Final Report:

Background/Motivation for the Study

I would like to explore the effects of sleep on mental and physical health. In a journal published in 2021 by Clement-Carbonell, Portilla-Tamarit, Rubio-Aparicio, and Madrid-Valero, it was observed that sleep can have a biologically significant impact on a plethora of areas of mental and physical health (1). Sleep amount and quality can change the way our brains work in ways we are yet to understand. I am interested to see if there are any observable statistical correlations or relationships we can observe in the NHANES data.

Research Question and Hypothesis

Does the quality and amount of sleep people get impact their mental and physical wellbeing?

Data Description and Exploratory Data Analysis

Using the NHANES data, we will be exploring the relationship between sleep hours/night *(SleepHrsNight)*, and sleep trouble (Y/N) *(SleepTrouble)* with:

- BMI *(BMI)*

- General reported health (Excellent, Very Good, Good, Fair, Poor) [1-5] *(HealthGen)*

- Reported days of little interest (None, Several, Majority) [1-3] *(LittleInterest)*

- Reported days where depressed (None, Several, Majority) [1-3] *(Depressed)*

```
Warning: package 'NHANES' was built under R version 4.3.1

Warning: package 'dplyr' was built under R version 4.3.1


Attaching package: 'dplyr'

The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

Describe the observations and the general characteristics being measured in the targeted data.

library(psych)

describe(nhanes)

```
Warning: package 'psych' was built under R version 4.3.1

              vars    n  mean   sd median trimmed  mad   min   max range
BMI              1 6604 28.78 6.70  27.75   28.15 5.93 15.02 81.25 66.23
HealthGen*       2 6604  2.63 0.95   3.00    2.63 1.48  1.00  5.00  4.00
LittleInterest*  3 6604  1.30 0.58   1.00    1.17 0.00  1.00  3.00  2.00
Depressed*       4 6604  1.27 0.57   1.00    1.14 0.00  1.00  3.00  2.00
SleepHrsNight    5 6604  6.92 1.34   7.00    6.97 1.48  2.00 12.00 10.00
SleepTrouble*    6 6604  1.26 0.44   1.00    1.20 0.00  1.00  2.00  1.00
                skew kurtosis   se
BMI             1.27     3.45 0.08
HealthGen*      0.14    -0.30 0.01
LittleInterest* 1.82     2.16 0.01
Depressed*      1.96     2.70 0.01
SleepHrsNight  -0.22     0.80 0.02
SleepTrouble*   1.09    -0.80 0.01
```

After filtering out all data points that were missing data, there are 6,599 samples. The mean values for our continuous variables are as follows:

- BMI: 28.78

- SleepHrsNight: 6.92 hours/night

The median values of our categorical variables are as follows:

- HealthGen: 3=Good

- LittleInterest: 1=None

- Depressed: 1=None

- SleepTrouble: 1=No

```
Warning: package 'ggplot2' was built under R version 4.3.1


Attaching package: 'ggplot2'

The following objects are masked from 'package:psych':

