Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

variables to test the moderating effect of social risk factors. We tested the moderating models for sleep duration and sleep regularity separately. We used the Wald test and Archer–Lemeshow goodness-of-fit statistic to test the interaction terms and compare the model fit, respectively. Significant interactions were further examined and illustrated using Stata's margins plots command. All test values were 2-sided, with the significance level set at α=0.05.

3.7 Ethical considerations

This study was deemed exempt by University Institutional Review Boards.

4. RESULTS

4.1 Sample characteristics

The study participants (n=24,337) ranged in age from 10 to 17 years, with a weighted mean age of 13.56 years old and linearized standard deviation of 0.03. Nearly half were female (49.35%) and White (51%). One-third of adolescents (n= 7,181) had overweight/obesity. Whereas 86% of participants always/usually went to bed at the same time on weeknights, 37% (n= 8,319) slept shorter than age-appropriate hours defined by the AASM.

4.2. Bivariate associations

Table 1 shows counts and weighted percentages/means of sample characteristics by BMI groups. Sleep shorter than age-appropriate hours (vs. healthy sleep duration) (design-based F=24.21, p<0.001) and rarely/never going to bed at the same time (vs. always/usually/sometimes) (design-based F=8.94, p<0.001) were significantly associated with overweight/obesity. Males had a slightly greater proportion of overweight/obesity than females (34.32% vs. 31.66%, design-based F=4.08, p=0.04). Adolescents who had daily exercise (design-based F=21.45, p<0.001) for at least 60 min, or who were free of depression (design-based F=22.86, p<0.001) and household smoking exposure (design-based F=27.87, p<0.001) had a smaller proportion of overweight/obesity compared with their counterparts (p<0.001). In terms of SDOH (Table 1), children who were non-White (vs. White) (design-based F=23.11, p<0.001) or whose families had income levels < 400% FPL (vs. $\geq$ 400% %) (design-based F=38.86, p<0.001), lived in a neighborhood having at least one distracting element (vs. none) (design-based F=8.46, p<0.001), and a primary caregiver who received $\leq$ a high school education (vs. > high school) (design-based F=75.97, p<0.001) also had a larger proportion of overweight/obesity.

4.3 Adjusted associations between sleep and BMI

Table 2 shows results from logistic regression with adjustment for covariates. For sleep duration, every level increase in a nominal scale from 1 to 7 (representing the range from <6 hours to ≥11 hours) was

Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

associated with 7% decrease in the odds of overweight/obesity (OR=0.93, 95% confidence interval [CI, 0.88, 0.99], p=0.045). There was no association between sleep regularity and overweight/obesity after controlling for sleep duration and covariates. Hispanic (OR=1.35, 95% CI [1.12, 1.62], p<0.001) and Black, non-Hispanic (OR=1.48, 95% CI [1.21, 1.81], p<0.001) adolescents versus their White counterparts had 36% and 45% increased odds of overweight/obesity, respectively. Compared with family income ≥ 400% FPL, lower family income levels were associated with 23-61% increased odds of overweight/obesity (p<0.05), with the greatest odds shown in families whose income was < 100% FPL (OR=1.61, 95% CI [1.31, 1.98], p<0.001). Adolescents whose primary caregiver had no more than a high school education (OR=1.47, 95% CI [1.24, 1.75], p<0.001) or lived in disadvantaged neighborhoods with three detracting elements (OR=1.64, 95% CI [1.14, 2.37], p=0.02) had an increased odds of overweight/obesity. Being female, daily exercise and being free of depression and household smoking exposure remained significantly associated with decreased odds of having overweight/obesity in the adjusted models (p<0.05).

