Investigating Causes and Effects of Insomnia Through Exploratory Analysis

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FINAL YEAR DESIGN PROJECT REPORT

This Report Presented in Partial Fulfillment of the Requirements for the **Degree of Bachelor of Science in Computer Science and Engineering**

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APPROVAL

This Project titled **"Investigating Causes and Effects of Insomnia Through Exploratory Analysis"**, submitted by Abdullah-Al-Safoan, ID No: **211-15-14629** and Hasibul Hassan, ID No: **211-15-14585** to the Department of Computer Science and Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 12 January, 2025.

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We hereby declare that this project has been done by us under the supervision of **Dr. Md. Taimur Ahad**, **Associate Professor and Associate Head**, Department of Computer Science and Engineering, Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

Insomnia, a common sleep disorder, radically affects an individual cognitive and neurological health and represents a challenge to personal and professional life. Young adults in urban academic settings of Bangladesh are very much affected by this alarming issue of insomnia which is our objective of this study. Current studies open up an interesting avenue focused on the robust association of insomnia with stress, anxiety, and lifestyle choices; however, they still lack providing explicit mechanisms that connect these factors with their consequences and brain regions affected. This dichotomy highlights the need for holistic investigative research that considers both the psychological and brain-based mechanisms of insomnia. To bridge this gap, this paper conducts a systematic exploratory analysis to map the complex relationships between insomnia causes and effects. By analyzing survey data collected from university students, performing statistical correlation analyses and clustering techniques, the study unearths significant contributors to insomnia, assesses their impact and outlines the brain regions influenced. It presents a novel insomnia scoring scale, drawing from concepts in established tools (e.g. Insomnia Severity Index (ISI)). Core results show that the symptoms of insomnia are shaped by psychological, environmental, physical and behavioral factors that can serve to influence essential brain functions, particularly in areas such as the prefrontal cortex, hippocampus and thalamus. Insomnia constitutes a significant portion of the burden of disease, yet understanding trends from differences in treatment approaches has a limited impact in clinical settings or intervention research and policy making. As such, it fills in an important gap in explanatory research and provides a foundation for targeted intervention and novel therapeutic approaches to help address the pervasive insomnia burden facing this age group. The findings will also contribute to precision treatment approaches and ultimately also can help mitigate insomnia's broad societal and economic consequences.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

This section provides an overview of insomnia's effects on young adults and addresses the motivation behind our work with insomnia. It also contains what outcomes we got from our research and a brief overview of our report.

1.1 Introduction

Insomnia disorder is one of the most common sleep-related problem. It is a common sleep complain which is characterized by individual's difficulty in falling asleep or staying asleep or maintaining sleep quality [1]. If not treated appropriately and carefully the disorder can cause serious mental disorders and also hamper proper functioning of brain. Insomnia has a significant association with anxiety, depression mental stress and so on. Therefore, it is extremely important to study about the factors which lead to insomnia, the affects which those factors lead to and the problems which occurs arise in individual's mental health due to the adverse affects of insomnia. People of different genders and age groups can get affected by insomnia. According to the studies, elders and women are more vulnerable to insomnia [2, 3]. A study conducted in the urban area of Kathmandu in Nepal has shown that around 29.1% of the elderly participants experienced clinically significant insomnia [3]. However, young adults also show a high association with the symptoms of insomnia. Young adults often have to put up with academic pressure, job related stress, and family expectations. Some young adults sometimes maintain an indifferent and casual lifestyle leading them towards sleep problems. A study conducted in India, that aimed to assess the intensity of insomnia among young adults discovered that 52% of the young adults have one or more symptoms of insomnia where 14% showed strong intensity of insomnia [4]. It is an alarming fact that a large percentage of young adults are at a stake of insomnia and symptoms of this disorder are expected to increase as young adults grow older. Therefore, it is really important to prevent the impacts of this disorder at an early age to keep the generation healthy and mindful for a long time.

So, in order to prevent insomnia, it is really important to identify, analyze and learn about the factors that cause insomnia. As well as, the findings regarding the brain regions that

gets affected due to the factors should also be taken into consideration. In this regard, exploratory researches like these are extremely useful to get a bigger picture of insomnia disorder.

1.2 Motivation

The prosperity and development of any country depends upon its working-class people. In this light, young adults can be considered the main driving force of a country. Bangladesh is one of the rising economies of the world and to sustain this advancement we need to utilize our huge working population especially, the young adults. However, many youths and adults in our country are suffering from a very common sleeping disorder known as Insomnia. According to [5] insomnia can significantly impact an individual's mental and physical health conditions, quality of life and productivity. Such reduction in productivity and degradation in health can affect individuals along with his/her family, organization he/she is working for and also in bigger picture the economy of this country.

Insomnia can lead a person to make errors at work and increase the likelihood of causing accidents. Some professions such as doctors, drivers, defense analysts and so on are quite sensitive and require constant explicit attention. Insomnia can bring disaster for such professions as they often have to deal with the narrowest margin of error. Insomnia also hampers decision-making ability, creativity, memorization and innovation of individuals. It keeps negative impacts on people of all professions and classes, eventually resulting in economic loss of a country. Apart from professional life insomnia can cause trouble in family and social life too. A study [6] has found a direct link of insomnia with reduced energy and stamina, poor mood, and reduced functional capacity, as well as an indirect link with reduced social interaction and isolation. Insomnia patients try to avoid interacting with people and reduce their social activities by thinking that these will improve their sleep.

In many cases, people are found to be either unaware of their insomnia symptoms or show a lack of interest in receiving a diagnosis and treatment of insomnia which intensifies their problems [7, 8]. Insomnia itself is not only a disorder but it can also cause other mental diseases and disorders. The symptoms of insomnia has significant effects on brain functionality and development. Insomnia can also cause psychiatric disorders, including mood disorders, anxiety disorders, substance use disorders, and psychotic disorders [9].

Therefore, it can be said that the effects of insomnia on young adults are miserable. And in order to, prevent and cure this disorder it is extremely necessary to know and analyze the factors, effects and mental health problems which it creates. Several studies have taken place on insomnia in the past discussing factors, effects, diseases and treatments. However, there is still room for a few more studies. In particular, the exploratory analysis of insomnia is scarcely found. This scarcity of exploratory analysis served as the main motivation for the study.

1.3 Objectives

The study revolves around three very important research questions and aims to pursue the answers to them. The questions include:
RQ1. Which factors are responsible for insomnia among the young adults living in Dhaka city of Bangladesh?
RQ2. Which effects do these factors of insomnia generate to the young adults living in Dhaka city of Bangladesh?
RQ3. Which parts of the brain get affected because of the effects generated from the factors of insomnia in the young adults living in Dhaka city of Bangladesh?
To address above research questions, the following objectives were built:
OBJ1. To determine factors that are responsible for insomnia among the young adults living in Dhaka, Bangladesh.
OBJ2. To study the effects that these factors of insomnia generate on young adults living in Dhaka, Bangladesh.
OBJ3. To identify the parts of the brain, which get affected due to the effects of Insomnia, in the young adults living in Dhaka, Bangladesh.
The study tries to find the most significant factors responsible for insomnia disorder. Then the study proceeds to find out which effects of insomnia have a relation with those factors. Furthermore, the study tries to shed light to the brain regions that get affected by the effects of insomnia.

1.4 Methodology

To conduct this study, at first, a questionnaire [10] was selected and then a survey was conducted on on that questionnaire. After data collection, hypotheses were developed to and build a conceptual model as well as an insomnia scoring scale. Then, pre-processing were done to obtain a clean dataset. Afterwards, hypothesis testing was conducted using a statistical correlation analysis. Chi-square testing was used for testing the hypotheses. The developed model based on Chi-square testing was used to find insomnia scores based on selected 8 target variables. Afterwards, k-means clustering was applied to find out the correlations between different effects of insomnia. Finally, the regions of the brain that which get affected due to the symptoms of insomnia were determined.

1.5 Research Outcome

The research assessed the correlations of the factors of insomnia with its effects. It determined which particular factor has a strong correlation with a certain effect. The study considered all the effects and assessed those with a sleep measurement scale. Then the effects were visualized with clustering graphs to determine how significant each of those effects are. The study also found out the regions of the brain which gets affected by

determined effects of insomnia through literature review.

1.6 Organization of the Report

Chapter 1, Introduction: This chapter depicts the problem that insomnia causes to young adults and the motivation behind this work. The chapter also include the objects that this study pursues and the expected outcome of this research.
Chapter 2, Background: This chapter illustrates the literature that was reviewed to gain insight for this research. The similar works and the research gap of previous works are also depicted here.
Chapter 3, Methodology: This chapter describes which techniques, method and tools were involved in data collection, data processing and data analysis. The research plan and task allocation scenarios were also presented in this chapter.
Chapter 4, Implementation and Results: The chapter will discuss on Implementation of methodology, code and results that were obtained from the research. The chapter includes graphs, explanations and the image and explanations and brain regions that get affected during insomnia.
Chapter 5, Engineering Standards and Design Challenges: This chapter illustrates which ethical standards were followed during data collection and dissertation writing. How our works impacts on life, society and environment and financial analysis is also included here. Besides, this chapter defines which complex engineering problems are addressed by our work.
Chapter 6, Conclusion: The conclusion sums up some very important insights regarding insomnia and its impacts on society as a whole. The findings not only point to important challenges which are correlated with insomnia, but also show the path for creative ways to think about and treat this complex disorder.

Chapter 2

Background

This section contains discussion regarding the type of papers that were reviewed during this study along with the key findings from those literature reviews. It sheds light to some similar works which were conducted and describes about the research gaps, overall highlighting the purpose and importance of this particular study regarding Insomnia.

2.1 Introduction

In order to conduct the research on insomnia quantitative, qualitative, cross-sectional studies, exploratory studies, epidemiological studies, longitudinal studies, validation studies and many more types of papers were reviewed to gain insights into the previous research. It was interesting to observe that some papers used Machine Learning models to predict insomnia while some used statistical analysis to identify the factors and impacts of insomnia. Many neuroscience related studies were also reviewed to gain knowledge regarding the parts of the brain that gets affected by the effects and symptoms of insomnia which in result degrades an individual's daily life.

2.2 Literature Review

For this study, different types of papers were reviewed. The review included studies regarding insomnia analysis, insomnia severity index, effects of insomnia symptoms on the brain, survey-related papers and so on. The following summary table sheds lights on the various papers and studies that were reviewed during this research:

Table 2.1: Summary of Literature Reviewed.

Author(s)	**Year**	**Title**	**Methodology**	**Key Findings**
Alexander A. Huang, Samuel Y. Huang [11]	2023	Use of Machine Learning to Identify Risk Factors for Insomnia	A retrospective and cross-sectional study using a machine learning model.	Depression, age, weight, and waist circumference were identified as the most significant risk factors for insomnia, and XGBoost model performed best.
Md. Muhaiminul Islam, Abu Kaisar Mohammad Masum, Sheikh Abujar, Syed Akhter Hossain [12]	2020	A systematic way of collecting data of insomniac patients: an analytical survey	Survey-based study using questionnaires followed by data validation and analysis.	Insomniacs slept 1–5 hours on average and had sleep disturbances, dissatisfaction, and psychological issues, while normal people had 5–10 hours of sound sleep in general.
Firoj Al-Mamun, Mohammed A Mamun, Md Emran Hasan, Moneerah Mohammad ALmerab, and David Gozal [13]	2024	Exploring Sleep Duration and Insomnia Among Prospective University Students: A Study with Geographical Data and Machine Learning Techniques.	A cross-sectional study with statistical analysis, GIS mapping, and predictive analysis.	CatBoost model performed best, while dissatisfaction with mock test results, anxiety symptoms, repeat test-taking status, and females were identified as the most vulnerable to factors of insomnia.

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Author(s)	Year	Title	Methodology	Key Findings
Zhao Su, Rongxun Liu, Keyin Zhou, Xinru Wei, Ning Wang, Zexin Lin, Yuanchen Xie, Jie Wang, Fei Wang, Shenzhong Zhang, and Xizhe Zhang [14]	2024	Exploring the Relationship Between Response Time Sequence in Scale Answering Process and Severity of Insomnia: A Machine Learning Approach	A cross-sectional study using response time data collected via the insomnia severity index and analyzed using machine learning models.	Logistic regression and multi-layer perceptron (MLP) performed best as machine learning models and found a significant association between response time and insomnia severity index.
Yan Ma, Ming Dong, Carol Mita, Shuchen Sun, Chung-Kang Peng, and Albert C. Yang [15]	2015	Publication Analysis on Insomnia: How Much Has Been Done in the Past Two Decades?	Bibliometric analysis of 5,841 PubMed and Google Scholar publications (1994–2013) by using MeSH terms and citation metrics to determine research trends.	Insomnia research increasingly focuses on nonpharmacological treatments like CBT-I and alternative therapies rather than clinical trials.
Sadeghniiat-Haghighi K, Yazdi Z, Firoozeh M [16]	2014	Comparison of Two Assessment Tools That Measure Insomnia: The Insomnia Severity Index and Polysomnography	A statistical analysis to perform a comparison between ISI scores and PSG results.	Significant correlations were found between ISI scores and PSG results, suggesting that ISI is a useful tool for quantifying perceived insomnia severity.

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Author(s)	Year	Title	Methodology	Key Findings
Zohreh Yazdi, Khosro Sadeghniiat Haghighi, Mohammad Ali Zohal, Khadijeh Elmizadeh [17]	2012	Validity and Reliability of the Iranian Version of the Insomnia Severity Index	A validation study that assesses the reliability and validity of the ISI by correlating it with polysomnography.	ISI is a reliable and valid tool for screening insomnia, showing strong correlations with fatigue, daytime sleepiness, PSQI scale, and ESS scale.
Zubia Veqar and Mohammed Ejaz Hussain [18]	2017	Validity and reliability of insomnia severity index and its correlation with Pittsburgh sleep quality index in poor sleepers among Indian university students.	A validation study that assessed the psychometric properties of the ISI and its correlation with the PSQI through statistical analysis performed using SPSS.	ISI has excellent internal consistency, test-retest reliability, and validity, as well as a significant association with the PSQI scale.
Sivertsen, B., Hysing, M., Harvey, A. G., & Petrie, K. J [19]	2021	The Epidemiology of Insomnia and Sleep Duration Across Mental and Physical Health: The SHoT Study	An epidemiological study, statistically analyzed (chi-squared tests, log-link binomial regression) data from a national survey to assess prevalence of sleep problems.	Insomnia and short sleep duration were found responsible for mental disorders and some unwell physical conditions, and mental disorders were more frequent than physical ones.
Hannah Morphy, Kate M. Dunn, Martyn Lewis, Helen F. Boardman, and Peter R. Croft [20]	2007	Epidemiology of Insomnia: A Longitudinal Study in a UK Population	Longitudinal study using postal questionnaires statistically (Cox Regression) assessed sleep problems based on 4 questions.	Insomnia has a link with anxiety, depression, and pain, and older people suffer more than the younger population.

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Author(s)	Year	Title	Methodology	Key Findings
Chen, S., Xing, L., Liu, Y., & Xu, J. [21]	2024	The Relationship between Urban Functional Structure and Insomnia: An Exploratory Analysis in Beijing, China.	An exploratory spatial analysis study that used Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) models to assess global and localized impacts of urban functionality on insomnia.	Urban functional structures significantly influence insomnia when spatial and temporal patterns show localized impacts, and balanced urbanization can mitigate bad effects.
Giorgio Cosenzo, L., Arias, D., & Alcántara, C[22]	2024	Exploring the social context of insomnia: a thematic content analysis of the lived experiences of insomnia of Latinx women and men.	An exploratory analysis thematic content analysis of focus group data discussing how social processes influence insomnia.	Social ties, stress, and control affect insomnia experiences, and women suffer more than men in insomnia.
Rumble, M. E., McCall, W. V., Dickson, D. A., Krystal, A. D., Rosenquist, P. B., & Benca, R. M. [23]	2020	An exploratory analysis of the association of circadian rhythm dysregulation and insomnia with suicidal ideation over the course of treatment in individuals with depression, insomnia, and suicidal ideation.	An exploratory analysis of circadian rhythm dysregulation, insomnia, and suicidal ideation using statistical approach (Multilevel Modeling).	Eveningness, insomnia severity, and delayed sleep timing have associations with suicidal ideation, and such ideation leads to lower physical activity.

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Author(s)	Year	Title	Methodology	Key Findings
Krause, A. J., Simon, E. B., Mander, B. A., Greer, S. M., Saletin, J. M., Goldstein-Piekarski, A. N., & Walker, M. P. [24]	2017	The sleep-deprived human brain	A review of neuroimaging, cognitive assessments, and experimental studies on the effects of sleep deprivation on brain functionality.	Sleep deprivation disrupts cognitive function, emotional regulation, and brain activity, particularly in the prefrontal cortex and hippocampus, with long-term consequences.
Telzer, E. H., Goldenberg, D., Fuligni, A. J., Lieberman, M. D., & Gálvan, A [25]	2015	Sleep variability in adolescence is associated with altered brain development	A neuroimaging (MRI) and behavioral assessments for examining the effects of sleep variability on brain development in adolescents.	Sleep variability during adolescence is associated with altered brain structure and function, which impacts cognitive control, emotional regulation, and increases susceptibility to mental health issues.

