ANALYSING THE IMPACT OF LIFESTYLE FACTORS ON HUMAN SLEEP HEALTH

PROJECT PROPOSAL

MIS 2231
INTRODUCTION TO CASE STUDY I

DEPARTMENT OF MATHEMATICS
UNIVERSITY OF RUHUNA

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INTRODUCTION TO CASE STUDY I

GROUP No.14
SC/2021/12505- E.M.C.G Ekanayake

SUPREVISOR
Ms. A.W Sachini P. Karunarathne

DEPARTMENT OF MATHEMATICS
UNIVERSITY OF RUHUNA

DECLARATION

I'm E.M.C.G Ekanayake, declare that the presented project report titled, "Analysing the impact of lifestyle factors on human sleep health" is uniquely prepared by me based on the group project carried out under the supervision of Ms. A.W Sachini P. Karunarathne, Department of Mathematics, Faculty of Science, University of Ruhuna, as a partial fulfillment of the requirements of the level II, Case Study course unit, MIS 2231 of the Bachelor of Science Honours Degree in Financial Mathematics and industrial Statistics in Department of Mathematics, Faculty of Science, University of Ruhuna, Sri Lanka.

It has not been submitted to any other institution or study program by me for any other purpose.

Signature: . . . .
Date: . . . .

SUPERVISOR'S RECOMMENDATION

I certify that E.M.C.G Ekanayake carried out this study under my supervision.

Signature:. . . . .
Date:. . . . .
Department of Mathematics
Faculty of Science
University of Ruhuna.

Abstract

This study investigates and analyzes the impact of lifestyle factors on human sleep health. Here, we are going to explore this relationship using a regression approach in a multiple linear regression model. The objective of this study is to identify the factors associated with sleep health and examine the combined effect of identified factors on sleep health.

Keywords: Sleep duration, Stress level, BMI Category, Heart rate, Sleep health, Multiple Linear Regression

Acknowledgment

First of all, my sincere gratitude goes to our supervisor Ms. A.W Sachini P. Karunarathne for her unending guidance and support for us to succeed in this research. Moreover, I extend my thanks to all the instructors who helped me to make this research a success. Also, I express my sincere appreciation to my team members for sharing their knowledge with me.

Contents

List of Tables

List of Figures

1 Introduction

1.1 Background of the Study

Sleep is indispensable for our overall health and well-being. During sleep, our bodies undergo essential processes for physical restoration, such as repairing tissues and muscles. Sleep is crucial for necessary memory consolidation, emotional regulation, hormonal balance, immune support, and cardiovascular health. Moreover, adequate sleep improves concentration, productivity, and performance in daily activities. In essence, sleep isn't just a luxury; it's a fundamental necessity for living a healthy. Furthermore, disruptions in sleep patterns have been linked to various adverse health outcomes, including obesity, cardiovascular disease, and mental health disorders [1]. In today's fast-paced world, where productivity often takes precedence over rest, the importance of sleep cannot be underestimated. Adequate sleep is associated with many health benefits, including improved cognitive function, emotional regulation, and immune support. Furthermore adequate sleep is not merely a period of inactivity; it's a critical physiological process that refreshes the body and mind, enabling us to function optimally. Sleep, a vital component of human health and well-being, is intricately influenced by various physiological and psychological factors [2, 3]. Among these factors, body mass index (BMI), heart rate, and stress levels have emerged as significant determinants of sleep duration. Sleep health is measured by the duration of sleep. Numerous studies have explored the relationship between these variables and sleep patterns. Besides, insufficient sleep has been linked to an increased risk of various health problems, such as obesity, heart disease, and mental health disorders [4]. By exploring the relationship between physiological and psychological factors on sleep duration, this study aims to improve through mathematical modeling.

1.2 Research Problem

How do variations in BMI, heart rate, and stress level affect sleep duration in our data set?

1.3 Significance of the Study

Despite of various research studies on sleep health, gaps remain in our understanding of how BMI, heart rate, and stress levels impact sleep duration. Existing literature often focuses on individual factors rather than examining the effects of multiple variables on sleep patterns [5, 6]. Thus, a detailed examination of the combined impact of BMI, heart rate, and stress levels on sleep duration is necessary to address this gap in knowledge.

1.4 Objectives of the Study

- To identify the factors associated with sleep health.
- To examine the combined effect of identified factors on sleep health.

2 Methodology

2.1 Study Design

- Multiple linear regression with one continuous and one categorical explanatory variable.

2.2 Data Collection

Data will be collected from the Kaggle website.
https://www.kaggle.com/datasets/uom190346a/sleep-health-and-lifestyle-dataset

2.3 Methodology

2.3.1 Identification of key Factors: Dependent and Independent variable

The data set consists of 374 observations and 4 variables.

Variables	Unit	Description	Type
Sleep duration (dependent)	Hours	The number of hours the person sleeps per day	Numerical
Stress level (independent)	Scale 1-10	A subjective rating of the quality of sleep, ranging from 1 to 10	Numeric
BMI category (independent)	-	The BMI category of the person	Categorical
Heart rate (independent)	bpm	The resting heart rate of the person in beats per minute	Numerical

Table 1: Variable description

This study expected to identify the relationship between stress level, BMI category and heart rate on sleep duration.

2.3.2 The Conceptual Model

The conceptual model presented below aids in understanding the proposed research methodology.