4.4 Moderating effect of SDOH

As shown in Table 2, race/ethnicity, family income, and primary caregiver education were significant moderators for sleep duration and overweight/obesity, such that the protective associations between increasing sleep duration and decreasing odds of overweight/obesity were significant only in the following social subgroups: White race (OR=0.88, 95% CI [0.82, 0.95], p<0.001), primary caregiver education >high school (OR=0.89, 95% CI [0.83, 0.95], p<0.001] and family income ≥400% FLP (OR=0.85, 95% CI [0.78, 0.92], p<0.001). Compared with White adolescents, Hispanic adolescents showed weakened and even reversed sleep-obesity association (OR=1.20, 95% CI [1.04,1.40], p=0.01). Having family income < 100% FPL (vs. ≥400%) (OR=1.20, 95% CI [1.04, 1.40], p=0.02) and the primary caregiver having education ≤ high school (vs. > high school) (OR=1.15, 95% CI [1.01, 1.31], p=0.04) also attenuated/reversed the negative association between sleep duration and odds of having overweight/obesity (Table 2). More specifically, as shown in the margins plot (Figure 1), compared with non-White (i.e., Hispanic) and lower SES groups (i.e., family income < 100% FPL and primary caregiver having education ≤ high school), adolescents with advantaged social factors (i.e., being White, family income ≥ 400% FPL, and primary caregiver education > high school) had a smaller probability of overweight/obesity and the group differences in overweight/obesity probability became larger with increasing sleep duration (p<0.05). The Archer-Lemeshow test suggests that models were a good fit for the data (p>0.05) and adding the interaction terms showed a statistically significant improvement in model fit (Wald test, p<0.05). Neighborhood condition was not a significant moderator between sleep duration and overweight/obesity (p>0.05). Also, there were no significant interactions between each SDOH variable (race/ethnicity, parent education, family income, and neighborhood condition) and sleep regularity (p>0.05; data not presented in Table 2).

Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

5. DISCUSSION

To the best of our knowledge, this is one of the first studies to examine how race/ethnicity and SES indicators amplify or attenuate the association between sleep and overweight/obesity using a nationally representative US sample of adolescents. Increasing sleep duration was associated with decreasing odds of overweight/obesity, with more robust association shown in White adolescents and those with family income≥ 400% FPL or primary caregiver > a high school education. These subgroups also had the lowest odds of overweight/obesity and the group differences increased with longer sleep duration, especially compared with Hispanic adolescents or those with family income <100% FPL and primary caregiver receiving no more than a high school education. Although neighborhood condition was not a significant moderator, poor neighborhoods with 3 detracting elements were independently associated with greater odds of having overweight/obesity. Sleep regularity was not independently associated with overweight/obesity or significantly interacted with SDOH on associations with overweight/obesity. Our findings inform future studies investigating the importance of sufficient sleep duration in conjunction with high SES to combating overweight/obesity.

More than one-third of our sample was classified as short sleepers or being overweight/obese. Consistent with the prior literature, overweight and obesity appear to differentially affect Hispanics, non-Hispanic Black and those with lower socioeconomic indicators in our sample (Ogden et al., 2018). Hispanic and non-Hispanic Black families and those with low SES disparately reside in disadvantaged neighborhoods due to "redlining", the historically discriminating US housing policy (Billings et al 2021). Lack of access to healthy food options, green space and/or safe environments for physical activity may contribute to increased risk for overweight/obesity (Jackson, 2017). Similarly, elements that depict poor neighborhood conditions such as vandalism/graffiti, rundown housing, and cleanliness jeopardize healthy sleep duration in adolescents (Billings et al., 2021).

Adolescents with longer sleep duration on weekday nights were less likely to have overweight/obesity, which parallels prior research findings suggesting insufficient sleep as a risk factor for overweight and obesity (Miller et al., 2018; Morrissey et al., 2020). Proposed mechanisms underlying sleep-related overweight/obesity variations include metabolic changes affecting appetite-regulating hormone, low physical activity and increased food intake relative to energy expenditure (Breitenstein et al., 2019). Controlling for sleep duration, we did not find significant associations between sleep regularity and overweight/obesity in adolescents. Using the NSCH dataset in previous years, Chehal and colleagues (2022) found that some variability (vs. always regular) in weeknight bedtime is associated with lower odds of obesity, although there were no additional differences between those with extensive variability and always regular in bedtime. The discrepancy with our study may be attributed to different sets of covariates and

classification of BMI levels (overweight/obesity vs. obesity). In contrast, lower sleep regularity measured using sleep diaries was associated with greater BMI in first-year college students (Wong et al., 2022). Mixed findings make this a continued gap and further research is needed to explore objectively measured sleep regularity with a longitudinal design.

Our findings of the interaction between sleep duration and SDOH both support and extend previous work. Obtaining sufficient sleep is associated with lower odds of obesity development among White adolescents and those with higher SES. Sufficient sleep may not be as protective against obesity risk in ethnic/minority and low SES groups, compared with their counterparts. These findings did not support our a priori hypothesis that the associations between shorter sleep and greater risk for overweight/obesity were more pronounced in adolescents in minority racial/ethnic and low SES groups. Prior research has also reported mixed results regarding the moderating role of race/ethnicity and SES (Bagley et al., 2015; Breitenstein et al., 2019). The associations between sleep duration and overweight/obesity did not vary by early-life SES calculated from caregiver education and household income among school-age children (Breitenstein et al., 2019) or ethnicity among low-income preschoolers (Vézina-Im et al., 2017). However, our findings, to some extent, align with study results suggesting that high SES early in life may buffer strong, negative associations between sleep duration and percent body fat and serve as a protective factor during middle childhood (Breitenstein et al., 2019). Additionally, whereas sleep extension intervention facilitates weight loss in adolescents under caloric restriction (Moreno-Frías et al., 2020), one experimental study showed that sleep extension intervention significantly improved sleep hours (by approximately 1 hour) only among non-Hispanic whites but not adolescents of racial/ethnic minority status (Tavernier & Adam, 2017).

