Associations between Body Mass Index, Sleep Duration, and Reported Snoring and Sleepiness Symptoms, By Age Stratification

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Abstract — To further clarify the associations between sleep and body mass index (BMI) using the most recent dataset from the National Health and Nutrition Examination Survey (NHANES). Our study is notable for the inclusion of analyses with age subpopulations and subjective sleep symptoms. Cross-sectional study was performed using the NHANES 2017-18 dataset. Weighted multivariate regressions were utilized. NHANES is a standardized survey conducted biennially in the United States, for a sample population which is weighted to represent national demographics. 6161 participants met inclusion criteria. Measurements were collected via NHANES protocol, with objective measurements collected by trained technicians and self-reported measurements collected via questionnaire. Our results corroborate a roughly U-shaped relationship of sleep duration with BMI, varying with age. Greatest magnitudes were observed in a bimodal age ranges of 18-30 and 61-75, with decreases in BMI of 0.248 and 0.385 associated with each marginal hour of sleep. Our secondary analysis with daytime sleepiness and snoring have a significant association with BMI. Snoring symptoms showed a decreasing magnitude of association with BMI as age increases; for ages 18-30, snoring at least once a week correlate with an increase in BMI of 3.571, while for ages 61-75, this correlated with an increase of 1.619. Our study adds to existing literature on the relationship of sleep and BMI. Age stratification methods were used to further clarify associations. Subjective sleep symptoms were used in a secondary analysis to identify clinical screening questions for adverse effects of sleep on BMI.

Index Terms — Sleep disorder, Body-mass index, Age stratification, Weighted linear regression.

I. INTRODUCTION

Multiple epidemiologic studies have found an association between obesity and decreased sleep [1]-[7]. Ongoing research on clarifying the nuances of this relationship, including associations drawn between obstructive sleep apnea [8], diabetes mellitus [9], metabolic syndrome [10], hypertension [11], and cardiovascular risk factors [12]-[14], has further elucidated a network of health concerns surrounding poor sleep. However, establishing causation among this associated network has continued to be elusive, which limits clinical and meaningful use of this information [15]. Mechanisms that have been proposed to explain this relationship include hormonal and physiological changes related to increased appetite, differences in diet, insulin insensitivity, and decreased exercise related to poor quality or duration of sleep [1], [16]-[19]. However, it is also plausible that people with obesity are prone to sleep disorders and poor sleep as a result [20]. It is difficult to quantify and predict the effects of poor sleep when the magnitude of its effects are unclear and appear to vary by demographics [20]-[22]. While survey data is limited in its ability to determine causation, there is still more to be established in terms of magnitude of associations of these variables in different demographics. In addition, more information should be obtained on whether sleep itself is associated with body mass index (BMI) even when controlling for other contributors listed above. Furthermore, clinical guidelines are still unclear as to who is affected by these conditions and how a clinician should screen for them.

In this study, we probe the associations between sleep and BMI using the most recent complete National Health and Nutrition Examination Survey (NHANES) from 2017-2018, with a clinical focus. We specifically focus on differences in age ranges including adolescent and adult patients, which has a varying effect with respect to BMI associations. We also take note to control for other known risk factors for obesity and the associations with different demographics. Our study, unlike previous literature, utilizes the most recent NHANES dataset to study the associations with sleep. In addition, we both control for metabolic risk factors and use age stratification methods (accommodating for NHANES survey weighting), spanning adolescent and adult populations. Our study is also notable in including reported sleep symptoms, in an additional analysis, with a goal of finding a threshold of symptom measures as a clinical screening tool for health practitioners.

II. PARTICIPANTS AND METHODS

The NHANES 2017-2018 survey was utilized for our data analysis. NHANES is a national survey collecting a wide array of factors including demographic, questionnaire, examination, and laboratory data, enacted by the Centers for Disease Control (CDC) on a recurring and continuous basis. Compilations are released in two-year cycles. Data collection methods and sampling techniques are discussed separately in previous publications from the CDC [23]. Self-reported data were collected using the following protocols: The screener and relationship questionnaires were administered to an adult household member aged at least 18 years or an emancipated minor determined by state-specific criteria. The family questionnaire was typically completed by the head of household (an adult family member aged 18 years or older or an emancipated minor). The sample person questionnaire was

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administered to all participants or their proxies; however, eligibility for each specific questionnaire section was determined by the participant's age and gender. Participants 16 years of age and older and emancipated minors were interviewed directly. An adult proxy provided information for survey participants who were under 16 years of age and for participants who could not answer the questions themselves. The Mobile Examination Center (MEC) interview was administered to participants 8 years of age or older. Eligibility for each specific questionnaire section was determined by the participant's age and gender. The Computer-Assisted Personal Interview (CAPI) portion was administered using a proxy interview or an interpreter if needed. Mentally impaired individuals, or participants who were unable to understand the language were not eligible.