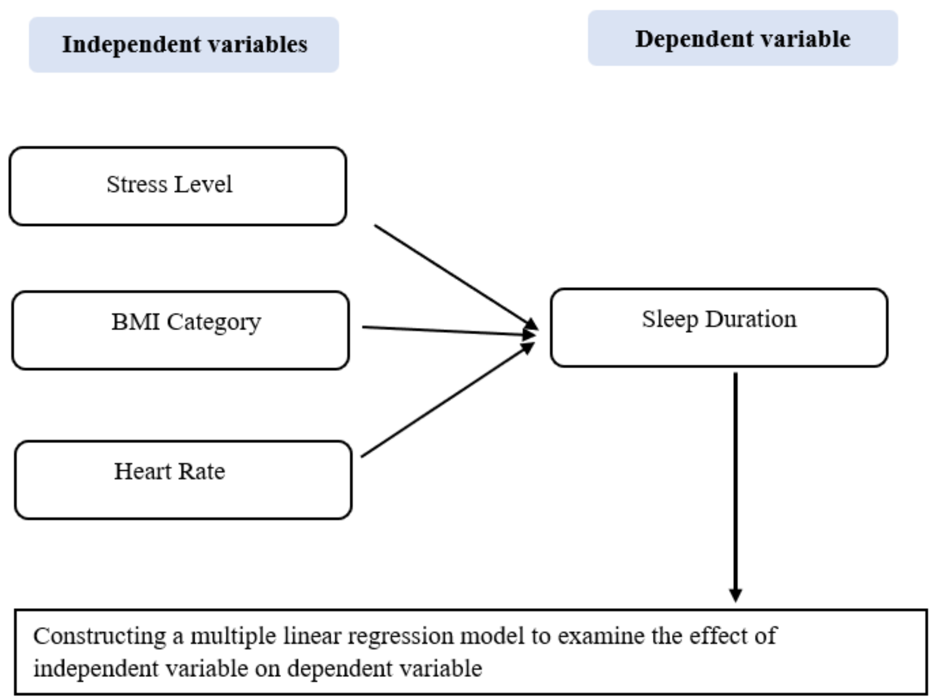

Figure 1: General Conceptual Model

2.3.3 Research Design

- **Least Square Method**

If we consider a simple linear regression model $Y = \beta_0 + \beta_1 X + \epsilon$ then,

According to the least square method, we aim to minimize the sum of the squared residuals, which is given by the equation.

$$\sum_{i=1}^{n} \epsilon^2 = \sum_{i=1}^{n} (y_i - \hat{y})^2, \tag{1}$$

Where,

ϵ_i - Represents the ith residual or error term

y_i – The observed value for the ith data point

ŷ– The predicted value of the dependent variable based on the regression model

This equation represents the concept of the least squares method in linear regression.

- **Multiple Linear Regression Method**

I used the quantitative research design; under the quantitative research design, I used multiple regression techniques to get the relationship between Sleep duration and selected influence factors. Under the multiple regression technique, we must have a dependent variable as a linear combination of two or more independent variables. In this case study I choose Sleep duration as my dependent variable and Stress level, BMI Category, and Heart Rate as my independent variables as a linear combination of my dependent variable Sleep duration. I used a Multiple linear regression model to get the relationship between dependent variable and independent variables. The formula below shows the general multiple model.

$$Y = \beta_0 + \beta_1 \text{ X}_1 + \beta_2 \text{ X}_2 + \ . \ . \ . \ + \beta_j \text{ X}_i + \epsilon \ ,$$

Where,
Y – Dependent Variable
X_i – Independent Variable i = 1,2,3, . . . , n
β_j– Regression Coefficients j = 1,2,3, . . . , n

- In our case multiple linear regression model is,

  $Y = \beta_0 + \beta_1 \text{ X}_1 + \beta_2 \text{ X}_2 + \beta_3 \text{X}_3$,

  Y = Sleeping Duration

  X_1 = Stress Level

  X_2 = BMI Category

  X_3 = Heart Rate

  β_1 = Coefficient of Stress Level

  β_2 = Coefficient of BMI Category

  β_3 = Coefficient of Heart Rate

  we get the multiple linear combination in this model.

2.4 Statistical Package

The data will be analyzed mainly using the R Software.

3 Result and Discussion

3.1 Assumptions Checking

3.1.1 Normality of residuals

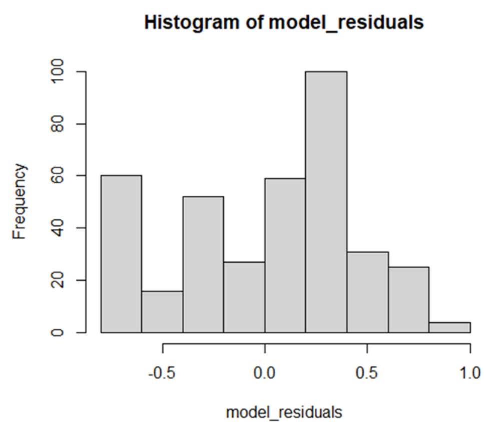

Figure 2: Histogram of model residuals

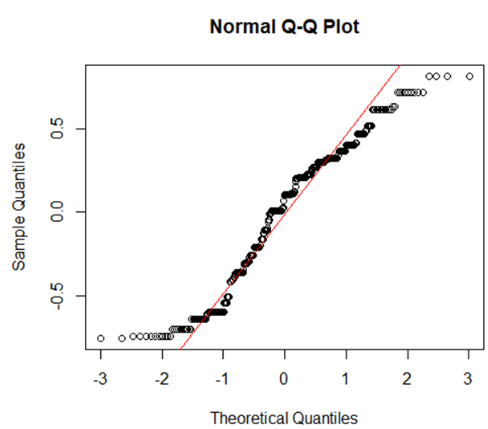

Figure 3: Normal Q-Q plot

According to the above Figure 2 the residual values are normally distributed.

3.1.2 Linearity

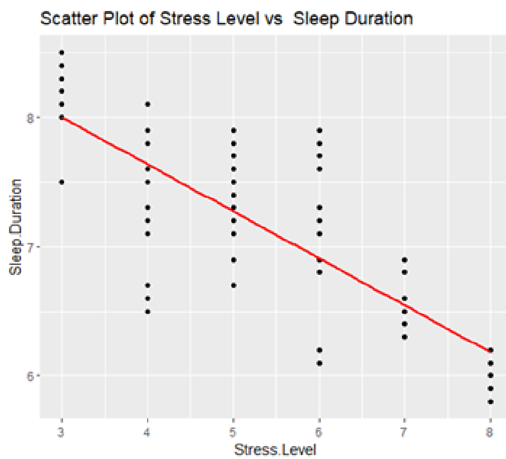

Figure 4: Scatterplot of stress level and sleep duration

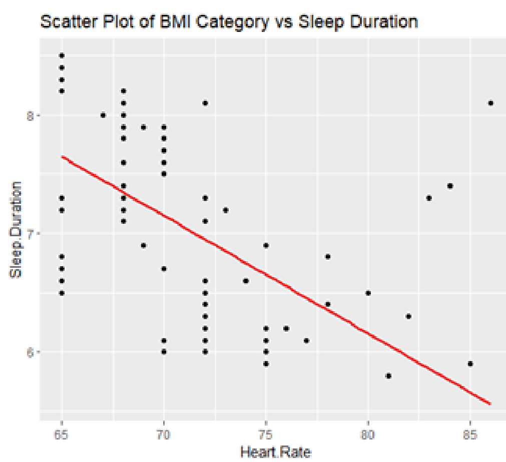

Figure 5: Scatterplot of BMI category and sleep duration

According to the above Figures 4,5, there is a linear relationship between Independent variables and Dependent variable.