    %+%, alpha

Warning: package 'ggridges' was built under R version 4.3.1
```
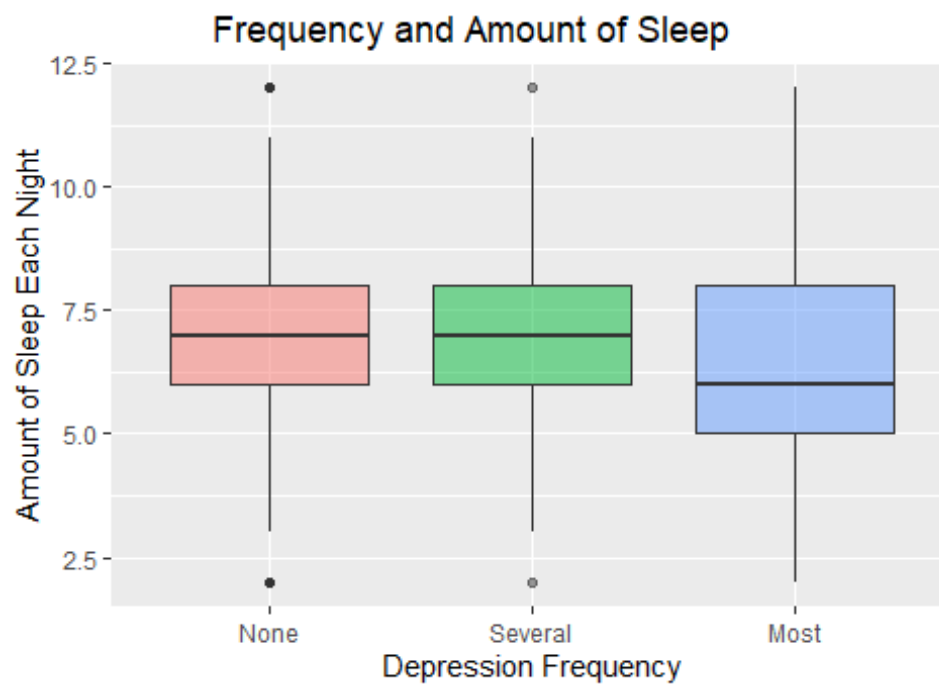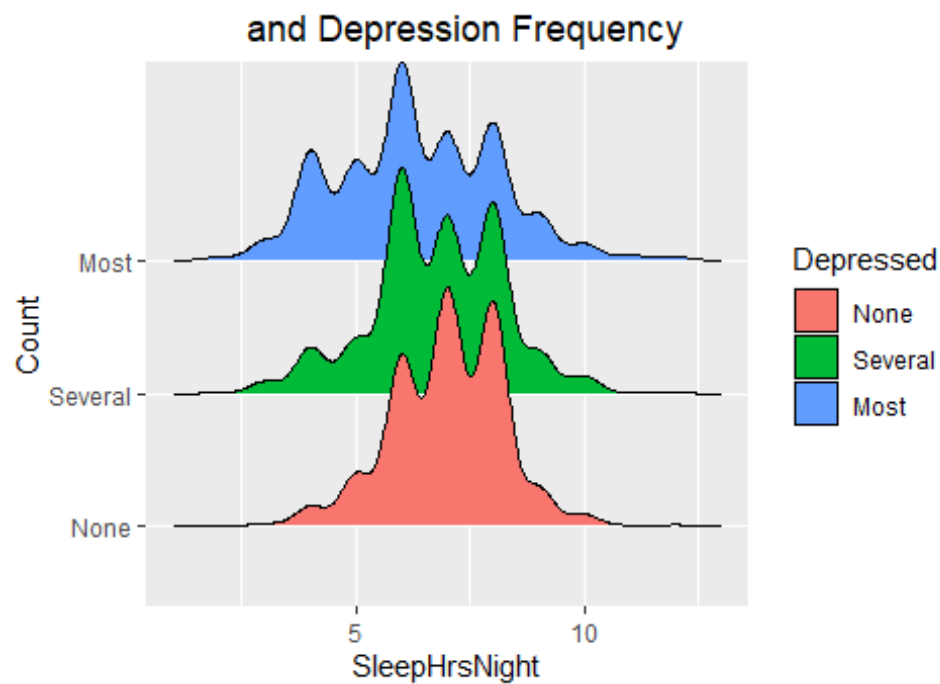
a: DB-Comparison of Depression Frequency and Amount of Sleep
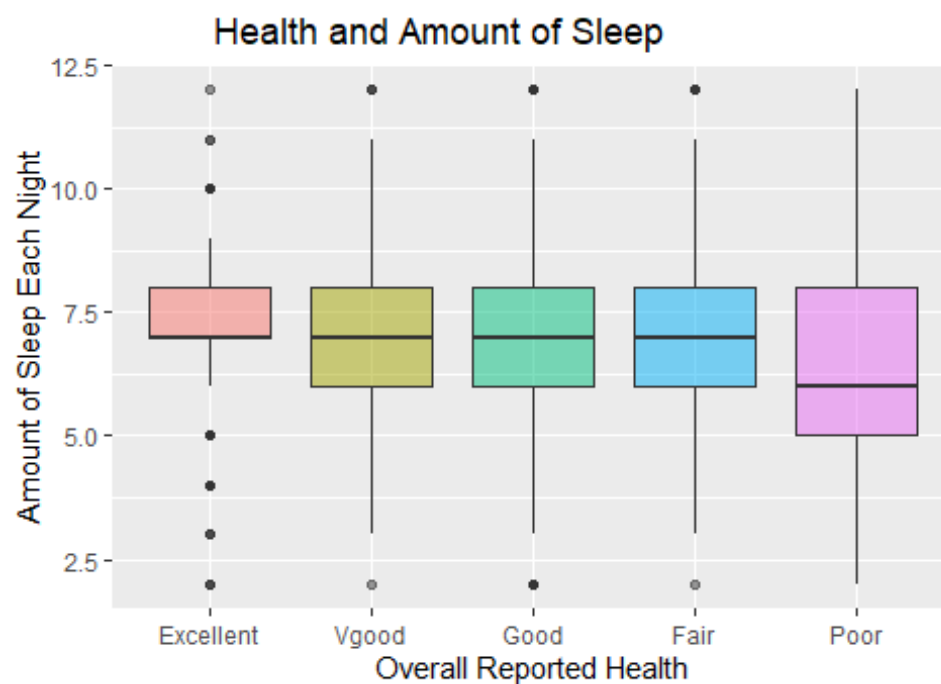


```
Picking joint bandwidth of 0.334
```

b: DB-Comparison of Amount of Sleep and Depression Frequency

c: DB-Comparison of Overall Reported

Health and Amount of Sleep