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Author(s)	Year	Title	Methodology	Key Findings
Yuki Motomura, Shingo Kitamura, Kentaro Oba, Yuri Terasawa, Minori Enomoto, Yasuko Katayose, Akiko Hida, Yoshiya Moriguchi, Shigekazu Higuchi, Kazuo Mishima [26]	2013	Sleep debt elicits negative emotional reaction through diminished amygdala-anterior cingulate functional connectivity	A functional magnetic resonance imaging (fMRI) examination to assess the effects of sleep debt on amygdala-anterior cingulate connectivity and emotional responses.	Sleep debt decreases connections between the amygdala and anterior cingulate cortex, consequently increasing negative emotional reactions and impaired emotional regulation.
Alexander A. Huang, Samuel Y. Huang [11]	2023	Use of Machine Learning to Identify Risk Factors for Insomnia	A retrospective, cross-sectional cohort study using a machine learning model.	Depression, age, weight, and waist circumference were identified as the most significant risk factors for insomnia and XGBoost model performed best.

2.2.1 Related Research

The study mainly focuses on the exploratory analysis on insomnia. This work is a combination of the correlation between the factors of insomnia and the effects of it, the calculation of the insomnia severity index based on the insomnia symptoms or effects and the parts of the brain that shows altered functionality as a consequence of insomnia symptoms. From the reviews of previous studies, it was observed that most of the papers used machine-learning models to detect insomnia based on survey data [11, 12, 13, 14, 15, 18] while some researches utilized actigraphy, polysomnography [16] and other devices to detect insomnia to detect insomnia. The insomnia severity index has been found an easy and cheap method which has consistency, validity and reliability in insomnia prediction [14, 15, 16, 17, 18]. The insomnia severity index (ISI) has been found to correlate with

other sleep disorder scales like Pittsburgh Sleep Quality Index (PSQI) [17, 18] and the Epworth Sleepiness Scale (ESS) [17]. The result of ISI has been found to have an association with polysomnography made it a dependable scale for primary measurement of insomnia [16, 17]. In most studies the researchers used SPSS software to conduct statistical analysis like test-retest reliability (ICC), internal consistency (Cronbach's alpha), correlation analysis (Pearson, Spearman correlation), descriptive statistics (mean, standard deviation), [17, 18] chi-square test, ptest [16] and so on. In this study, we used a scale similar to ISI, which we addressed as 'insomnia score' to assess the severity of the participants based on 8 symptoms of insomnia. Some epidemiological studies conducted on insomnia have found its link with depression, anxiety and pain [19, 20] through statistical analysis. A few exploratory studies were conducted which found relation between insomnia and its factors [22, 23]. The previous studies also found that insomnia affects more on mental health than the physical health [20]. Revewing existing literature shed lights on how sleep problems can affect the thalamus, amygdala [26], hippocampus, prefrontal cortex, orbitofrontal cortex, parietal cortex, intraparietal Sulcus, visual cortex, and occipital cortex [24] as well as brain networks [24] and tracts [25] and how this can effect on memory, mood, emotion and attention [24, 25, 26, 27].

2.3 Research Gap

Reviewing previous studies showed that a very small amount of exploratory analysis were done in this topic. The literature review showed many studies predicting insomnia from surveys [11, 13, 14] as well as identification of most significant factors of insomnia [11]. The studies couldn't overcome the expectation to explain the factors of insomnia associated with particular effects. So, in-spite of the studies finding significant factors responsible for insomnia it didn't show the link to effects caused by the factor. Meanwhile, the exploratory research which were studied also focused mostly on the factors [21, 22]. Few exploratory studies focused on observing connection of insomnia with many mental and physical problems [19, 23]. However these exploratory studies also failed to display any explicit relation between the factors and effects of insomnia. This study focuses on filling this gap by displaying explicit association between every factor and every effect. Although the previous studies have tried to show how insomnia symptoms (effects due to factors) affect brain functionality, but those studies were only based on 4-5 symptoms. Therefore, if someone (A researcher or healthcare professional) wants to know how brain organization gets altered by the effects of insomnia then he/she has to study multiple research papers. Eventually, it is observable that, the studies that shows insomnia factors, insomnia symptoms and the effects of those symptoms on the brain are scarce.

2.4 Summary

The literature review made it clear that, despite lots of studies conducted on insomnia in the past, there is still space and need for more work to be done. Literature review revealed that most of the studies focused on detecting insomnia, analyzing factors of insomnia, examined validity of insomnia severity index and other scales for estimating the possibility of insomnia, what type of bad effects insomnia can cause and how insomnia affecting brain leads to problems in daily life. However, not too many exploratory studies were conducted which provided a bigger picture of the factors, effects and brain dysfunctions caused by insomnia disorder.

Chapter 3

Research Methodology

This section involves description of our data collection, hypothesis development and coding procedures as well as our planning.

3.1 Methodology/Requirement Analysis

The section has 3 sub sections, which includes overview, proposed methodology, and functional and non-functional requirements of the research conducted.

3.1.1 Overview

This chapter describes the methodology applied to explore the impact of insomnia on the brain through exploratory analysis. The research methodology involves systematic stages that are interlinked enabling a progressive flow of problem identification, data collection and analysis. The proposed procedure involves determining specific research questions, reviewing relevant literature, and using suitable data analysis methods for obtaining valid results. This framework helps the study to have focus, evidence-based conclusions, and actionable elements.

3.1.2 Proposed Methodology

The section portrays the proposed methodology, in a phased step-by-step‘ process. The primary steps include:
Interpretation and Identification of the Problem: That includes acknowledging the dangers insomnia represents to people's cognitive and neurological well-being. Other aspects of the plan involve spotting alternative research directions.
Literature Review and Direction of the Research: It includes a thorough review of previous studies and publications to establish a theoretical basis and validate the relevance of the research objectives.
Key factors identification and data collection: Primary data collection is conducted through means such as surveys and interviews while secondary data is used from estab-

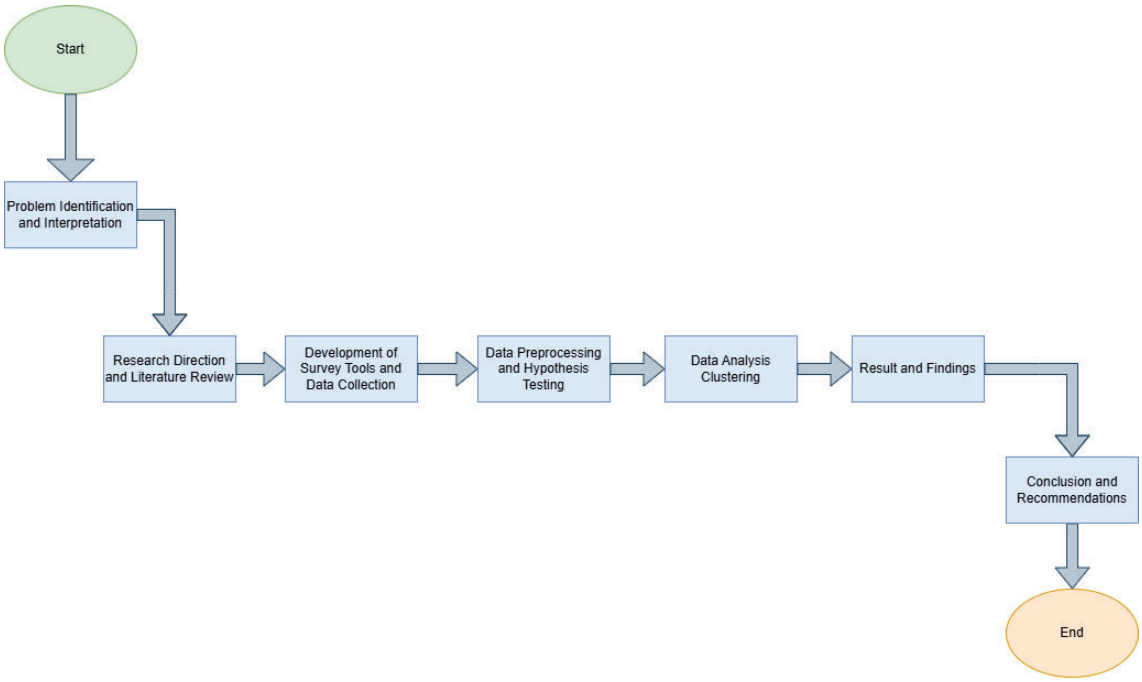

Figure 3.1: Proposed Methodology

lished sources; mapping insomnia symptoms and effects to measurable variables.
Data Analysis and Hypothesis Testing: We applied statistical methods, clustering techniques and hypothesis validation to extract meaningful patterns and insights.
Results and Findings: Results are reported, pertaining to the association of insomnia and its neurologically detrimental effects.
Conclusions and Recommendations: They are then used to propose recommendations that can be applied to lessen the effects of insomnia and explore alternative interventions based on the findings.
The research flow is represented in the diagram (Figure 3.1) and highlights the significance of each process from data gathering to actionable results and recommendations.

3.1.3 Functional and Nonfunctional Requirements

The study's functional and non-functional requirements are:

Functional Requirements:

- Conduct research on insomnia and its impact on a person's daily life to create a survey or questionnaire.
- Leverage clustering, and statistical models to identify the relationships between the factors.
- Describe actionable insights that can help healthcare professionals interpret the effect of insomnia for these patients. content...

Nonfunctional Requirements:

- For the sake of ethics, always ensure anonymity and confidentiality in data collection procedures.
- Computationally efficient → The analytical framework needs to run efficiently, especially with large datasets.
- Findings must be presented using visualization tools to a degree that makes them accessible and understandable.

3.2 Detailed Methodology and Design

This section is dives deep into the details about the methodology that has been implemented for this research.

3.2.1 Hypothesis Development

From previous studies it was observed that total sleep time, sleep onset latency, wake after sleep onset, awakenings after sleep Onset, sleep efficiency, sleep quality (SQ), sleep disturbances, sleep architecture, insomnia etc were used as sleep measurement parameters [28]. Based on these studied parameters the effects that contributes to a person's insomnia were selected like micro-sleep, poor sleep quality, trouble falling asleep, sleep disturbance, daytime sleepiness, feeling of having insomnia, frequent waking at night, restless sleep and variable bedtime etc.
Psychological factors: Rumination [29], mental stress [29, 30], sleep related worry [31], sadness [8], and worry at bedtime [32, 33] are significant psychological factors of insomnia.
Physical factors: Pain [34], chronic chest disease [35] and restless legs [36] are the significant physical factors that can cause insomnia.
Environmental factors: Light disturbance, noise disturbance [37], and jobs with rotating shifts [38] are the strongest environmental factors that lead towards insomnia.
Behavioral factors: Sleep schedule frequency [39], substance before bed [40], and daily nap [41] are most important behavioral factors for insomnia.
The hypothesis is developed based on psychological [29, 30, 31, 32, 33], physical [34, 35, 36], environmental [37, 38] and behavioral factors [39, 40, 41] of insomnia.

3.2.2 Data collection

To collect data for this study, A questionnaire on sleep disorders was used. Data was collected from young adults who were familiar with insomnia. For data collection, quota sampling and snowball sampling techniques were applied. The questionnaire were provided to 603 people, and among them, 256 responded. The dataset had 175 questions

Table 3.1: Hypothesis Table

No.	Hypothesis
H1	The factors of insomnia contribute in individuals in getting little to no sleep
H2	The factors of insomnia amplify poor quality sleep that leads to insomnia.
H3	The factors of insomnia positively affect the trouble of falling asleep which leads to insomnia.
H4	Factors related to insomnia increases frequent night waking that lead toward insomnia
H5	The factors of insomnia increase sleep disturbance that guides toward insomnia.
H6	The is insomnia factors positively affects the perception of insomnia
H7	Factors related to insomnia positively affects restless sleep that leads to insomnia
H8	The factors of insomnia increase variable bedtime that guides toward insomnia

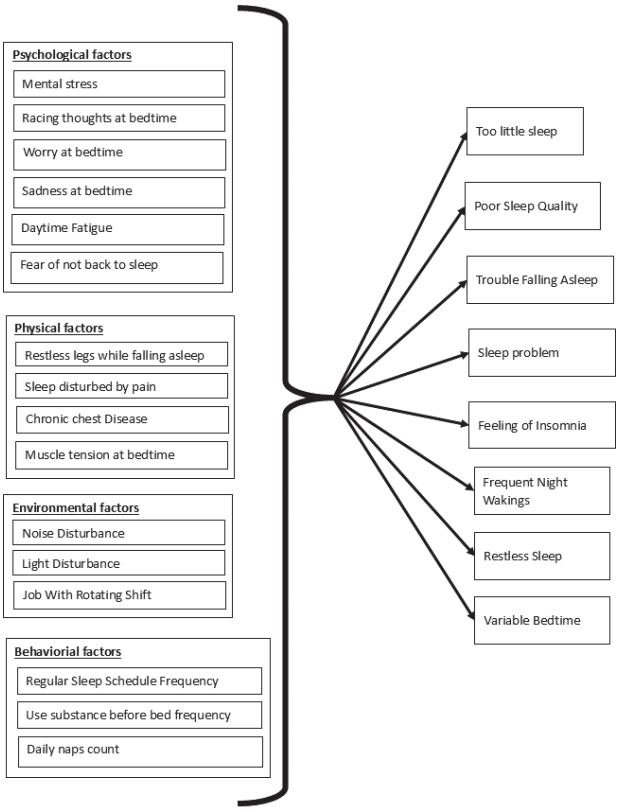

Figure 3.2: Conceptual Model

about sleep disorders. It included the questions about different reasons and factors for multiple sleep-related problems.

Survey procedure: Survey is useful for locating to the appropriate respondents and capturing information reliably and efficiently [42]. In order to, relate the reasons for insomnia with its symptoms and effects the survey was conducted on the young adults from 4 private and public universities of Dhaka, Bangladesh. The survey of this research primarily focused on young working age people who are educated and have acquaintance with insomnia and other sleep disorders.

Selection of universities and survey participants: The survey was conducted at 2 public and 2 private universities in Dhaka. The reason behind choosing Dhaka for data collection is, it being the capital of Bangladesh and the most developed city of Bangladesh that attracts people from all over the country to come here for education. Therefore, the universities of Dhaka, often possess a diversity of students from different districts of Bangladesh. Participants included, individuals from both private and public universities, whom from different backgrounds and statuses. The data were collected from the classrooms of Daffodil International University, hostels of Jahangirnagar University, Sher-E Bangla Agricultural University and campus of City University. Primarily chosen young adults were our main participants in the survey, due to several studies finding high insomnia rate in this age group [43].

University students often remain busy with studies, part-time jobs, and night jobs and they also like to hang out with friends which leads many of them to sleep late at night. Therefore, in this research, they were considered as primary targets. The questionnaire, used to collect was composed in the English language. Therefore, data was collected from only those who know English.

The population, sample and participants: The intended population for this study was educated university students who knew about insomnia. For this survey, the quota sampling and snowball sampling methods were used. In quota sampling, researchers select people of a particular category to conduct their survey. This technique is effective when time is limited and a frame is available [44]. University students were considered as an effective representative of young adults. The wasn't collected from universities through questionnaires but also, they were also asked to share that with their friends, classmates and relatives who are young adults like them. Here, concept of snowball sampling played its role. In snowball sampling, one participant recruits others and then those participants recruit others and this process continues. This method gives access to the hidden population and requires fewer staff to execute [44]. The survey was conducted on these young adults because of several reasons:

University students are familiar with insomnia.

University students have to stay awake till late hours at night due to several reasons.

University students often undergo difficult situations.

The nature of the university were different or heterogeneous. While Daffodil International University and City University were private, Jahangirnagar University and She-E-Bangla

Agricultural University were public. Sher-E-Bangla Agricultural University accommodates students only from agricultural studies while other university has versatile departments. Both male and female students from different departments were included in this study.

Developing and Pre-testing the questionnaire: This research used a survey which administered the factors and effects of sleep disorders on young adults in Bangladesh. The questionnaire for this study was taken from Stanford Healthcare. The questionnaire was used in the detection of some sleep disorders like Sleep Apnea, Narcolepsy, Psychiatric sleep disorder and Periodic limb movement disorder. The reason for selecting this questionnaire in this study was that, the questionnaire was recommended by some biomedical researchers and doctors as it provided a complete picture of ones sleep habits and patterns. A google form was generated based on this questionnaire and only English language was used for this questionnaire as all the participants were educated people and the questionnaire was quite simple to understand. It was a large questionnaire with 175 questions, therefore we shuffled the order of the questionnaire in several segments to ensure that the questions with higher priority stayed ahead. The questionnaire was revised several times to avoid any unintentional spelling or any other kind of mistake. While creating the Google form clarity was maintained in sorting questions and answers. For this study all the question were close ended and participant had to select the answer to his/her honesty.

The pilot study: Pilot study is used by the researchers to define what should be done to improve the efficiency of their research and how they can do it. The pilot study is conducted on a small sized population before conducting a final survey on a large population [45]. Researchers often use pilot studies to assess and determine the process, resource and management for their research [46]. A pilot survey was also conducted in this study to test wording, ordering, readability, understand-ability, organization and layout of the selected questionnaire. 12 people took took part in the pilot study, among whom 10 were boys and 2 were girls. Out of 12 people, 6 filled out the questionnaire and provided neutral feedback regarding the questionnaire which means 50% of the participants who took part in the pilot test thought that it was a decent questionnaire. Among the other six 4 provided mostly positive observation. According to them the questionnaire might be large but it was worthy of trying because it covered almost all the insights related to an individual's sleep. They added that this would be an effective questionnaire to assess the relationship between the factors and effects of insomnia. However, according to two people the questionnaire was quite long and at the end felt a bit monotonous to complete it. Besides they advised on reconsidering some of personal questions as well as questions that require confirmation(snorting) from other people or questions that are not relevant(drowsy at driving) to all people. Their suggestion were taken into consideration and some changes were made to the questions, such as, making few answers not mandatory, which allowed the participants to avoid those if they didn't feel like it. Overall, the reviews were 83% non negative according to the pilot study.

