

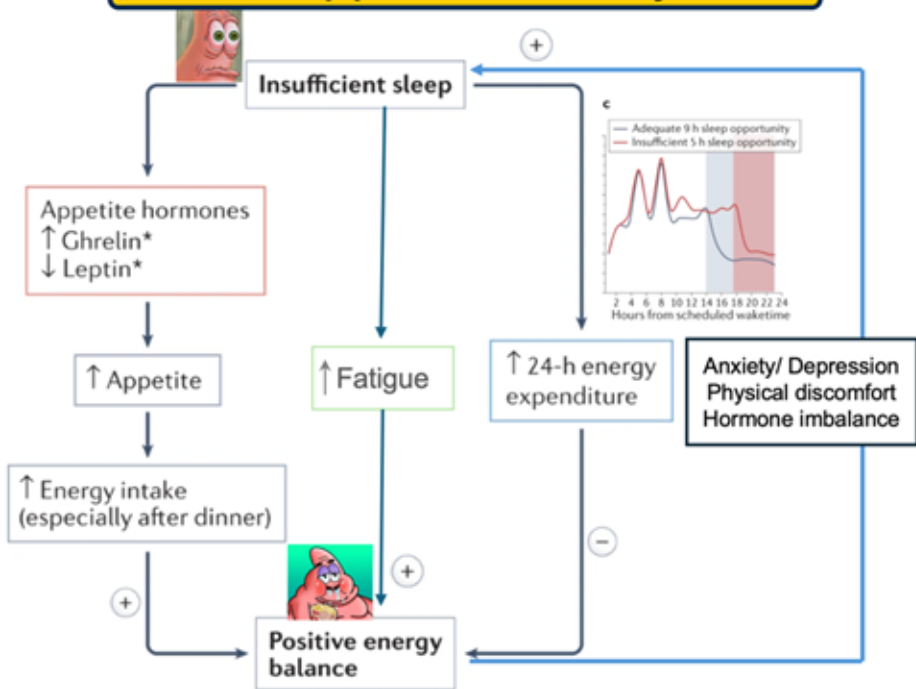
+

# Investigating the Relationship Between Low Sleep and BMI



# Is Sleep Deprivation Associated with a Higher BMI in U.S. Adults (20+)?

## Sleep problem and Obesity



## Outcome of Interest: BMI

### WHO CLASSIFICATION OF WEIGHT STATUS

WEIGHT STATUS	BODY MASS INDEX (BMI), Kg/m <sup>2</sup>
Underweight	<18.5
Normal range	18.5 – 24.9
Overweight	25.0 – 30.0
Obese	≥ 30
Obese class I	30.0 – 35.0
Obese class II	35.0 – 40.0
Obese class III	≥40

[https://www.hw.infprojects.fhsu.edu/final\\_project/obesity.html](https://www.hw.infprojects.fhsu.edu/final_project/obesity.html)

