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Authors
Dong, Lu
DAmico, Elizabeth
Dickerson, Daniel
et al.

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Food Insecurity, Sleep, and Cardiometabolic Risks in Urban American Indian/Alaska Native Youth

Lu Dong, PhD MHS[a], **Elizabeth J. D'Amico, PhD**[a], **Daniel L. Dickerson, DO, MPH**[b], **Ryan A. Brown, PhD**[a], **Alina I. Palimaru, PhD**[a], **Carrie L. Johnson, MD**[c], **Wendy M. Troxel, PhD**[d]

[a]RAND Corporation, Santa Monica, CA

[b]UCLA Integrated Substance Abuse Program, Semel Institute for Neuroscience and Human Behavior, Los Angeles, CA

[c]Sacred Path Indigenous Wellness Center, Los Angeles, CA

[d]RAND Corporation, Pittsburgh, PA.

Abstract

Objectives: Food insecurity contributes to racial/ethnic disparities in health. This is the first study to examine associations among food insecurity, sleep, and cardiometabolic outcomes in urban American Indian/Alaska Native (AI/AN) youth.

Design: Participants were 142 urban AI/AN youth (mean age = 14 years, 58% female). Food insecurity and self-reported sleep disturbance were measured using validated surveys. A multi-dimensional sleep health composite was derived using questionnaires (i.e., satisfaction, alertness) and actigraphy-derived indices (i.e., duration, efficiency, regularity, timing). Cardiometabolic measures included body mass index (BMI), blood pressure, glycosylated hemoglobin, waist circumference, cholesterol, and triglycerides. Covariates were sex, age, and single-parent household.

Results: Greater food insecurity was significantly associated with greater BMI ($b = 0.12$, $p = 0.015$), higher systolic blood pressure ($b = 0.93$, $p = 0.03$), and greater sleep disturbance ($b = 1.49$, $p < .001$), and marginally associated with lower sleep health composite scores ($b = -0.09$, $p = 0.08$). There was a significant indirect path from greater food insecurity to greater waist circumference through poorer sleep health (0.11, 95% bootstrapping CI: [0.01, 0.30]).

Conclusion: Food insecurity is an important correlate of sleep and cardiometabolic health among urban AI/AN youth and should be addressed to reduce emerging health risks during this important developmental period. Policies to reduce food insecurity and increase access to healthy foods as well as sleep interventions for these youth could help, as preliminary findings suggest that sleep health may mediate the negative impact of food insecurity on cardiometabolic risks.

Corresponding Author: Lu Dong, 1776 Main Street, Santa Monica, CA 90401, +1-310-393-0411, ldong@rand.org.

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Keywords

American Indian/Alaska Native; adolescents; food insecurity; sleep; obesity

Introduction

American Indian/Alaska Native (AI/AN) individuals experience disproportionate rates of food insecurity,[1,2] defined as limited and uncertain availability of healthy foods due to financial constraints.[3] Analyses of regional and national surveys found high rates of food insecurity among AI/AN individuals across the U.S., and that AI/AN individuals were more likely to be affected by food insecurity than White individuals.[4] Among other racial/ethnic groups, living in urban areas is typically associated with less food insecurity.[5,6] However, limited evidence suggests that urban AI/AN people may experience greater food insecurity than AI/AN people living in rural areas or on reservations[4] because urban AI/AN people are geographically dispersed and socially isolated with limited access to culturally appropriate resources and services than their counterparts living in tribal or rural areas.[4,7] In addition, AI/AN people, including those living in urban settings, are affected by high rates of poverty,[8] which is also a strong driver of food insecurity.[9]

AI/AN people are also affected by significant health disparities, including sleep problems and cardiometabolic disease,[10,11] both of which may be affected by food insecurity.[12,13] Insufficient sleep appears to be more prevalent among AI/AN adults compared to non-Hispanic White adults, although sleep remains under-investigated in AI/AN communities.[14,15] The prevalence of type 2 diabetes among AI/AN adults is more than twice that of non-Hispanic Whites and highest compared to all other racial/ethnic groups,[16] and heart disease among AI/AN adults is at least 20% higher than all other racial/ethnic groups in the U.S..[17] Although adolescence is a critical stage for health promotion,[18] evidence is scarce for sleep and cardiometabolic health in AI/AN youth.

