Analysis of Sleep and Depression as Sex-Specific Risk Factors for Diabetes

Abstract

The purpose of our analysis is to investigate the interaction between sleep duration and depression frequency by sex as risk factors for diabetes, building on existing research that has established each of these risk factors independently. Using 2018 National Health Interview Survey data from the IPUMS database, we fit four logistic regression models with diabetic/non-diabetic status as the response variable. We found both sleep and daily or weekly depression to be significant predictors of diabetes in a simple model including both men and women and only the variables of interest. Sleep and daily or weekly depression were also significant in a full model including both sexes, all variables of interest and covariates. When analyzed separately by sex, daily or weekly depression frequency was found to be significant for both men and women. Sleep was found to be significant only for men. This research adds to the growing evidence of a link between mental and physical health.

Introduction

With over 34 million Americans, or more than 1 in 10, diagnosed with the condition, diabetes is one of the most prevalent chronic diseases in the US [1]. Diagnosed diabetics face an overall 60% greater risk of early death than non-diabetics, underlining the importance of identifying the most potent risk factors [2]. In addition to other modifiable factors such as diet and physical activity, sleep and mental health have been explored as possible predictors of diabetes risk.

There is a relatively strong consensus among the literature that short sleep (<6 hours) is a significant risk factor of diabetes [2],[3],[4]. Several studies indicate that excessively long sleep (>8 hours) could be a risk factor also, however this finding is less conclusive across the literature [5],[6]. Specifically, a systematic review of 36 studies showed that sleep disturbances, including sleep duration less than 6 hrs, have an effect on diabetes risk comparable to traditional risk factors, such as family history of diabetes and overweightness, and exceeding the risk associated with physical inactivity [2]. Sleep in relation to diabetes risk has also been found to vary between sexes. A systematic search of 10 studies, for instance, found an especially large increase in diabetes risk for men sleeping less than 5-6 hrs compared to women sleeping a similar amount [7]. Several mechanisms explaining sleep's association with diabetes have been proposed. Shortened or disturbed sleep, for instance, has been linked to the stimulation of cortisol through the hypothalamic-pituitary axis, leading to both increased production of glucose and decreased glucose utilization, and eventually insulin resistance [3],[8]. Short sleep is also thought to increase levels of the inflammatory marker C-reactive protein, which inhibits the binding of leptin and contributes to weight gain and impaired glycemic control [7],[8]. The causal effect of long sleep is considerably more speculative, with some concern that the relationship is purely the result of unidentified confounding bias. Others have shown that long sleep duration elevates inflammatory markers similarly to shortened sleep, making the same inhibited leptin pathway a possibility [6].

Elevated rates of depression have been consistently found among those diagnosed with diabetes and vice-versa, indicating a bidirectional relationship [9],[10],[11]. One study found that among adults with major depression, short sleep (<6.5 hours) and male sex were also significant risk factors [9]. However, another study found that after controlling for baseline covariates, the relationship between depression and diabetes was not significant. This result conflicts with the majority of the literature [3]. This study also included sex, and found that women who do not have depression are more likely to be diagnosed with diabetes than men who do not have depression, but this discrepancy becomes insignificant when both women and men have depression [3]. Other studies found, however, that women were more likely to experience comorbid depression and diabetes, indicating the relationship between sex, depression, and diabetes may be inconsistent and worthy of further exploration [12],[10].

Lastly, short sleep (< 5-7 hrs) has been shown to strongly correlate with increased risk of depression [13],[14],[15],[16],[9]. Excessive sleep is also well-established as a symptom of depression. Sleep and depression are thus closely linked physiologically.

Despite having well-established relationships with diabetes independently, sleep and depression have not been thoroughly examined simultaneously as predictors of the condition. Because there is such a clear relationship between sleep and depression as well, a potential interaction effect between sleep and depression may be of interest when analyzing the relationship between sleep and diabetes risk. In this report we examine sleep and depression in tandem to diabetes risk.

Methods

Data

This study uses data from IPUMS-NHIS, the National Health Interview Survey from 2018. The data was collected by obtaining a random sample of 35,000 U.S. households and randomly selecting one adult and one child (if any were present) from each. Data analysis was restricted to those 18 years and older. An observational unit comprised of an individual adult in the U.S. surveyed by the CDC's National Center for Health Statistics. The population to which we intend to generalize our analysis is the non institutionalized adult population of the United States (roughly 300 million individuals total).