## Predictor of interest: Night Sleep Hrs (Less than 7 hours)

Recommended Sleep hours (adults) : 7-9 hours

<https://www.nhlbi.nih.gov/health/sleep/how-much-sleep>

## Covariates: 19 variables

**Demographic** : Gender<sup>3</sup>, Age<sup>4</sup>, Race<sup>1</sup>, Marital Status<sup>5,6</sup>, Income

**Physical** : Pulse, Blood Pressure Avg(systolic & diastolic)

**Health** : Cholesterol(HDL), Diabetes, Health, little Interest, Depressed<sup>7</sup>, Sleep Trouble<sup>7</sup>

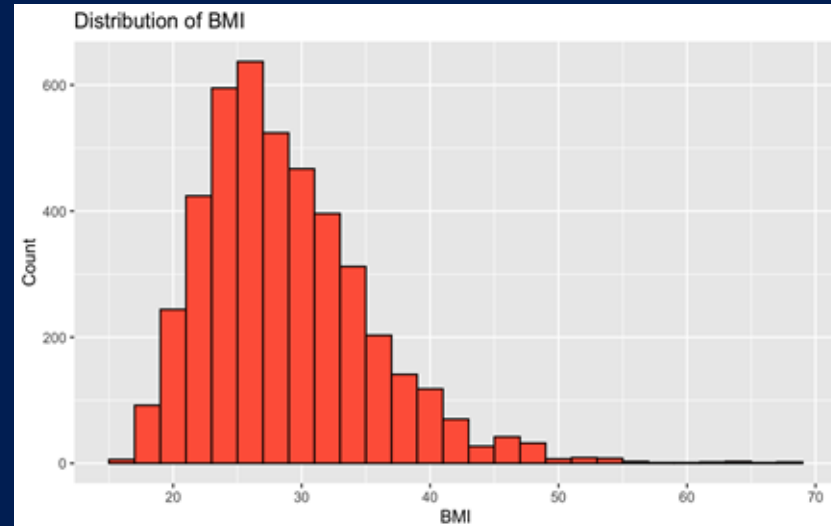
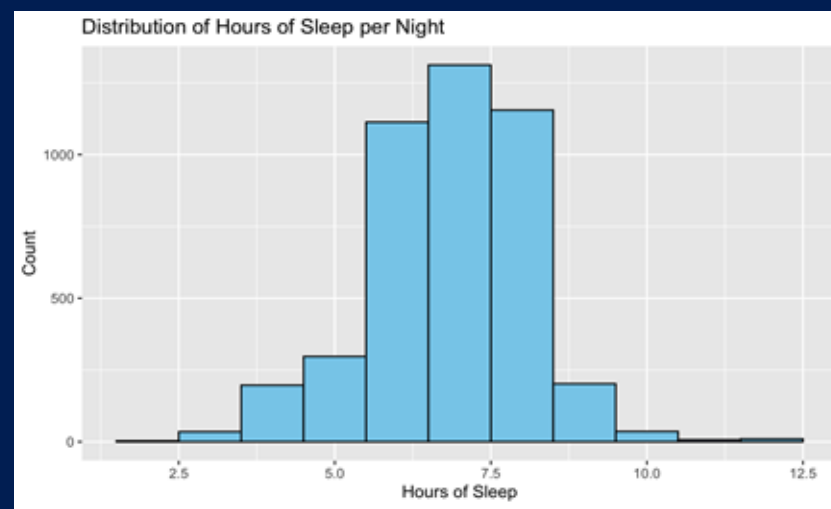
**Lifestyle** : Physical Activity<sup>8</sup>, Alcohol Year<sup>9</sup>, Smoke<sup>100</sup>, Sex Age

## Subjects: Adults (Age: 20 – 80)

Adapted from Chaput et al. (2022)<sup>1</sup>, *Nature Reviews Endocrinology*  
 Fignorilli et al. (2025)<sup>2</sup> *Nutrition, Metabolism and Cardiovascular Diseases*

# Exploratory Analysis

- Sleep Hours has a roughly normal distribution
- BMI has a right skewed distribution



# Descriptive Statistics Stratified by Sleep Duration

- Low sleep more common (68%)
- Low sleepers were less physically active ( $p = 0.036$ ) and more depressed ( $p < 0.001$ )

Characteristic	Sleep Duration Group			p-value <sup>2</sup>
	Overall N = 4,367 <sup>1</sup>	Adequate Sleep ( $\geq 7h$ ) N = 1410 (32%) <sup>1</sup>	Low Sleep ( $< 7h$ ) N = 2957 (68%) <sup>1</sup>	
Body Mass Index (kg/m <sup>2</sup> )	29 (7)	29 (7)	29 (6)	0.6
Sleep Hours per Night	7 (1)	8 (1)	6 (1)	<0.001
Household Income				0.10
0-4999	62 (1.4%)	13 (0.9%)	49 (1.7%)	
5000-9999	76 (1.7%)	29 (2.1%)	47 (1.6%)	
10000-14999	199 (4.6%)	70 (5.0%)	129 (4.4%)	
15000-19999	203 (4.6%)	69 (4.9%)	134 (4.5%)	
20000-24999	237 (5.4%)	73 (5.2%)	164 (5.5%)	
25000-34999	408 (9.3%)	125 (8.9%)	283 (9.6%)	
35000-44999	365 (8.4%)	113 (8.0%)	252 (8.5%)	
45000-54999	389 (8.9%)	130 (9.2%)	259 (8.8%)	
55000-64999	324 (7.4%)	86 (6.1%)	238 (8.0%)	
65000-74999	297 (6.8%)	84 (6.0%)	213 (7.2%)	
75000-99999	597 (14%)	204 (14%)	393 (13%)	
more 99999	1,210 (28%)	414 (29%)	796 (27%)	
Gender				<0.001
female	2,015 (46%)	761 (54%)	1,254 (42%)	
male	2,352 (54%)	649 (46%)	1,703 (58%)	
Race/Ethnicity				0.2
Black	428 (9.8%)	121 (8.6%)	307 (10%)	
Hispanic	216 (4.9%)	64 (4.5%)	152 (5.1%)	
Mexican	333 (7.6%)	116 (8.2%)	217 (7.3%)	
White	3,129 (72%)	1,030 (73%)	2,099 (71%)	
Other	261 (6.0%)	79 (5.6%)	182 (6.2%)	
Physically Active	2,549 (58%)	855 (61%)	1,694 (57%)	0.036
Sleep Trouble	1,193 (27%)	291 (21%)	902 (31%)	<0.001
Depressed				<0.001