```
Picking joint bandwidth of 0.311
```
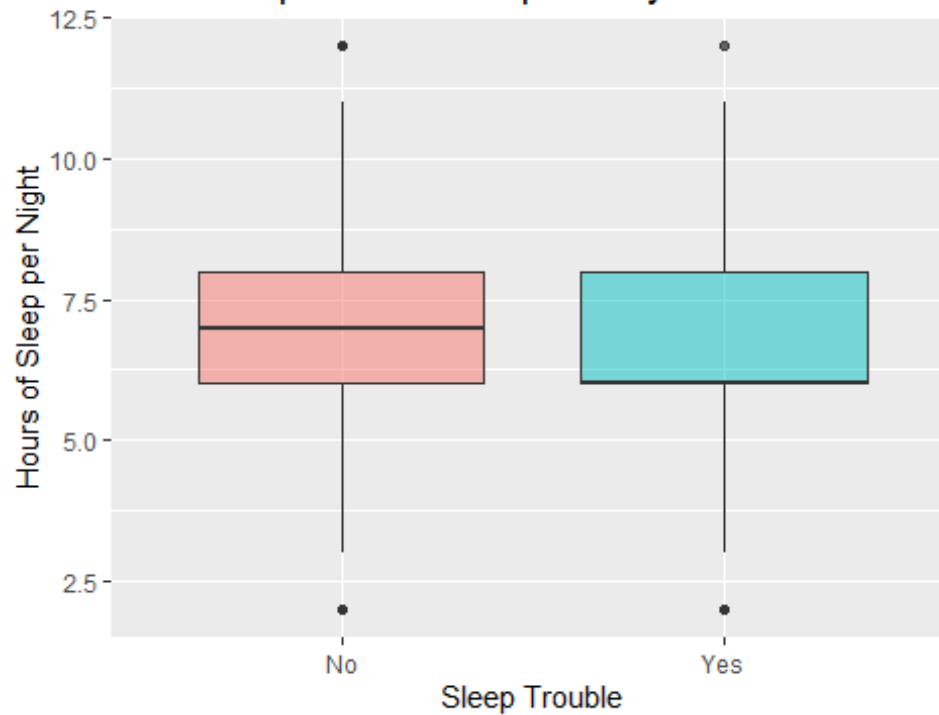
d: DB-Comparison of Amount of Sleep

and Reported General Health
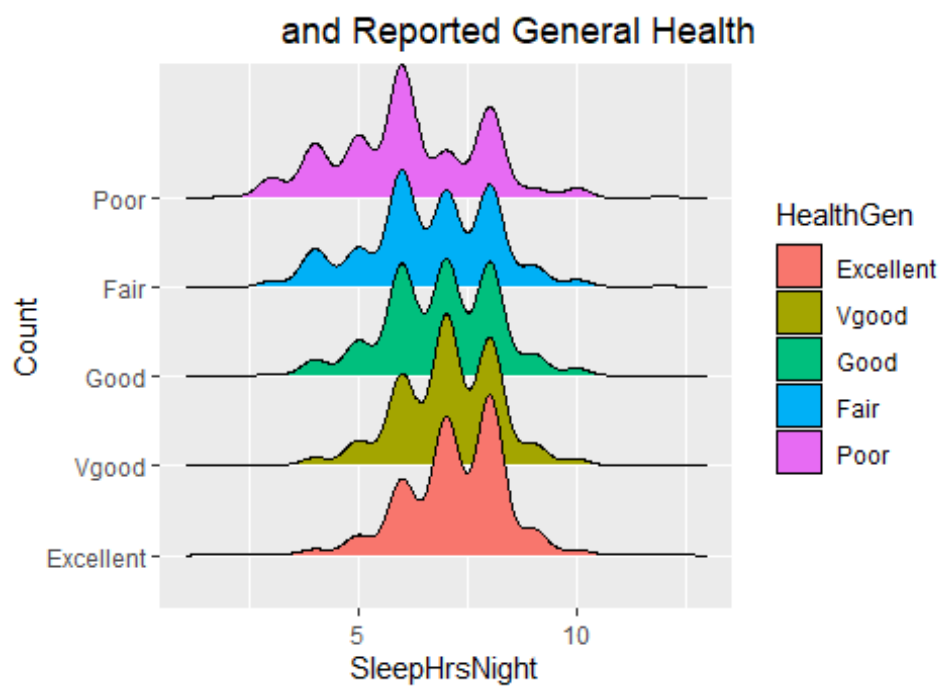
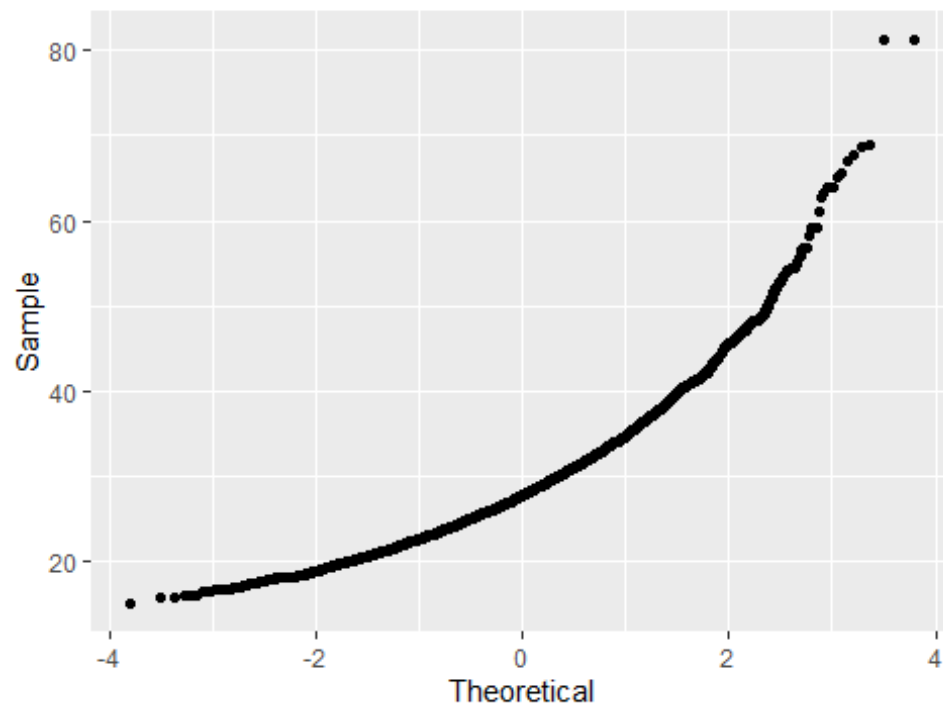e: DB-Comparison of Frequency of Lack of Interest and Amount of Sleep
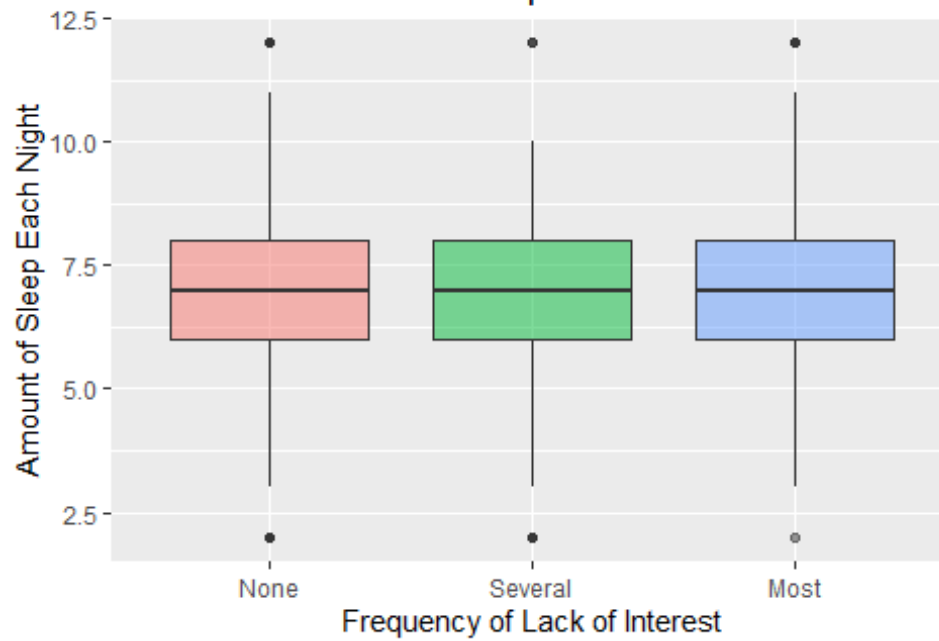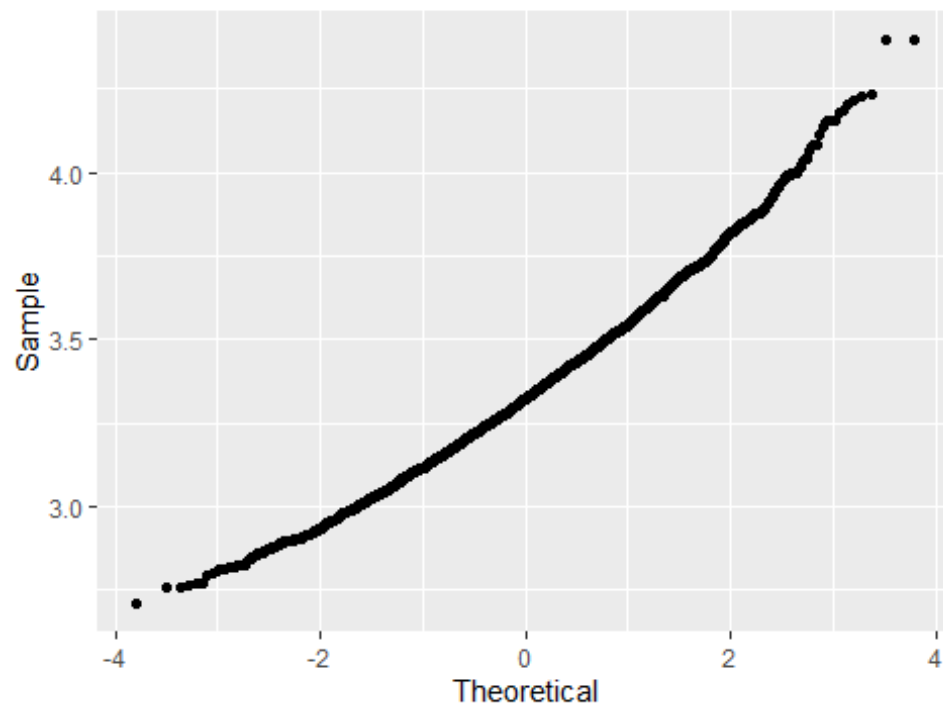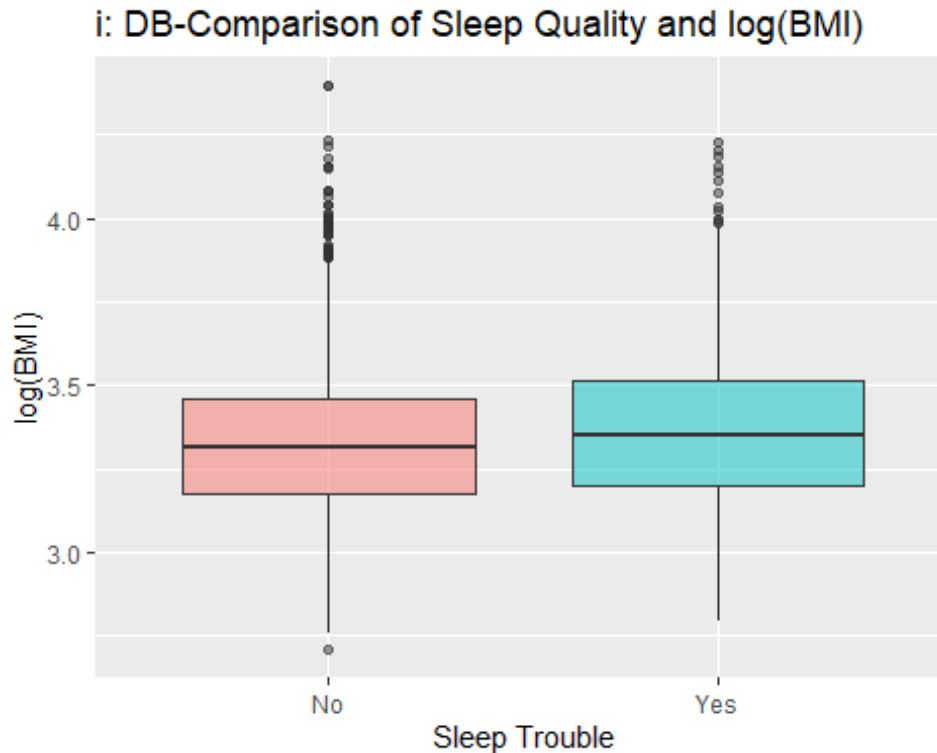

f: DB-Comparison of Sleep Quality and Duration

Warning: `qplot()` was deprecated in ggplot2 3.4.0.

g: DB-BMI qqplot

h: DB-log(BMI) qqplot

i: DB-Comparison of Sleep Quality and log(BMI)

For this analyses, boxplots were primarily used to help compare categorical and continuous variables.

Figure a: The first plot compares the reported frequency of depression to amount of sleep per night. The first two groups that reported having none and several days of depression have near identical spreads and medians. However, the group that reported having depression on most (>50%) days had a visibly lower median and range. This shows there may be a correlation between more serious cases of depression and getting less sleep.