The lack of sleep-obesity association in racial/ethnic minority groups and those with low SES may be due to the multifaceted nature of obesity development in these groups. Compared with sleep impact, other risk factors such as poorer diet quality may explain a greater variance in overweight/obesity in those vulnerable groups. Since these vulnerable groups continue to live in socially disadvantaged environments, the cumulative and intergenerational differences in inopportune exposures could contribute to disparate risk of physiological dysregulation and its cascade of metabolic health consequences. As such, sleep duration on its own may not provide enough protection, and future obesity interventions may consider social and family-level changes in conjunction with multimodal health behavior changes that are culturally-relevant and place-based (because of pervasive racial residential segregation) (Jackson, 2017). Meanwhile, adolescents who have positive social risk factors and are having sufficient sleep may have a lower burden of allostatic load, thereby less likely to have overweight/obesity. Such that, increasing sleep duration enlarges the gap in overweight/obesity risk between socially disadvantaged groups (i.e., Hispanics, FPL<100% and primary caregiver receiving < high school education) and those with advantaged social

Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

factors (i.e., being White, high SES status). Despite the nationwide "Hispanic paradox" (refers to the epidemiological findings of comparable/better health outcomes but lower SES than the non-Hispanic White) in obesity prevalence (Valencia et al., 2020), Hispanic children and adolescents are more vulnerable to obesity than their White peers (Ogden et al., 2018). The integration of multimodal health disparity pathways and sleep mechanisms is essential to understand and address obesity health disparities in adolescents with diverse racial/ethnic and socioeconomic backgrounds.

5.1 Implications for practice and future research

Sleep and obesity disparities disproportionately affect the same groups who suffer overall health disparities (Billings et al., 2021). Moreover, the negative impact of SDOH can accumulate over a lifetime, and intergenerationally transmit through family systems, and ultimately alter life course health trajectories (Piccolo et al., 2013; Solar & Irwin, 2010). These long-term public health impacts highlight the necessity for screening and intervention for unhealthy sleep and weight status early in the life course. Such tasks often fall onto pediatric providers, who are burdened with addressing multiple health domains during short well child visits (Billings et al., 2021). Unhealthy sleep and overweight/obesity are each multi-etiological and complex in that they are determined by a myriad of factors at the individual, social, and environmental levels. The addition of an interdisciplinary team of health care providers (e.g., school nurses, pediatric dentists, social workers), school teachers, religious leaders and other community stakeholders is needed to address sleep and cardiometabolic health inequities (Billings et al., 2021).

The current study suggests that the influence of socio-contextual factors may vary by race/ethnicity and SES. Prior to intervention development, more work is needed to better understand the complex mechanisms (beyond sleep behaviors) among these at-risk groups. With machine learning techniques, big data resources such as national surveillance, electronic health record and biobanks can be exploited to examine the interplay between sleep and other individual (e.g., diet), family (e.g., parenting), social (e.g., social norms and cultural perception) and systemic factors and identify the most important factors for obesity development, particularly among racial/ethnic minority and low SES groups. Also, over a lifetime, this cyclical relationship of poor sleep leading to obesity and then obesity leading to worse sleep will only further health inequities (Jackson, 2017). Use of longitudinal design in future studies will help tease apart the likely bidirectional relationship between sleep duration and overweight/obesity in the context of SDOH. In terms of interventional studies, lack of acknowledgment of large-scale social factors will impede the success of individual health behavior interventions to improve sleep and obesity, which will further exacerbate health inequities. As such, consideration of multi-level biobehavioral and socio-contextual factors, using youth, family and community-based perceptions are essential for the success of future obesity interventions, particularly those aimed at racial/ethnic minority groups (Billings et al., 2021).

Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

5.2 Study Limitations

Several potential limitations should be considered in the interpretation of results. First, the cross-sectional design does not support causal inferences. Reciprocal associations between sleep and overweigh/obesity are likely and should be considered especially with longitudinal datasets to examine the trajectory of BMI in response to changes in sleep over time. Second, sleep and BMI measures relied on caregiver reports, which may pose a potential risk for bias. For example, parents tend to overestimate child sleep time, which may explain the lower rates of insufficient and irregular sleep in our sample, compared with a US national study using self-report (Wheaton et al., 2018). Additionally, using a single item to capture sleep duration and sleep irregularity limits construct variability and may impede its proper capture. Third, meta-analyses suggest that sleep more than age-appropriate hours predicts a greater risk of obesity in adults (Liu et al., 2019). However, there were only 1.54% of adolescents in this secondary analysis classified as long sleepers, thereby not supporting further examination of U-shaped associations between sleep and BMI. Fourth, due to data availability, we did not account for other behavioral and contextual differences related to weight status, especially dietary intake, screen time/screen-based sedentary behaviors. Access to calorie-dense/nutrition-poor foods, cultural habits for sleep and diet as well as screen behaviors could explain the observed moderating effect. Finally, there may be other moderators/mediators in the statistical model, such as sex, household smoking, daily exercise, and depressive symptoms. Given the focus of this study, we did not test the moderation, mediation or moderated mediation of these variables. Future research is needed to identify the complicated relationships among multi-level variables.

6. CONCLUSION

Given the growing disparities in sleep health and obesity, our findings extend previous research by elucidating how the relationship between sleep and overweight/obesity varies based on race/ethnicity and SES among adolescents aged 10-17 years old. Longer sleep is associated with a lower overweight and obesity risk among adolescents who are White and from families with high SES, compared with their counterparts. SDOH have implications for the development of nurse-led weight management programs, as focusing on individual behaviors in the absence of consideration of social contributions may be unsuccessful. Future research is needed to investigate the most important contributing factors among adolescents from racial/ethnic minority groups and families with low SES to understand their vulnerability to overweight and obesity.

References

Araújo, J., Severo, M., & Ramos, E. (2012, Nov). Sleep duration and adiposity during adolescence. *Pediatrics, 130*(5), e1146-1154. https://doi.org/10.1542/peds.2011-1116

Bagley, E. J., Kelly, R. J., & El-Sheikh, M. (2015, Mar). Longitudinal relations between children's sleep and body mass index: the moderating role of socioeconomic risk. *Sleep Health, 1*(1), 44-49. https://doi.org/10.1016/j.sleh.2014.12.001

Billings, M. E., Cohen, R. T., Baldwin, C. M., Johnson, D. A., Palen, B. N., Parthasarathy, S., Patel, S. R., Russell, M., Tapia, I. E., Williamson, A. A., & Sharma, S. (2021). Disparities in Sleep Health and Potential Intervention Models: A Focused Review. *Chest, 159*(3), 1232-1240. https://doi.org/10.1016/j.chest.2020.09.249

Breitenstein, R. S., Doane, L. D., & Lemery-Chalfant, K. (2019). Early life socioeconomic status moderates associations between objective sleep and weight-related indicators in middle childhood. *Sleep Health, 5*(5), 470-478. https://doi.org/10.1016/j.sleh.2019.04.002

Chehal, P. K., Shafer, L., & Cunningham, S. A. (2022). Examination of Sleep and Obesity in Children and Adolescents in the United States. *American Journal of Health Promotion, 36*(1), 46-54.

DeBoer, M. D., Gurka, M. J., Woo, J. G., & Morrison, J. A. (2015). Severity of metabolic syndrome as a predictor of cardiovascular disease between childhood and adulthood: the Princeton Lipid Research Cohort Study. *Journal of the American College of Cardiology, 66*(6), 755-757.

Gariepy, G., Danna, S., Gobiņa, I., Rasmussen, M., de Matos, M. G., Tynjälä, J., Janssen, I., Kalman, M., Villeruša, A., & Husarova, D. (2020). How are adolescents sleeping? Adolescent sleep patterns and sociodemographic differences in 24 European and North American countries. *Journal of Adolescent Health, 66*(6), S81-S88.

Grandner, M. A., Jackson, N. J., Izci-Balserak, B., Gallagher, R. A., Murray-Bachmann, R., Williams, N. J., Patel, N. P., & Jean-Louis, G. (2015). Social and behavioral determinants of perceived insufficient sleep. *Frontiers in Neurology, 6*, 112.