Depressed				<0.001
None	3,434 (79%)	1,160 (82%)	2,274 (77%)	
Several	684 (16%)	196 (14%)	488 (17%)	
Most	249 (5.7%)	54 (3.8%)	195 (6.6%)	
Marital Status				0.001
Divorced	454 (10%)	139 (9.9%)	315 (11%)	
LivePartner	406 (9.3%)	109 (7.7%)	297 (10%)	
Married	2,474 (57%)	851 (60%)	1,623 (55%)	
NeverMarried	830 (19%)	261 (19%)	569 (19%)	
Separated	103 (2.4%)	19 (1.3%)	84 (2.8%)	
Widowed	100 (2.3%)	31 (2.2%)	69 (2.3%)	
General Health				<0.001
Excellent	516 (12%)	202 (14%)	314 (11%)	
Vgood	1,469 (34%)	475 (34%)	994 (34%)	
Good	1,734 (40%)	559 (40%)	1,175 (40%)	
Fair	557 (13%)	153 (11%)	404 (14%)	
Poor	91 (2.1%)	21 (1.5%)	70 (2.4%)	
Pulse (bpm)	73 (11)	73 (11)	72 (12)	0.2
Alcohol Consumption (per year)	76 (100)	82 (104)	73 (98)	0.018
Smoked 100+ cigarettes	2,062 (47%)	602 (43%)	1,460 (49%)	<0.001
Sex and Age Group	17 (3)	17 (3)	17 (3)	0.029
Systolic BP (mmHg)	119 (15)	119 (16)	119 (15)	0.051
Diastolic BP (mmHg)	71 (12)	71 (12)	72 (12)	0.15
Direct Cholesterol (mg/dL)	1.37 (0.42)	1.39 (0.43)	1.36 (0.42)	0.021
Little Interest in doing things				0.13
None	3,377 (77%)	1,113 (79%)	2,264 (77%)	
Several	705 (16%)	218 (15%)	487 (16%)	
Most	285 (6.5%)	79 (5.6%)	206 (7.0%)	
Diabetes Status	363 (8.3%)	116 (8.2%)	247 (8.4%)	0.9
Age (years)	43 (13)	44 (14)	43 (13)	0.3