Measures of sleep were collected from self-reported questionnaire. The sleep time and awake time questions in the sleep questionnaire were adapted from the Munich ChronoType Questionnaire [24], which included questions on usual sleep and awake times on weekend or non-workdays. Eligible subjects included aged 16 and older participants. These questions were asked in the home, by trained interviewers, using CAPI system, which has limited built-in consistency checks to reduce data entry errors. Edits were made to ensure completeness, consistency, and analytic usefulness of the data. Approximately 3% of audio recordings of interviews were reviewed to validate unusual times reported. Summary variables for usual number of hours of sleep on weekdays and weekends were derived from reported times. Hours were rounded to the nearest half hour. Hours of ‘less than 3’ and ‘more than 14’ were grouped and recoded with these value labels.

In this cycle of the NHANES survey, there were a total of 9254 participants for the interview portion and 8704 for the examination portion. Criteria for inclusion in our study included participants aged 16 or older, who participated in both interview and examination components, which resulted in 6161 participants included in our analysis.

Summary statistics for the age, demographics, and prevalence of morbidities of the surveyed population included in this study are presented in Table I, which include demographic statistics, self-reported data relating to hyperlipidemia, diabetes mellitus, hypertension, and obesity, and the corresponding lab measurement data.

The primary outcome variable, body mass index (BMI), was calculated as weight in kilograms divided by height in meters squared, and then rounded to one decimal place. The body measures data were collected, in the MEC, by trained health technicians. The health technician was assisted by a recorder during the body measures examination. The 2017–2018 data were reviewed for unusual and erroneous values. During the data review, values that were above the 99th percentile or below the 1st percentile, for a particular age or age-gender group, were flagged for review. When records were flagged, the entire body measurements record was reviewed for reasonableness. Values that were determined to be unrealistic were deleted from the file. None of the original body measures data were changed and there are no imputed values in this file. Additional covariates were collected from the NHANES demographic, questionnaire, examination, and laboratory datasets.

### Table I: Summary Statistics for Surveyed Population

| Characteristic                      | N (%)       |
|-------------------------------------|-------------|
| Gender                              |             |
| Male                                | 2992 (48.6%)|
| Ethnicity                           |             |
| Hispanic                            | 1405 (22.8%)|
| Non-Hispanic White                  | 2123 (34.5%)|
| Non-Hispanic Black                  | 1415 (23.0%)|
| Non-Hispanic Asian                  | 889 (14.4%)  |
| Other Race (including multiracial)  | 329 (5.3%)   |
| Ages by range                       |             |
| 16 - 17                             | 449 (7.3%)   |
| 18 - 30                             | 1056 (17.1%) |
| 31 - 45                             | 1267 (20.6%) |
| 46 - 60                             | 1380 (22.4%) |
| 61 - 75                             | 1388 (22.5%) |
| 76 and over                         | 621 (10.1%)  |
| Self-reported diagnosis of hyperlipidemia | 1968 / 6161 (31.9%) |
| Measured Total cholesterol >240     | 505 / 5446 (9.3%) |
| Measured diagnosis of diabetes mellitus | 883 / 6161 (14.3%) |
| Measured Hemoglobin A1c             | 698 / 5828 (15.1%) |
| Self-reported diagnosis of hypertension | 2137 / 6161 (34.7%) |
| Measured averaged (across 3 readings) | 2269 / 5527 (41.1%) |
| Systolic BP >130 AND/OR DBP >80     |             |
| Self-reported history of being told to control/lose weight | 1668 / 6161 (27.1%) |
| Self-reported history of stroke     | 273 / 6161 (4.4%) |
| Self-reported history of myocardial infarction (MI) | 270 / 6161 (4.4%) |
| Self-reported history of congestive heart failure (CHF) | 201 / 6161 (3.3%) |
| Self-reported diagnosis of coronary artery disease | 265 / 6161 (4.3%) |

Initial survey weights were obtained from the original NHANES dataset as calculated from estimation techniques to reflect representation of the overall national demographics [23]. Survey weights were adjusted accordingly when analyses were carried out on subsets of populations.