Jackson, C. L. (2017, Oct). Determinants of racial/ethnic disparities in disordered sleep and obesity. *Sleep Health, 3*(5), 401-415. https://doi.org/10.1016/j.sleh.2017.08.001

Johnson, D. A., Jackson, C. L., Williams, N. J., & Alcántara, C. (2019). Are sleep patterns influenced by race/ethnicity - a marker of relative advantage or disadvantage? Evidence to date. *Nature and Science of Sleep, 11*, 79-95. https://doi.org/10.2147/NSS.S169312

Liu, W., Zhang, R., Tan, A., Ye, B., Zhang, X., Wang, Y., Zou, Y., Ma, L., Chen, G., Li, R., & Moore, J. B. (2019, Jun 1). Long sleep duration predicts a higher risk of obesity in adults: a meta-analysis of prospective cohort studies. *Journal of Public Health (Oxf), 41*(2), e158-e168. https://doi.org/10.1093/pubmed/fdy135

McGuire, S. (2012). Institute of Medicine (IOM) Early Childhood Obesity Prevention Policies. Washington, DC: The National Academies Press; 2011. *Advances in Nutrition (Bethesda, Md.), 3*(1), 56-57. https://doi.org/10.3945/an.111.001347

Mead, M. P., Vargas, E. A., & Knutson, K. L. (2022, 2022/02/01). Racial Disparities in Sleep: Potential Mediation by Discrimination and Psychological Distress. *Journal of Racial and Ethnic Health Disparities*. https://doi.org/10.1007/s40615-022-01247-0

Miller, M. A., Kruisbrink, M., Wallace, J., Ji, C., & Cappuccio, F. P. (2018). Sleep duration and incidence of obesity in infants, children, and adolescents: a systematic review and meta-analysis of prospective studies. *Sleep, 41*(4), zsy018.

Moreno-Frías, C., Figueroa-Vega, N., & Malacara, J. M. (2020). Sleep extension increases the effect of caloric restriction over body weight and improves the chronic low-grade inflammation in adolescents with obesity. *Journal of Adolescent Health, 66*(5), 575-581.

Morrissey, B., Taveras, E., Allender, S., & Strugnell, C. (2020). Sleep and obesity among children: a systematic review of multiple sleep dimensions. *Pediatric Obesity, 15*(4), e12619.

Ogden, C. L., Fryar, C. D., Hales, C. M., Carroll, M. D., Aoki, Y., & Freedman, D. S. (2018). Differences in obesity prevalence by demographics and urbanization in US children and adolescents, 2013-2016. *JAMA, 319*(23), 2410-2418.

Paruthi, S., Brooks, L. J., D'Ambrosio, C., Hall, W. A., Kotagal, S., Lloyd, R. M., Malow, B. A., Maski, K., Nichols, C., & Quan, S. F. (2016). Consensus statement of the American Academy of Sleep Medicine on the recommended amount of sleep for healthy children: methodology and discussion. *Journal of Clinical Sleep Medicine, 12*(11), 1549-1561.

Piccolo, R. S., Yang, M., Bliwise, D. L., Yaggi, H. K., & Araujo, A. B. (2013). Racial and socioeconomic disparities in sleep and chronic disease: results of a longitudinal investigation. *Ethnicity & disease, 23*(4), 499.

Reither, E. N., Krueger, P. M., Hale, L., Reiter, E. M., & Peppard, P. E. (2014). Ethnic variation in the association between sleep and body mass among US adolescents. *International Journal of Obesity, 38*(7), 944-949.

Solar, O., & Irwin, A. (2010). *A conceptual framework for action on the social determinants of* health. WHO Document Production Services. Retrieved March 18, 2022, https://www.who.int/publications/i/item/9789241500852

Tavernier, R., & Adam, E. K. (2017). Text message intervention improves objective sleep hours among adolescents: the moderating role of race-ethnicity. *Sleep Health, 3*(1), 62-67.

Valencia, A., Zuma, B. Z., Spencer-Bonilla, G., López, L., Scheinker, D., & Rodriguez, F. (2020). The Hispanic paradox in the prevalence of obesity at the county-level. *Obesity Science & Practice, 7*(1), 14-24. https://doi.org/10.1002/osp4.461

Vézina-Im, L. A., Hughes, S. O., Baranowski, T., & Nicklas, T. A. (2017). Association between sleep duration and body mass index among US low-income preschoolers. *Obesity, 25*(10), 1770-1775.