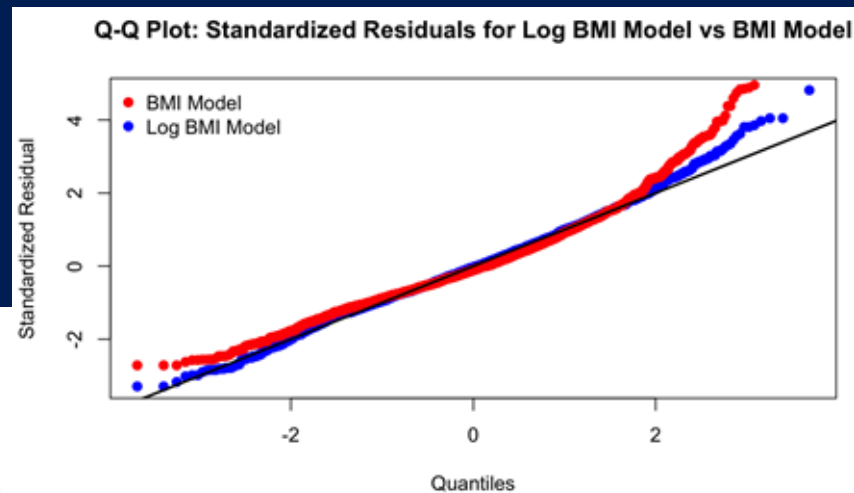
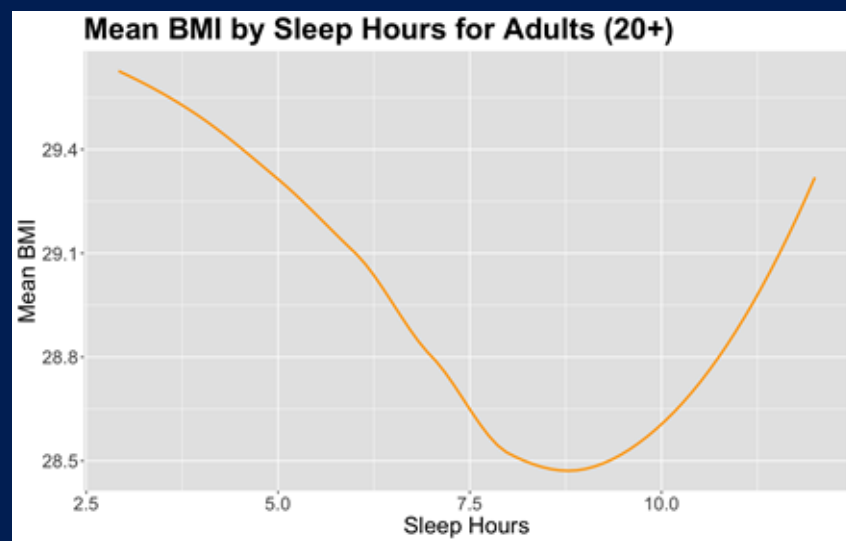
<sup>1</sup> Mean (SD); n (%)

<sup>2</sup> Wilcoxon rank sum test; Pearson's Chi-squared test

# + Model

- BMI and hours of sleep have a quadratic relationship  $\Rightarrow$  piecewise linear
- Tested sleep x covariate interactions iteratively to find significant ones that improved model fit
- Found that  $\log(\text{BMI})$  improved normality and influence of residuals

$$\begin{aligned} \log(\text{BMI}_i) = & \beta_0 + \beta_1 (\text{low\_sleep}_i) + \beta_2 (\text{Gender}_i) + \beta_3 (\text{Race1}_i) + \beta_4 (\text{PhysActive}_i) \\ & + \beta_5 (\text{SleepTrouble}_i) + \beta_6 (\text{Depressed}_i) + \beta_7 (\text{HealthGen}_i) + \beta_8 (\text{MaritalStatus}_i) + \beta_9 (\text{Pulse}_i) \\ & + \beta_{10} (\text{AlcoholYear}_i) + \beta_{11} (\text{Smoke100}_i) + \beta_{12} (\text{SexAge}_i) + \beta_{13} (\text{BPSysAve}_i) + \beta_{14} (\text{BPDiaAve}_i) \\ & + \beta_{15} (\text{DirectChol}_i) + \beta_{16} (\text{LittleInterest}_i) + \beta_{17} (\text{Diabetes}_i) + \beta_{18} (\text{Age}_i) \\ & + \beta_{19} (\text{HHIncome}_i) + \beta_{20} (\text{low\_sleep}_i \times \text{Gender}_i) + \beta_{21} (\text{low\_sleep}_i \times \text{PhysActive}_i) \\ & + \beta_{22} (\text{low\_sleep}_i \times \text{Depressed}_i) + \beta_{23} (\text{low\_sleep}_i \times \text{AlcoholYear}_i) + \beta_{24} (\text{low\_sleep}_i \times \text{Smoke100}_i) + \varepsilon_i \end{aligned}$$