Food insecurity is a key social determinant of poor sleep and cardiometabolic health in under-resourced populations.[12,13] In nationally representative samples of adults, food insecurity is associated with poor self-reported sleep (e.g., insufficient sleep, trouble falling and staying sleep).[19-23] Food insecurity may be associated with sleep problems via increased stress, psychological distress, rumination, and hunger, all of which are known risk factors for poor sleep.[24,25] Most studies of food insecurity rely on self-reported sleep; however, one study found food insecurity to be associated with poor actigraphy-measured sleep (e.g., shorter sleep duration, lower sleep efficiency) in low-income African American adults.[13] No prior work has examined food insecurity and sleep in general adolescent populations or in AI/AN adolescents. With regards to cardiometabolic health, food insecurity is strongly linked to obesity, diabetes, hypertension and other cardiometabolic risk in general adolescent [26] and adults in the U.S.;[27] however, few studies have investigated the links between food insecurity and cardiometabolic risk in AI/AN people, despite studies showing that AI/AN people have elevated risk for both.[28]

The significant socioeconomic and health disparities experienced by AI/AN people have been shown to be linked to historical trauma and other sources of structural racism.[29]

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Following the Indian Relocation Act of 1956, the forced relocation from reservations to urban centers resulted in numerous psychosocial problems that persist across generations in AI/AN people, including high rates of homelessness, unemployment, poverty, financial instability, behavioral health and mental health issues, and disconnect with their cultural base or community.[30,31] According to the 2010 U.S. Census, approximately 70% of the AI/AN population reside in urban settings outside of reservations or tribal areas, and over 2.1 million self-identified AI/AN individuals are under the age of 24.[32] Yet there is little research on the health disparities concerning *urban* AI/AN populations in general, including youth.[33]

In particular, little is known about how food insecurity may affect health and contribute to health disparities, such as sleep and cardiometabolic outcomes, among urban AI/AN youth. Sleep is an important correlate of cardiometabolic health in AI/AN populations,[34,35] and based on the multidimensional sleep health framework, sleep-wake function may contribute to a broad range of outcomes in health, disease, and function.[36] Hence, it is crucial to understand risk factors, such as food insecurity, and pathways (e.g., food insecurity may affect sleep, which in turn may increase cardiometabolic risks) for health disparities in AI/AN youth so that early prevention intervention efforts can target these processes.

To our knowledge, this study is the first to examine associations among food insecurity, sleep, and cardiometabolic outcomes in urban AI/AN youth. First, we examined whether food insecurity was a significant correlate of sleep and cardiometabolic outcomes. Next, we conducted exploratory analyses to examine whether food insecurity was associated with cardiometabolic outcomes through the indirect effects of sleep, given that sleep is an important correlate of cardiometabolic health in AI/AN populations.[34] We conceptualized sleep as both sleep disturbance and multidimensional sleep health; the latter is based on the sleep health framework.[36] This framework posits that sleep is a multidimensional construct comprising six dimensions of sleep and circadian functioning (i.e., regularity, satisfaction, alertness, timing, efficiency, duration) that play a positive role in supporting overall health and functioning.[36] We hypothesized that greater food insecurity would be associated with more sleep disturbance, poorer sleep health, and worse cardiometabolic outcomes (e.g., higher systolic and diastolic blood pressure, BMI). We also expected that greater sleep disturbance and poorer sleep health would be supported as indirect paths between greater food insecurity and poor cardiometabolic outcomes. Our study is also unique in that our measure of sleep health is comprised of both self-reported and objective (via actigraphy) measures of sleep.

Methods

Participants

Participants were 142 AI/AN youth residing in urban settings in California who completed a baseline assessment from March 2018 to March 2020 as part of the Native American Youth Sleep Health and Wellness (NAYSHAW) study. In order to be eligible, youth needed to be 12-16 years old and self-identify as AI/AN. Youth with major neurologic (including intellectual disability), chronic medical conditions (e.g., cancer, diabetes, cardiovascular disease), or diagnosis of sleep apnea or restless legs syndrome were excluded. Pregnant

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young women were also excluded due to heightened safety concerns related to the blood draw. The mean age of the sample was 14 years old, with 58% self-reporting as female and 53% living in single-parent households. Although all participants were required to identify as AI/AN by either themselves or a parent, 10% did not identify as AI/AN on their baseline assessment, consistent with prior research among urban AI/AN adolescents.[37]

Data were collected through a home visit, including survey and anthropometric assessments, as well as 7 days of actigraphy and diary data collection. A community-based participatory approach was used to engage AI/AN communities, which included pilot testing of all materials with community members, creating the study logo with community input, holding dinners and informational meetings to address questions, hiring AI/AN recruiters, and conducting cultural awareness and competency training for all staff. All participants' parents or guardians provided informed consent, and participants provided informed assent. All procedures were approved by RAND's institutional review board and by the communities that participated in this study.