Figure b: The second graph is based on the same data as plot c. However, this time it is visualized differently by using a ridge plot. This allows us to visualize the distribution of sleep time across each independent group of depression frequencies. There is a progressive increase in the area under the curve near lower amounts of sleep as you move from least to most reported depression.

Figure c: The third plot compares overall reported health to amount of sleep. For the most part, from Excellent to fair, there is not much difference between the median amounts of sleep. However, there is a clear dropoff when looking at the group that reported having poor overall health. Not only is there a increase in the range of the sample suggesting variable sleep schedules, but there is also a visible decrease in the median amount of sleep as compared to every other group.

Figure d: The fourth graph is based on the same data as plot e. Using a ridge plot allows us to see a similar trend that was seen between figures c and d. However, in this data, we see the trend of poor health progressively stretching the graph's range on both sides. It is more

dramatic on the end of getting less sleep, but there is a slight increase in the upper range as well.

Figure e: The fifth plot compares amount of sleep to the frequency people reported that they do not have much interest in doing things. There does not appear to be a strong relationship between these variables. Their ranges and means are nearly identical.

Figure f: The sixth plot displays the relationship between sleep quality and duration. While the sample range appears similar, the median amount of sleep for people suffering from sleep troubles is visibly lower than the group not suffering from sleep troubles.

Figure g: Qqplot to test the normalcy of the BMI data. It is shown to not have normal distribution.

Figure h: Taking the log of BMI normalized the data.

Figure i: The seventh graph shows the relationship between sleep quality and normalized BMI. It appears there is a visual difference between the groups of people having no sleep trouble and those having sleep trouble. BMI did not follow a normal distribution previously.

Analysis