Wheaton, A. G., Jones, S. E., Cooper, A. C., & Croft, J. B. (2018, Jan 26). Short Sleep Duration Among Middle School and High School Students - United States, 2015. *MMWR Morb Mortal Wkly Rep, 67*(3), 85-90. https://doi.org/10.15585/mmwr.mm6703a1

WHO. (2021). *Fact sheet – Obesity and overweight.* Retrieved March 15 from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

Wohlfahrt-Veje, C., Tinggaard, J., Winther, K., Mouritsen, A., Hagen, C., Mieritz, M., de Renzy-Martin, K., Boas, M., Petersen, J., & Main, K. (2014). Body fat throughout childhood in 2647 healthy Danish children: agreement of BMI, waist circumference, skinfolds with dual X-ray absorptiometry. *European Journal of Clinical Nutrition, 68*(6), 664-670.

Wong, P. M., Barker, D., Roane, B. M., Van Reen, E., & Carskadon, M. A. (2022). Sleep regularity and body mass index: findings from a prospective study of first-year college students. *Sleep Advances, 3*(1). https://doi.org/10.1093/sleepadvances/zpac004

Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

Table 1. Survey Descriptive Statistics [a] of the Study Sample by BMI status (n=24,337)

	Overall Sample	BMI status, n(%)	
		Healthy BMI (n=17,156)	Overweight/Obesity [b] (n=7,181)
Age, M±SD	13.56(0.03)	13.66±0.03	13.35±0.05*
Sex			
Male	12,553(50.65)	8,491(65.68)	4,062(34.32)
Female	11,784(49.35)	8,665(68.34)	3,119(31.66)
Daily exercise			
No	20,051(81.05)	13,878 (65.33)	6,173(34.67)***
Yes	4,222(18.95)	3,228(74.17)	994(25.83)
Current depression			
No	22,530(94.60)	16,071(67.64)	6,459 (32.36)
Yes	1,665(5.40)	992(56.22)	673(43.78)
Parent education			
>high school	20,313(67.04)	14,780(71.70)	5,533(28.30)***
≤ high school	4,024(32.96)	2,376(56.69)	1,648(43.31)
Family Income			
0-99% FPL	2,728(19.09)	1,656(56.60)	1,072(43.40)***
100-299% FPL	7,491(36.91)	4,933(63.11)	2,558(36.89)
300-399% FPL	3,542(12.05)	2,502(70.71)	1,040(29.29)
≥ 400% % FPL	10,576(39.14)	8,065(76.43)	2,511(23.57)
Race/Ethnicity			
White, non-Hispanic	17,185(50.71)	12,443(72.40)	4,742(27.60)***
Hispanic	2,728(25.72)	1,739(60.33)	989(39.67)
Black, non-Hispanic	1,587(14.08)	930(58.43)	657(41.57)
Multi-racial/other	2,837(9.49)	2,044(69.34)	793 (30.66)
Neighborhood condition			
Good	19,259(75.62)	13,783(69.15)	5,476 (30.85)***
1 detracting element	3,069(15.88)	2,089(63.62)	980(36.38)
2 detracting elements	948(4.84)	621(61.67)	327(38.33)
3 detracting elements	585(3.67)	351(50.51)	234(49.49)
Household smoking			
No	20,357(84.55)	14,720(68.59)	5,637(31.41)***
Yes	3,729(15.45)	2,267(59.31)	1,462(40.69)
Sleep duration			
Normal	16,018(62.71)	11,598(69.74)	4,420(30.26)*
Insufficient	8,319(37.29)	5,558 (62.50)	2,761(37.50)
Sleep regularity			
Always	5,880(27.70)	3,987(63.32)	1,893(36.68)***
Usually	15,101(57.83)	10,933(69.96)	4,168(30.04)
Sometimes	2,396 (9.98)	1,624(65.44)	772 (34.56)
Rarely or never	897(4.49)	565(57.62)	332 (42.38)

Note. [a] Weighted percentage and weighted mean ± linearized standard deviation; [b] According to the Center for Disease Control's BMI-for-Age Growth Charts, overweight/obesity is defined as BMI ≥85th percentile and healthy BMI as 5-85th percentile for age. Chi-square (categorical variables) and Mann Whitney U (age) tests examined whether the overall differences in proportions of healthy BMI vs. overweight/obesity are different between groups with following significance indicators: *p<0.05; **p<0.01; ***p<0.001

Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

Table 2. Survey Logistic regression models [a] on overweight/obesity [OR(95% CI)]