Survey instrument: The final survey was conducted on the google form in the English language. Most of the questions were categorical and had 5 options (ordinal data). All the

questions were closeended and the participants had to simply tick on their answers. The most significant questions were placed on top so that the participants spend most time behind those. The order of the questions was from the chronology of most significant to least significant. In order to keep the participant in comfort and out of hesitation it was made sure that no personal data were collected. Google form was distribute via text and also printed copies of QR that'll take individuals to the link were also distributed freely among the participants.

Items and variables: Researchers can decide which independent variable would do what tasks [47]. In a cause and effect relationship, causes are considered as independent variables and effects are considered as the dependent variables. Researchers can manipulate or categorize the independent variables to manipulate their influence over the target variable [48]. 8 target variables and 15 independent variables were selected based on the reviews of the previous studies conducted on insomnia. Independent variables were used to map to the target variables to detect how strongly they are correlated with each other. The factors responsible for insomnia was used as independent variable and the symptoms and reasons for insomnia was put into target column. Target variables were used to find an insomnia score in insomnia severity scale. Each of the target columns had 5 values based on the severity of the symptoms where 'Never' was considered as the least severe and 'Always' was considered as the most severe stage. The factors that were used in this studies were mostly mentioned on the previous researches and therefore found to be the most significant factors for establishing the relation between the causes and effects of insomnia and the severity score calculation.

Measurement: A five-point Likert scale, with options ranging from 'Never' to 'Always' was used for almost all questions. The options were labelled as '1. Never', '2. Rarely', '3. Sometimes', '4. Usually' and '5. Always' which can be denoted as '1. strongly disagree', '2. disagree', '3.not sure', '4. agree' and '5. strongly agree'.

The survey process: After preparing the questionnaire follow ups an meetings took place with the mentors. Upon approval and corrections mentors were also request to spread the question also. With their help many participants were collected. A small token of appreciation were also provided to the participants. Different university campuses were explored and visited too for collection of data. People taking the survey were provided with contacts for feedback. The research questionnaire received both positive and negative reviews, while most of the reviews were positive.

3.2.3 Establishing Insomnia Scoring Model

Eight effects (dependant variables) were selected by analyzing sleep measurement parameters and based on those effects an insomnia intensity scoring scale was developed. This scale is similar to other sleep measurement scales like Insomnia Severity Index (ISI), Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS) and so on. The highest value of this scale would be 8X4 = 0 and the lowest value would be 8X0 = 0. The values of

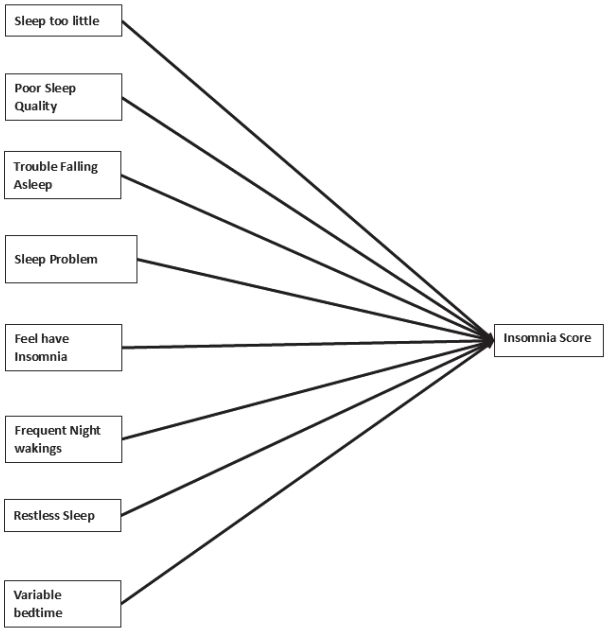

Figure 3.3: Insomnia Scoring Model

each item of the scale would range from 0 to 5 and the label would be '0 for Never', '1 for Rarely', '2 for Sometimes', '3 for Usually' and '4 for Always'. According to participants' response the values of the items would be added.

3.3 Research Plan

Completing a research project requires proper planning and success of a research project to a large extent depends on the execution of the planning. Planning for this research project is as follows:

Phase 1: Literature Review and Planning
Duration: 2 weeks
Key Tasks:
• A complete literature review of the topic insomnia to define the symptoms, consequences on the brain, and exploratory analysis implications.
• Constructing the framework and method for data collection, where the required survey or other data gathering tools would be corresponding to the aims of the research.
• Testing data collection tools beforehand to a) make sure that the tool is clear and captures the needed information.
Phase 2: Data Collection
Duration: 4 weeks

Key Tasks:

• Distributing surveys to participants; specifically targeting individuals suffering from symptoms of insomnia Different people are chosen according to specific criteria to ensure diversity and relevance.

• Gathering responses with standardized and validated instruments (surveys, interviews, or questionnaires). It also makes sure that ethical aspects like consent from the participants are met before data collection.

• Check and solve any problems during the data collection process, e.g. if they did not respond completely or if some questions are unclear.

Phase 3: Data Pre-Processing and Processing

Duration: 2 weeks

Key Tasks:

• Data cleaning involves correcting the data to be complete and more accurate by dealing with missing values, outliers, or inconsistencies to ensure the quality of the data.

• Converting qualitative data into quantitative data (if needed) for the purpose of clustering and/or statistical analysis

• Normalizing and standardizing with respect to the dataset and preprocessing it with respect to the analysis.

Phase 4: Analysis

Duration: 3 weeks

Key Tasks:

• Hypothesis testing: testing if initial assumptions about insomnia's effect on brain is correct

• Using clustering techniques to find patterns in the data, such as segmenting participants by symptom or severity level.

• Validation to evaluate the correctness and confidence of the clustering and analysis outputs.

Phase 5: Reporting

Duration: 3 weeks

Key Tasks:

• Grouping results into a logical and organized format, such as tables, diagrams and other graphs that help visualize the interpretation of the results.

• Prepare the final research paper, recasting findings to define methodologies and conclusions while complying with academic and publication standards.

• Building out visualizations that will help showcase findings, as well as bolster your main points.

3.4 Task Allocation

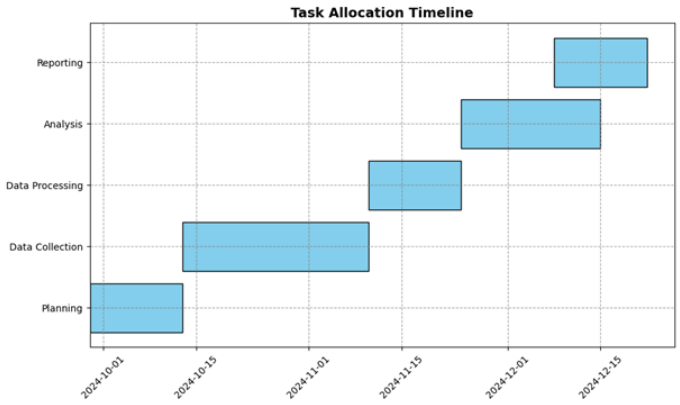

Figure 3.4: Task Allocation Timeline

Planning (October 1, 2024 – October 15, 2024)
Duration: 2 weeks
The objective in this first step is to lay the groundwork by establishing a literature review, creating tools for data collection, and pre-testing them for reliability. That is, the Gantt chart should show the shorter bar relative to the critical work of this process.
Period of Data Collection (October 15, 2024 – November 12, 2024)
Duration: 4 weeks
This longer bar, the corresponding phase in the diagram illustrates the relevance of collecting survey responses or additional data needed from the respondents. This process consumes the most time since it has the most detailed interactions and collecting accurate responses becomes challenging.
Data Processing Phase: (November 12, 2024 – November 26, 2024)
Duration: 2 weeks
The time for cleaning, encoding, and preprocessing the collected data is marked with the shorter bar in this phase. These tasks prepare the data to be clean and structured for analysis, which is essential to keep the results integrity intact.
Analysis Period (November 26, 2024 – December 17, 2024)
Duration: 3 weeks
A medium-length bar was chosen for this phase as this is when we do clustering, perform hypothesis testing and validate the results. Extracting relevant data is essential to gain an insight in to the relationship between insomnia and its effects on the brain.
Reporting (December 17, 2024)
Duration: 3 weeks (Approximately)
The last bar depicts the little research associated with putting jointly results, preparation effects, and creating the finishing investigate report. This provides time to refine and

present the results in a professional light.

3.5 Summary

For gaining our desired output we collected data through a questionnaire and cleaned those data. We developed a hypothetical model to associate the factors of insomnia with the effects that insomnia causes. We also developed an insomnia measurement scale to assess the probability of someone having an insomnia disorder.

Chapter 4

Implementation and Results

This chapter focuses on the technical implementations of the research, by providing details on environment setup, testing and evaluation process and describing results obtained from the exploratory analysis. The chapter first describes the computational environment, which then follows testing and evaluating methodologies which were applied by us. Afterwards the chapter sheds lights on detailed results that we obtained from this study.

4.1 Environment Setup

In order to obtain reliable accuracy and efficiency of data processing, visualization and modeling the research was conducted in a robust computational environment. The tools and libraries that were used for this research are as follows:

Python (Version 3.12.7): Python is a very popular programming language among the data scientists. The language possesses built in libraries and to make data analysis and mathematical problem solving easier. For this reasons Python was used as primary programming language for this research.
Jupyter Notebook: Jupyter Notebook is an interactive platform which allows programmers to execute chunks of code at a single time. This is used widely for data analysis and data visualization. We used Jupyter Notebook interface for running our Python code interactively.
Libraries Used: The following libraries were used for the research.
Pandas: It is a Python library used to work with data collections. It provides programmers with necessary features for data exploration, cleaning, analysis and manipulation. This library was used for data manipulation and cleaning.
NumPy: NumPy is basically a library which is used to work with arrays which has functions for working with linear algebra, Fourier transform and matrices. Full form NumPy is Numerical Python. For numerical analysis in this research, we used NumPy.
Scikit-learn: An open-source and user-friendly Python Library that provides tools for many machine-learning tasks such as, Classification, Regression, Clustering, and many

more. In this research this library was used for machine learning algorithms like K-means clustering, PCA, and hypothesis testing.
Matplotlib/Seaborn: Matplotlib is a library with which users can create variety of visualizations including bar charts, scatter plots, and histograms while Seaborn is a library that is built on top of Matplotlib. Seaborn provides more sophisticated and statistically complex data representations. In this research both of these libraries were used for creating necessary visualizations to represent clustering and variable analysis.
The hardware specifications included:
Processor: AMD Ryzen 5 8640HS
RAM: 16 GB
Operating System: Windows 11 Pro
GPU: NVIDIA GTX 1660 Ti (where applicable).
All the data were processed and stored locally with regular backups to cloud services for security.

4.2 Hypothesis Testing

The chi-square test was used for hypothesis testing which is very efficient in finding relationships between categorical variables. Chi-square statistic of a given dataset is calculated based on the following formula:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \tag{4.1}$$

Then the degree of freedom (row-1) (column-1) is calculated. After that a mathematical function is applied on Chi-Square statistic and degrees of freedom to obtain the p-value. When the p-value is smaller than a chosen significance level (0.05) the null hypothesis is rejected which suggests a significant relation between the variables. P-value always ranges between 0 and 1.

H1 Testing

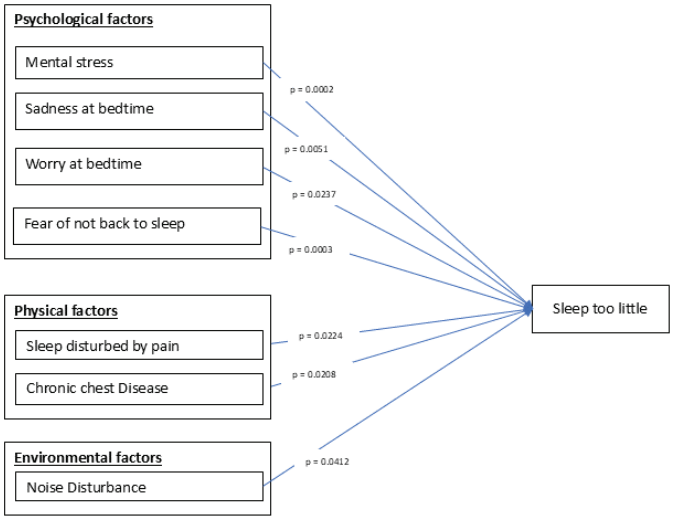

Figure 4.1: Factors Influencing Sleep Too Little.

For sleep too little, p-values of mental stress, sadness at bedtime, worry at bedtime, fear of not getting back to sleep, sleep disturbed by pain, chronic chest disease, and noise disturbance were found to be below 0.05. Therefore, these factors should be considered as responsible for too little sleep.

H2 Testing

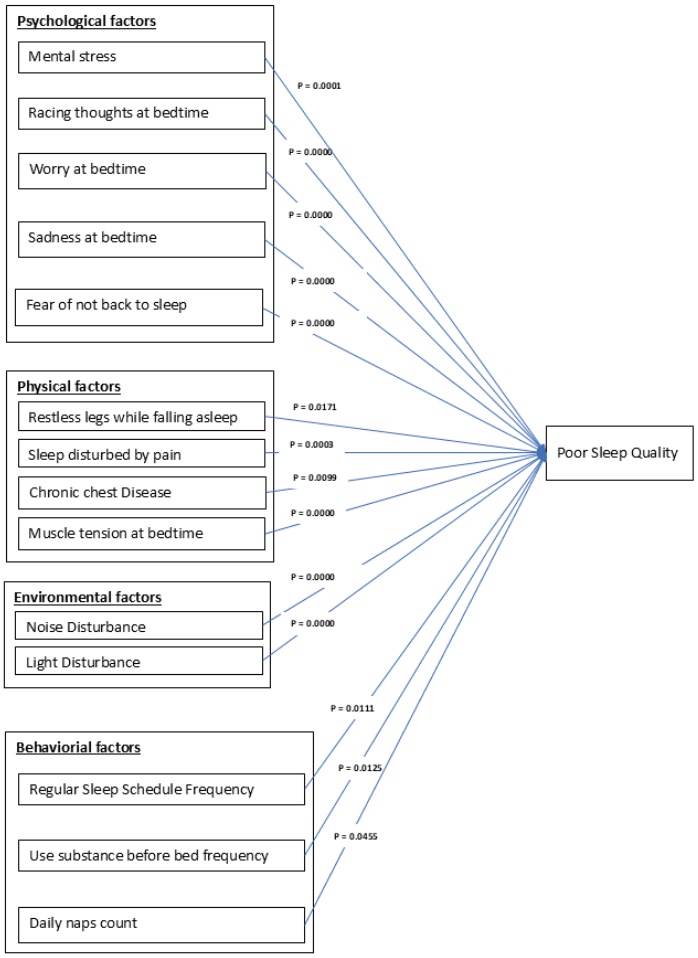

Figure 4.2: Factors Influencing Poor Sleep Quality.

For poor sleep quality, p-values of mental stress, racing thoughts at bedtime, worry at bedtime, fear of not back to sleep, restless legs while falling asleep, sleep disturbed by pain, chronic chest disease, muscle tension at bedtime, noise disturbance, light disturbance, regular sleep schedule frequency, use substance before bed, daily naps count frequency were below 0.05. Therefore, these factors should be considered as responsible for poor sleep quality.

H3 Testing

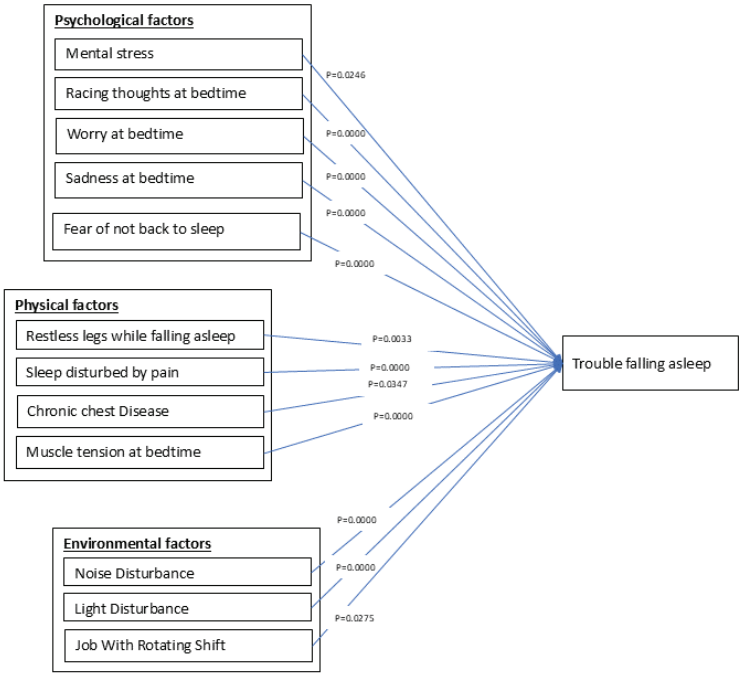

Figure 4.3: Factors Influencing Trouble Falling Asleep.

For trouble falling asleep p -score of mental stress, racing thoughts at bedtime, worry at bedtime, sadness at bedtime, fear of not back to sleep, restless legs while falling asleep, sleep disturbed by pain, chronic chest disease, muscle tension at bedtime, noise disturbance, light disturbance, job with rotating shift were less than 0.05. Therefore these factors have significant correlation with trouble falling asleep.