Weighted linear multivariate regressions were carried out in R software version 3.6.3. In addition to the primary explanatory and response variables, potential confounding variables were included in the models as covariates. These covariates included measures of demographics (gender, race, family income level), hyperlipidemia (as measured by continuous variable for total serum cholesterol levels), diabetes mellitus (as measured by continuous variable for serum hemoglobin A1c values), hypertension (as measured by continuous variable for averaged triplicate blood pressure checks), activity levels (as reported on questionnaire). Statistical significance was defined as a p-value of 0.05 or less.

The formulation of the problem is: among sleep duration, gender, ethnicity, family income, smoking, hemoglobin A1c, total cholesterol, and physical activity, which variables have strong correlation with BMI and to what is the robustness of the relationship? The covariates were chosen based on the following criteria: 1) Availability in the dataset; 2) Likelihood for showing impact to BMI based on past studies; 3) Low tendency to correlate with other chosen covariates and result in collinearity problems.

The representation of the regression used for our primary model can be simplified as:

\[
BMI = \beta_0 + \beta_1(\text{male gender}) + \beta_2(\text{ethnicity}) + \beta_3(\text{family income}) + \beta_4(\text{smoking}) + \\
\beta_5(\text{hemoglobin A1c}) + \beta_6(\text{total cholesterol}) + \beta_7(\text{physical activity}) + \beta_8(\text{sleep duration})
\]
where female gender is used as reference for male gender comparison and non-Hispanic white is used as reference for other races, as it was the most common ethnicity selected on questionnaire. Family income was assessed as a ratio to poverty line. Smoking was a binary variable with 1 being respondents who reported smoking at least 100 cigarettes over their lifetime, surveyed for adults (age 18+) only. Hemoglobin A1c (or glycohemoglobin) and total cholesterol were measured values from the NHANES laboratory data. Physical activity was defined for adults (age 18+) as the number of minutes of “vigorous” or “moderate” physical activity during the course of a typical week, either as work or leisure. For adolescent patients (ages 16-17 in this study), this physical activity measure was reported differently in the questionnaire as the number of days a week of physical activity. Sleep duration was calculated from a weighted average of self-reported times of sleep initiation and awakening during weekdays and weekends.

We initially carried out our analysis without age stratification, in adult populations and controlling for age as a continuous variable. Adolescent populations were not included in this initial analysis due to differences in questionnaire variables reporting physical activity and smoking variables. Covariates were gradually added into two additional models. We then carried out additional analyses on subpopulations with age stratification.

We carried out secondary analyses of sleep symptoms on BMI, stratified by age. Models were the same as in our initial study with BMI as the response variable, but with the binary variable for symptom frequency instead of the continuous variable for average sleep duration. Symptoms of snoring were assessed by binary variables indicating a frequency of snoring 1 or more nights a week, 3 or more nights a week, or 5 or more nights a week. In an additional analysis, symptoms of daytime sleepiness were assessed by binary variables indicating a frequency of snoring 1 or more times a month, 2 or more times a month, or 5 or more times a month.

In our secondary analyses of sleep symptoms on BMI, stratified by age, the formulation of the problem is: Among sleep symptom frequency, gender, ethnicity, family income, smoking, hemoglobin A1c, total cholesterol, and physical activity, what variables have strong correlation with BMI? Here, sleep symptom frequency is snoring frequency or daytime sleepiness frequency.

The NHANES survey was conducted with approval from the NCHS Research Ethics Review Board (ERB). Our study meets ethical guidelines for research including the tenets of the Declaration of Helsinki, and all data was de-identified upon retrieval from the NHANES website. The authors have no conflicts of interest to disclose.

III. RESULTS

Table II shows our regression coefficients for our model with age as a continuous variable. These results show that sleep duration is significantly associated with BMI, even when controlling for other covariates. However, interestingly, age was associated with BMI as well, which prompted the question of whether there was any variation of the effects of sleep on BMI, with varying age.