3.1.3 Multicollinearity

	Sleep Duration	Stress Level	BMI numeric	Heart Rate
Sleep Duration	1.0000000	-0.8110230	0.3765181	-0.5164549
Stress Level	-0.8110230	1.0000000	-0.1654506	0.6700265
BMI numeric	0.3765181	-0.1654506	1.0000000	-0.3365791
Heart Rate	-0.5164549	0.6700265	-0.3365791	1.0000000

Table 2: Correlation matrix

The correlation between two independent variables must be less than 0.8. There is no multicollinearity.

3.1.4 Homoscedasticity

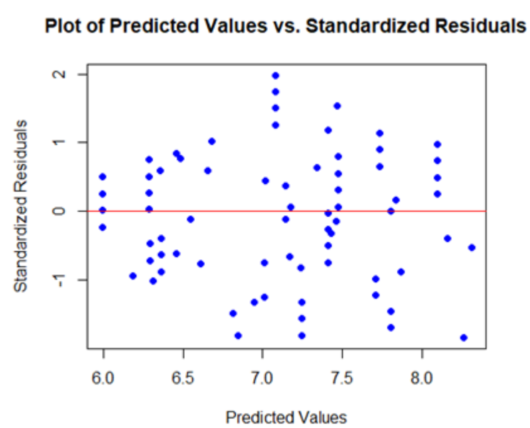

Figure 6: Plot of Predicted values vs Standardized Residuals

Points are equally distributed across all the values of the independent variables.

If the assumptions (normality of residuals, linearity, multicollinearity, and homoscedasticity) are not violated, these interpretations are valid. If assumptions are violated, consider transforming variables or using different modeling techniques.

3.2 Primilinary Analysis

3.2.1 Sleep Duration (Y)

Sleep Duration	Number of persons
5.8-6.0	37
6.0-6.2	37
6.2-6.4	22
6.4-6.6	46
6.6-6.8	10
6.8-7.0	3
7.0-7.2	55
7.2-7.4	19
7.4-7.6	15
7.6-7.8	52
7.8-8.0	20
8.0-8.2	26
8.2-8.4	19
8.4-8.6	13
	Total = 374

Table 3: Frequency table of Sleep Duration

According to the Table 3, There are 374 persons in the data set. The sleep duration range with the highest number of persons is 7.0-7.2 hours, with 55 persons. The range with the lowest number of persons is 6.8-7.0 hours, with only 3 persons. There is a notable variability in sleep duration, with a range spanning from 5.8 to 8.6 hours.

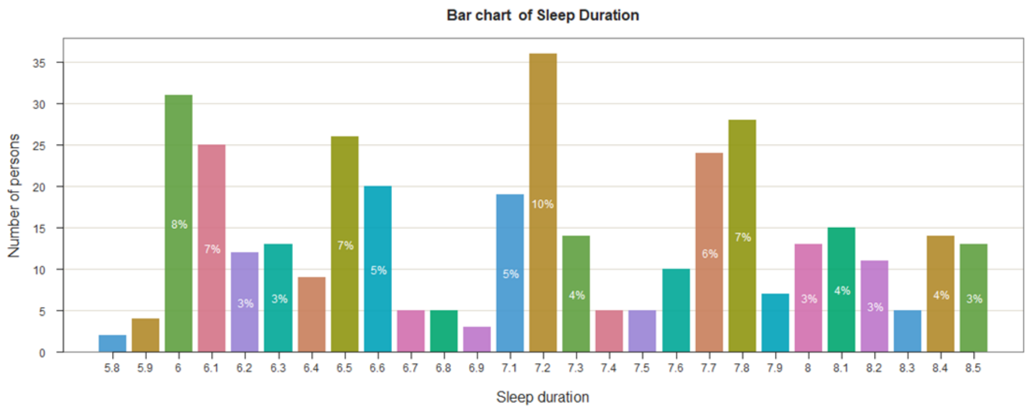

Figure 7: Bar Chart of Sleep Duration

According to Figure 7, There are 27 sleep duration ranges. The sleep duration of 7.2 hours has the highest number of persons, with over 35 individuals. It represents 10% of the total sample. The next highest sleep duration is 6 hours, with over 30 individuals. It represents 8% of the total sample. The sleep duration range of 5.8 hours has the fewest number of persons, with less than 3 persons.

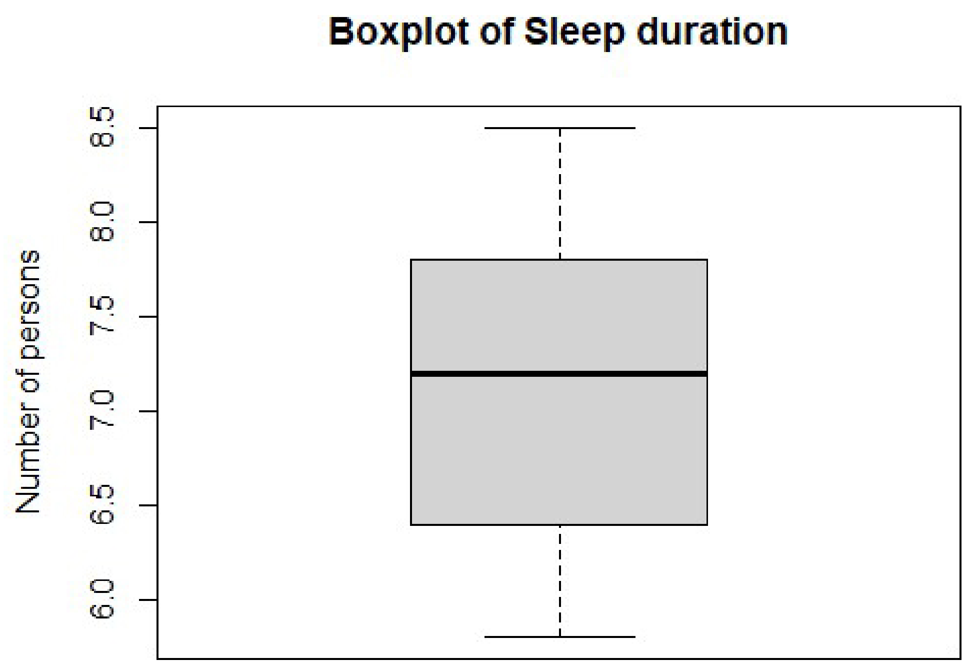

Figure 8: Boxplot of Sleep Duration

According to Figure 8, The thick black line inside the box represents the median sleep duration. It appears to be around between 7.5-7 hours, indicating that half of the individuals sleep less than this duration, and the other half sleep more. The box represents the interquartile range, which is the middle 50% of the data. The lower edge of the box (Q1) is approximately 6.5 hours, and the upper edge (Q3) is approximately 8 hours. This means that 50% of the individuals sleep between 7 and 8 hours. The "whiskers" extend from the box to the smallest and largest values within 1.5 times the IQR from the first and third quartiles. The lower whisker appears to extend to around 6 hours, and the upper whisker extends to around 8.5 hours. There are no outliers in this boxplot, as all data points are within the whiskers' range. The distribution of sleep duration seems fairly symmetrical, as the median is approximately in the center of the box, and the whiskers are of roughly equal length.