H4 Testing

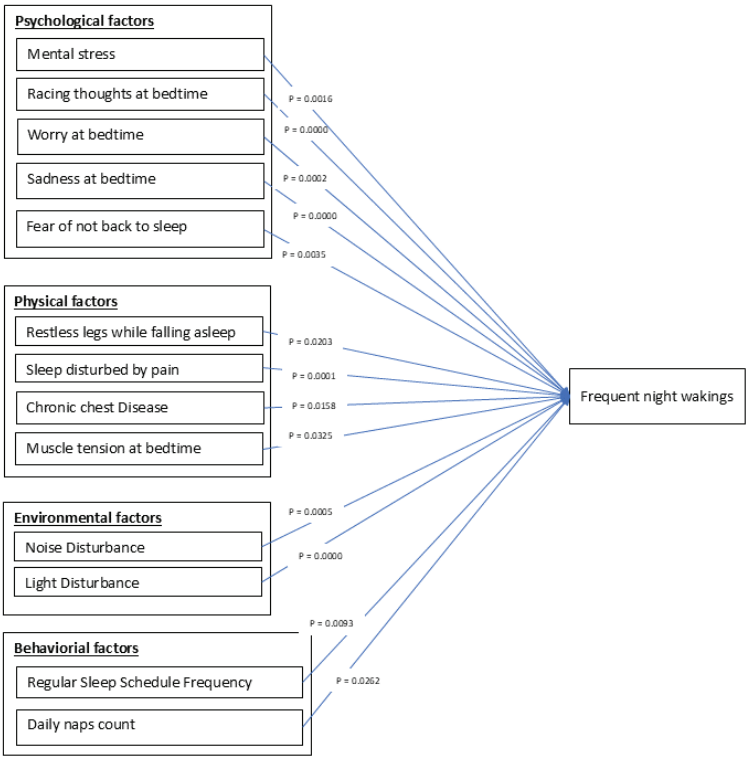

Figure 4.4: Factors Influencing Frequent Night Wakings.

For frequent night wakings, p-values of mental stress, racing thoughts at bedtime, worry at bedtime, sadness at bedtime, fear of not back to sleep, restless legs while falling asleep, sleep disturbed by pain, chronic chest disease, muscle tension at bedtime, noise disturbance, light disturbance, regular sleep schedule frequency, daily naps count were below 0.05. Therefore, these factors should be considered as responsible for frequent night waking.

H5 Testing

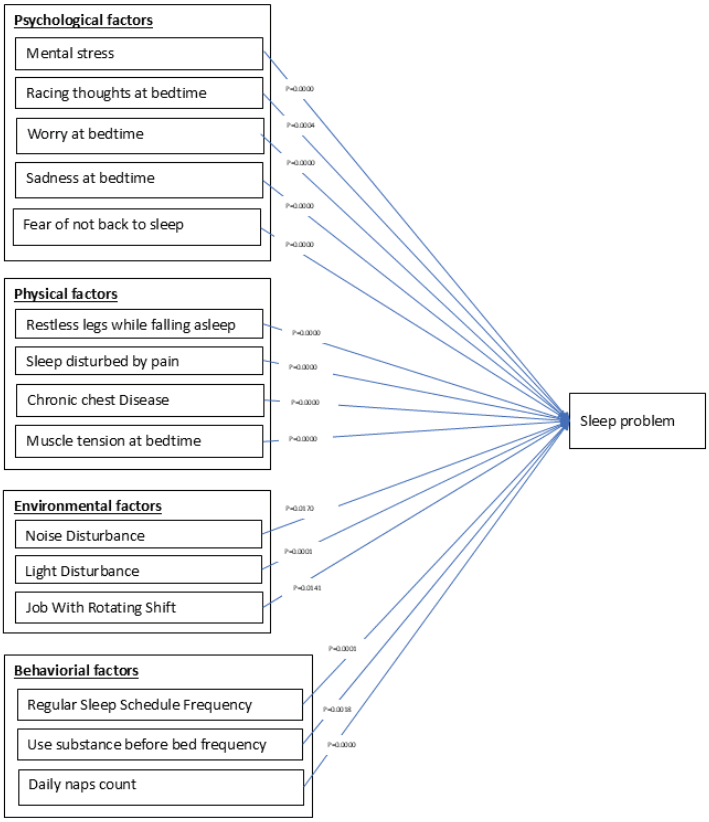

Figure 4.5: Factors Influencing Sleep Problem.

For sleep problem, p-values of mental stress, racing thoughts at bedtime, worry at bedtime, sadness at bedtime, fear of not back to sleep, restless legs while falling asleep, sleep disturbed by pain, chronic chest disease, muscle tension at bedtime, noise disturbance, light disturbance, job with rotating shift, regular sleep schedule frequency, use substance before bed frequency, daily naps count were below 0.05. Therefore, these factors should be considered as responsible for sleep problem.

H6 Testing

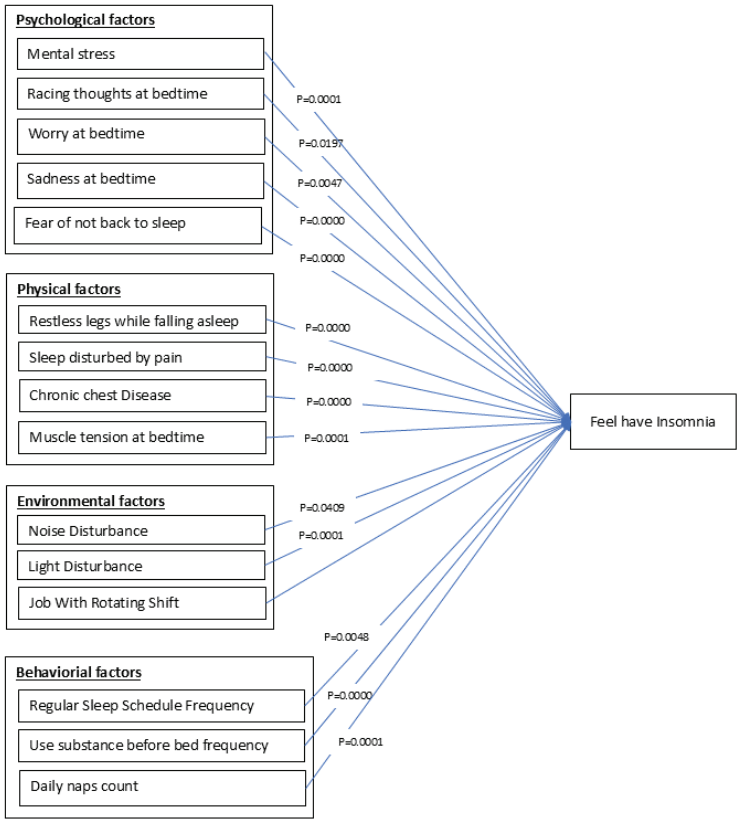

Figure 4.6: Factors Influencing Perception of Insomnia.

For feel have insomnia, p-values of mental stress, racing thoughts at bedtime, worry at bedtime, sadness at bedtime, fear of not back to sleep, restless legs while falling asleep, sleep disturbed by pain, chronic chest disease, muscle tension at bedtime, noise disturbance, light disturbance, job with rotating shift, regular sleep schedule frequency, use substance before bed frequency, daily naps count were below 0.05. Therefore, these factors should be considered as responsible for feel have insomnia.

H7 Testing

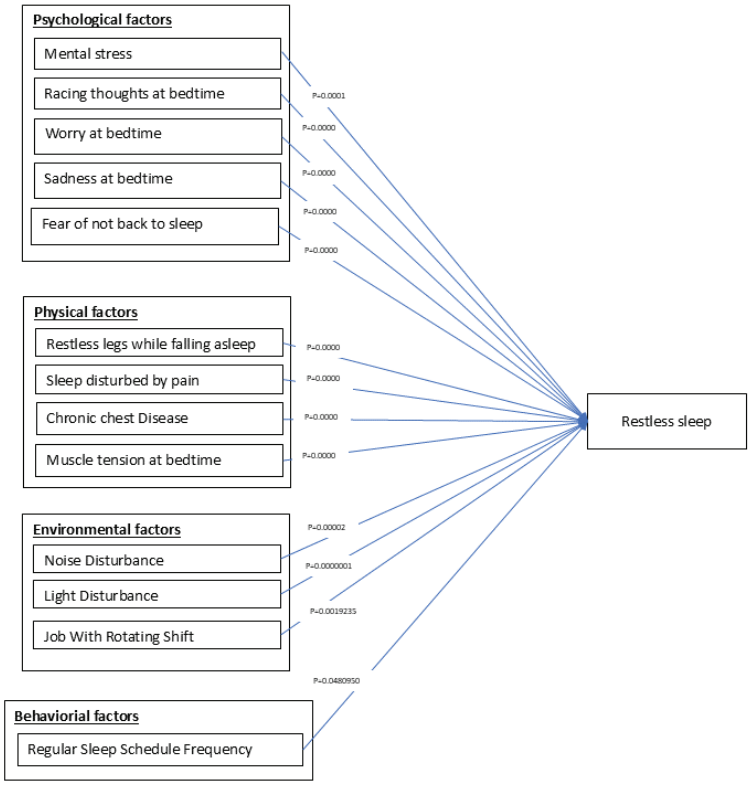

Figure 4.7: Factors Influencing Restless Sleep.

For restless sleep, p-values of mental stress, racing thoughts at bedtime, worry at bedtime, sadness at bedtime, fear of not back to sleep, restless legs while falling asleep, sleep disturbed by pain, chronic chest disease, muscle tension at bedtime, noise disturbance, light disturbance, job with rotating shift and regular sleep schedule frequency were below 0.05. Therefore, these factors should be considered as responsible for restless sleep.

H8 Testing

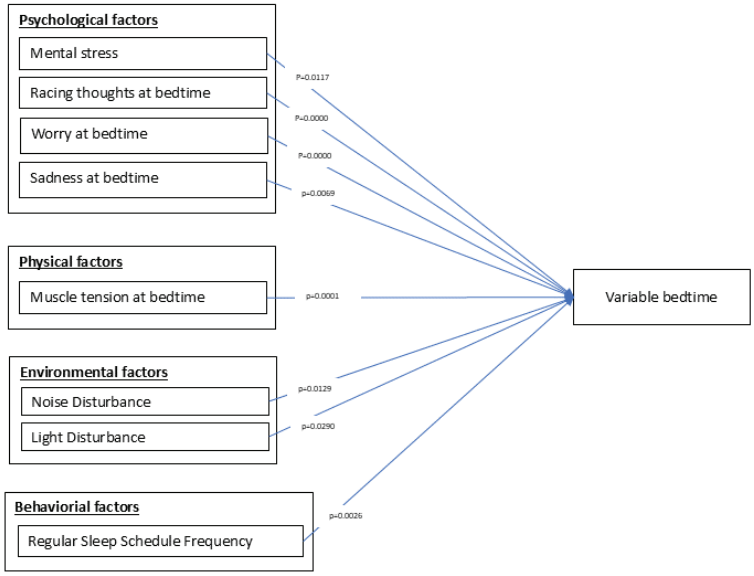

Figure 4.8: Factors Influencing Variable Bedtime.

For restless sleep, p-values of mental stress, racing thoughts at bedtime, worry at bedtime, sadness at bedtime, fear of not back to sleep, restless legs while falling asleep, sleep disturbed by pain, chronic chest disease, muscle tension at bedtime, noise disturbance, light disturbance, job with rotating shift and regular sleep schedule frequency were below 0.05. Therefore, these factors should be considered as responsible for restless sleep.

4.3 Results and Discussion

The result of the analysis shed light to many critical patterns and associations regarding insomnia.

Clustering analysis (Result and Explanation)

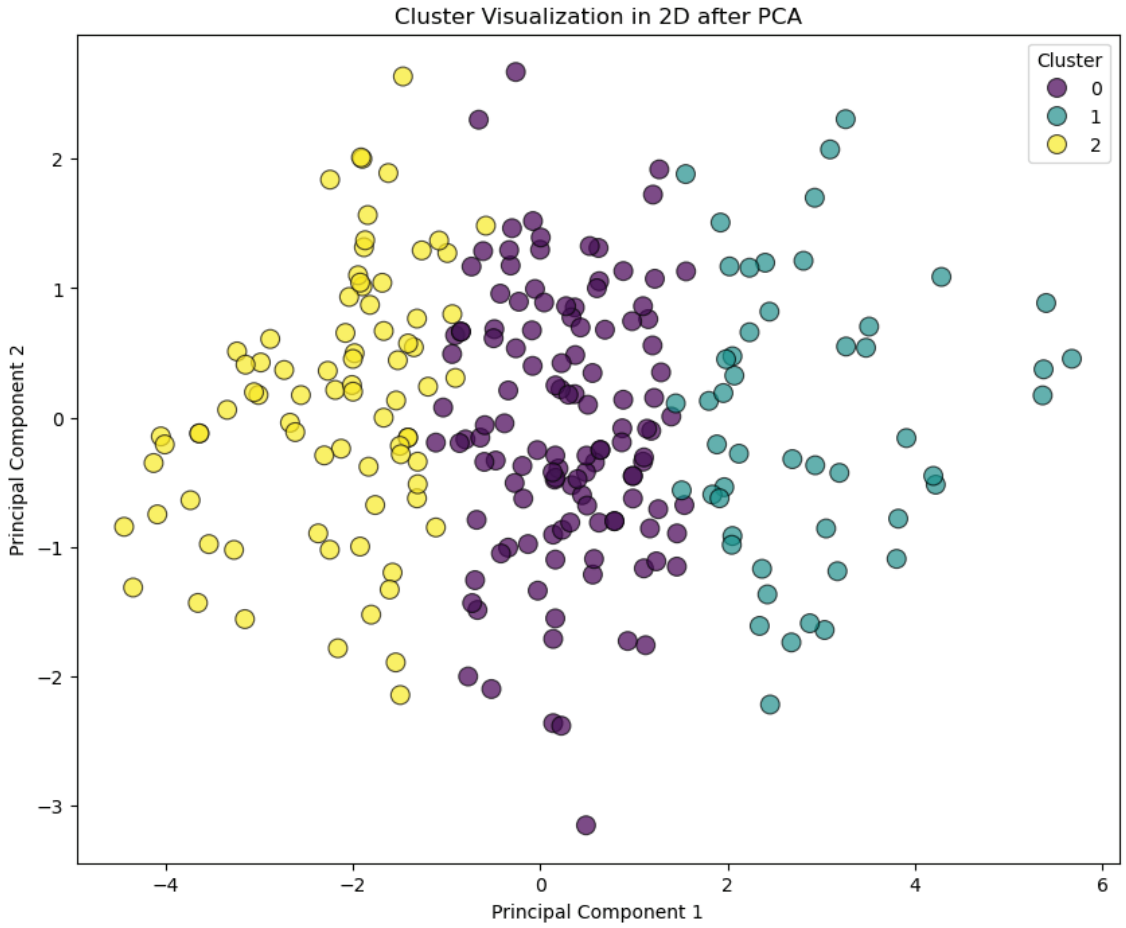

Figure 4.9: Cluster Visualization of Insomnia Patterns Using PCA for Dimensionality Reduction.

The clustering algorithm grouped participants into three different clusters based on similar insomnia patterns. In above graph, the X-Axis represents Insomnia Score while the Y-Axis represents individuals with a specific insomnia score. On X-Axis we have Principal Component 1 and on Y-Axis we have Principal Component 2. The graph shows people with moderate insomnia symptoms/traits with Purple (Cluster 0), Mild insomnia symptoms/traits with Yellow (Cluster 2) which is showing a very little overlap with both mild and severe cases, Severe insomnia symptoms/traits with Teal (Cluster 1).

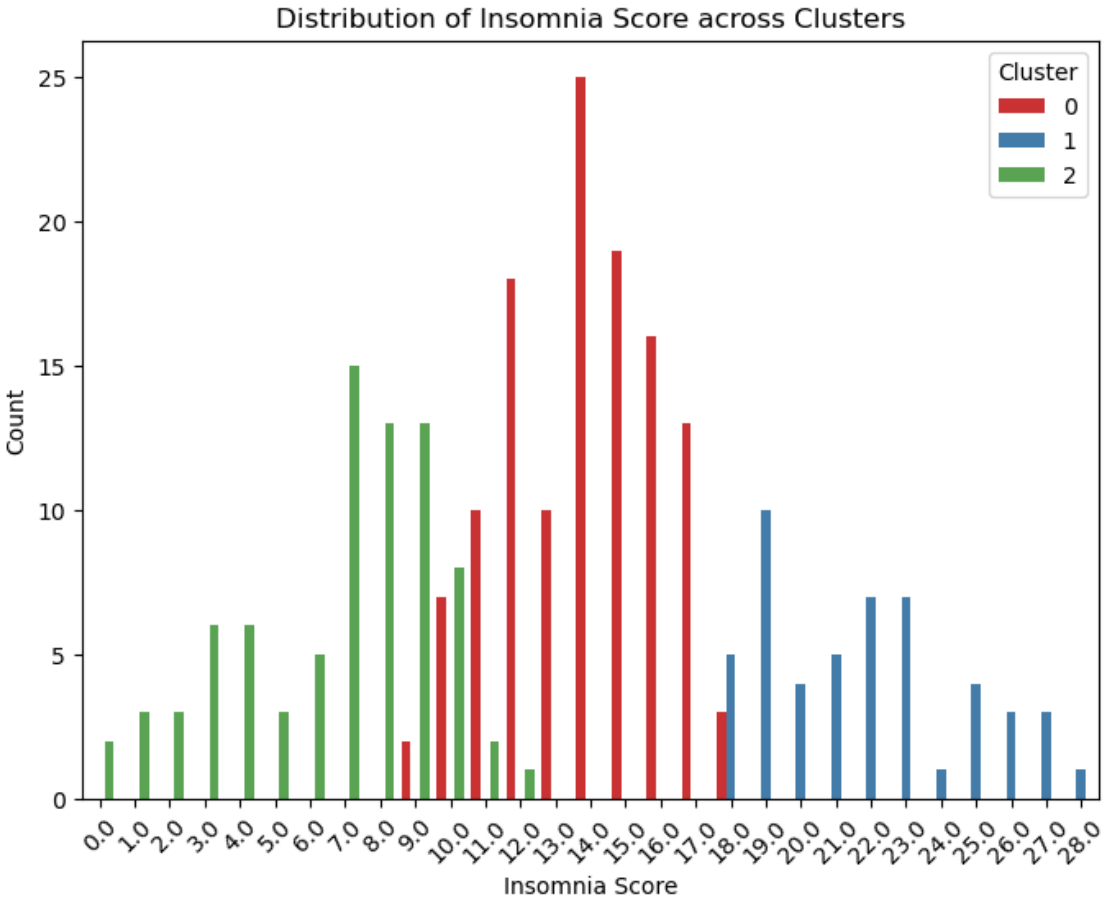

Figure 4.10: Distribution of Insomnia Scores Across Identified Clusters

The X-Axis in this graph represents calculated insomnia score (Severity of Insomnia) from low to high, while the Y-Axis represents the count of individuals who have certain types of insomnia severity. The color red (Cluster 0) represents population with moderate insomnia score, while the color green (Cluster 2) represents population with mild to no insomnia and the color blue (Cluster) represents population with high insomnia score (sever insomnia). Moderate insomnia score is the most common here as Cluster 0 peaks around 14. Which means on a randomly picked population among young adults, most of the people will somehow have moderate insomnia scores. We can observe some overlaps between clusters. For example: Score 12-14 include bot cluster 0 and cluster 2, while score 18-20 are shared by cluster 0 and 1. This overlap is very natural as severity of insomnia due to many factors is actually a spectrum.