```
Warning: package 'multcomp' was built under R version 4.3.1

Loading required package: mvtnorm

Warning: package 'mvtnorm' was built under R version 4.3.1

Loading required package: survival

Loading required package: TH.data

Warning: package 'TH.data' was built under R version 4.3.1

Loading required package: MASS


Attaching package: 'MASS'

The following object is masked from 'package:dplyr':

    select


Attaching package: 'TH.data'

The following object is masked from 'package:MASS':

    geyser

[1] "Test Depressed|SleepHrsNight"
```

```
[1] "One-Way ANOVA for Depressed|SleepHrsNight"

             Df Sum Sq Mean Sq F value Pr(>F)
Depressed      2    195   97.68   55.45 <2e-16 ***
Residuals   6601  11629    1.76
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = SleepHrsNight ~ Depressed, data = nhanes)

$Depressed
                   diff        lwr        upr p adj
Several-None -0.2453500 -0.3531953 -0.1375048 3e-07
Most-None    -0.6524557 -0.8117027 -0.4932088 0e+00
Most-Several -0.4071057 -0.5894991 -0.2247123 5e-07

[1] "SleepHrsNight were grouped for Chi-Square"


           2-4    5    6    7    8    9   9+  Sum
  None     164  360 1157 1613 1523  265  110 5192
  Several   76   70  291  227  246   55   25  990
  Most      70   53  106   68   74   25   14  410
  Sum      310  483 1554 1908 1843  345  149 6592

[1] "Chi-Square Test for Depressed|SleepHrsNight"


    Pearson's Chi-squared test

data:  depTable2
X-squared = 283.45, df = 21, p-value < 2.2e-16

[1] "Residuals for Depressed|SleepHrsNight"


               2-4          5          6          7          8          9
  None  -6.6679913 -1.3700855 -2.6174843  3.9486467  2.5957014 -0.5313246
  Several 4.5406491 -0.3156831  4.1754301 -3.9551292 -2.0745454  0.4665507
  Most   11.8750091  4.3357241  1.0283315 -5.1096854 -4.1566276  0.7872179
  Sum     0.0000000  0.0000000  0.0000000  0.0000000  0.0000000  0.0000000


                9+        Sum
  None  -0.8770597  0.0000000
  Several 0.5798214  0.0000000
  Most    1.5884052  0.0000000
  Sum     0.0000000  0.0000000
```

```
[1] "Test HealthGen|SleepHrsNight"

[1] "One-Way ANOVA for HealthGen|SleepHrsNight"

            Df Sum Sq Mean Sq F value Pr(>F)
HealthGen    4    265   66.14   37.76 <2e-16 ***
Residuals 6599  11560    1.75
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

  Tukey multiple comparisons of means
    95% family-wise confidence level


Fit: aov(formula = SleepHrsNight ~ HealthGen, data = nhanes)

$HealthGen
                     diff        lwr          upr      p adj
Vgood-Excellent -0.1474852 -0.2991823  0.004211906 0.0613416
Good-Excellent  -0.3251230 -0.4731816 -0.177064484 0.0000000
Fair-Excellent  -0.5498536 -0.7260914 -0.373615711 0.0000000
Poor-Excellent  -1.0307789 -1.3390121 -0.722545760 0.0000000
Good-Vgood      -0.1776379 -0.2830101 -0.072265561 0.0000423
Fair-Vgood      -0.4023684 -0.5446419 -0.260094822 0.0000000
Poor-Vgood      -0.8832937 -1.1734483 -0.593139179 0.0000000
Fair-Good       -0.2247305 -0.3631180 -0.086343051 0.0000932
Poor-Good       -0.7056559 -0.9939248 -0.417386919 0.0000000
Poor-Fair       -0.4809254 -0.7846315 -0.177219196 0.0001536

[1] "SleepHrsNight were grouped for Chi-Square"


            2-4     5     6     7     8    8+   Sum
  Excellent  14    35   134   244   282    59   768
  Vgood      49   125   449   741   626   148  2138
  Good      122   215   672   701   683   206  2599
  Fair       96    84   248   204   217    72   921
  Poor       29    24    51    18    35     9   166
  Sum       310   483  1554  1908  1843   494  6592

[1] "Chi-Square Test for HealthGen|SleepHrsNight"


    Pearson's Chi-squared test

data:  hlthTable2
X-squared = 326.86, df = 30, p-value < 2.2e-16

[1] "Residuals for HealthGen|SleepHrsNight"


                  2-4            5            6            7            8
```

```
       Excellent -3.83763112 -2.97712426 -3.83632288  1.62237852  5.10143079
       Vgood     -5.68305962 -2.81492233 -2.85034452  5.80176156  1.36131559
       Good      -0.02271885  2.02447917  2.84725904 -2.25533727 -1.94770094
       Fair       8.40049949  2.12415375  2.31384588 -4.29702272 -2.82120147
       Poor       7.72495741  3.48001809  2.03263444 -4.71703160 -1.81738047
       Sum        0.00000000  0.00000000  0.00000000  0.00000000  0.00000000


                        8+          Sum
       Excellent  0.20028070  0.00000000
       Vgood     -1.07506775  0.00000000
       Good       0.91558220  0.00000000
       Fair       0.37920904  0.00000000
       Poor      -1.00042510  0.00000000
       Sum        0.00000000  0.00000000
[1] "Test LittleInterest|SleepHrsNight"