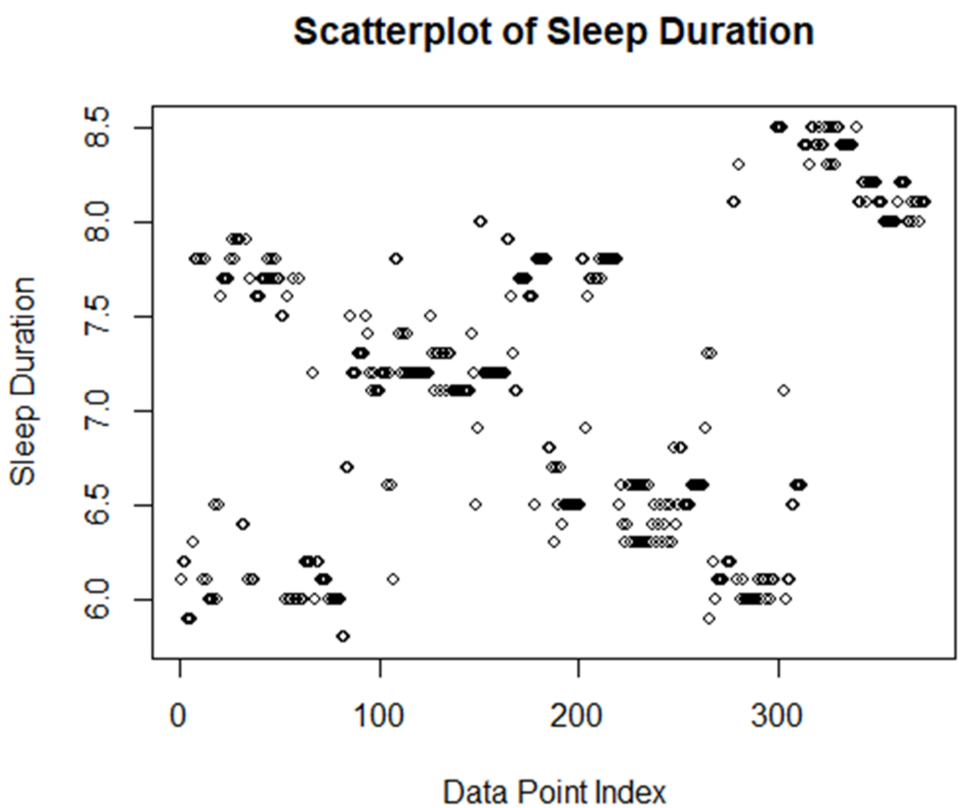

Figure 9: Scatterplot of Sleep Duration

Figure 9, Displays the relationship between the data points index and their corresponding sleep durations. Each point represents an individual's sleep duration, plotted along the y-axis. The scatterplot shows several clusters of data points, indicating that individuals tend to have similar sleep durations within certain ranges. There are clusters around the 6.0-6.5 hours and 7.5-8.5 hours ranges. This suggests that many individuals fall into these sleep duration categories. The plot shows variability in sleep duration across the sample. While there are clusters, there are also points spread out across the entire range of 6.0-8.5 hours. The scatterplot shows that data points are distributed relatively evenly across the index, meaning there is no apparent bias or trend in the order of the data collection.

3.2.2 Stress Level (X_1)

Stress Level	Number of persons
3	71
4	70
5	67
6	46
7	50
8	70
	Total = 374

Table 4: Frequency table of Stress Level

The Table 4, illustrates there are different ranges of Stress levels and the number of persons that ranges have. The Stress level of 3 has the most number of persons. It has 71 persons. The highest Stress level is 8. It has 70 number of persons. the fewest number of persons is in the 6 range and it has 46 persons.

n	Mean	sd	Meadian	Min	Max	Range	Skew	Kurtosis	Se
374	5.39	1.77	5	3	8	5	0.15	-1.33	0.09

Table 5: Summary Statistics about Stress Level

	Stress Level	Sleep Duration
Stress Level	1.000000	-0.811023
Sleep Duration	-0.811023	1.000000

Table 6: Correlation analysis between Stress Level and Sleep Duration

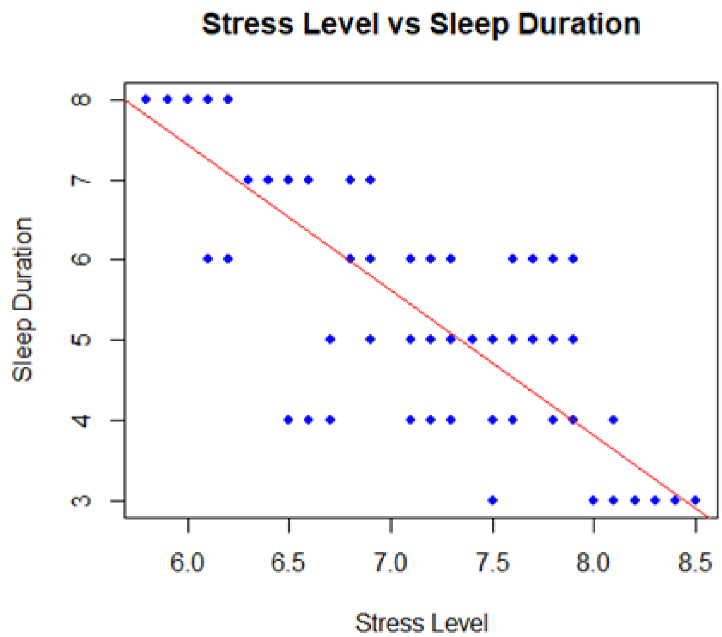

Figure 10: Scatterdiagram between Stress level and Sleep duration

According to Figure 10, The scatter diagram shows a negative correlation between stress level and sleep duration. As stress levels increase, sleep duration tends to decrease. The red line represents the line of best fit, indicating the trend in the data. The downward slope of the line further confirms the negative relationship between stress level and sleep duration. The data points are somewhat scattered around the line of best fit, suggesting that while there is a clear trend, there is also some variability in the data. Not all data points fall exactly on the line, indicating that other factors might influence sleep duration besides stress level. Generally, higher stress levels are associated with shorter sleep durations. This can be interpreted in the context of how stress affects sleep quality and quantity, potentially leading to shorter sleep duration as stress increases.