Food Insecurity Measure

Food insecurity was measured using the Food Security Survey Module for Children Ages 12 Years and Older from the Child Food Security Survey Module.[38] Participants rated 9 items (e.g., "Did you worry that food at home would run out before your family got money to buy more?"; "Did the food that your family bought run out, and you didn't have money to get more?") on a scale from 1 (a lot) to 3 (never). We calculated the number of questions to which participants indicated they experienced food insecurity either "a lot" or "sometimes." The reliability coefficient (α) for the 9 items in the current sample was 0.85. For descriptive purposes, we used the following established cut-offs to report prevalence of food insecurity:[38] 0 = high food security, 1 = marginal food security, 2-5 = low food security, and 6-9 = very low food security. The continuous variable of food insecurity was used in the analyses.

Objective and Subjective Sleep Measures

Sleep disturbance was measured using 10 items from the School Sleep Habits Survey for Adolescents[39] that assess frequency of erratic sleep/wake behaviors over the past 2 weeks (e.g., stayed up past 3:00 a.m. or later, had an extremely hard time falling asleep) on a scale of 0 (never), 1 (once), 2 (twice), 3 (several times), to 4 (every day/night). Reliability coefficient (α) for the 10 items in the current sample was 0.80. The sleep disturbance score was calculated as a summary score of all items; higher scores indicate greater sleep disturbance.

Objective measures of sleep (actigraphy).—Actigraph-2 (Phillips/Respironics) was used to obtain an objective assessment of sleep-wake patterns for 7 consecutive days as recommended in the literature.[40] Wrist actigraphy has been extensively validated as a measure of sleep-wake activity in samples from infants to older adults.[41] Validated scoring algorithms were used to calculate sleep parameters, using diary reported bedtimes and wake-up times to set the sleep intervals.[42] We derived the following sleep variables from actigraphy: 1) sleep duration, calculated as the total time slept (time in bed – sleep onset

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latency – wake after sleep onset – terminal wakefulness); 2) sleep efficiency, or the percent of time in bed spent asleep (total sleep time/time in bed x 100); 3) midpoint sleep, calculated as the midpoint between bedtime and waketime.

The sleep health composite was derived using a combination of questionnaire measures (i.e., satisfaction, alertness) and actigraphy-derived indices (i.e., sleep duration, sleep efficiency, regularity, timing) following prior literature.[43,44] Specifically, we dichotomized each dimension as "good" versus "suboptimal" using cut-offs chosen primarily based on recommendations and consensus in the extant literature.[44] The sleep health composite was calculated by summing the six binary variables for individual dimensions (each dimension is equally weighted), with higher scores indicating greater sleep health. This approach is consistent with the prior literature operationalizing the sleep health framework,[44-46] and has clinical utility as it provides a straightforward method for clinicians to summary multidimensional sleep health into a clinically meaningful score to easily discriminate between "healthy" and "suboptimal" dimensions. A growing literature supports the validity of the sleep health composite as it relates to other mental and physical health domains in adolescent and adult samples.[43-45]

Details of the derivation of the sleep health composite is presented in the Supplemental Table 1. Each of the six sleep health dimensions were defined as follows: *Satisfaction* was measured using one item (i.e., "how would you rate your sleep quality overall?" rated on a 4-point scale: very good, fairly good, fairly bad, very bad) from the Pittsburgh Sleep Quality Index[47] and was defined as rating sleep quality as "fairly good" or "very good." *Alertness* was measured by two items from the School Sleep Habits Survey for Adolescents [39,48,49] (fallen asleep in a morning class in the past 2 weeks, fallen asleep in an afternoon class in the past 2 weeks) rated on a scale of 0 (never), 1 (once), 2 (twice), 3 (several times), to 4 (every day/night). Alertness was defined as responded "never" to both questions. *Regularity* was defined as average within-person standard deviation (*SD*) in actigraphy-assessed sleep duration across a 7-day actigraphy ≤ 60 min/1 hour. *Timing* was defined as average midpoint sleep across 7-day actigraphy before 4AM. *Efficiency* was defined as average sleep efficiency of the 7-day actigraphy ≥ 85%. *Duration* was defined as total sleep time (TST) average across 7-day actigraphy between 8-10 hours.