TABLE II: MULTIVARIATE REGRESSION WITH AGE AS CONTINUOUS VARIABLE

| Model 1 | Model 2 | Model 3 |
|---------|---------|---------|
| $\beta$ (95% CI) | $\beta$ (95% CI) | $\beta$ (95% CI) |
| Sleep duration | -0.25* [-0.46 -0.03] | -0.24* [-0.46 -0.02] | -0.25* [-0.47 -0.03] |
| Age | 0.02* [0.00 0.04] | -0.01 [-0.02 0.00] | -0.02* [-0.03 0.00] |
| Gender | -0.38 [-0.99 0.22] | -0.47 [-1.08 0.14] | -0.36 [-0.99 0.26] |
| Ethnicity | | | |
| Hispanic | 0.75* [0.09 1.41] | 0.41 [0.25 0.79] | 0.43 [0.32 1.85] |
| Non-hispanic | 1.57*** [1.02 2.16] | 1.09** [0.64 1.54] | 1.08** [0.57 1.60] |
| Black | 0.82 2.33 | 0.25 1.79 | 0.32 1.85 |
| Non-hispanic | -3.49*** [-3.90** -3.96***] | -4.54 -3.25 | -4.63 -3.29 |
| Asian | -4.11 -2.86 | | |
| Other race | 0.85 | 0.64 | 0.57 |
| Family income | -0.08 [-0.26 0.10] | -0.06 [-0.23 0.12] | -0.06 [-0.24 0.12] |
| to poverty ratio | | | |
| Hemoglobin | 1.70*** | 1.66*** | |
| A1c | | | |
| Total | | | |
| cholesterol | | | |
| Smoking | | | |
| Physical activity | | | |

Note: BMI is the dependent variable. The significance and magnitude of the relationship between average sleep duration and BMI remains robust with progressive addition of covariates from Model 1 to Model 3. Table entries show the $\beta$ coefficient of each dependent variable, and the 95% confidence interval.

Accordingly, we carried out additional analyses on subpopulations with age stratification. Table III presents the regression coefficients for this analysis. Results show coefficients with a roughly U-shaped variation but a bimodal distribution of greatest magnitude and significance of association in ages 18-30 and 61-75. Non-Hispanic black ethnicity was associated with increased BMI as compared to the reference non-Hispanic white ethnicity, and non-Hispanic Asian was associated with decreased BMI as compared to the reference. Physical activity was most significantly associated with BMI in age ranges 18-30 and to a lesser extent in ages 31-60, but with a small magnitude. Hemoglobin A1c was also significantly associated with increased BMI. Fig. 1 presents a graphical depiction of the primary result, magnitude of association between average sleep duration and BMI, by age stratification.

![Fig. 1. Magnitude of association between average sleep duration and BMI, with age stratification. There is a roughly U-shaped relationship with age, with peaks in magnitude and significance of the association at ages 18-30 and 61-75.](image-url)
Table IV(A-B) presents the regression coefficients in our secondary analyses of sleep symptoms on BMI, stratified by age. Models were the same as in Table III with BMI as the response variable, but with the binary variable for symptom frequency instead of the continuous variable for average sleep duration. Limited regression coefficients (for only the sleep symptom of interest by frequency) for comparison are displayed. Table IV(A) displays the regression coefficients in these models for the snoring frequency variable only. There appears to be a significant relationship between presence of snoring and BMI, with decreasing magnitude as age increases. Table IV(B) displays the regression coefficients in these models for the daytime sleepiness frequency variable only. There also appears to be a statistically significant relationship between the presence of daytime sleepiness and BMI, but it did not trend with frequency of daytime sleepiness and the magnitude of the association did not change with age. Fig. 2 presents a graphical depiction of the magnitude of association between snoring frequency and BMI, with age stratification.

TABLE III: MULTIVARIATE REGRESSION OF SLEEP DURATION ON BMI, WITH COVARIATES, BY AGE STRATIFICATION

| Age | Sleep Duration | Gender | Ethnicity | Physical activity | Family income to poverty ratio | Smoking | Hemoglobin A1c | Total cholest. |
|-----|----------------|--------|-----------|-------------------|-------------------------------|---------|---------------|--------------|
| 16-17 | -0.07 | -0.40 | 2.41* | -0.27 | -0.84 | 0.27 | 0.26 | 0.02 |
| 18-30 | [-0.72, 0.58] | [-0.25, -0.35] | [0.16, 0.65] | [-0.80, -0.18] | [-0.30, -0.25] | [0.38, 0.91] | [0.15, 0.50] | [-0.01, 0.05] |
| 31-45 | [-0.47, -0.03] | [-0.35, -0.32] | [-0.11, 1.19] | [-0.08, -0.18] | [-0.37, -0.30] | [-0.93, 0.53] | [0.34, 0.05] | [-0.00, 0.00] |
| 46-60 | [-0.40, 0.10] | [-0.25, -0.32] | [-0.70, 0.72] | [-0.18, -0.07] | [-0.30, -0.16] | [-0.88, 0.82] | [0.42, 2.30] | [-0.00, 0.00] |
| 61-75 | [-0.45, 0.13] | [-0.45, -0.32] | [-0.73, 0.85] | [-0.07, -0.06] | [-0.34, -0.22] | [-0.86, 0.82] | [-0.90, 1.18] | [-0.00, 0.00] |
| 76+ | [-0.70, -0.07] | [-0.39, -0.45] | [-0.14, 0.49] | [-0.02, -0.01] | [-0.30, -0.16] | [-0.66, 1.26] | [-1.68, 2.31] | [-0.00, 0.00] |