Variables

The variables in our analysis include a binary response variable indicating whether or not an individual has diabetes, with average number of hours of sleep per night as the primary explanatory variable, a three-level categorical variable for the frequency an individual reports experiencing depression as the secondary explanatory variable, and sex as the tertiary explanatory variable. The three levels for depression frequency are "often" (defined as daily or weekly), "monthly", and "rarely" (defined as a few times a year or never). In order to include this categorical variable in our model, we separated it into two binary variables for being depressed monthly or not and being depressed often or not, with being depressed rarely as the reference group.

Our covariates include age, BMI, activity level, income, and race. We created a numerical variable for activity score using the Oncology Nursing Society formula Weekly leisure activity score = (9 × Strenuous) + (5 × Moderate) + (3 × Light) from the Godin Leisure-Time Exercise Questionnaire. We substituted strength exercise for light exercise due to the availability of the IPUMS data, and we think strength training is analogous to light exercise for the purposes of our analysis. For simplicity and based on an analysis of faceted scatter plots, we collapsed the categorical race variable into 3 binary variables indicating black/African American or not, Asian or not, and Native American/Alaska Native or not, with white race as the reference group. For income level, we created two binary variables indicating high income (annual family income over $75,000 or not) and middle income (annual family income between $35,000 and $75,000 or not), with low income (annual family income below $35,000) as the reference group. Since our data is based on survey responses, all values are self-reported. Additionally, we did not include in our analysis any values that corresponded to non-response, unavailability, or extreme values that had been top or bottom coded.

Analysis

In order to analyze our primary, secondary, and tertiary hypothesis, we fit 4 different logistic regression models with the binary variable for diabetes or not as the response. Our first model includes only our primary and secondary explanatory variables in order to observe these relationships without accounting for the covariates. Our second model includes all of our explanatory variables and covariates, including the interaction terms between hours of sleep and depression frequency. Our third and fourth models represent males and females separately in order to observe differences by sex. Both include all covariates. We chose to perform a quadratic transformation on the sleep variable for all models in order account for the observation that both excessively short and long sleep are likely to increase diabetes risk, while a moderate amount of sleep (7-8 hours) is ideal.

In order to test the significance of each coefficient, we performed individual z-tests. In order to evaluate and compare the overall models, we performed likelihood ratio tests and calculated the percentage of concordant pairs for each model.

Results

After filtering out non-applicable observations, we performed our analysis with a sample size of 21,229, with 46.4% males and a median age of 51 years. 1.9% (n = 407) of the individuals in the sample are classified as having chronic diabetes. The median number of hours of sleep per night is 7. The majority of individuals (83.78%) reported experiencing depression rarely, with 6.48% experiencing depression monthly, and 10.21% daily or weekly. The median BMI is 27.11, and the median activity score is 896. The income distribution is fairly even, with 38.54% classified as high income, 28.61% classified as middle income, and 32.87% classified as low income. The majority of individuals (81.09%) identify as white, with 5.51% identifying as Asian, 11.97% identifying as black, and 1.43% identifying as Native American or Alaskan Native.

Based on individual z-tests, the coefficients for the simple model (model 1), including both sexes and only the explanatory variables, were all found to be significant, evaluated at a p = 0.05 level. For the full model including both sexes and all covariates (model 2), the coefficients for sleep and daily or weekly depression

frequency remained significant ($p < 0.05$ and $p < 0.001$, respectively). Monthly depression frequency and the interactions between sleep and depression frequency were not significant. For both models 3 and 4 (including only females and males, respectively), the coefficient for daily or weekly depression frequency was found to be significant ($p < 0.01$). The coefficients for sleep were significant only for males ($p < 0.05$). The likelihood ratio tests for all models yielded significant p-values ($p < 0.05$), indicating that all four models were effective at explaining the data. However, the simple model (model 1) was less effective than the models including the covariates (models 2-4) according to the percentages of concordant pairs (60.0%, 85.7%, 85.8%, and 86.3% respectively).