[1] "One-Way ANOVA for LittleInterest|SleepHrsNight"

                 Df Sum Sq Mean Sq F value   Pr(>F)
LittleInterest    2     82   40.88   22.98 1.13e-10 ***
Residuals      6601  11743    1.78
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = SleepHrsNight ~ LittleInterest, data = nhanes)


$LittleInterest
                   diff        lwr        upr      p adj
Several-None -0.2071468 -0.3108362 -0.1034574 0.0000086
Most-None    -0.3643218 -0.5218741 -0.2067695 0.0000002
Most-Several -0.1571750 -0.3352680  0.0209180 0.0964386

[1] "SleepHrsNight were grouped for Chi-Square"


           2-4    5    6    7    8    9   9+  Sum
  None     178  323 1180 1572 1442  271   97 5063
  Several   73  114  268  261  307   53   27 1103
  Most      59   46  106   75   94   21   25  426
  Sum      310  483 1554 1908 1843  345  149 6592

[1] "Chi-Square Test for LittleInterest|SleepHrsNight"


    Pearson's Chi-squared test
```

```
data:  intTable2
X-squared = 198.17, df = 21, p-value < 2.2e-16

[1] "Residuals for LittleInterest|SleepHrsNight"


                     2-4           5           6          7          8
  None    -5.02176427 -3.23308463 -0.53219425  3.83495283  0.96688278
  Several  3.10148199  3.92855733  0.55032626 -3.68279440 -0.08839669
  Most     8.95601684  2.74118762  0.60208920 -4.78145143 -2.52100334
  Sum      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000

                     9          9+         Sum
  None     0.47765290 -2.08900420  0.00000000
  Several -0.65857882  0.43528087  0.00000000
  Most    -0.28256834  5.06424541  0.00000000
  Sum      0.00000000  0.00000000  0.00000000

[1] "Test SleepTrouble|SleepHrsNight"

[1] "SleepHrsNight were grouped for Chi-Square"


        2-4    5    6    7    8    9   9+  Sum
  No    142  263 1085 1492 1479  284  137 4882
  Yes   168  220  469  416  364   61   12 1710
  Sum   310  483 1554 1908 1843  345  149 6592

[1] "Chi-Square Test for SleepTrouble|SleepHrsNight"


    Pearson's Chi-squared test

data:  slpTable2
X-squared = 330.83, df = 14, p-value < 2.2e-16

[1] "Residuals for SleepTrouble|SleepHrsNight"


             2-4          5          6          7          8          9          9+
  No   -7.371476  -6.429188  -2.605738   2.861710   4.195677   2.276442   3.215414
  Yes  10.594713   9.240402   3.745119  -4.113016  -6.030272  -3.271835  -4.621379
  Sum   0.000000   0.000000   0.000000   0.000000   0.000000   0.000000   0.000000

            Sum
  No    0.000000
  Yes   0.000000
  Sum   0.000000

[1] "Test SleepTrouble|BMI"
```

```
[1] "BMI was grouped for Chi-Square *groupings reflect CDC reported values
(2)*"


     Underweight (15-18.5) Normal Weight (18.5-25) Overweight (25-30)
 No                      94                   1477                   1633
 Yes                     27                    468                    520
 Sum                    121                   1945                   2153

     Obese (30+)  Sum
 No        1684 4888
 Yes        701 1716
 Sum       2385 6604

[1] "Chi-Square Test for SleepTrouble|BMI"


    Pearson's Chi-squared test

data:  bmiTable2
X-squared = 22.743, df = 8, p-value = 0.00371

[1] "Residuals for SleepTrouble|BMI"


     Underweight (15-18.5) Normal Weight (18.5-25) Overweight (25-30)
 No             0.5939857              1.3446985              1.3606902
 Yes           -0.8529956             -1.9310599             -1.9540248
 Sum            0.0000000              0.0000000              0.0000000