# Results

Variable	Estimate	p.value	Signif	CI
(Intercept)	3.296	0.000	***	[3.208, 3.383]
Low Sleep	0.020	0.006	**	[0.0058, 0.0346]
Gender Is Male	-0.026	0.001	***	[-0.0399, -0.0111]
Physically Active	-0.026	0.000	***	[-0.0404, -0.0124]
Sleep Trouble	0.003	0.695		[-0.0105, 0.0158]
Smoke	-0.035	0.000	***	[-0.0487, -0.0207]
Diabetes	0.077	0.000	***	[0.0556, 0.0977]
Pulse	0.001	0.000	***	[5e-04, 0.0015]
Alcohol Days (last year)	0.000	0.288		[-1e-04, 0]
Age of First Sex	-0.002	0.006	**	[-0.0041, -7e-04]
Blood Pressure Systolic	0.001	0.000	***	[9e-04, 0.0018]
Blood Pressure Diastolic	0.001	0.000	***	[6e-04, 0.0017]
Direct Cholesterol (HDL)	-0.193	0.000	***	[-0.2081, -0.1784]
Age	0.001	0.000	***	[8e-04, 0.0019]
Race				
Hispanic	-0.081	0.000	***	[-0.1115, -0.0512]
Mexican	-0.045	0.001	**	[-0.0715, -0.018]
White	-0.064	0.000	***	[-0.0829, -0.0441]
Other	-0.120	0.000	***	[-0.1492, -0.091]
Marital Status				
Live Partner	-0.022	0.097		[-0.0471, 0.0039]
Married	0.002	0.836		[-0.0171, 0.0211]
Never Married	-0.017	0.139		[-0.0398, 0.0056]
Separated	-0.017	0.398		[-0.0563, 0.0224]
Widowed	0.005	0.791		[-0.0347, 0.0455]

Variable	Estimate	p.value	Signif	CI
Depressed				
Several	0.005	0.620		[-0.0152, 0.0256]
Most	0.048	0.012	*	[0.0105, 0.0846]
Self-reported Health				
Vgood	0.057	0.000	***	[0.0381, 0.0752]
Good	0.096	0.000	***	[0.0772, 0.1149]
Fair	0.111	0.000	***	[0.087, 0.1349]
Poor	0.175	0.000	***	[0.1315, 0.2186]
Little Interest				
Several	0.022	0.011	*	[0.0049, 0.0386]
Most	-0.022	0.126		[-0.0495, 0.0061]
Household Income				
5000-9999	-0.050	0.111		[-0.1114, 0.0114]
10000-14999	-0.017	0.521		[-0.0695, 0.0352]
15000-19999	-0.041	0.128		[-0.0929, 0.0117]
20000-24999	0.003	0.920		[-0.0489, 0.0542]
25000-34999	-0.004	0.873		[-0.0534, 0.0453]
35000-44999	0.026	0.310		[-0.024, 0.0755]
45000-54999	0.007	0.780		[-0.0425, 0.0566]
55000-64999	-0.010	0.691		[-0.0608, 0.0403]
65000-74999	0.008	0.761		[-0.0431, 0.0589]
75000-99999	0.011	0.658		[-0.0378, 0.0598]
more 99999	0.004	0.863		[-0.0438, 0.0522]
Low Sleep:Gender Is Male	-0.026	0.000	***	[-0.0387, -0.0127]
Low Sleep:Physical Active	0.011	0.102		[-0.0022, 0.0241]
Low Sleep:Depressed-Several	0.001	0.888		[-0.0151, 0.0174]
Low Sleep:Depressed-Most	-0.024	0.020	*	[-0.0442, -0.0039]
Low Sleep:Alcohol Days	0.000	0.768		[-1e-04, 1e-04]
Low Sleep:Smoke	-0.015	0.023	*	[-0.0287, -0.0021]

