insecurity had 79% higher odds (OR=1.79, 95% CI: 1.72, 1.87) of obesity compared to children living in food-secure households after adjusting for age, sex, race/ethnicity, education, and poverty level. Physical activity was not a confounder nor an effect measure modifier. However, physical activity mediates 11.59% of the association between food insecurity and obesity. Evidence of mediation was more pronounced in Non-Hispanic Whites (proportion mediated=13.55%) and when comparing children less physically active to the most physically active (proportion mediated=24.1%).

Conclusion: Physical activity partially mediates the association between food insecurity and obesity in children.

Keywords: Public health; Dietary intake; Body composition; Nutritious meals; Food insecurity

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Introduction

Childhood obesity and food insecurity constitute a global public health concern. The COVID-19 pandemic exerts a disproportionate burden on low-income children and families, magnifying their vulnerability to both food insecurity and pediatric obesity [1]. A study conducted at the early stage of the COVID-19 pandemic found that 34.5% of U.S households with children surveyed were food insecure, which corresponds to a 3-fold increase between Mars and April 2020 [2]. Food insecurity is detrimental for children as it is associated with behaviour problems, disrupted social interactions, compromised school performance and attendance, poor dietary intake, physical activity, altered daily activities, and

poor health [3].

Previous studies emphasized the need to better understand the mechanisms and consequences of childhood experiences of food insecurity for later well-being [4,5]. Understanding the mechanisms by which food insecurity could increase childhood obesity involves assessing the contribution of different variables including physical activity.

The association between food insecurity and obesity was previously found to be mediated by diet quality, sleep duration and quality, living situation, and smoking [6-8]. Few studies have assessed the role of physical activity in the association between

food insecurity and obesity. Vander Velde et al. found that physical activity was not a significant mediator [6] while Martinez et al. reported that physical activity mediates the relationship between food insecurity and obesity among college students [8]. Another study found that the combination of physical inactivity, insufficient sleep duration, food insecurity, and income inequality explained 53% of obesity rates in US adults [9]. Effect measure modification by physical activity has been rarely reported and most studies did not include physical activity in their model [10-12] which would make sense as physical activity is less likely to be a confounder.

To our knowledge, the contribution of physical activity in the association between food insecurity and obesity has not been fully investigated, especially in the pediatric population. This study aimed to explore the role of physical activity in the association between food insecurity and obesity in children.

METHODS

Data source and study population

This study used data from the National Survey of Children's Health (NSCH) for the years 2016-2020. The NSCH was designed to generate national and state-level representative prevalence estimates for a variety of children's health indicators [13,14]. Parents from randomly selected households with one or more children under the age of 18 received a mailed invitation asking for participation online or *via* mail. Questions covered a variety of areas relating to children's physical and psychological health and quality of care received, as well as determinants of health in the context of family, community, and school [13]. The national weighted interview completion rate varied between 69.7% in 2016 and 81.2% in 2020 [15,16]. A total of 174,551 children aged 0 to 17 were surveyed for the years 2016-2020. Children with available information on the outcome (aged 10-17 years), exposure, and covariates of interest were included in the present analysis.

Outcome

The outcome of interest was obesity. In the NSCH, Body Mass Index (BMI) was calculated based on parents' reporting of their child's height and weight. Centers for Disease Control and Prevention (CDC) sex-specific BMI-for-age categories are provided in the NSCH data set. In this study, obesity status was dichotomized. Participants were classified as either without obesity (<95th percentile for BMI) or with obesity (>95th percentile for BMI) for children of the same age and sex [17,18].

Exposure

Food insecurity was the exposure of interest. In the survey, primary caregivers were asked: "Which of these statements best describes the food situation in your household in the past 12 months?" The response options were: "1=we could always afford to eat good nutritious meals", "2=we could always afford enough to eat but not always the kinds of food we should eat", "3=sometimes we could not afford enough to eat" and "4=often we could not afford enough to eat". Following the recommendation

of previous studies [19,20], respondents having any of the latter three responses were considered as experiencing food insecurity. Respondents who indicated that they could always afford to eat good, nutritious meals were classified as food secure.

Physical activity

We investigated the role of physical activity in the link between food insecurity and obesity. Physical activity was based on the parent's response to the question "During the past week, on how many days did this child exercise, play a sport, or participate in physical activity for at least 60 minutes".

Covariates

The covariates included were age, sex, race/ethnicity, education, and poverty ratio. Age was categorized into 4 groups: 10-11, 12-13, 14-15, and 16-17. The race/ethnicity of the selected child included 5 groups: non-Hispanic White, non-Hispanic Black, Hispanic (of any race), non-Hispanic Asian, and non-Hispanic other which include American Indian or Alaska Native, Native Hawaiian, and Other Pacific Islander, some other race, two or more races. Adult with the highest education in the family was used for education, which was categorized as less than high school, high school/General Education Development, some college, and college graduate or higher. The poverty level was categorized as below the federal poverty line (<100%) and at or above the federal poverty line (\geq 100%). All variables were self-reported by the primary caregiver.