	Model 1	Model 2	Model 3	Model 4
Age	0.92(0.89, 0.95)***	0.92(0.89, 0.95)***	0.92(0.89, 0.95)***	0.92(0.89, 0.95)***
Female (vs. male)	0.85(0.74, 0.97)*	0.85(0.75, 0.97)*	0.85(0.75, 0.97)*	0.85(0.77, 0.97)*
Sleep duration	0.93(0.88, 0.99)*	0.89(0.83, 0.95)***	0.88(0.82, 0.93)***	0.85(0.78, 0.92)***
Sleep regularity (vs. Always)				
Usually	1.03(0.74, 1.43)	1.03(0.74, 1.43)	1.03(0.74, 1.44)	1.01(0.73, 1.43)
Sometimes	0.79(0.58, 1.09)	0.80(0.58, 1.09)	0.79(0.57, 1.09)	0.78(0.57, 1.07)
Rarely or never	0.83(0.58, 1.19)	0.84(0.59, 1.19)	0.83(0.59, 1.19)	0.82(0.58, 1.17)
Parent education ≤high school (vs.>high school)	1.47(1.24, 1.75)***	0.83(0.48, 1.47)	1.46(1.23, 1.73)***	1.46(1.23, 1.73)***
Family Income (vs. ≥ 400% FPL)				
0-99% FPL	1.61(1.31, 1.98)***	1.59(1.29, 1.95)***	1.60(1.30, 1.97)***	0.75(0.39, 1.42)
100-299% FPL	1.45(1.25, 1.67)***	1.43(1.25, 1.66)***	1.45(1.26, 1.67)***	0.91(0.52, 1.61)
300-399% FPL	1.23(1.12, 1.49)*	1.21(1.01, 1.47)*	1.22(1.01, 1.48)*	0.71(0.31, 1.59)
Race/ Ethnicity (vs. White)				
Hispanic	1.35(1.12, 1.62)**	1.33(1.11, 1.60)**	0.62(0.33, 1.18)	1.34(1.12, 1.61)**
Black, non-Hispanic	1.48(1.21, 1.81)***	1.48(1.21, 1.81)***	1.15(0.56, 2.37)	1.48(1.21, 1.81)***
Multi-racial/other	1.03(0.85, 1.24)	1.03(0.85, 1.24)	0.97(0.51, 1.84)	1.04(0.86, 1.25)
Neighborhood conditions (vs. no detracting element)				
1 detracting element	1.13(0.92, 1.38)	1.12(0.92, 1.38)	1.13(0.93, 1.39)	1.12(0.92, 1.38)
2 detracting elements	1.05(0.74, 1.51)	1.05(0.73, 1.50)	1.05(0.74, 1.50)	1.05(0.74, 1.50)
3 detracting elements	1.64(1.14, 2.37)**	1.64(1.14, 2.37)**	1.64(1.14, 2.38)**	1.64(1.14, 2.36)**
Household smoking	1.29(1.09, 1.54)**	1.29(1.09, 1.54)**	1.29(1.08, 1.53)**	1.31(1.10, 1.55)**
Daily exercise (vs. no daily exercise)	0.58(0.48, 0.70)***	0.58(0.48, 0.70)*	0.58(0.48, 0.70)*	0.58(0.48, 0.70)
Depression (vs. no depression)	1.67(1.34, 2.09)***	1.66(1.33, 2.06)***	1.66(1.33, 2.07)***	1.67(1.33, 2.08)***
Interaction terms				
Sleep duration x parent education≤ high school		1.15(1.01, 1.31)*		
Sleep duration x race/ethnicity				
Hispanic			1.20(1.04,1.40)*	
Black, non-Hispanic			1.05(0.89,1.26)	
Multi-racial/other			1.01(0.87,1.18)	
Sleep duration x family income				
0-99% FPL				1.20(1.04, 1.40)*
100-299% FPL				1.12(0.98, 1.27)
300-399% FPL				1.14(0.94, 1.39)
Archer–Lemeshow test	F=1.29, p=0.23	F=1.12, p=0.35	F=0.45, p=0.91	F=0.64, p=0.76
Wald test		F=11.35, p<0.001	F=6.03, p<0.001	F=7.66, p<0.001

Note. [a] Model 1: basic model accounting for complex sampling weights and covariates; Model 2: Model 1+ sleep duration and parent education interaction; Model 3: Model 1+ sleep duration and race/ethnicity interaction; Model 4: Model 1+ sleep duration and income interaction. Results presented were odds ratio (95% confidence interval). Interaction terms tested but not significant (not presented in table) include sleep duration and neighborhood conditions, and sleep regularity and each SDOH variable. Sleep regularity and duration were tested separately. [b] According to the Center for Disease Control's BMI-for-Age Growth Charts, overweight/obesity is defined as BMI ≥85th percentile and healthy BMI as 5-85th percentile for age. Archer–Lemeshow test: p>0.05 indicates good model fit. Wald test: p<0.05 indicates adding the interaction term improves model fit. *p<0.05; **p<0.01; ***p<0.001