Cardiometabolic Measures

Body mass index (BMI) was measured using a digital scale and stadiometer to assess weight and height, respectively. BMI was defined as weight divided by the square of height (kg/m2), and standardized scores (z-scores) were derived from Centers for Disease Control and Prevention standards. Three measurements of resting blood pressure (after 10 min resting) were collected by a certified reader using clinically validated blood pressure monitors (Omron HEM-907 XL professional blood pressure monitors). The latter two pressures were averaged. Waist circumference (inches) was measured at the level of the umbilicus. A trained phlebotomist obtained the non-fasting blood draw (to reduce participant burden) from the antecubital vein during the home visit. Quest Diagnostics performed assays for glycosylated hemoglobin A1c (HbA1c), cholesterol (low-density lipoproteins and

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high-density lipoproteins), and triglycerides. The measures were chosen as they are less burdensome for participants and less affected by sampling in a non-fasting state.[50]

Statistical Methods

We used multiple regression in Stata 16[51] to examine the association between food insecurity and continuous sleep or cardiometabolic outcome variables and conducted path analysis using Mplus 8.0.[52] Data analyses were based on completed cases; the maximum sample size for each outcome is reported in Table 2. Specifically, we tested a simple mediation path model [53] to examine the indirect effect of food insecurity on cardiometabolic outcomes via sleep (sleep disturbance and the sleep health composite score, respectively). We used a bootstrapping procedure with 10,000 replications to test the statistical significance of the indirect effect, reported 95% bootstrap confidence intervals,[54] and used a statistical significance cutoff of 0.05. A direct effect between the independent variable (X) and dependent variable (Y) is not a pre-requisite for testing indirect effects, which can be significant/present when direct effects are not significant/absent.[53]

All models controlled for youths' sex and age as well as whether they live in a single parent household, which is a strong predictor of food insecurity in youth.[55] Single parent household was derived using the demographic question about parental marital status (i.e., "how would you describe your parents'/primary caregivers' marital status?"); single parent household was coded as 1 if the response was "married or living as married" and 0 if the responses were "single/never married, separated, divorced, or widowed." In addition, we conducted follow-up analyses adding financial hardship as a covariate (in addition to the standard covariates) as a proxy for family's socioeconomic status. Financial hardship was calculated as the number of participants answering "somewhat hard" or "very hard" to the question "how hard is it for you to pay for basics like food, housing, medical care and heating?" in the parent survey.

Results

Sample characteristics are presented in Table 1, and descriptive statistics for all study variables are presented in Table 2. As shown in Table 2, over half of the sample (55%) was categorized as being food insecure, defined as having marginal to very low food security.

As shown in Table 3, greater food insecurity was associated with more self-reported sleep disturbance ($b = 1.49$, $p < 0.001$, 95% CI: [0.84, 2.14]). There was also a marginally significant association between greater food insecurity and lower sleep health composite scores ($b = -0.09$, $p = 0.08$, 95% CI: [−0.19, 0.01]). For cardiometabolic outcomes, greater food insecurity was significantly associated with higher BMI z-scores ($b = 0.12$, $p = 0.015$, 95% CI: [0.02, 0.22]), and higher systolic blood pressure ($b = 0.93$, $p = 0.03$, 95% CI: [0.11, 1.76]). Food insecurity was not significantly associated with HbA1c, diastolic blood pressure, waist circumference, low-density lipoproteins, high-density lipoproteins, or triglycerides.

In exploratory analyses, we examined whether there were indirect effects of food insecurity on cardiometabolic outcomes via either sleep disturbance or the sleep health composite

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score (see Supplemental Table 2). As shown in Figure 1, we found a significant indirect effect from greater food insecurity to larger waist circumference through lower sleep health composite scores (indirect effect: 0.11, 95% bootstrapping CI: [0.01, 0.30]). We found a marginally significant indirect effect from greater food insecurity to higher BMI z-score via lower sleep health composite scores (indirect effect: 0.01, 95% bootstrapping CI: [−0.003, 0.04]). There was also a marginally significant indirect effect from greater food insecurity to higher levels of HbA1c via lower sleep health composite scores (indirect effect: 0.003, 95% bootstrapping CI: [0.00, 0.01]). There was no evidence for indirect effects of food insecurity on cardiometabolic outcomes via self-reported sleep disturbance.