# Model Diagnostics

Linearity/Equal Variance

Independence

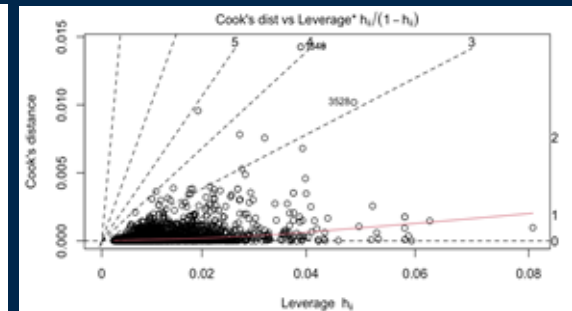
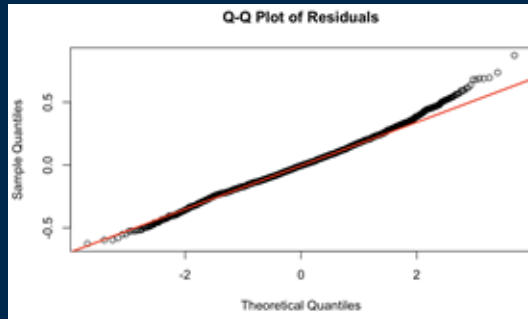
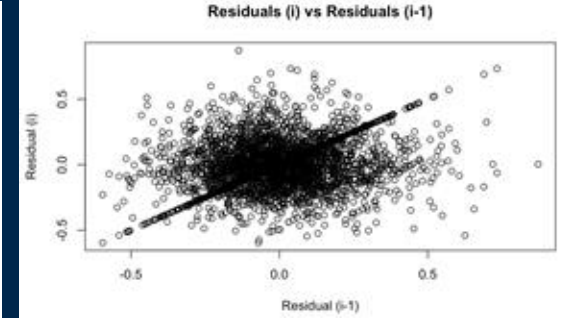
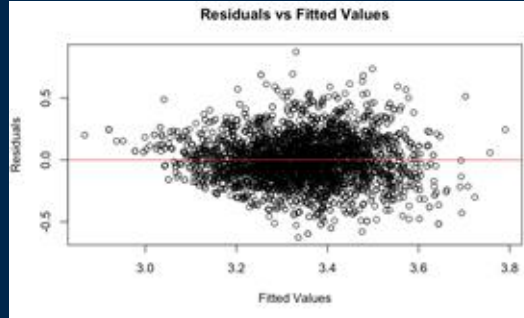
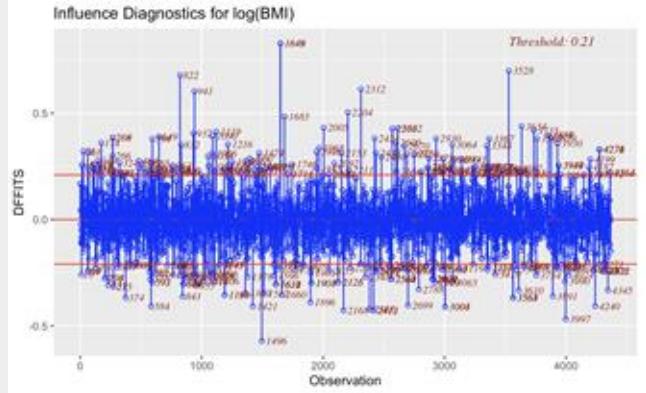
Largest VIF: Depressed (approx 2.04)