This analysis highlights the negative relationship between stress levels and sleep duration, emphasizing the impact that stress can have on one's sleep patterns.

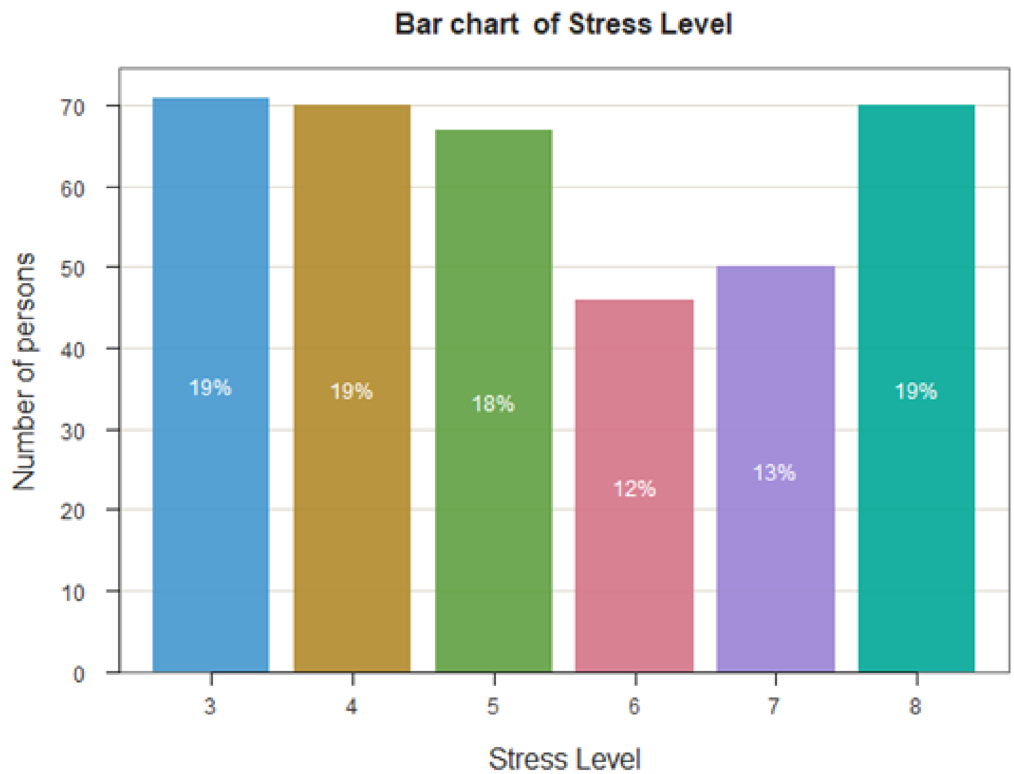

Figure 11: Bar chart of Stress Level

According to Figure 11, the X-axis represents different stress levels, ranging from 3 to 8. The y-axis shows the number of persons at each stress level. The stress levels are distributed unevenly across the sample. Stress Levels 3, 4, and 8 each have the highest proportion of individuals, with 19% each. Stress Level 6 has the lowest proportion of individuals, at 12%. This distribution suggests that most individuals in the dataset experience moderate to moderately high stress levels (3, 4, and 8). The lower number of individuals at stress levels 6 and 7 might indicate that these levels are less common among the group. This data can be used to understand the stress profile of the group and its potential impact on sleep duration and quality.

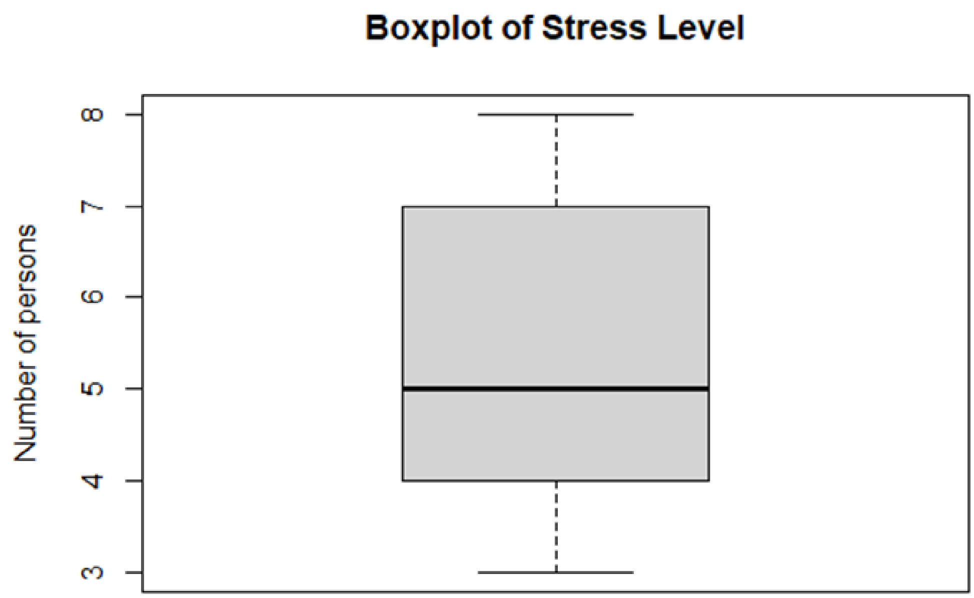

Figure 12: Boxplot of Stress Level

According to Figure 12, The thick line inside the box represents the median stress level, which appears to be 5. The box spans from the first quartile (Q1) to the third quartile (Q3). Q1 is approximately at 4, and Q3 is approximately at 7. This indicates that the middle 50% of the stress levels fall between 4 and 7. The whiskers extend from the box to the minimum and maximum values within 1.5 times the IQR from Q1 and Q3. The lower whisker extends to 3, and the upper whisker extends to 8. The median stress level is 5, suggesting that the central value of stress levels in the sample is moderate. The IQR (from 4 to 7) shows where the middle 50% of the stress levels lie, indicating moderate variability in the stress levels. The range from the lower whisker (3) to the upper whisker (8) includes most of the data points, indicating that stress levels generally fall within this range. There are no outliers in this data set, as all data points fall within the whiskers.