We ran follow-up models controlling for financial hardship as an indicator of socioeconomic status in addition to the standard covariates. Results from both regression analyses and tests of mediation remain the same. Multiple regression results are presented in Supplemental Table 3. For our exploratory analyses testing sleep as a putative mediator, the significant indirect effects from greater food insecurity to larger waist circumference through lower sleep health composite scores remain the same (indirect effect: 0.09, 95% bootstrapping CI: [0.003, 0.29]). We also conducted sensitivity analyses using the subsample of those who self-identified as AI/AN on the survey ($n = 128$). In these analyses, regression and mediation results were similar in direction (albeit with a loss of statistical significance given the smaller sample size) as results with the full sample; these results are available upon request.

Discussion

The current study adds to the literature on understanding health disparities among urban AI/AN youth by showing inter-relationships among food insecurity, sleep, and cardiometabolic health outcomes. Our sample reported a high prevalence of food insecurity, which has been shown in other AI/AN communities.[4,56]

Overall, we found that food insecurity was associated with sleep and cardiometabolic health in this sample of urban AI/AN youth and provided preliminary evidence supporting the indirect effect of sleep health on selected cardiometabolic outcomes. Our findings of the association between greater food insecurity and worse sleep outcomes align with limited prior research in adults.[13,20,21] To our knowledge, this study is the first to report the association between food insecurity and poor sleep, including both subjective and objective sleep measures, in an adolescent sample and with AI/AN individuals.

Our findings that food insecurity was associated with greater BMI and higher SBP were also consistent with prior studies in general adolescent populations.[26] To our knowledge no existing studies have examined food insecurity and cardiometabolic risks in urban AI/AN youth; however a study by Jernigan and colleagues found no association between food insecurity and self-reported obesity in low-income AI/AN adults living in California.[28] The discrepant results may be due to different measures of BMI (e.g., self-reported BMI is likely to be an underestimate) and restricting analysis to low-income households in Jernigan et al as well as differences in age groups (adults versus youth).[28] The nature of and mechanisms behind the positive association between food insecurity and increased

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BMI should be further explored in qualitative designs with both nutritional experts and AI/AN community members. Importantly, our findings in AI/AN youth suggest that the associations between food insecurity and indicators of cardiometabolic risks emerge early in life. Thus, policy changes to mitigate food insecurity are critical during this developmental period. For example, state and local governments in charge of administering the federal Supplemental Nutrition Assistance Program (SNAP) program should partner with community-based organizations to ensure that screening, referral, and enrollment pathways are tailored to reach all vulnerable communities.[57] In addition to food provision, public health authorities should also support culturally based nutrition education to empower families to pursue healthy food options within constrained budgets. Research has shown, for example, that removing structural barriers can increase healthy food purchasing in AI/AN communities.[29,58] Further qualitative or mixed method approaches are needed to continue to understand the structural, social, psychological, and family factors that link food insecurity with negative health outcomes so that programming can better target these factors.

Our exploratory analyses showed that food insecurity was associated with higher waist circumference via poorer sleep health, which was indicated by a composite score incorporating both subjective and objective measures of sleep. Note that the direct association between food insecurity and greater waist circumference was in the expected direction but did not reach statistical significance, possibly due to insufficient statistical power. This association was not required as a precondition for testing any indirect effects,[53] and we observed significant associations between food insecurity and poor sleep health and between poor sleep health and greater waist circumference. In addition, there was some evidence for the indirect effects of food insecurity on higher HbA1c and BMI via poorer sleep health (though these indirect effects did not reach statistical significance). We did not find any other indirect effects of sleep because neither sleep disturbance nor the sleep health composite score was significantly associated with cardiometabolic outcomes in this sample (except for waist circumference; see Supplemental Table 2). To date, no studies have examined sleep-cardiometabolic associations in AI/AN youth; however, there have been reports that short sleep durations were associated with higher odds of reporting diabetes, stroke, coronary heart disease in AI/AN adults.[34] Thus, it is possible that some of these association may not emerge until adulthood. Nevertheless, our finding that sleep health was associated with waist circumference is consistent with the literature that poor sleep is a risk factor for childhood obesity.[59] Note that our findings were exploratory in nature based on cross-sectional data, which precludes casual inferences. Together, our preliminary results suggest that sleep may be a modifiable intervention target in AI/AN youth, which, if replicated in future large-scale longitudinal studies, could help increase cardiometabolic health and potentially reduce risk for obesity, diabetes, and hypercholesterolemia later in life in this population.