     Obese (30+)          Sum
 No    -2.6924983   0.0000000
 Yes    3.8665734   0.0000000
 Sum    0.0000000   0.0000000
```

A one-way ANOVA was used for analysis of the relationship between *Depressed, HealthGen, LittleInterest* and *SleepHrsNight*. A one-way ANOVA was selected to compare the variance when there were more than two groups. Following this, the Tukey-Kramer method was used to determine which specific groups had statistically significant differences between themselves. To further visualize this point, a Chi-Square test was done on every comparison to determine whether or not the variables of interest were associated. In order to run a Chi-Square test for all samples, some of the variables had to be grouped to satisfy all the assumptions of the test. Namely, having large samples. Data was grouped using the cut() function in R.

Conclusions

The first test ran tested the relationship visualized in *Figure a* and *Figure b*. The initial results of the one-way ANOVA returned a p-value much less than 0.05, suggesting there was a statistically significant difference between some of the groups. Upon further analysis

with the Tukey-Kramer method, a 95% confidence interval was determined, and indicated that there was a statistically significant difference between every observed group. The adjusted p-value also remained less than 0.05. Those that reported depression on several days had 0.25 less hours of sleep per night on average compared to the group that reported no depression. This trend is further amplified by the group that reported symptoms of depression on most days, having on average 0.65 less hours of sleep per night than the group that did not report any depression. To further analyze this data, a Chi-Square test was performed, and a similar trend was observed. The biggest standout was that people that reported being depressed most days reported sleeping 7 or 8 hours much less than the other groups, but reported getting only 2-4 hours of sleep per night much more often than the other groups. The Mayo Clinic has reported that it is best that adults get at least 7 hours of sleep per night, and anything less can have serious impacts on mental and physical health (3). Another interesting observation was that people suffering from depression most days also are more likely to sleep for 9+ hours per night than any other group on average. It is difficult to determine whether the sleep abnormality is a causative agent or a symptom of depression. More data such as psychological analyses would be needed to provide a more accurate assessment of this data. However, there does appear to be strong evidence of a link between abnormal sleep and depression.

Furthermore, the same tests were applied to test hours of sleep per night against reported overall health as shown in *Figure c* and *Figure d*. The one-way ANOVA provided a statistically significant p-value. When applying the Tukey-Kramer method, there was significant difference between every group except for the "excellent" and "very good" groups. As expected, the largest difference was seen between the "poor" and "excellent" groups, with 95% confidence that groups reporting poor overall health getting 1.03 less hours of sleep per night on average. A Chi-Square test was also performed on these variables. A similar statistically significant (p-value<0.05) trend was noticed to the depression variable, where those with worse physical health tended to get much less sleep than all other groups. However, the shared trend was only observed for getting less sleep, unlike depression having an increased correlation with having 9+ hours of sleep per night. This is also difficult to determine the cause of, as some health conditions may impact the quality of sleep. Additional information such as type of health problems they suffer from would be helpful in determining the nature of this observed relationship.

Another variable that was analyzed against hours of sleep per night was lack of interest. This was previously visualized in *Figure e* Analysis via ANOVA and Chi-Square showed that a near-identical relationship exists between lack of interest and depression. The only main difference observed was in the Tukey-Kramer test, where it was shown that the difference between people reporting lack of interest on most days and several days had a p-value above 0.05. This suggests that the variables *LittleInterest* and *Depressed* are not entirely independent. All other results of these tests for lack of interest were statistically significant and followed the same trend of the *Depressed* variable.

For further analysis, I wanted to test the reliability of the *SleepTrouble* variable. This was originally plotted in *Figure f*. By conducting a Chi-Square test of it against hours of sleep per night, I was able to see that the data made sense, and supported using *SleepTrouble* as a good indicator. The trend observed followed the same trend seen with the *HealthGen*

variable. Getting 7 or more hours of sleep was more common for those who did not report sleep trouble, and getting under 7 hours of sleep was more common for those who did report sleep trouble. This observation makes sense. The analysis was mainly performed to check the validity of this observation.

The final variable analyzed in *Figure g, h,* and *i* was BMI. *Figures g* and *h* were used to show that BMI does not follow a normal distribution like the other variables tested did. However, due to the large sample size, I still decided to proceed with a Chi-Square test. The results had a p-value of 0.004. This is larger than many of the other significant reported p-values throughout this report, but is still smaller than 0.05. The test indicated that it is more likely for a person that is suffering from sleep trouble to be considered obese (2). The purpose of this test was to provide an example of a health condition that may negatively impact sleep as mentioned at the end of the analysis of the general health data vs hours of sleep per night. Conditions often caused by obesity such as sleep apnea can have a great impact on the quality of one's sleep. However, it has also been reported by many that abnormal sleeping habits can also have a link to weight gain (4). This is another case where having more information about the health conditions people in the data set suffer from would greatly help us to draw conclusions.

Altogether, the analysis of this data has shown that there is sufficient evidence that the amount and quality and sleep have an effect on the mental and physical well-being of people. Thus, we reject the null hypothesis. Due to this being an observational study, we are unable to confirm that sleep is a direct cause of abnormal physical or mental health, but we can confidently say there is a strong correlation.

Citations

1. Clement-Carbonell, V., Portilla-Tamarit, I., Rubio-Aparicio, M., & Madrid-Valero, J. J. (2021). Sleep Quality, Mental and Physical Health: A Differential Relationship. *International journal of environmental research and public health*, *18*(2), 460. https://doi.org/10.3390/ijerph18020460
2. Centers for Disease Control and Prevention. (2022, June 3). *Defining adult overweight & obesity*. Centers for Disease Control and Prevention. https://www.cdc.gov/obesity/basics/adult-defining.html#:~:text=If%20your%20BMI%20is%20less,falls%20within%20the%20obesity%20range.
3. Mayo Foundation for Medical Education and Research. (2023, February 21). *How many hours of sleep do you need?*. Mayo Clinic. https://www.mayoclinic.org/healthy-lifestyle/adult-health/expert-answers/how-many-hours-of-sleep-are-enough/faq-20057898
4. *Sleep*. Obesity Prevention Source. (2016, April 13). https://www.hsph.harvard.edu/obesity-prevention-source/obesity-causes/sleep-and-obesity/