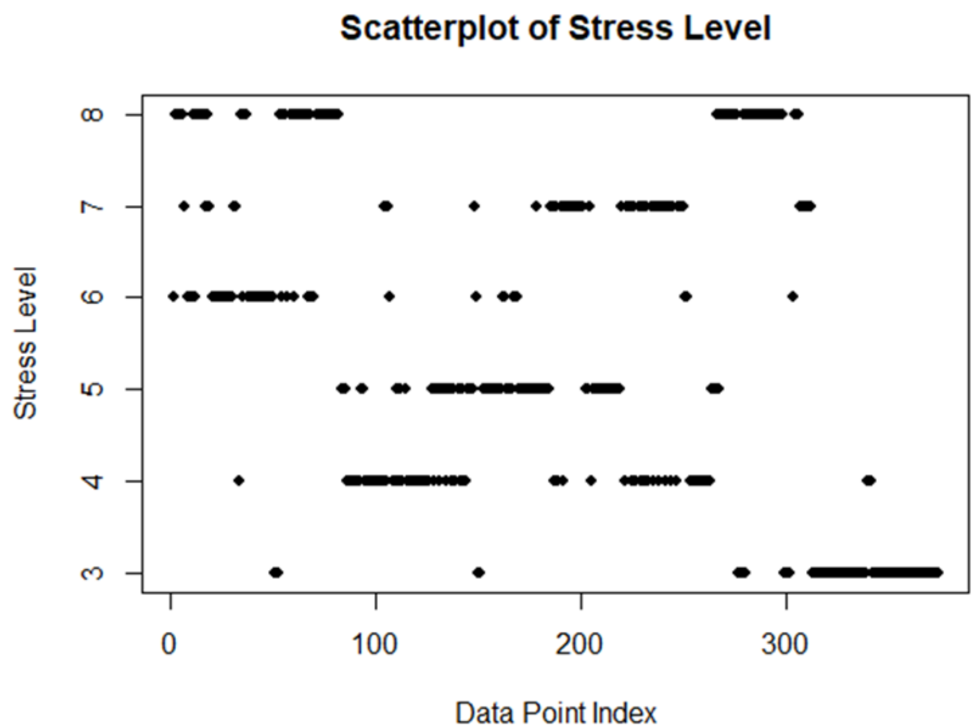

Figure 13: Scatterplot of Stress Level

Figure 13, illustrates that the Stress levels are discrete, taking on integer values between 3 and 8. The data points indicate multiple instances of each stress level value. Stress levels of 8 and 6 appear to have more data points clustered around them, suggesting that these stress levels might be more common in the dataset. Lower stress levels, such as 3, have fewer data points, indicating they are less common. The scatterplot shows a varied frequency of each stress level, with no apparent pattern or trend based on the data point index.

There are noticeable clusters of points at stress levels 6, 7, and 8, indicating that a significant portion of the data points fall within these stress levels. Less clustering is seen at lower stress levels (3 and 4), suggesting these levels are less frequently observed. This scatterplot provides an overview of the stress levels in the dataset, highlighting the distribution and frequency of each stress level.

3.2.3 BMI Category (X_2)

BMI Category	Number of persons
Normal	216
Overweight	158
	Total = 374

Table 7: Frequency table of BMI Category

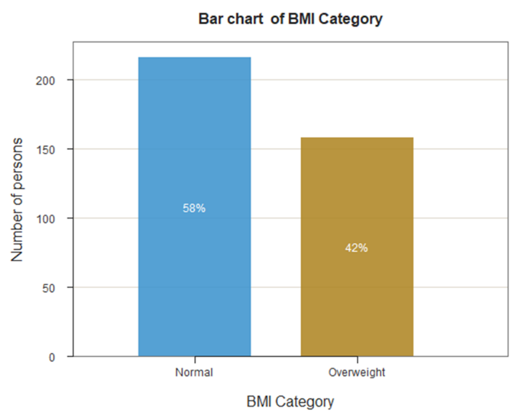

Figure 14: Bar chart of BMI Category

According to Figure 14, There are two BMI categories represented: "Normal" and "Overweight." The y-axis shows the number of persons in each category.

The chart includes percentages within each bar, indicating the proportion of the total individuals in each category.

The blue bar represents the "Normal" BMI category. Approximately over 200 persons fall into this category. This category constitutes 58% of the total individuals in the dataset. The brown bar represents the "Overweight" BMI category. Approximately over 150 persons fall into this category. This category constitutes 42% of the total individuals in the dataset. This suggests that while most of the individuals in the dataset maintain a normal BMI, there is a substantial proportion that falls into the overweight category. This distribution can be used to understand the general health profile of the data set.

3.2.4 Heart Rate (X_3)

Herat Rate	NUmber of persons
60-65	67
65-70	176
70-75	109
75-80	12
80-85	8
85-90	2
	Total = 374