Points of Leverage > 0.2: 0

Partial Regression Potential Concerns

Largest Cook's: 1648, 1649 and 3528

Largest Corvatio: 822, 2725 and 1846



Normality

Influential Points

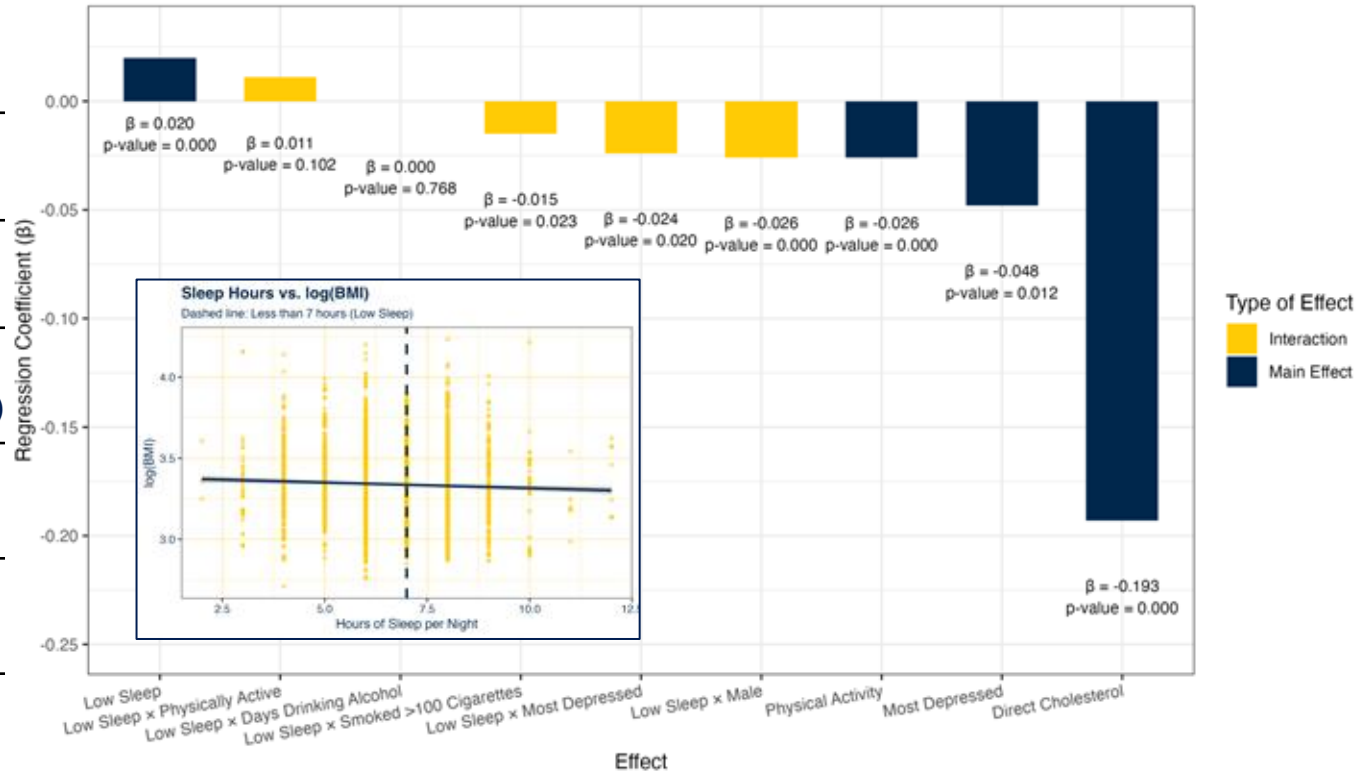


# Finding: Low Sleep Is Linked to Higher BMI

+

Statistic	Value
Residual Standard Error	0.18 (df = 4319)
Multiple R-squared	0.30
Adjusted R-squared	0.29
F-statistic	38.49 (df = 47, 4319)
Overall Model p-value	$< 2 \times 10^{-16}$
Low Sleep Coefficient	0.02
Low Sleep p-value	0.006

Effect Sizes on log(BMI)





# Limitations & Discussion

- Only includes adults aged 20 and above in the United States
- R-Squared (0.29) is moderate, but not quite the ideal (0.4) for social sciences
- $\log(\text{BMI})$ : interpretation is less intuitive
- Self-reported data: might not accurately represent the real trend
- Divide SleepHrsNight into two categories: low\_sleep (<7) and others
  - Original thoughts: 3 segments low(<7), ideal(7-9), long(>9)
  - Only few observations in long sleep category
  - Found an obvious downward trend in low
  - Only focus on relation bt low\_sleep & outcome



# References

1. Figorilli, M., Velluzzi, F. & Redolfi, S. Obesity and sleep disorders: A bidirectional relationship. *Nutr Metab Cardiovasc Dis* **35**, 104014 (2025).
2. Chaput, J.-P. *et al.* The role of insufficient sleep and circadian misalignment in obesity. *Nat Rev Endocrinol* **19**, 82–97 (2023).
3. Jaiswal, S. J. *et al.* Association of Sleep Duration and Variability With Body Mass Index: Sleep Measurements in a Large US Population of Wearable Sensor Users. *JAMA Intern Med* **180**, 1694–1696 (2020).
4. Grandner, M. A., Schopfer, E. A., Sands-Lincoln, M., Jackson, N. & Malhotra, A. The Relationship between Sleep Duration and Body Mass Index Depends on Age. *Obesity (Silver Spring)* **23**, 2491–2498 (2015).
5. Tang, F., Pan, Y. & Deng, H. Effect of marriage on overweight and obesity: evidence from China. *BMC Public Health* **24**, 3591 (2024).
6. Nikolic Turnic, T. *et al.* The Association between Marital Status and Obesity: A Systematic Review and Meta-Analysis. *Diseases* **12**, 146 (2024).
7. Kim, J., Yoon, K. & Park, J.-E. Associations between sleep deprivation, sleep irregularity, depressive symptoms, and obesity using the KNHANES 2020. *Comprehensive Psychoneuroendocrinology* **24**, 100318 (2025).
8. Hou, X. *et al.* Association between physical activity, trouble sleeping, and obesity among older Americans: a cross-sectional study based on NHANES data from 2007 to 2018. *BMC Geriatr* **25**, 165 (2025).
9. Traversy, G. & Chaput, J.-P. Alcohol Consumption and Obesity: An Update. *Curr Obes Rep* **4**, 122–130 (2015).