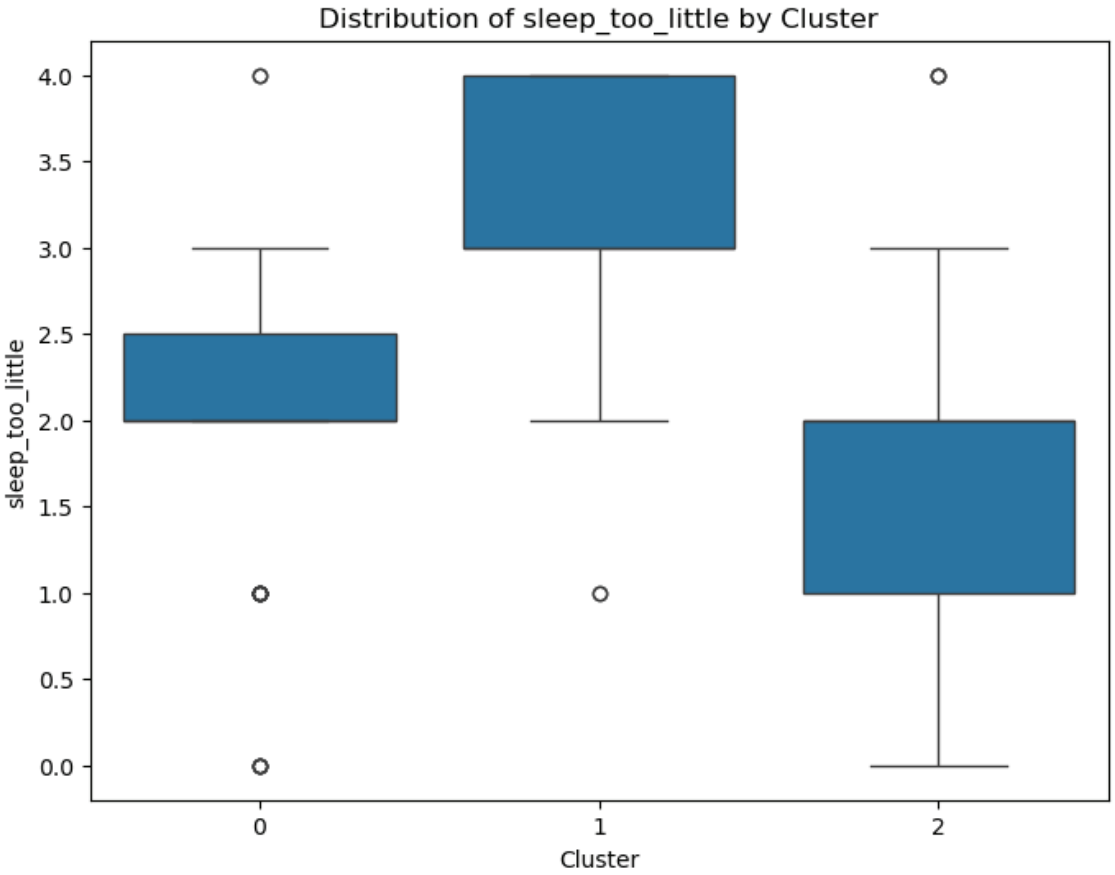

Figure 4.11: Distribution of 'Sleep Too Little' Scores Across Clusters

The box plot for cluster 0 displays low median with high IQR (Inter Quartile Range), suggesting the group reporting lower level of sleeping too little. We can see highest median and widest IQR in Cluster 1, which means this group experiences most variability in sleeping too little. The graph of cluster 2 shows little smaller median than cluster 1 with less variability than cluster 0 and 1.

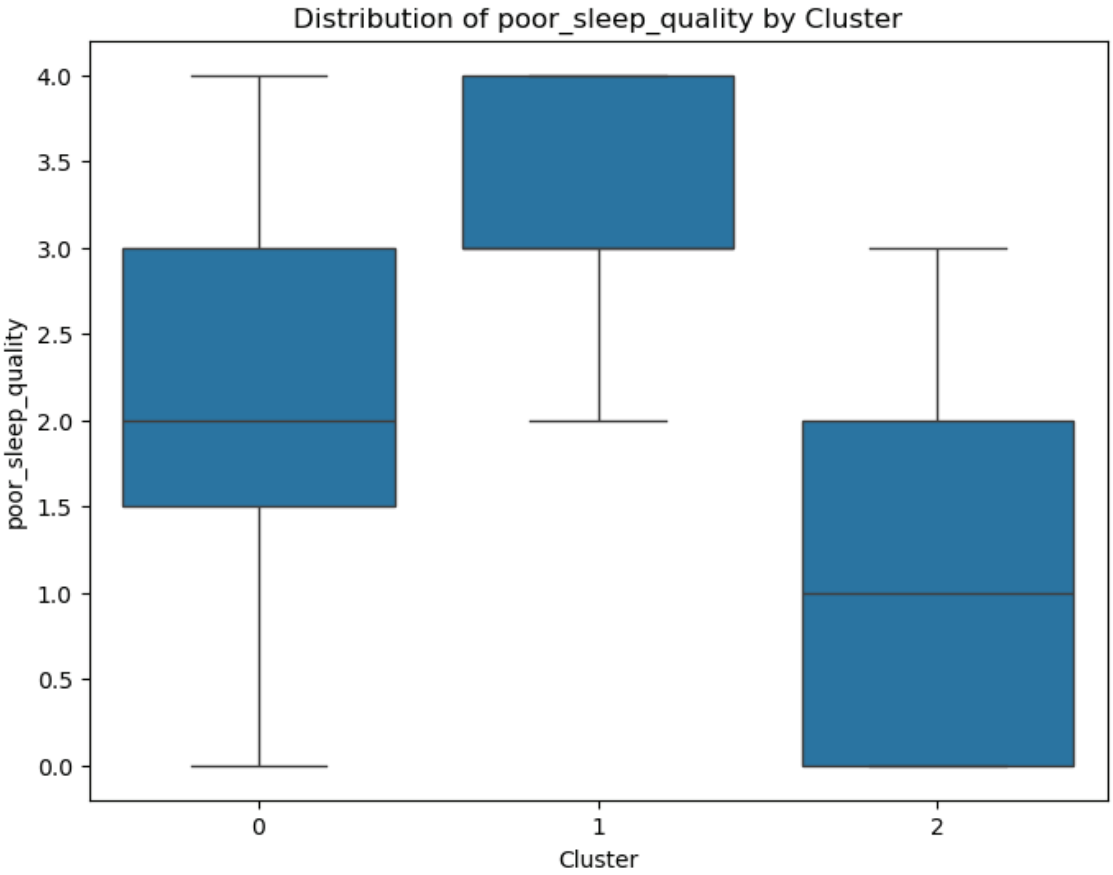

Figure 4.12: Distribution of 'Poor Sleep Quality' Scores Across Clusters

We can observe a moderate median with a wide IQR, meaning more variability with sleep quality in cluster 0. It is clear that cluster 1 has the highest median which means this group of population often experience poorest sleep quality. Cluster 2 are basically individuals with 'quality sleep' based on the box plot as it's showing lower median along with narrower IQR.

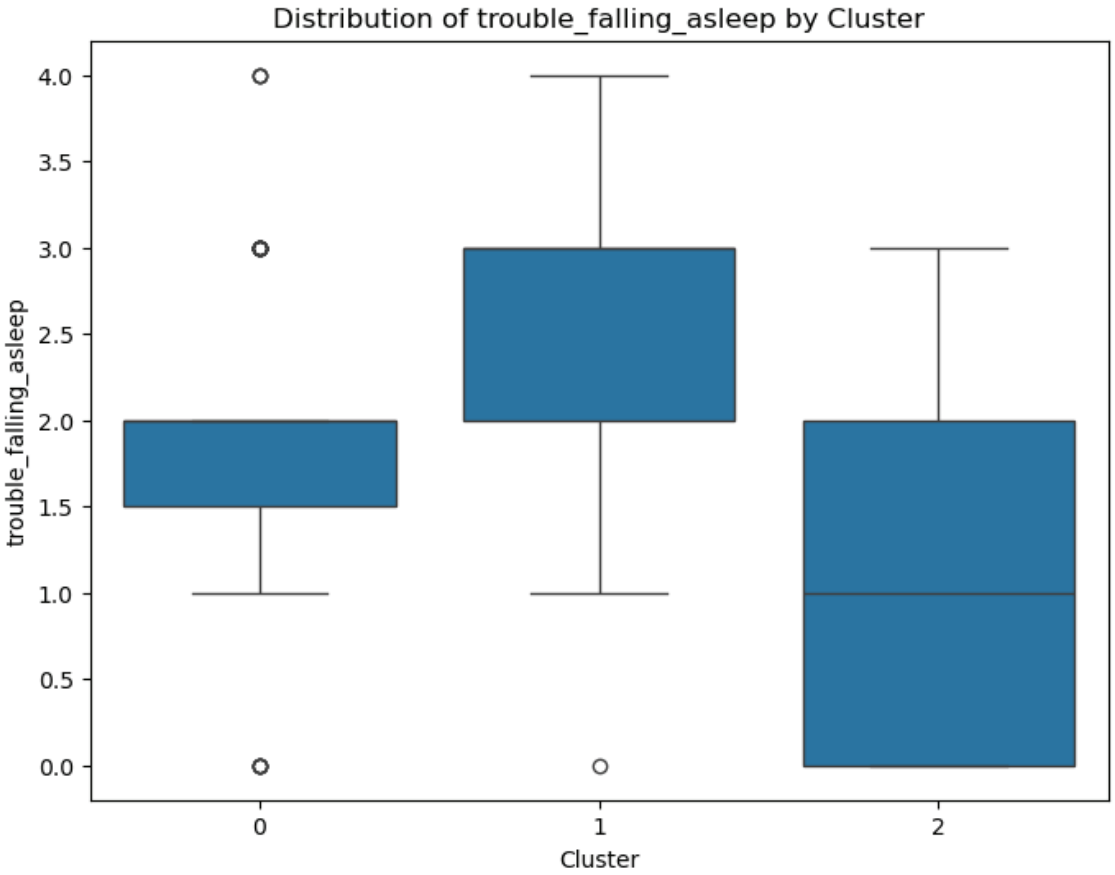

Figure 4.13: Distribution of 'Trouble Falling Asleep' Scores Across Clusters

We can see low median, which means people usually don't have problems with falling asleep in cluster 0. Cluster 1 with highest mean median and largest IQR, explain that this cluster of population experiences highest difficulty in falling asleep. Plot of cluster 2 states a lower variability than Cluster 1 with a moderate median.

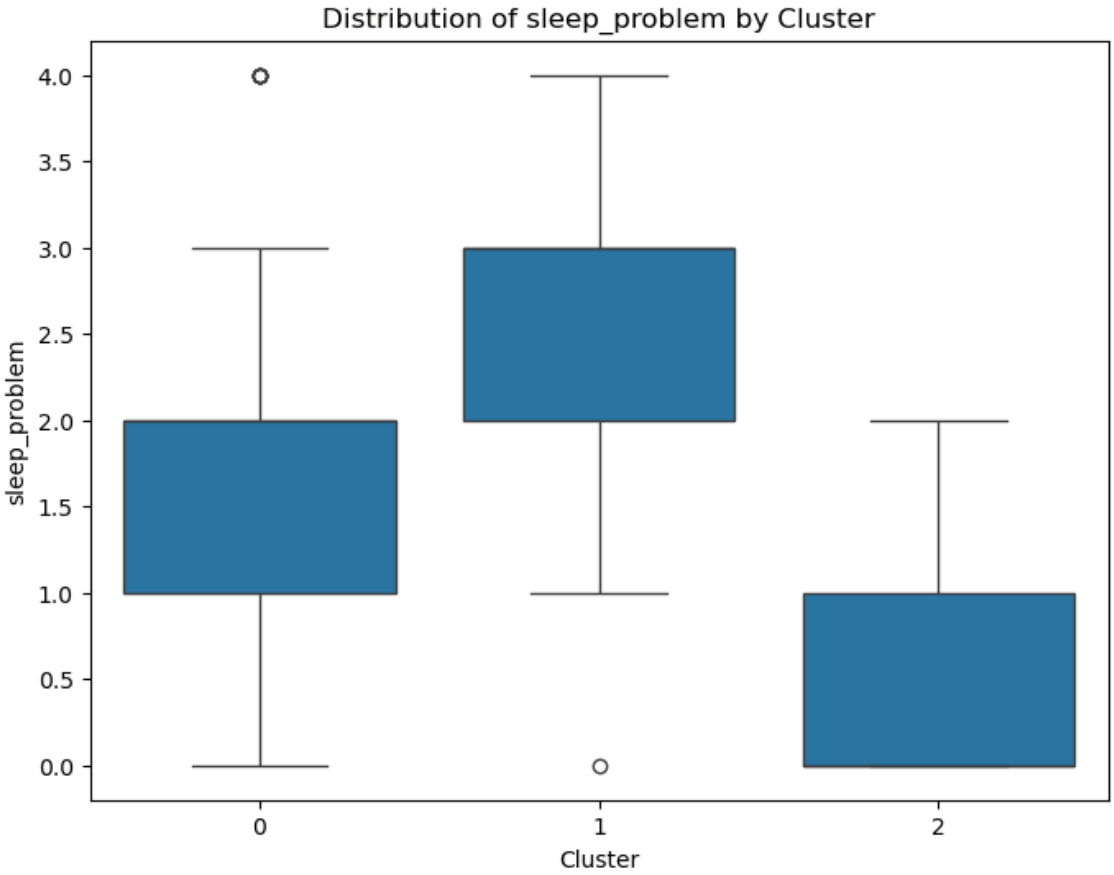

Figure 4.14: Distribution of 'Sleep Problem' Scores Across Clusters

Cluster 0 can be interpreted as moderate level of sleep problems with some existing outliers while, Cluster 1 has the highest median, which indicates that this group of people struggle from problem with their sleep the most. Cluster 2 here This displays lowest level of sleep problems on an average.

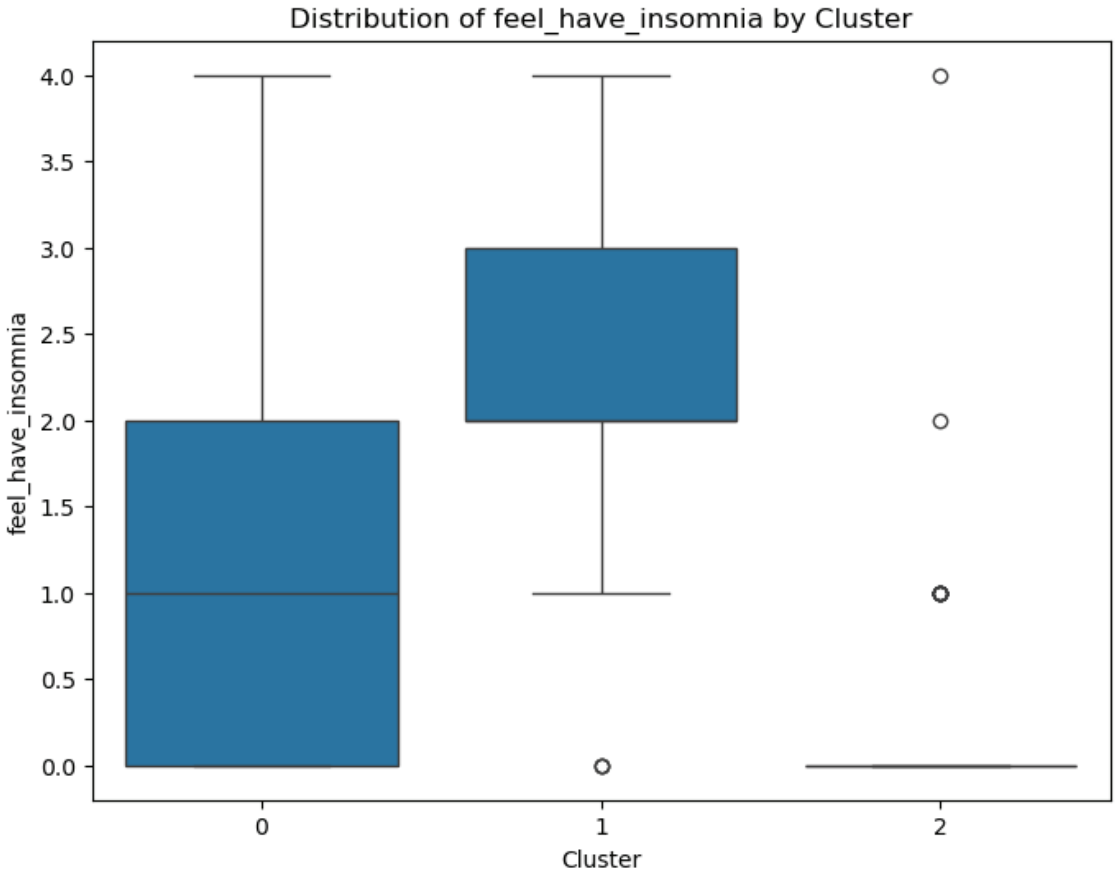

Figure 4.15: Distribution of 'Insomnia Perception' Scores Across Clusters

Cluster 0 box Plot indicates that this cluster reports low levels of self-perceived insomnia. Cluster 1 shows significant amount of self-perceived insomnia with the highest median and IQR. Cluster 2 Reports minimal self-perception of insomnia.