Table 8: Frequency table of Heart Rate

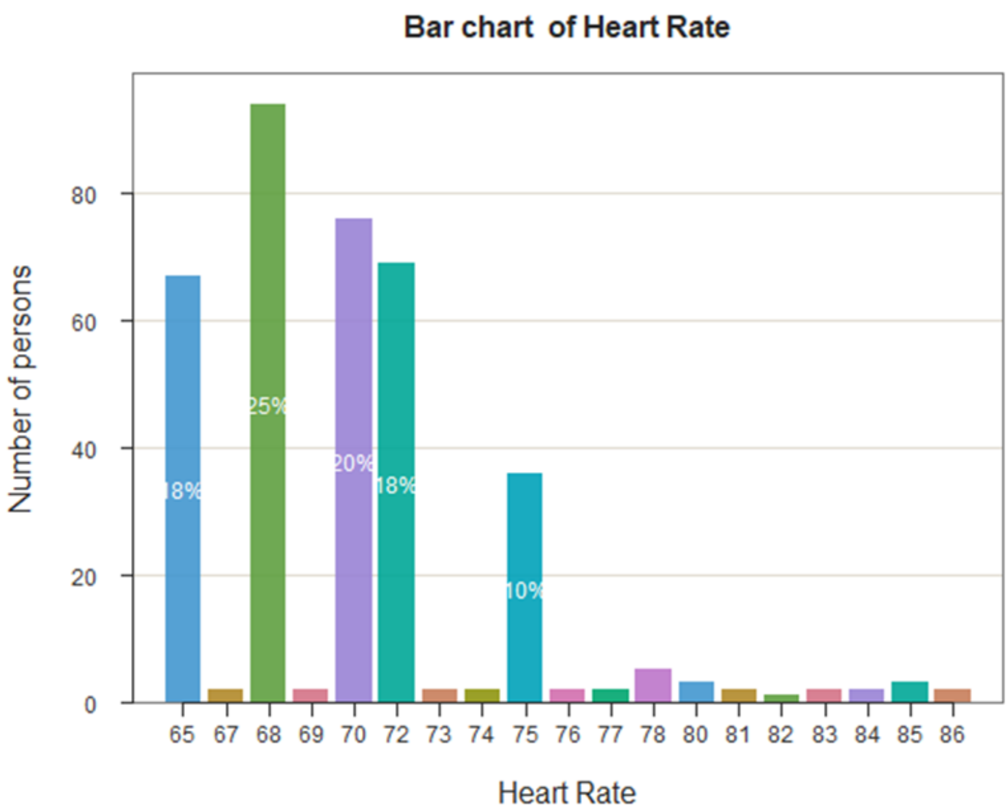

Figure 15: Bar chart of Heart Rate

The Figure 15 illustrates that the heart rates range from 65 bpm to 86 bpm. The heart rate of 68 bpm has the highest frequency, with above 80 persons, representing 25% of the sample. followed by 65 bpm, 70 bpm, 72 bpm, and 75 bpm. These heart rates have high frequencies. These five represent 91% of the sample.9% represents the rest of all other heart rates. For heart rates above 75 bpm, the number of persons decreases significantly. The distribution is right-skewed, with a concentration of lower heart rates (around 67-70 bpm) and fewer higher heart rates (above 75 bpm). The central tendency of the data appears to be around 67-70 bpm. The heart rate values above 80 bpm are quite rare, indicating outliers or less common higher heart rates.

n	Mean	sd	Meadian	Min	Max	Range	Skew	Kurtosis	Se
374	70.17	4.14	70	65	86	21	1.22	2.21	0.21

Table 9: Summary Statistics about Heart Rate

	Heart Rate	Sleep Duration
Heart Rate	1.000000	-0.5164549
Sleep Duration	-0.5164549	1.000000

Table 10: Correlation analysis between Heart Rate and Sleep Duration

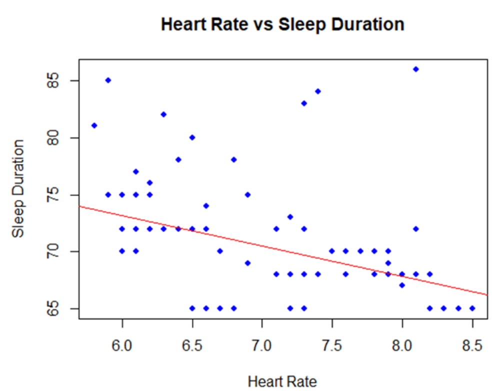

Figure 16: Scatterdiagram between Heart Rate and Sleep duration

In Figure 16 the scatter diagram of heart rate vs sleep duration provides a visual representation of the relationship between these two variables. The red line slopes downward, indicating a negative correlation between heart rate and sleep duration. The scatter of data points around the trend line indicates it may not be very strong. There is considerable variability in sleep duration for any given heart rate. This suggests that as heart rate increases, sleep duration tends to decrease. At lower heart rates (around 6.0 to 6.5), sleep duration is more varied, with some data points spread across the entire range from 65 to 85. A few data points at the higher end of the sleep duration range (above 80) are present across different heart rates, indicating that some individuals have longer sleep durations regardless of heart rate.

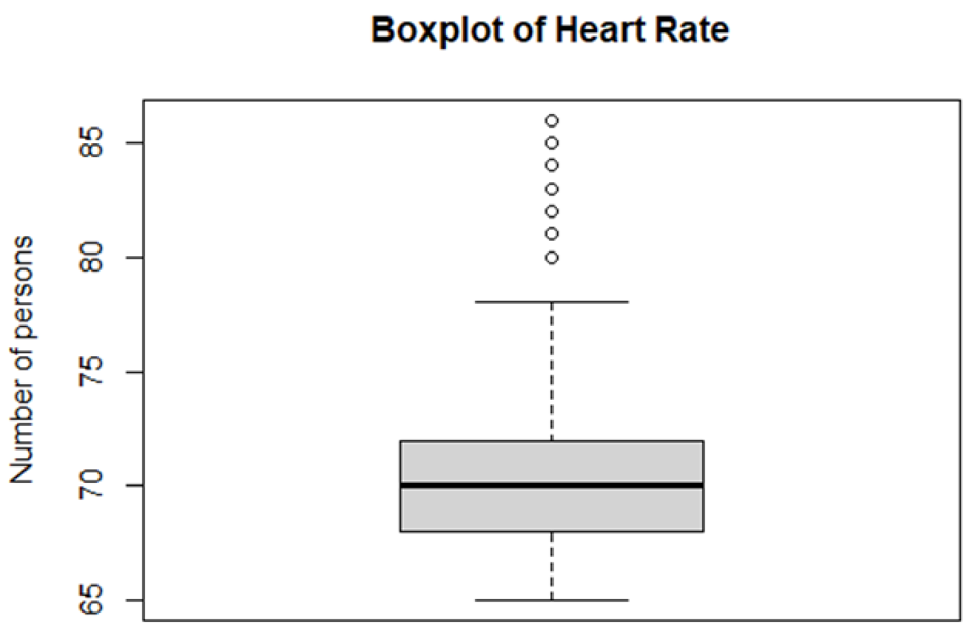

Figure 17: Boxplot of Heart Rate

According to the above Figure 17 the central box represents the interquartile range (IQR), which contains the middle 50% of the data. The bottom of the box is the first quartile (Q1), and the top is the third quartile (Q3). A line inside the box indicates the median (Q2) of the data set, which is the middle value when the data are sorted. The "whiskers" extend from the box to the smallest and largest values within 1.5 times the IQR from the first and third quartiles. The median heart rate appears to be around 70 bpm. The lower whisker extends to about 65 bpm, and the upper whisker extends to about 80 bpm. These whiskers indicate the range of typical heart rates, excluding outliers. Data points beyond the whiskers are considered outliers and are represented by individual points. There are several outliers above the upper whisker, Visually ranging from about 80 bpm to 85 bpm. These are considered unusually high heart rates compared to the rest of the data. The presence of outliers suggests that a few individuals have higher heart rates compared to the rest of the group.