Note: BMI is the dependent variable. Results show coefficients with U-shaped variation but a bimodal distribution of greatest magnitude and significance of effects in ages 18-30 and 61-75. Table entries show the β coefficient of each dependent variable, and the 95% confidence interval.

IV. DISCUSSION

In our initial set of regressions in Table II, we demonstrated that there is a significant association of sleep duration with BMI. Even when controlling for other risk factors, the magnitude of the association is consistent. The coefficient of -0.25 can be interpreted as: for each marginal hour of averaged sleep per night, there is a reduction in BMI of 0.25 points. This finding corroborates those found in previous literature that there is a significant relationship between sleep duration and BMI [6]. However, this relationship does not appear to be a straightforward linear relationship: other studies have suggested a U-shaped curvilinear relationship between sleep duration and BMI [25] and a U-shaped relationship between sleep and obesity with respect to age. In this study, we do corroborate a similar U-shaped curvilinear relationship with respect to age. To add on to previous studies, this relationship appears to be most significant in a bimodal distribution, from ages 18-30 and ages 61-75. The negative coefficient in our model is consistent across age groups, except our highest age group of age 76+, suggesting a greater value of average sleep duration is associated with decreased BMI in populations up to age 76. In contrast to the previous study with age stratification, we regress against a continuous variable, BMI, instead of a binary obesity variable, to account for the fact that individuals may have significant increases BMI without satisfying criteria for obesity. Our study also clarifies further, in contrast to other studies, that this association is robust even when controlling for these possible confounding factors of diabetes mellitus, hyperlipidemia, and physical activity.

Our second set of age-stratified regressions using sleep symptoms as an explanatory variable in place of sleep duration was done with the intent of finding symptoms to screen in clinical settings. As illustrated in our summary statistics in Table I, the percentages of self-reported diagnoses of multiple comorbidities (hypertension, diabetes mellitus) are consistently less than diagnoses by objective measures (reported hypertension is 34.7% compared with measures of SBP>130 and/or DBP>80 at 41.1%). We propose that cost-effective screening questions for sleep symptoms could be one such tool to screening for patients who might be at risk for sleep-related increased BMI and other comorbidities. We show that snoring has a significant association with BMI in the age ranges from 18-75, while controlling for the covariates as above. Interestingly, an increased frequency of snoring does not appear to increase the magnitude of this relationship, but increased age appears to decrease the magnitude of this relationship. One may posit that as age increases, the magnitude of the effect of sleep-
related conditions contributing to BMI may decrease. For the age range 18-30, snoring at least once a week correlates with an increase in BMI of 3.571, while for the age range 61-75, this correlates with an increase in BMI of just 1.619. Therefore, as a clinical screening question, healthcare practitioners asking about the presence of snoring symptoms may help to identify patients at risk for increased BMI related to sleep-related conditions (increased appetite, increased sedentary activities, insulin insensitivity), even aside from other known metabolic risk factors (lack of physical activity, hyperlipidemia, ethnicity, age, gender, diabetes mellitus). Our additional analysis on the symptom of daytime sleepiness shows that it may also show promise as a screening tool, within the same age ranges of 18-75. The magnitude of this association does not appear to trend with age nor frequency of daytime sleepiness.