Statistical analyses

Sample descriptive characteristics were analyzed. Bivariate and multivariable logistic regression was employed to assess the association between food insecurity and childhood obesity. An interaction term (food insecurity*physical activity) was added to the model to test for interaction. A p-value of the interaction term <.05 was considered significant. Confounding by physical activity was assessed by Change In the Estimate (CIE) in the bivariate and multivariable model. A CIE \geq 10% was considered evidence of confounding. In mediation, the causal mediation analysis within the counterfactual framework was used to decompose the total effect of food insecurity into natural indirect and direct effects. The mediated proportion was computed as the natural indirect effect divided by the total effect and the 95% confidence interval (95% CI) was estimated by repeating 1,000 bootstrapped computations. The mediation analysis was further stratified by sex and race/ethnicity.

In a sensitivity analysis, we first restricted the analysis to children who were not physically active "0 days" and physically active every day. Second, we restricted the analysis to respondents who answered "1=we could always afford to eat good nutritious meals" and "4=often we could not afford enough to eat" to the food security question. Third, we restricted the analysis to children included in both the first and second sensitivity analyses. The percentages in the descriptive statistics and logistic regression were weighted to account for the multiple-stage sampling design. The analysis was performed in SAS[®] 9.4 software (SAS Institute Inc. Cary, NC.).

Results

In total, 85,003 children aged 10 to 17 years were included in this analysis. **Table 1** shows the participant's characteristics. The prevalence of obesity and food insecurity was 15.8% and 32.4%, respectively. Children with the lowest level of physical activity (0 days) were 11.7% while 18.2% had the highest level of physical activity (every day).

In the bivariate logistic regression, food insecurity was associated with 2-fold increase odds of obesity (OR=2.14, 95% 1.94-2.36). Adjusting for physical activity slightly reduces the strength of the association with a change in estimate of 4.7%. In the model adjusted for age, sex, race/ethnicity, education, and poverty, food insecurity remains associated with obesity. Further adjusting for physical activity slightly reduces the strength of the association

with a change in estimate of 3.6% (Supplemental Table 1). When an interaction term (food insecurity*physical activity) was added to the model, the p-value was not significant ($p=0.7740$). **Table 2** presents the direct and indirect effect (through physical activity) of food insecurity on prevalent childhood obesity. Food insecurity was significantly associated with obesity after adjusting for age, sex, race/ethnicity, education, and poverty level (OR=1.79, 95% CI: 1.72, 1.87). The proportion mediated by physical activity was 11.59%. Evidence of mediation was more pronounced in Non-Hispanic Whites (proportion mediated=13.55%). In sensitivity analysis (**Table 3**), physical activity mediates 24.06% of the association between food insecurity and obesity when the analysis was restricted to children with the lowest and highest physical activity.

Table 1: Descriptive statistics of study participants (n=85,003).

| Characteristics | Frequency (n) ^a | Weighted % |
|--------------------------------------|----------------------------|------------|
| Sex | | |
| Male | 43,789 | 51.1% |
| Female | 41,214 | 48.1% |
| Age group | | |
| 10-11 | 17,676 | 24.73 |
| 12-13 | 19,540 | 25.31 |
| 14-15 | 22,216 | 25.11 |
| 16-17 | 25,571 | 24.84 |
| Race ethnicity | | |
| NH ^b White | 59,688 | 51.39 |
| NH Black | 5,281 | 13.42 |
| Hispanic | 9,759 | 25.24 |
| NH Asian | 4,337 | 4.42 |
| NH other ^c | 5,938 | 5.53 |
| Education^d | | |
| Less than high school | 2,153 | 10.81 |
| High school | 11,337 | 19.81 |
| Some college | 20,366 | 22.42 |
| College degree or + | 51,147 | 47.42 |
| Poverty level | | |
| Below (<100 % FPL) ^e | 30,380 | 33.38 |
| Above (≥100 % FPL) | 54,623 | 66.62 |
| Obesity status | | |
| With Obesity | 11,291 | 15.79 |
| Without obesity | 73,712 | 84.21 |
| Food security | | |
| Food secure | 62,853 | 67.6 |
| Food insecure | 22,150 | 32.4 |
| Physical activity^f | | |
| 0 days | 9,322 | 11.72 |
| 1-3 days | 34,692 | 42.25 |
| 4-6 days | 26,158 | 27.84 |
| Every day | 14,632 | 18.2 |

Note: ^a Unweighted frequency; ^b NH, non-Hispanic; ^c Other included American Indian or Alaska Native, Native Hawaiian and Other Pacific Islander, Some Other Race, Two or More Races; ^d highest level of education among reported adult; ^e FPL, federal poverty level; ^f Number missing=199.