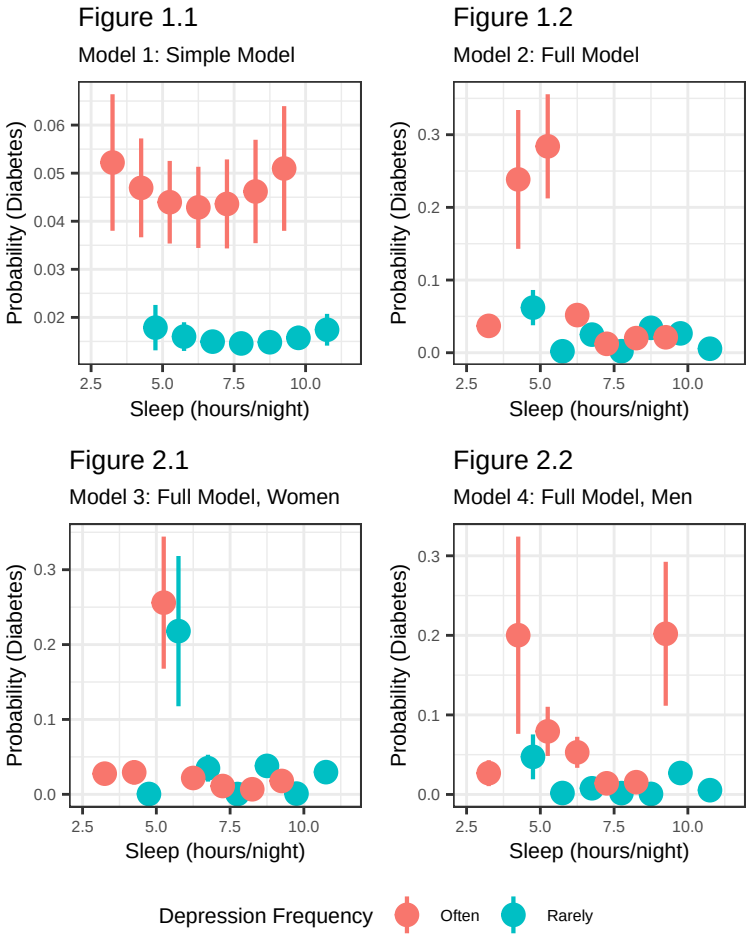
Discussion

Our analysis aimed to assess the relationship between sleep duration and depression in relation to diabetes risk. Without accounting for covariates, both short (< 7 hrs) and long (> 8 hrs) sleep were clearly correlated with an increased probability of having diabetes (Figure 1.1). This finding aligns with past studies documenting a U-shaped relationship between sleep duration and diabetes risk. After accounting for the covariates, this U-shaped relationship between sleep and diabetes persisted, albeit attenuated, for the overall and men-only samples (Figures 1.2 and 2.2) and disappeared in the women-only sample (Figure 2.1). Without the covariates, experiencing depression daily or weekly was clearly associated with a much higher probability of having diabetes, compared to experiencing depression monthly or rarely (Figure 1.1). This observation supports our hypothesis as well as the pre-existing literature. After controlling for covariates, this association persisted for all three sample groups (Figures 1.2, 2.1, and 2.2).

Our finding that the sleep-diabetes relationship remains significant only for men corroborates a systematic review by Cappuccio et. al, where diminished sleep was more strongly associated with diabetes risk for men compared to women. The reason behind this sex-specific association is not completely clear; however, disturbed sleep has been previously shown to interfere with testosterone in men with T2DM, and given the benefits of testosterone on glucose metabolism, low sleep might conceivably lead to poorer glycemic control [17]. A similar explanation for women and estrogen has yet to be established.

Since sleep disturbance and depression are known to be closely linked, we were surprised that we did not find any significant relationship between the sleep-depression interaction and diabetes risk based on our models. However, one cohort study found short sleep (< 6 hours) to be a significant risk factor of diabetes independent from mental health conditions including depression, which is consistent with our results [3]. This cohort study has the limitation that most of the participants were relatively young and physically fit. Thus, it would be beneficial to do more research on the interaction of sleep and depression in relation to diabetes risk using older folks, as diabetes risk increases with age.

Probability of Having Diabetes by Sleep and Depression Frequency



Limitations

The limitations of our analysis include the inability to account for additional covariates including diet, genetics, sleep quality and other health conditions, as well as the fact that all values are self-reported, which could result in less accurate data. In particular, diagnosis of depression and diabetes was not verified during data collection. Additionally, although our sample was representative for the US population, more dedicated studies of the relationship between sleep, depression, sex, and diabetes ought to be carried out for minority groups. Transgender individuals experiencing hormone therapies, for instance, might experience changes in sleep and depression that would go on to affect diabetic risk. It could also be useful to account for gender in addition to sex because non-binary individuals likely experience higher rates of depression due to discrimination. Furthermore, we cannot draw any causal inferences due to the nature of the data. Future studies in a controlled setting ought to examine the direction of the relationship between diabetes, sleep, and depression.

Conclusion

Overall, our research indicates a potential sex-specific relationship between sleep and diabetes risk and adds to rapidly growing evidence of a link between mental and physical health. Our findings that both short and long sleep and depression are significant risk factors of diabetes support the body of previous research. We

would be curious to investigate further the influence of sex as related to these risk factors as well as the interaction between sleep and depression in relation to diabetes risk.

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