Our study has several limitations. First, as mentioned, results are based on cross-sectional data, which precludes inferences regarding causality. Future studies should try to replicate these preliminary results and examine the direct and indirect paths among food insecurity, sleep, and cardiometabolic outcomes using longitudinal data; this is important because food insecurity and poor sleep health may share similar risk factors. Alternative methods (e.g., causal mediation analysis) of testing the direct and indirect effects should also be

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considered in future research to fully assess the robustness of our results. Second, sleep was examined as an indirect path in our mediation analyses based on the multidimensional sleep health framework, which posits that various dimensions of sleep-wake function can affect health such as cardiometabolic outcomes.[36] However, it is possible that poor cardiometabolic health adversely affects one or more sleep health dimensions. Third, though our dichotomous approach to derive the sleep health composite has been used in several prior studies,[43-46] the sleep health framework is still an emerging construct and there is no single accepted approach for capturing this multi-dimensional construct. Hence, it is possible that the findings may be different based on alternative operationalizations of sleep health or using other statistical approaches. Fourth, our sample comprised AI/AN youth residing throughout urban areas in California; therefore, results may not be generalizable to other parts of the country or to youth residing on reservations. Another limitation is the use of non-fasting blood draw, which was chosen to reduce participant burden, based on input provided by our community-based advisory board. However, we also note, that cardiometabolic measures, including HbA1c, were specifically selected as they have been validated in non-fasting states.[50] Finally, we did not include a measure of household income because this may not be reliably assessed via adolescent report.[60] However, when we added financial hardship (a proxy for family's socioeconomic status) as a covariate, results remained the same. Despite limitations, the current study represents an important first step in understanding how food insecurity may contribute to health disparities affecting urban AI/AN youth.

In summary, this is the first study to report that food insecurity was associated with greater sleep disturbance and worse cardiometabolic outcomes in a sample of urban AI/AN youth, supporting the notion that food insecurity is a social determinant of health for this population. Understanding the associations among food insecurity, sleep health, and cardiometabolic risks can better contextualize these issues among AI/AN youth, thereby helping to formulate and enhance interventions to offset future health problems. For example, our findings indicate that sleep interventions for this population may need to also recognize the role of food insecurity. Addressing fundamental upstream causes of food insecurity as well as poor sleep health, including historical trauma, relocation, and oppression of AI/AN people is critical to reduce the disproportionate risk for cardiometabolic disease in AI/AN youth.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

AI/AN	American Indian/Alaska Native

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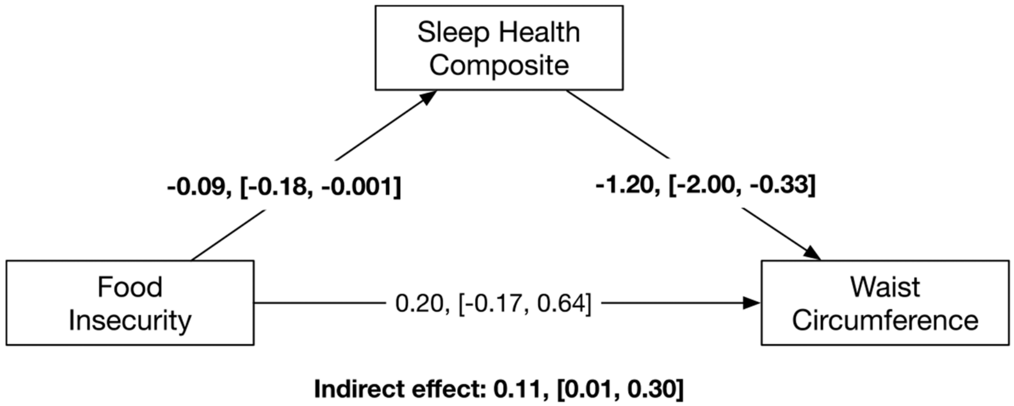

Figure 1. Indirect Effects through Sleep Health Composite

Note. Coefficients and 95% bootstrap confidence intervals are shown; significant paths coefficients and indirect effect are in bold font.