Table 2: Direct and Indirect Effect (through physical activity) of Food Insecurity on Childhood Obesity (n=85003).

| Food insecure vs. food secure | Total Effect OR (95% CI) | Direct Effect OR (95% CI) | Indirect Effect OR (95% CI) | % Mediated ^a % (95% CI) |
|-------------------------------------|--------------------------|---------------------------|-----------------------------|------------------------------------|
| Unstratified | 1.79 (1.72, 1.87) | 1.70 (1.63, 1.78) | 1.05 (1.05, 1.06) | 11.59 (10.10, 13.10) |
| Stratified by sex | | | | |
| Male | 1.67 (1.58, 1.77) | 1.59 (1.50, 1.68) | 1.05 (1.04, 1.06) | 12.46 (10.37, 14.89) |
| Female | 1.98 (1.85, 2.12) | 1.87 (1.76, 2.01) | 1.06 (1.05, 1.07) | 10.90 (9.01, 12.92) |
| Stratified by race/ethnicity | | | | |
| NH ^b White | 1.84 (1.75, 1.96) | 1.73 (1.64, 1.83) | 1.07 (1.06, 1.08) | 13.55 (11.55, 15.62) |
| NH Black | 1.61 (1.41, 1.84) | 1.56 (1.37, 1.78) | 1.04 (1.02, 1.06) | 9.02 (5.02, 14.63) |
| Hispanic | 1.61 (1.44, 1.81) | 1.55 (1.39, 1.74) | 1.04 (1.02, 1.05) | 9.36 (6.04, 13.90) |
| NH Asian | 1.51 (1.13, 2.00) | 1.49 (1.12, 1.98) | 1.02 (0.99, 1.05) | 4.96 (-4.39, 19.49) |
| NH other ^c | 2.07 (1.77, 2.46) | 2.02 (1.73, 2.38) | 1.03 (1.01, 1.04) | 4.88 (2.27, 8.12) |

Note: ^a The percent mediated was calculated as the natural indirect effect divided by the total effect and therefore depended on both the total effect and the indirect effect; ^b NH, non-Hispanic; ^c Other included American Indian or Alaska Native, Native Hawaiian and Other Pacific Islander, Some Other Race, Two or More Races

Table 3: Direct and Indirect Effect (through physical activity) of Food Insecurity on Childhood Obesity in restricted population.

| | Total Effect OR (95% CI) | Direct Effect OR (95% CI) | Indirect Effect OR (95% CI) | % Mediated ^a % (95% CI) |
|--|--------------------------|---------------------------|-----------------------------|------------------------------------|
| Restricted to not physically active and active every day (n=23,954) | | | | |
| Food insecure vs. food secure | 1.86 (1.70, 2.03) | 1.66 (1.52, 1.81) | 1.13 (1.10, 1.14) | 24.06 (20.16, 27.77) |
| Restricted to "1 = we could always afford to eat good nutritious meals" and "4 = often we could not afford enough to eat" (n=63,233) | | | | |
| Food insecure vs. food secure | 2.16 (1.74, 2.66) | 2.05 (1.67, 2.54) | 1.05 (1.01, 1.09) | 9.18 (2.55, 15.73) |
| Restricted to (not physically active and active every day), and ("1 = we could always afford to eat good nutritious meals" and "4 = often we could not afford enough to eat") (n=17,343) | | | | |
| Food insecure vs. food secure | 2.04 (1.44, 2.79) | 1.83 (1.31, 2.48) | 1.11 (1.04, 1.21) | 20.4 (6.19, 37.37) |

Note: ^a The percent mediated was calculated as the natural indirect effect divided by the total effect and therefore depended on both the total effect and the indirect effect.

Discussion

In this study, we found that children experiencing food insecurity had higher odds of obesity. In addition, our results indicate that physical activity acts as a mediator in the link between food insecurity and childhood obesity. Evidence of mediation was even more pronounced in Non-Hispanic Whites and when comparing children less physically active to the most physically active.

To our knowledge, this study is the first to report that physical activity mediates the effect of household food insecurity on obesity in a pediatric population. Our finding is consistent with Martinez et al. who reported that physical activity mediates the relationship between food insecurity and obesity among college students [8]. They found that food insecurity was related to fewer days of physical activity, which in turn was related to an increase in Body Mass Index. Our study adds to that by quantifying the degree to which physical activity mediates the relationship between food insecurity and childhood obesity. Food insecurity might influence weight status through limited physical activity.

Children who experience food insecurity may be less likely to involve in physical activity due to feelings of tiredness, weakness, fatigue (resulting from poor dietary intake), limited financial possibilities to engage in sports, or living in an area with limited options for physical activity. Our finding of apparent difference of proportion mediated by race/ethnicity should be confirmed in future studies given the limited sample in the race/ethnicity group other than Non-Hispanic Whites.

Limitations of this study include the self-reported nature of the data, subject to misclassification. However, such misclassification would be non-differential and would bias the result toward the null. Furthermore, the food insecurity-obesity link may differ by country or region [21] therefore the findings from this study might not be generalizable to children outside of the United States.

Finally, this study is cross-sectional which is a weaker design to infer causation. Despite these limitations, this study relies on a large sample from a survey that utilized complex survey sampling to make inferences about U.S. children.

Conclusion

In this study, we found that physical activity mediates the link between food insecurity and childhood obesity and perform subgroup and sensitivity analysis which strengthen our results. Numerous food assistance programs have contributed to improved food security in the US. However, subsequent efforts should be implemented to expand and improve these programs.

Conflict of Interest

The authors declare that they have no competing interests.

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