Accepted Manuscript
Version of record at: https://doi.org/10.1111/jan.15513

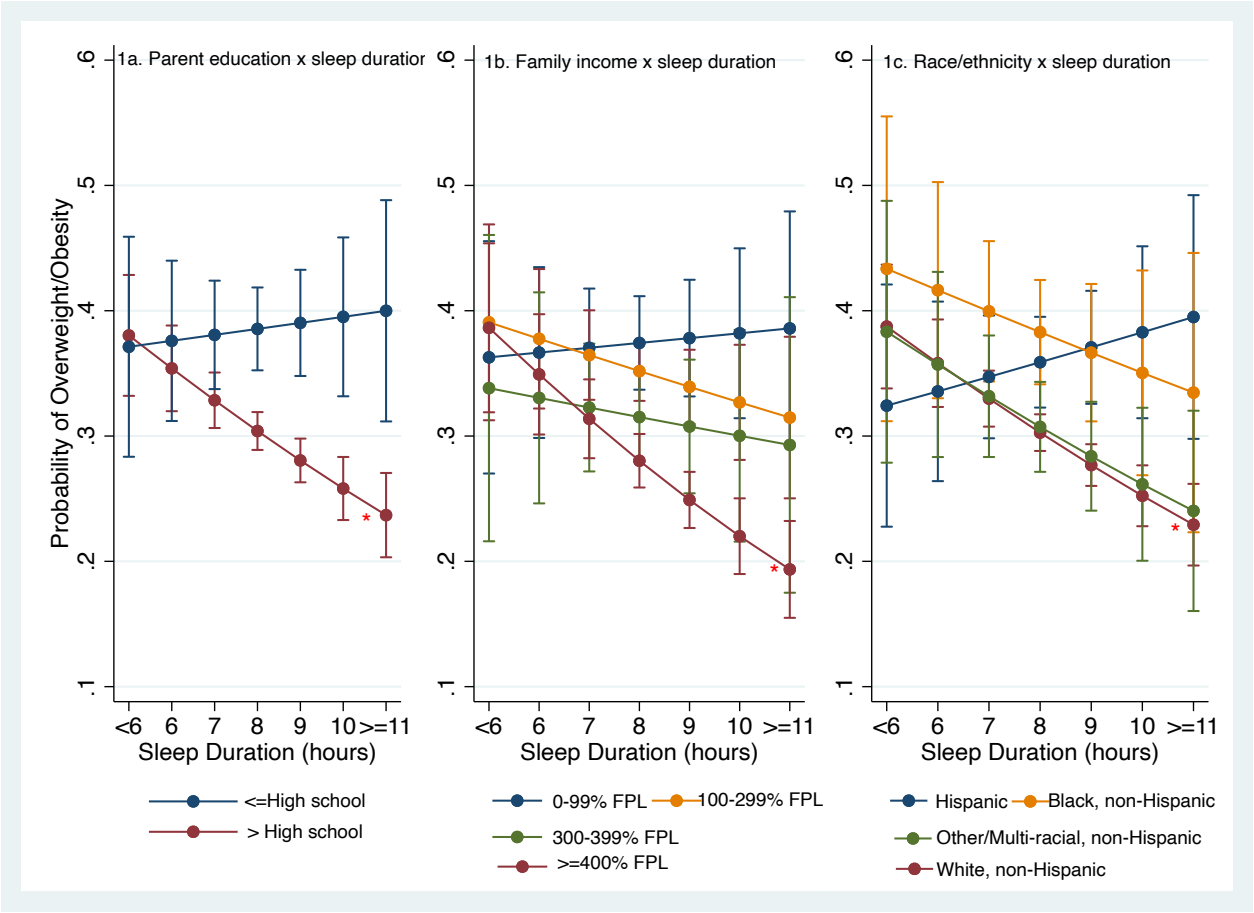

Figure 1. Interaction between sleep duration and social determinants of health on overweight/obesity
Note. The margins plots are derived using the Margins command in Stata based on logistic regression with complex survey design. The plots show the marginal effects of social determinants of health on probability of overweight/obesity (y-axis) with 95% confidence intervals when sleep duration (x-axis) is held constant at different values.
*The associations between increasing sleep duration and decreasing probability of overweight/obesity were significant in subgroups: primary caregiver education ≥high school, family income ≥400% FLP and White ($p<0.05$).