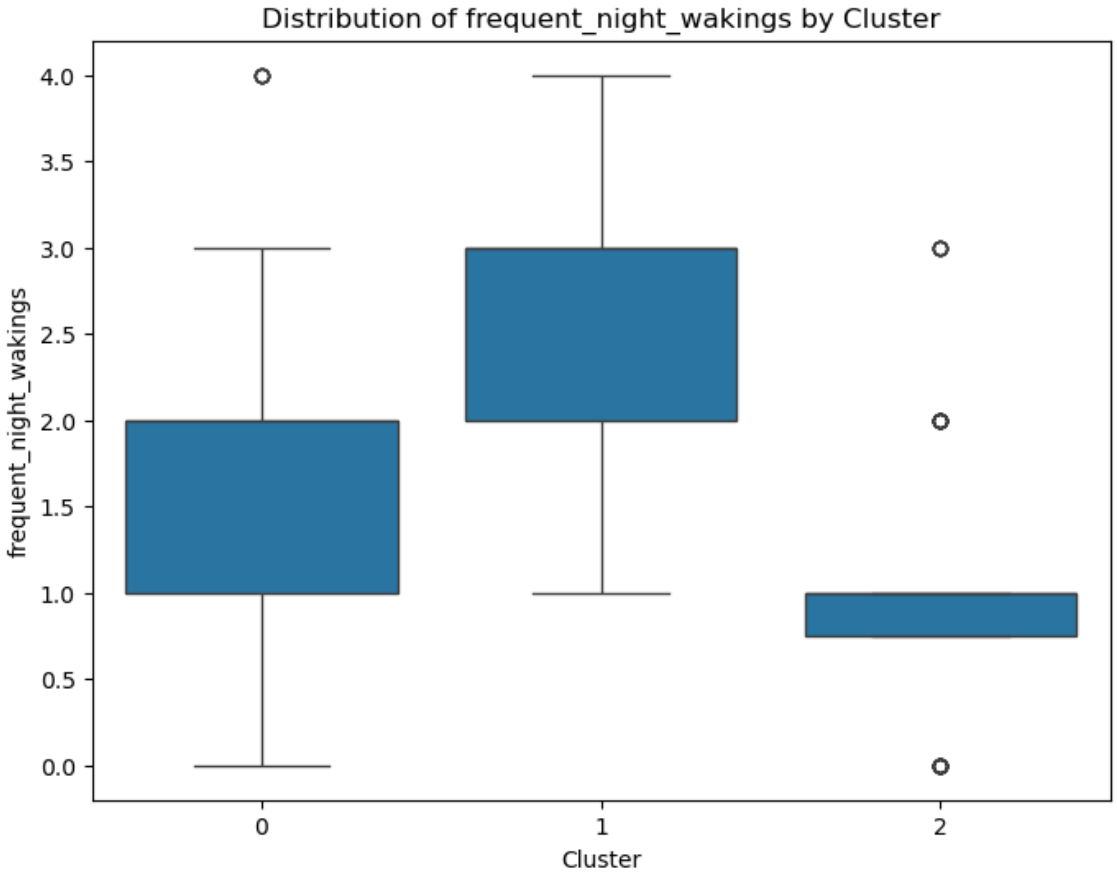

Figure 4.16: Distribution of 'Frequent Night Wakings' Scores Across Clusters

The box plot shows that Cluster 0 Experiences moderate amount of frequent night wakings while, the cluster 1 shows significant disruptions in sleep can be interpreted from this cluster as this has the highest variability and median. From cluster 2 We can interpret consistent low levels of night wakings from this plot, as it displays low median and small range.

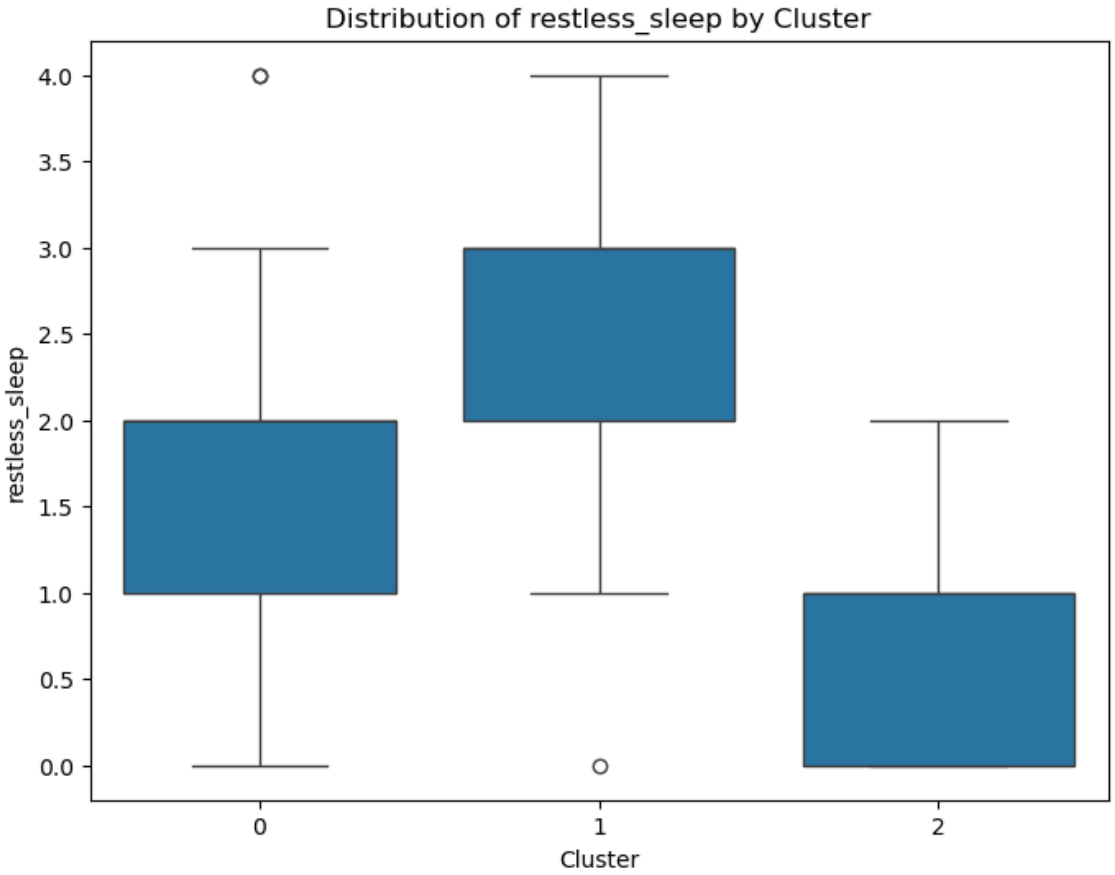

Figure 4.17: Distribution of 'Restless Sleep' Scores Across Clusters

Cluster 0 box Plot indicates that this cluster reports moderate levels of restless sleep. Cluster 1 shows highest levels of restless sleep among participants with the highest median and IQR. Cluster 2 Reports minimal self-perception of insomnia.

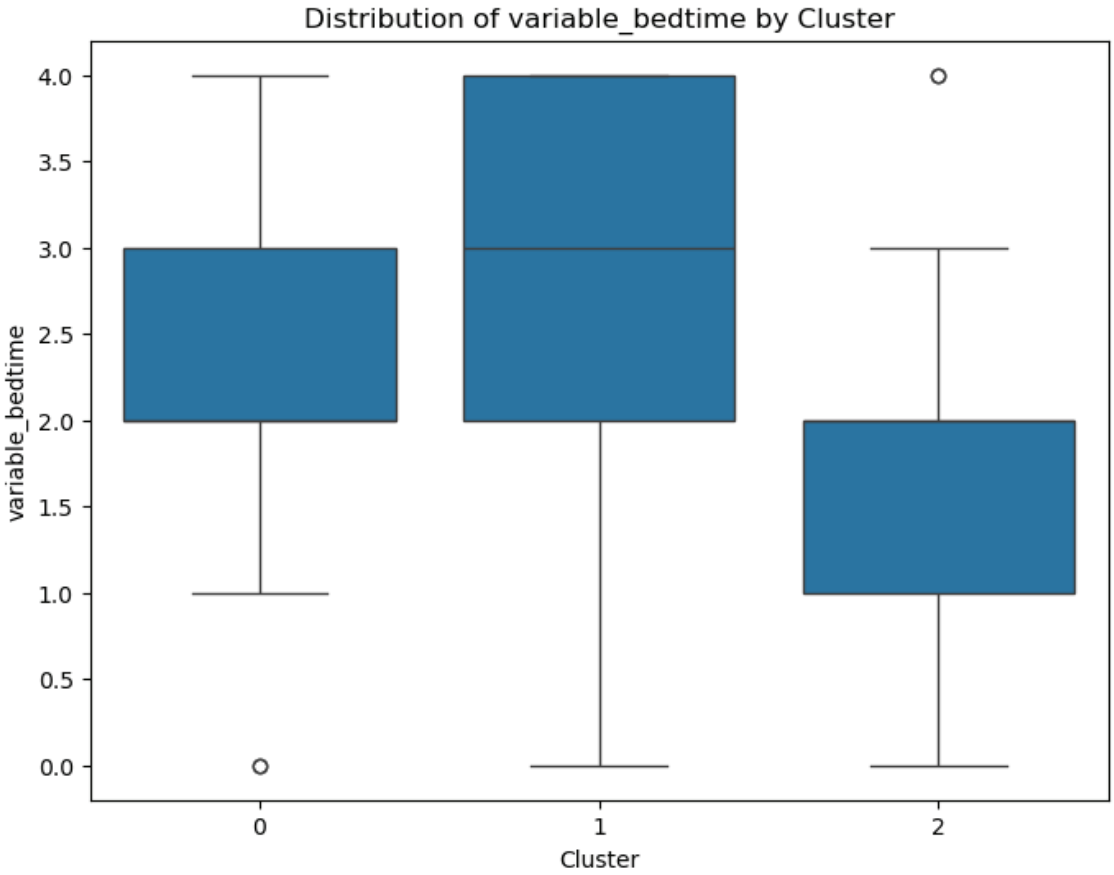

Figure 4.18: Distribution of 'Variable Bedtime' Scores Across Clusters

The plot shows that bedtime variability is moderate in cluster 0. Meanwhile, Cluster 1: Indicates irregular sleep schedules displaying highest levels of variability in bedtime. On the other hand, Cluster 2: Indicates most regular sleep schedules in this group as it has the lowest median.

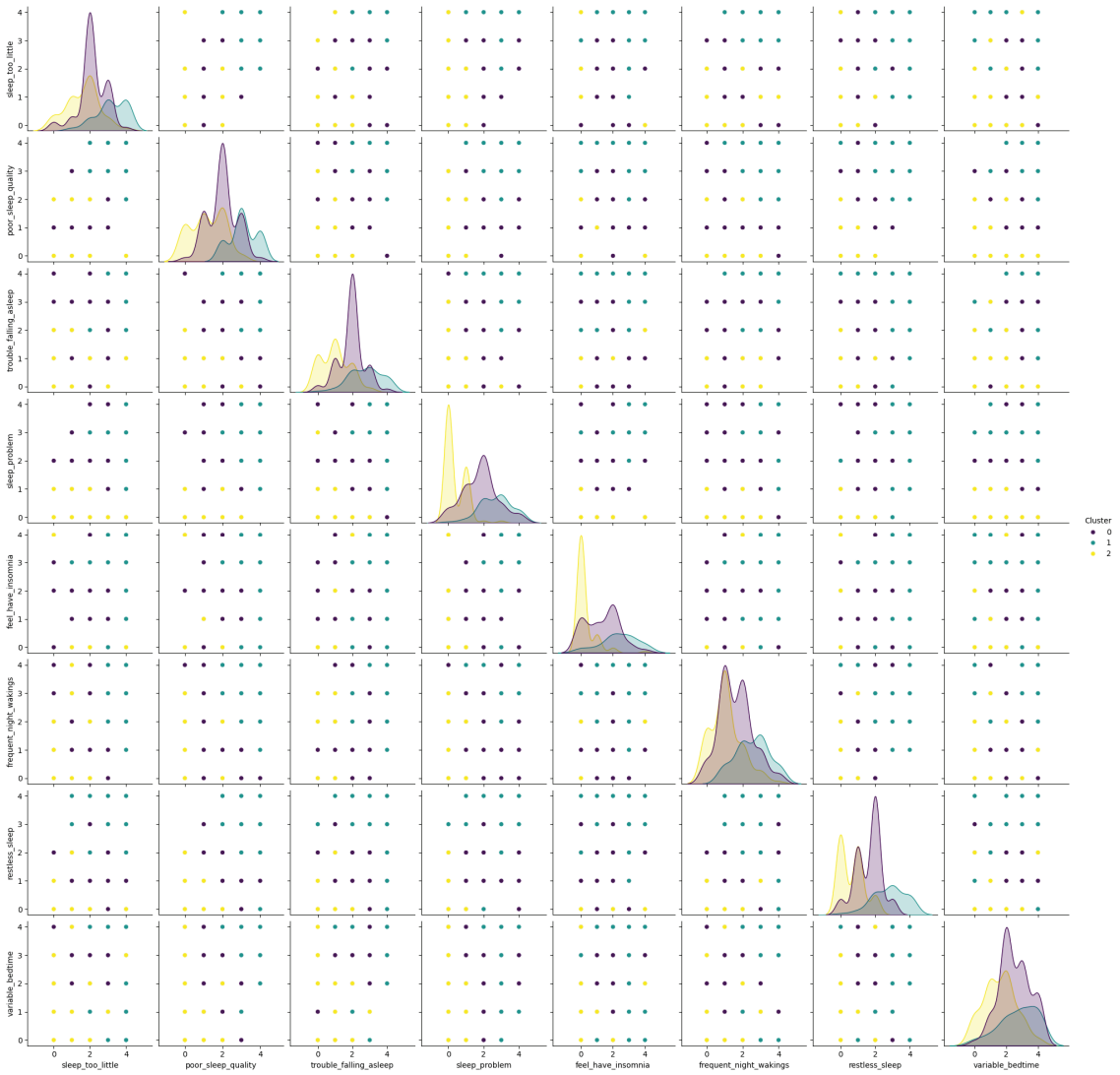

Figure 4.19: Distribution of 'Variable Bedtime' Scores Across Clusters

This pair plot shows distribution of insomnia-related variables across 3 clusters in the 2D plane.

In cluster 0, individuals show minimum symptoms of insomnia, which is seen as low density in fields like 'trouble_falling_asleep' and 'poor_sleep_quality.' Meanwhile, cluster 1 demonstrates the highest densities, corresponding to severe insomnia symptoms on a range of variables. And, finally, cluster 2 demonstrates moderate symptoms.

We can see some strong associations between variable pairs (e.g., 'restless_sleep' and 'frequent_night_wakings' in 1). This clustering analysis reveals the various expressions of insomnia and underscores the necessity of tailoring interventions to each level of severity.