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Table 1.

NAYSHAW Sample Demographics (*N* = 142)

Sample Characteristics	***M (SD, range) or N (%)***
Age	
12 years old	23 (16%)
13 years old	33 (23%)
14 years old	32 (23%)
15 years old	25 (18%)
16 years old	29 (21%)
Mean age, years (continuous)	14.03 (1.37, 12-16)
Sex	
Male	58 (41%)
Female	84 (59%)
Race/Ethnicity [a]	
AI/AN [b]	128 (90%)
Hispanic/Latino(a)	73 (51%)
Asian American/Pacific Islander	13 (9%)
Asian	3 (2%)
Black/African American	13 (9%)
White American	18 (17%)
Other	3 (2%)
Grade	
5th grade	0 (0%)
6th grade	4 (3%)
7th grade	25 (18%)
8th grade	36 (25%)
9th grade	35 (25%)
10th grade	21 (15%)
11th grade	21 (15%)
Father’s education	
Did not finish high school	31 (22%)
Graduated from high school	42 (30%)
Some college	17 (12%)
Graduated from college	13 (9%)
Don’t know	39 (27%)
Mother’s education	
Did not finish high school	18 (13%)
Graduated from high school	40 (28%)
Some college	30 (21%)
Graduated from college	38 (27%)
Don’t know	16 (11%)

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Sample Characteristics	***M (SD, range) or N (%)***
Single-parent households	66 (47%)
Financial hardship [c]	71 (51%)

Note.

[a]Race/ethnicity categories are not mutually exclusive.

[b]All participants were identified as AI/AN either by their parents or community elder to be eligible ; here we report participant's self-reported AI/AN identity.

[c]Financial hardship was calculated as the number of participants answering "somewhat hard" or "very hard" to the question "how hard is it for you to pay for basics like food, housing, medical care and heating?" in the parent survey. There were 4 missing values on this variable ($n = 138$).

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Table 2.

Descriptive Statistics for Study Variables (*N* = 142)

Variable	*N*	*M (SD, range) or %*
Continuous food insecurity *	142	1.54 (2.15, 0-9)
Categorical food insecurity *	142	
High food security	64	45%
Marginal food security	29	20%
Low food security	39	28%
Very low food security	10	7%
Sleep disturbance	142	15.58 (8.89, 0-43)
Sleep health composite	136	3.13 (1.31, 0-6)
BMI z-score	141	0.91 (1.26, −2.67-3.18)
HbA1c	130	5.21 (0.26, 4.6-6.5)
SBP	141	110.32 (10.70, 75-146)
DBP	141	67.13 (8.41, 50-88)
Waist circumference (inches)	141	34.37 (5.74, 24.6-50)
LDL	129	73.71 (21.68, 35-142)
HDL	131	52.32 (12.06, 25-94)
Triglycerides	131	113.35 (68.87, 21-417)

Note.

* We reported the categorical food insecurity variables for descriptive purposes; the continuous food insecurity variable was used in all analyses. HbA1c = Hemoglobin A1C; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; LDL = Low-Density Lipoprotein; HDL = High-Density Lipoprotein.

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Table 3.

Multiple Regression Results with Food Insecurity as Independent Variable

Outcome	Coef.	*p*	95% CI
Sleep Outcomes			
Sleep disturbance	1.49	< 0.001	[0.84, 2.14]
Sleep health composite *	−0.09	0.08	[−0.19, 0.01]
Cardiometabolic Outcomes			
BMI z-score	0.12	0.02	[0.02, 0.22]
HbA1c	0.00	0.79	[−0.02, 0.03]
SBP	0.93	0.03	[0.11, 1.76]
DBP	0.23	0.51	[−0.45, 0.90]
Waist circumference	0.30	0.18	[−0.14, 0.75]
LDL	−0.23	0.81	[−2.05, 1.60]
HDL	0.05	0.92	[−0.93, 1.03]
Triglycerides	0.37	0.90	[−5.49, 6.221

Note. All models controlled for adolescents’ age and sex, and whether they live in single-parent household.

* Higher sleep health composite scores indicate better sleep health. HbA1c = Hemoglobin A1C; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; LDL = Low-Density Lipoprotein; HDL = High-Density Lipoprotein.