| TABLE IV(A): MODELS FOR SNORING FREQUENCY REGRESSED AGAINST BMI |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Snoring frequency     | Age 16-17 β β [2.5% 97.5%] | Age 18-30 β β [2.5% 97.5%] | Age 31-45 β β [2.5% 97.5%] | Age 46-60 β β [2.5% 97.5%] | Age 61-75 β β [2.5% 97.5%] |
| 1+/wk                 | 0.87                   | 3.57***               | 3.31***               | 2.82***               | 1.62**                |
|                       | [-0.85 2.59]           | [2.88 4.27]           | [2.46 4.15]           | [1.81 3.82]           | [0.55 2.69]           |
| 3+/wk                 | 1.99                   | 3.35***               | 3.19***               | 2.61***               | 2.12**               |
|                       | [-0.59 4.58]           | [2.73 3.97]           | [2.49 3.89]           | [1.79 3.43]           | [1.21 3.03]           |
| 5+/wk                 | 3.45*                  | 3.24***               | 2.95***               | 2.66***               | 2.50***               |
|                       | [0.22 6.68]            | [2.56 3.91]           | [2.22 3.69]           | [1.81 3.50]           | [1.42 3.58]           |

Note: BMI is the dependent variable. Independent variables are snoring, age, gender, ethnicity, family income to poverty ratio, smoking, physical activity, Hemoglobin A1c, and total cholesterol. Only the coefficient on the snoring frequency variable is displayed, for comparisons. Table entries show the β coefficient of each dependent variable, and the 95% confidence interval.

| TABLE IV(B): MODELS FOR DAYTIME SLEEPINESS FREQUENCY REGRESSED AGAINST BMI |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Daytime Sleepiness    | Age 16-17 β β [2.5% 97.5%] | Age 18-30 β β [2.5% 97.5%] | Age 31-45 β β [2.5% 97.5%] | Age 46-60 β β [2.5% 97.5%] | Age 61-75 β β [2.5% 97.5%] |
| 1+/month              | 2.29**                | 1.71***               | 1.91***               | 2.15***               | 2.84***               |
|                       | [0.06 4.53]           | [0.97 2.45]           | [1.08 2.73]           | [1.22 3.08]           | [1.69 4.00]           |
| 2+/month              | 0.03                  | 1.26***               | 1.33***               | 1.60***               | 1.62**                |
|                       | [-1.70 1.76]          | [0.66 1.87]           | [0.65 2.02]           | [0.81 2.39]           | [0.71 2.52]           |
| 5+/month              | -0.27                 | 1.99***               | 2.17***               | 2.00***               | 1.46**               |
|                       | [-2.26 1.72]          | [1.31 2.67]           | [1.41 2.93]           | [1.14 2.87]           | [0.42 2.50]           |

Note: BMI is the dependent variable. Independent variables are snoring, age, gender, ethnicity, family income to poverty ratio, smoking, physical activity, Hemoglobin A1c, and total cholesterol. Only the coefficient on the daytime sleepiness frequency variable is displayed, for comparisons across models. Table entries show the β coefficient of each dependent variable, and the 95% confidence interval.

![Fig. 2. Magnitude of association between snoring frequency and BMI, with age stratification. The magnitude of the coefficients is similar across snoring frequencies but decrease with age.](image)

Our study is limited by its cross-sectional, survey-based design of utilizing the NHANES questionnaire, which limits evaluation for causation. Instead, as with previous studies, we rely on correlations for our analysis. In addition, the survey questionnaire component (with options for refusal to respond) necessarily introduces the possibility of self-reporting bias. Further directions of research may include longitudinal studies which may track sleep measures and BMI over time, such as in a case-control or cohort study. We anticipate conducting future studies related to our secondary analysis on sleep symptoms, such as trialing a screening questionnaire with simple sleep questions in primary care clinics to identify individuals who are likely to be experiencing adverse effects of sleep conditions on BMI, which may warrant further evaluation in sleep clinic or the use of sleep interventions.

### V. CONCLUSIONS

#### A. Figures and Tables

Our study corroborates previous studies’ findings of a roughly U-shaped curve in the magnitude of the association between sleep duration and BMI, with a new findings that the greatest association lies in a bimodal distribution in ages 18-30 and 61-75. In contrast to previous studies, we use BMI instead of obesity as our response variable and control for other metabolic factors including, diabetes mellitus and hyperlipidemia.

In addition, we use subjective measures of sleep-related symptoms in our analysis to identify a potential screening question for healthcare practitioners. We find that sleep related symptoms of snoring and daytime sleepiness are associated with increased BMI even when controlling for covariates, which is significant for age ranges 18-75. The magnitude of the relationship does not appear to be affected by increased frequency of these symptoms. Interestingly, the magnitude of this significant relationship appears to decrease with age for snoring, but this trend is not seen for daytime sleepiness.

Our study contributes additional nuances to the findings of

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the interconnections between sleep and BMI, with additional potential implications for clinical practice.

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