Distribution of variable across the insomnia score

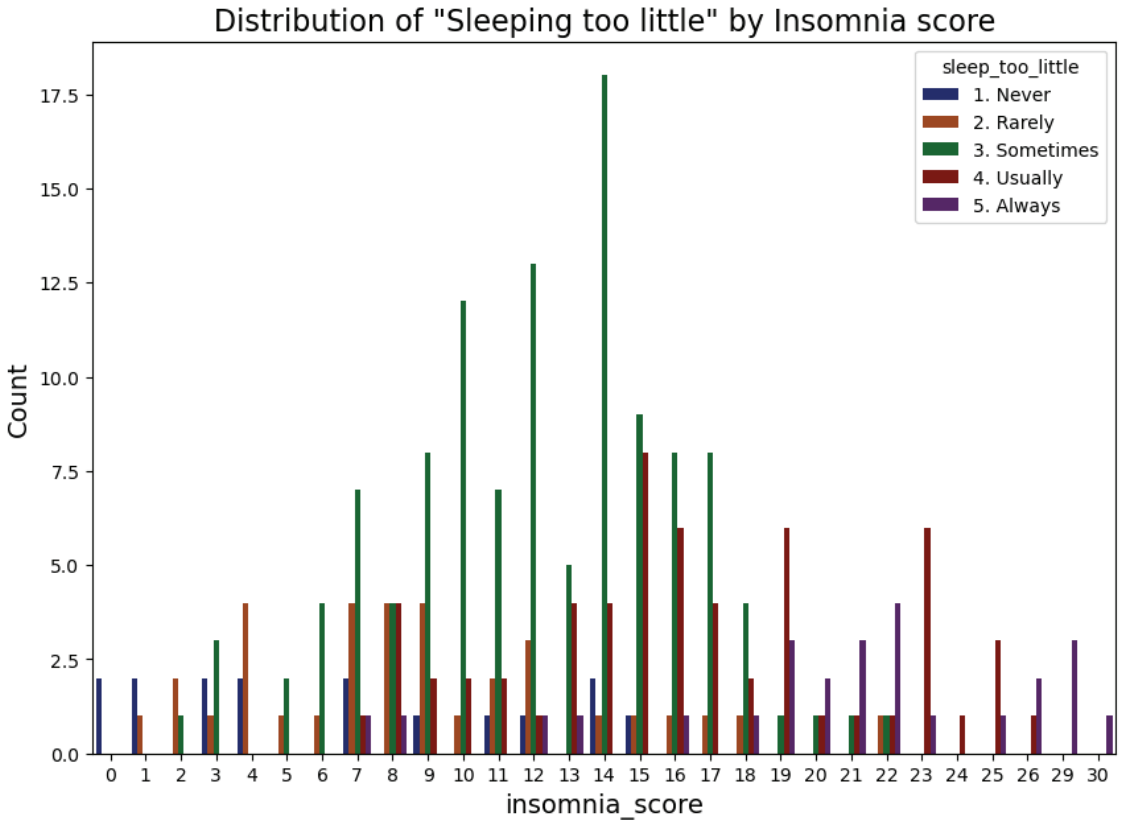

Figure 4.20: Distribution of 'Sleeping Too Little' Frequency by Insomnia Score

The graph plots insomnia scores on x-axis which basically means severity of insomnia. The y-axis represents the height of count of observations for corresponding combinations of 'Insomnia Score' and individuals sleeping too little. The graph clearly displays that "3. Sometimes" is the most frequent response here. Which means individuals who report moderate insomnia occasionally deal with sleeping too little. We can see that higher insomnia has "Usually" and "Always" as response. Which means severity of insomnia is strongly associated with sleeping too little. It can also be interpreted that people with low Insomnia score doesn't generally report sleeping too little.

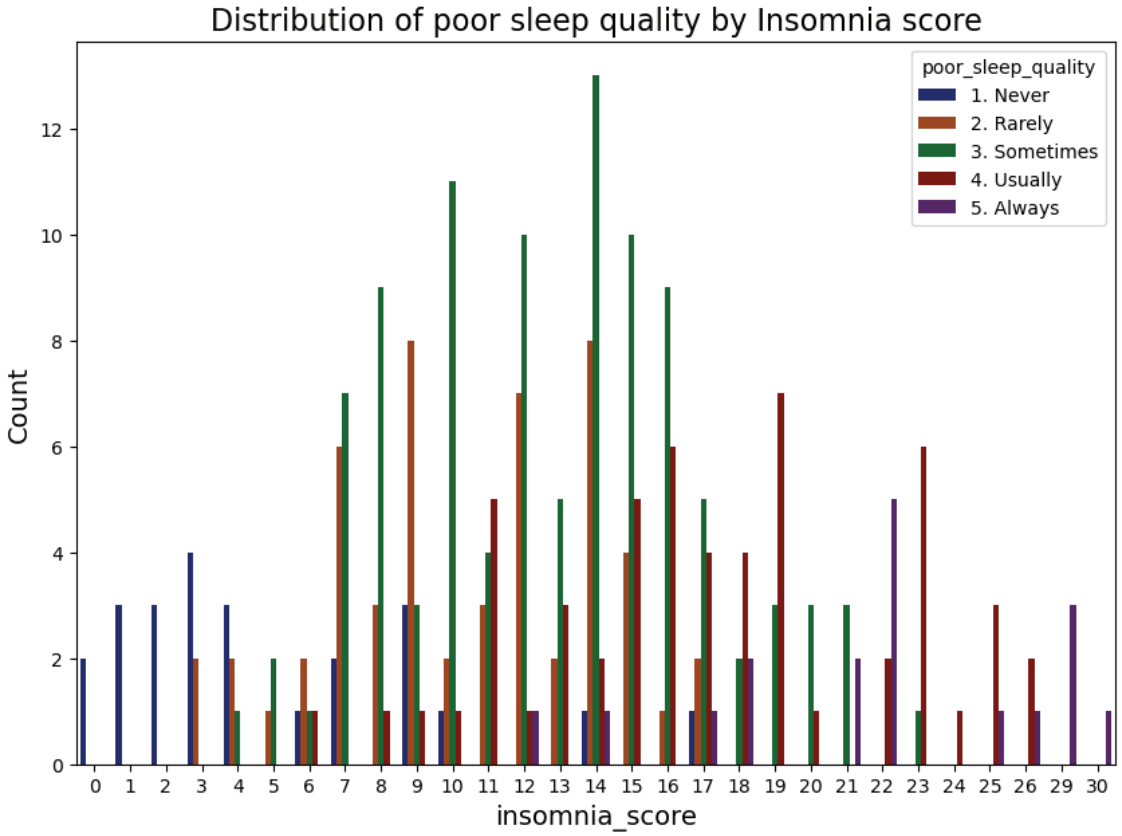

Figure 4.21: Distribution of Poor Sleep Quality Frequency by Insomnia Score

The graph shows that, people who have low Insomnia Score (1-10) doesn't usually report Poor Sleep Quality. As we move forward in observation, we can see individuals are reporting that they sometimes have poor sleep quality. This is the most common response in this graph. It is clear that, people who sometime suffers from poor sleep quality has a moderate insomnia score (10-16). If we move further in the observation, insomnia score increases and we can see more responses like, "Usually" and "Always". This means individuals having higher Insomnia score often report poor sleep quality.

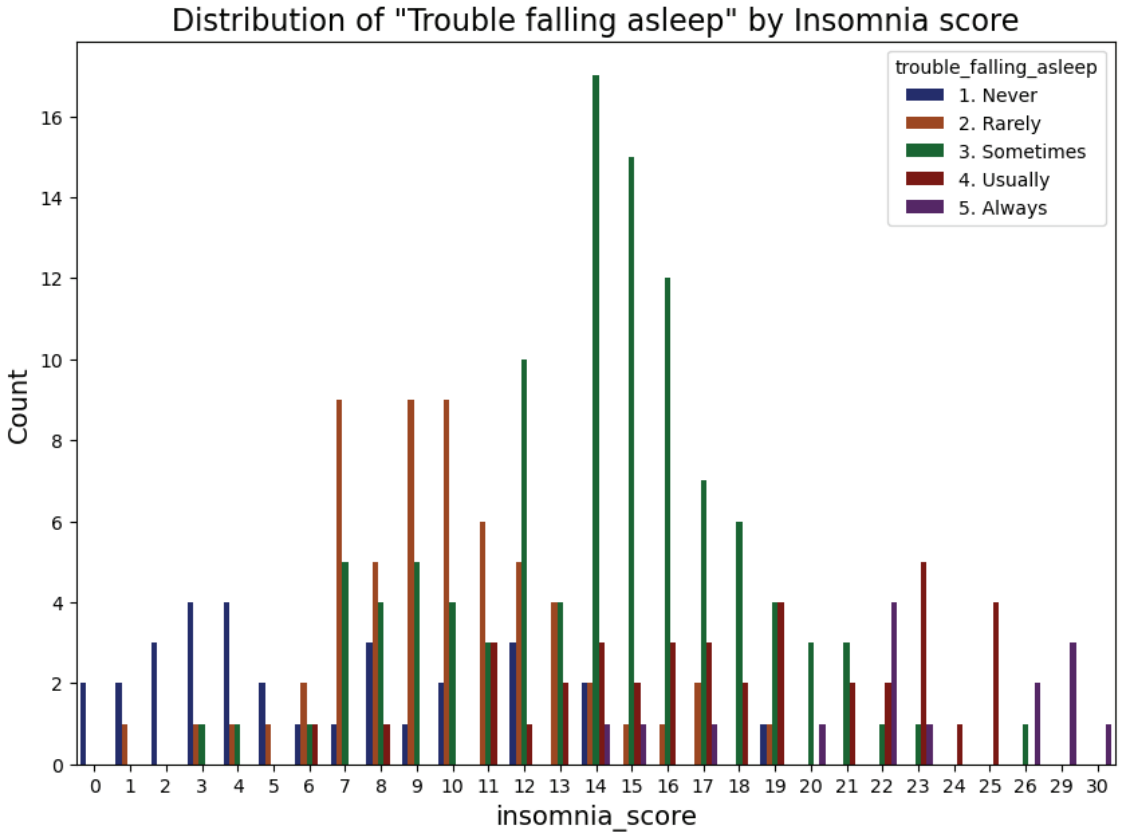

Figure 4.22: Distribution of Trouble Falling Asleep Frequency by Insomnia Score

In this graph, we can see that people with low insomnia score (0-10) rarely report trouble falling asleep hence this region is dominated by "Never" and "Rarely" responses. Moderate insomnia score region (10-16) is dominated by "Sometimes" and "Usually" responses. Which means individuals who have moderate insomnia score report occasionally report trouble falling asleep. We can see further, that trouble falling asleep issue becomes more consistent as insomnia severity increases. And individuals with higher insomnia score (20-30) often reports difficulty falling asleep.

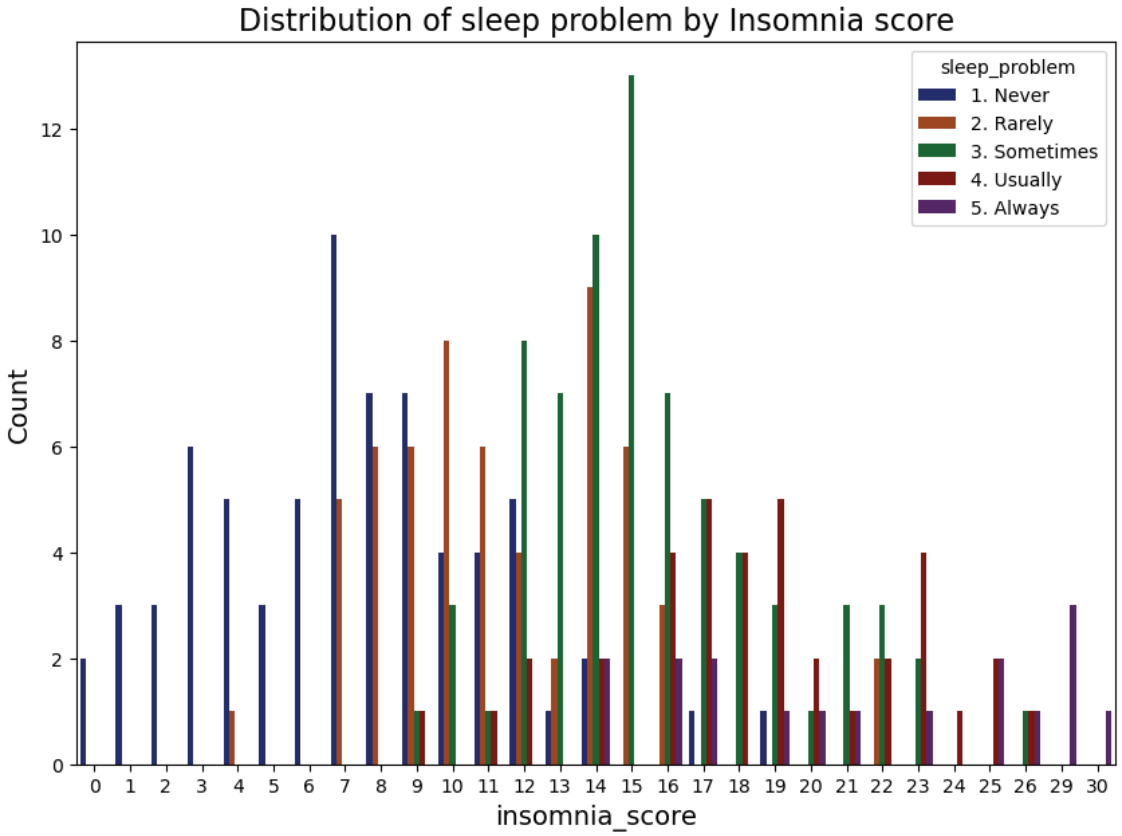

Figure 4.23: Distribution of Sleep Problem Frequency by Insomnia Score

The graph shows that low insomnia score (0-10) individuals rarely report problem with their sleep. The response in this region is dominated by "Never" and "Rarely". Individuals who have moderate insomnia score (10-16) occasionally report problem with their sleep. As we move forward in this chart, we can clearly an increase in "Usually" and "Always" responses. This indicates that as the insomnia score increases people feel sleep problem more and more. We can also observe the fact that, people with high Insomnia score often report sleep problem.

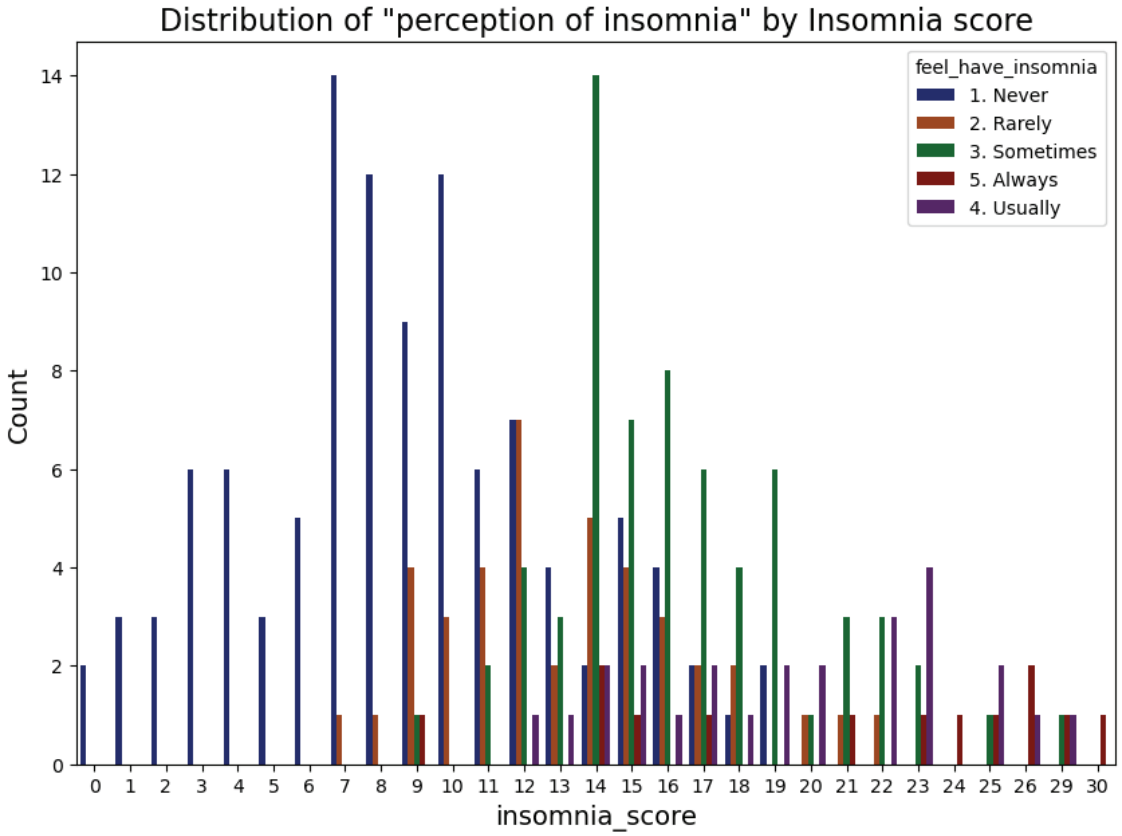

Figure 4.24: Distribution of Perception of Insomnia Frequency by Insomnia Score

We can observe from the graph that, at low insomnia score (0-10) we can observe no perception of insomnia. Then, at moderate insomnia score (10-16) people perceive insomnia sometimes. This is interesting because even they have moderate score, they usually perceive it sometimes. This indicates lack of self-awareness during moderate insomnia. We can also see that; at high insomnia score (20 and above scores) people usually perceive they have insomnia.