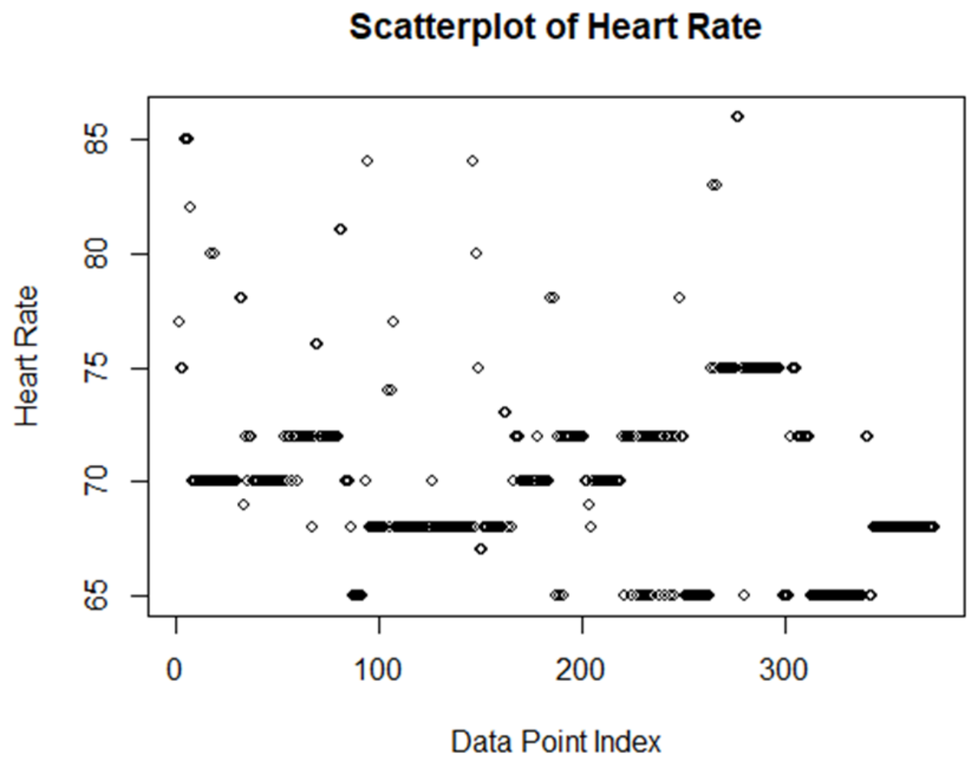

Figure 18: Scatterplot of Heart Rate

Figure 18 provides a visual representation of individual heart rate measurements against their data point index. Here's an analysis and interpretation of the scatterplot. There are clusters of data points at specific heart rates, indicating that certain heart rates are more common within the sample. The scatterplot shows a high concentration of points around the lower heart rate values (65-75 bpm). There are several points scattered above 80 bpm, which can be considered outliers. The scatterplot reveals that certain heart rates, particularly around 65, 70, and 75 bpm, have more data points clustered together, indicating these are more common heart rates within the sample.

3.3 Hypothesis Analysis

3.3.1 Hypothesis 1

- Null hypothesis (H_0):The reduced model is suitable for this study.

- Alternative hypothesis (H_a):The full model is suitable for this study.

Full model
Model 1: Sleep.Duration = Stress.Level + BMI numeric + Heart.Rate

Reduced model
Model 2: Sleep.Duration = Stress.Level + Heart.Rate

	Res.Df	Rss	Df	Sum of Sq	F	$Pr(> F)$
1	370	63.281				
2	371	80.504	-1	-17.223	100.7	$< 2.2e - 16 * **$

Table 11: ANOVA table of Model 1 and model 2

$$p\text{-value} < 0.05$$

We reject H_0 , at 0.05 Significant level.
$\therefore$ Full model is suitable for this study.

3.3.2 Hypothesis 2

- Null hypothesis (H_0): The model coefficients are not significant.

- Alternative hypothesis (H_a): The model coefficients are significant

Coefficients	Estimate	Std. Error	t value	Pr(> $\|t\|$)
(Intercept)	6.725784	0.470959	14.281	$< 2e - 16 * **$
Stress.Level	-0.392407	0.016316	-24.051	$< 2e - 16 * **$
BMI numeric	0.463081	0.046146	10.035	$< 2e - 16 * **$
Heart.Rate	0.032095	0.007332	4.377	1.56e-05 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.4136 on 370 degrees of freedom
Multiple R-squared: 0.732, Adjusted R-squared: 0.7298
F-statistic: 336.9 on 3 and 370 DF, p-value:$< 2.2e - 16$

Table 12: Summary table

$\beta_0 = 6.725784$

H_0: $\beta_i = 0$,H$_1$: $\beta_i \neq 0$

β_1 = Stress.Level
p-value < 0.05
Reject H_0 ,at 0.05 Significant level.
$\therefore \beta_1 \neq 0$

That is the coefficient value of Stress.Level
$\beta_1 = -0.392407$

β_2 = BMI numeric
p-value < 0.05
Reject H_0 ,at 0.05 Significant level.
$\therefore \beta_2 \neq 0$

That is the coefficient value of BMI numeric
$\beta_2 = 0.463081$

β_3 = Heart.Rate
p-value < 0.05
Reject H_0 ,at 0.05 Significant level.
$\therefore \beta_3 \neq 0$

That is the coefficient value of Heart.Rate
$\beta_3 = 0.032095$

summarizes the result of regressions model. In this section, the multiple linear regression analysis was used to assess the effect of independent variables on Sleep duration. The results indicate independent variables affecting Sleep duration significantly. Therefore, the regression model is obtained as follows,

Sleep.Duaration = 6.725784 - 0.392407Stress.Level +0.463081BMInumeric +0.032095Heart rate

The coefficients for these independent variables tell how each variable contributes to changes in Sleep Duration.

4 Conclusion

According to the findings, there is a negative relationship between Stress level and Sleep duration in our data set. and there is a positive relationship between BMI Category and Sleep duration in our data set. And also, there is a weak positive relationship between Heart rate and Sleep duration.

Approximately 73.2% of the variance in Sleep duration is explained by Stress level, BMI Category, and Heart Rate.

Therefore, these findings imply the impact of lifestyle factors on human sleep health.

5 Appendix

https://docs.google.com/document/d/1Con5r8OqByserj9lx6i9j7wD4kGHlG4w/edit?usp=sharing&ouid=114486221924963648392&rtpof=true&sd=true

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