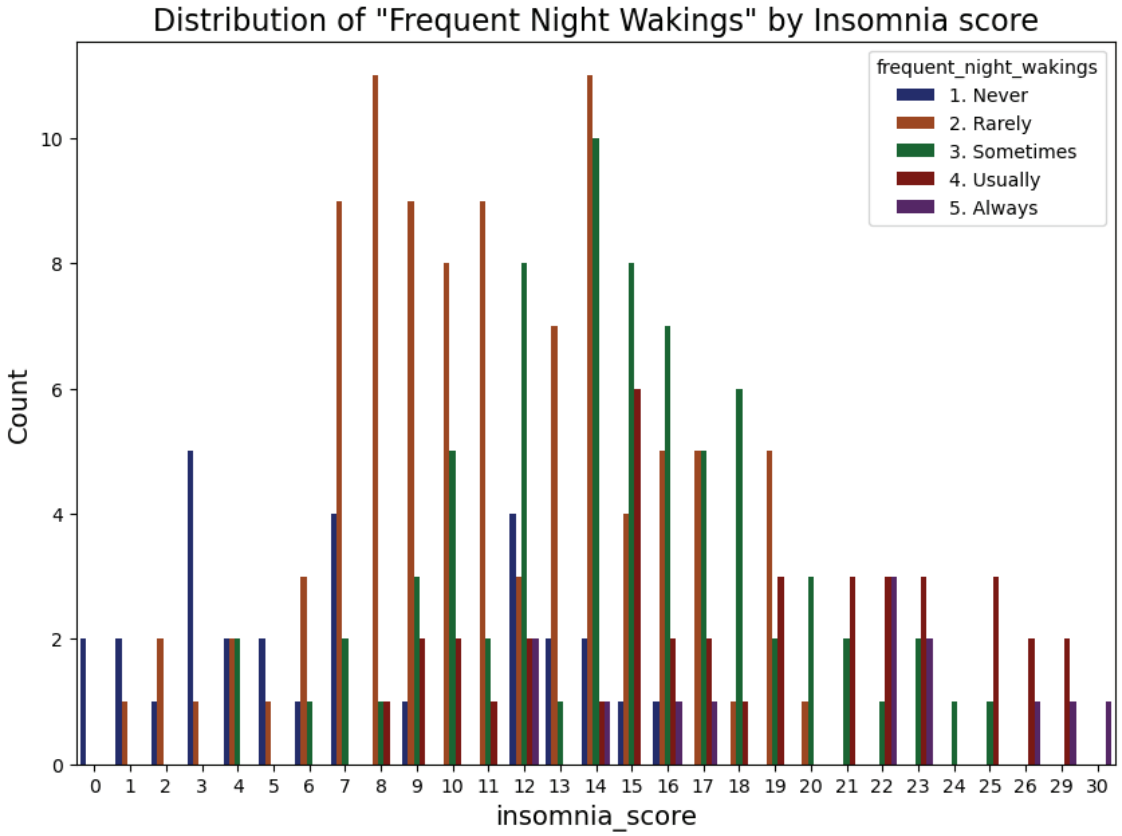

Figure 4.25: Distribution of Frequent Night Wakings by Insomnia Score

We can observe in the graph that people who have low Insomnia Score (1-10) rarely report waking up during the nighttime, which indicated better sleep quality. As we move forward in observation, we can see insomnia score increasing and we can see individuals reporting night wakings more frequently. People with moderate insomnia score experience less frequent night waking than those, who have severe or high insomnia score. If we move towards the higher insomnia score in our observation, insomnia score increases and we can see more responses like, "Usually" and "Always". This means individuals having higher Insomnia score often report frequent night waking and having very poor quality of sleep.

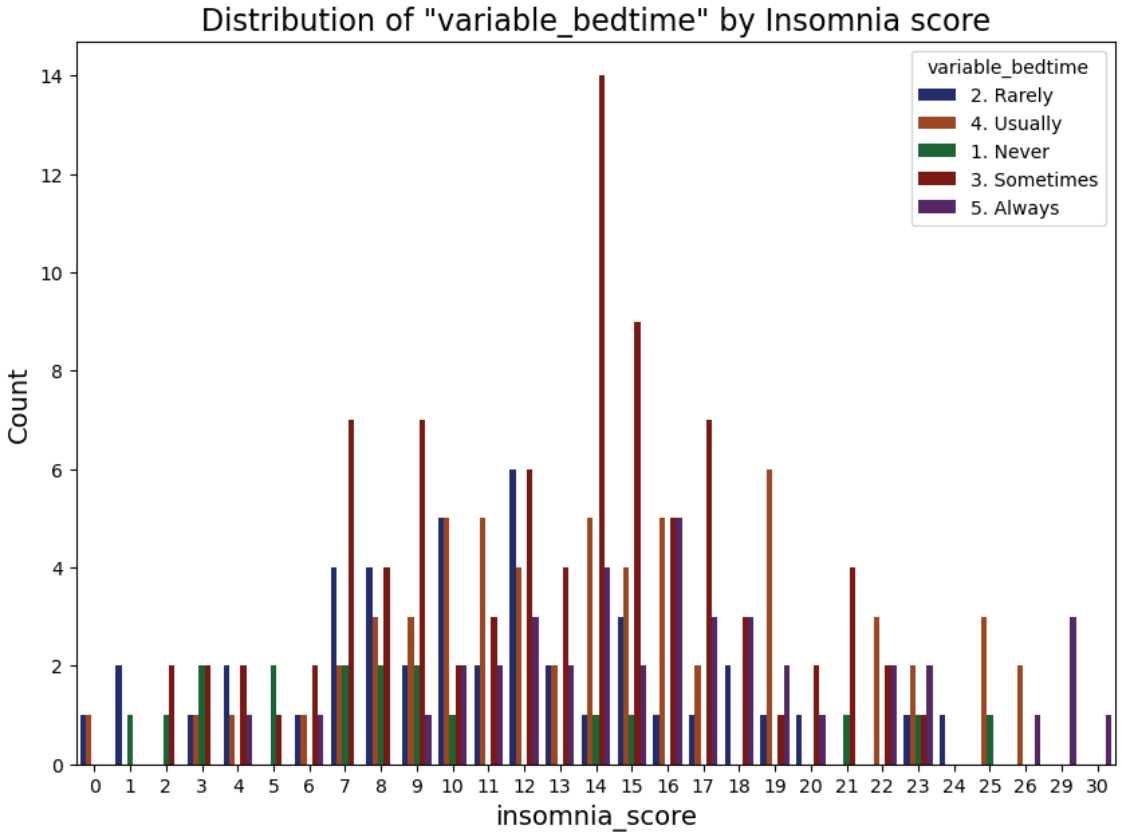

Figure 4.26: Distribution of Variable Bedtime Frequency by Insomnia Score

From the chart, we can see that individuals who have low insomnia score usually have a consistent bedtime. As we move toward the moderate insomnia score range, we can observe people responding with "Something" more frequently. Which means, people with moderate insomnia score are more likely to report variable bedtimes. In high insomnia score range we can observe individuals reporting that they are "Usually" or "Always" having variable bedtime.

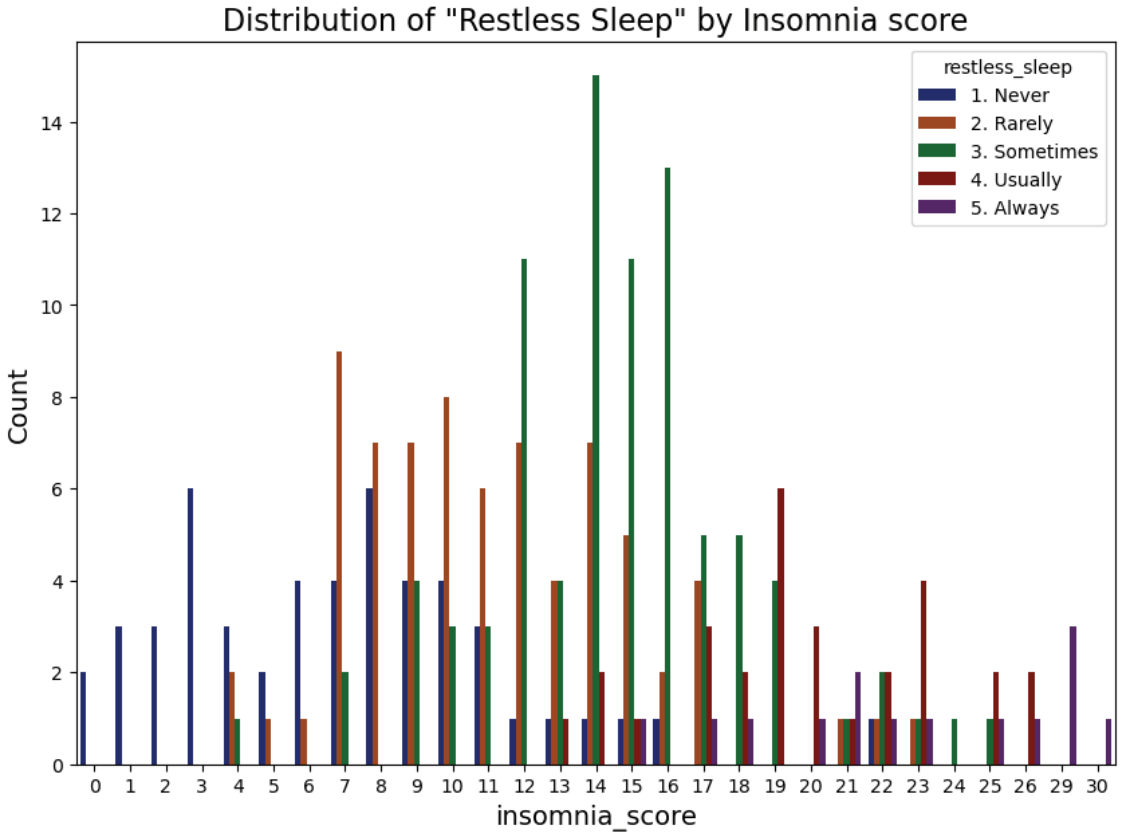

Figure 4.27: Distribution of Restless Sleep Frequency by Insomnia Score

The graph indicated that, individuals who have low insomnia score (1-10) rarely have restless sleep. The graph also indicates that people with moderate insomnia score (10-16) sometimes have restless sleep due to multiple factors. We can also observe that, the individuals with severe insomnia (higher insomnia score), frequently report to have restless sleep.

Brain Regions affected (Brain model):

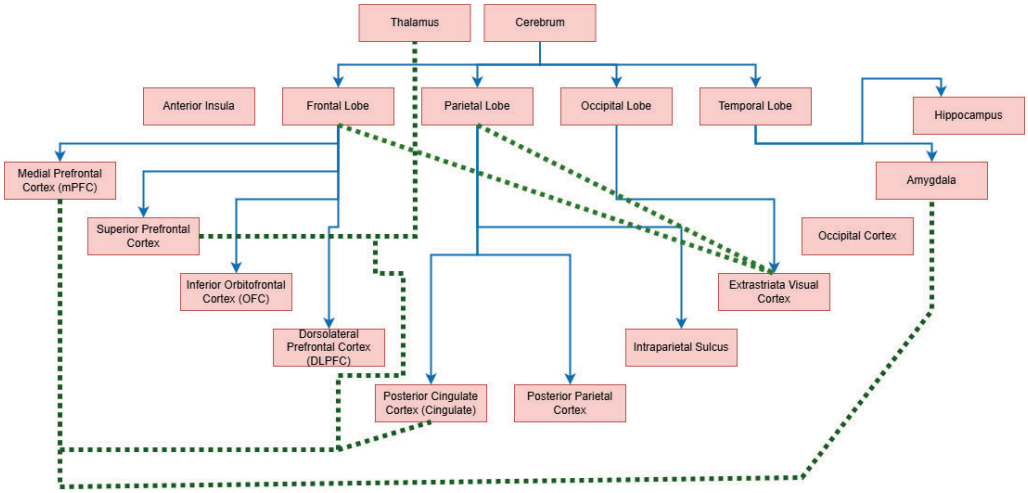

Figure 4.28: Affected regions of the brain on insomnia

Brain modeling (Analyzing effected regions):

The causes of insomnia affect several parts of the brain, which causes1 alteration in activity, impaired connection and dysfunction in the brain. Reasons for insomnia decreases activity in the dorsolateral prefrontal cortex (DLPFC) of the frontal lobe and intraparietal sulcus of Parietal Lobe at the time of performing attentional tasks while performing visuospatial attention tasks. It also impairs the connectivity of the frontal region and parietal region with the Extrastriate Visual Cortex of the Occiptal Lobe [24]. These change in neural function causes problems when someone tries to concentrate on one particular stimulus while ignoring distractions around that person [24] or defects in organizing attentional resources from top to bottom like orienting a location where a target is predicted to come [24]. Apart from disturbing concentration at a particular moment, sleep loss reduces the ability to hold on to concentration for a medium or long period. Thus, the reduced activity in the dorsolateral prefrontal cortex (DLPFC) and intraparietal sulcus leads to failure in attentional tasks [24]. The deprivation from sleep can affect human behavior which involves cognitive functions, emotional processes, muscular activity, and kinematics. It can also alter a range of behaviours that involve crude changes in large brain regions like the prefrontal cortex, thalamus and hippocampus [49].
Sleep deprivation weakens connectivity among the default mode network (DMN), the dorsal attention network, and the auditory, visual and motor networks [24]. The connection between the midline anterior node(Medial Prefrontal Cortex (mPFC)) and midline posterior node (Posterior Cingulate Cortex (PCC), Precuneus) under the default mode network (DMN) is reduced by deprived sleep [24]. This hampers selective attentional tasks and results poor performance at tasks that require attention. The thalamic connectivity with anterior and posterior cingulate regions of the DMN [24] as well as with the superior and

medial prefrontal cortex (mPFC) [24, 49] decreases during the resting period.
The extrastriate (visual) cortical region of the optical lobe and frontoparietal areas that contain the frontal lobe and the parietal lobe show reduced activity at the time of performing the working memory task. Poor sleep reduces dorsolateral prefrontal cortex (DLPFC) and posterior parietal activity and deducts working- -memory and attention task performance[24]. Sleep deprivation influences Medial PFC (mPFC) and inferior orbitofrontal cortex (OFC) regions of the frontal lobe and alters their functionality which results in the alteration of motivational behaviours like risk-taking, impulsive activity and so on. Sleep loss can make brain areas involved in salience detection, and value assessment overreactive and sensitive which can impair one's ability to compare between reward and risk. It causes inaccurate coding of the Medial Prefrontal Cortex (mPFC) and encourages one to take serious and unnecessary risks [24].
Sleep problem causes amygdala hyper-reactivity which leads to a loss of regulatory control and impairs functional connectivity between top-down control regions of the mPFC and the amygdala [24, 26] and causes reduced frontal lobe inhibition which triggers changes in negative emotional processing like irritability, emotional volatility, anxiety, aggression and so on. In sleep-deprived people, regions of the amygdala, insula and cingulate that deal with salience detection cannot discriminate between stimuli of different emotional strengths. People with sleep deprivation find both negative and neutral expressions as negative due to the high activity of the amygdala. They have a weaker correlation between the activity of the central and peripheral autonomic system which disables them in detecting and recognizing emotion. People who suffer from the higher degree of sleep debt show reduced connectivity between the left amygdala and ventral anterior cingulate cortex [26] which is associated with mood deterioration [26, 27]. This down regulation of the amygdala by the ventral anterior cingulate cortex followed by the activation of the amygdala in response to negative emotional stimuli leads to extreme physiological and psychological responses and mood deterioration[26].
The hippocampus is very important for spatial, contextual, and declarative memory [27]. Sleep loss impacts initial hippocampus-dependent memory encoding [24, 27]. It reduces hippocampal protein synthesis associated with neuroplasticity as well as weakens hippocampal neurogenesis. Loss of sleep disturbs learning and encoding-related activity of the temporal lobe's hippocampus. At the time of visual episodic-memory encoding, functional connectivity between the hippocampus and perceptual regions of the occipital (visual) cortex as well as nearby regions in the medial temporal lobe gets disrupted under sleep loss [24]. Sleep Deprivation affects the signaling mechanisms that involves in regulating transcription and translation processes in memory [27].
Sleep variability can hamper the development of white matter in the human brain. Variable bedtime is responsible for reduced fractional anisotropy in frontocortical and frontostriatal tracts, association tracts, projection tracts and the interhemispheric tract. Greater sleep variability can cause Specially, internal capsule, anterior thalamatic radiation, posterior thalamatic radiation, cingulum, superior corona radiata, posterior corona radiata and su-

perior longitudinal fasciculus of projection and association tracts to get affected due to large level variability in sleep. Therefore, sleep variability can impair cognitive and socioemotional well-being by disrupting the integrity of white matter development in these tracts [25].

4.4 Summary

This chapter described the technical implementation of the research with its computational environment, testing and evaluation methodologies, as well as the results obtained from the exploratory analysis. Using clustering and hypothesis test, the study was able to discover significant variable influencing insomnia, as well as cluster meaningful groups of the participants. These findings corroborate previous insights about the impacts of insomnia and provide an important foundation for further exploration.

Chapter 5

Engineering Standards and Design Challenges

This section describes which ethical standards we followed in the pathway of this thesis how our work would impact and contribute to the life and society. This section also includes which sections of complex engineering are addressed by work.

5.1 Compliance with the Standards

The section clarifies the concerns regarding the compliance with the standards. It describes ethical considerations, data collection method, data quality assurance of the research.

5.1.1 Data collection Standards

Ethical consideration: We have collected data from people who are at least 18 years old. We explained our study's purpose and procedures to them and informed them about how their data would be used. To ensure the privacy of the participants we collected their anonymous data and all the participants provided data in consent and consciously.

Data collection method: We have used a questionnaire of a well-known organization for our survey. Questions were kept as clear as possible so that no misunderstanding occurs and data was kept protected in cloud storage system.

Data Quality Assurance: We have collected data from 4 well known universities of Dhaka city. People from different parts of the countries take admission and studies in these university. Therefore, the data we collected represents participants from different regions which reduced the biasness of data. Data was collected from educative young adults who knows English language and who have idea about insomnia disorder. Data was collected in a particular time period to maintain data standard.

5.1.2 Writing Standards

We have written this paper from an unbiased and neutral view. We ensured that no particular group of people or individuals were unfairly criticized through our writing. While writing this paper we tried to use precise words and sentences so that our writng do not create any kind of confusion among people. We have avoided our personal opinion and explained everything according to the evidence of our findings. We reviewed literatures neutrally not just those which support our hypothesis. The reference we used here were from reputed journals and we provide them credit for using their information in our studies. The confidentiality of the participants was maintained and data was only used for the purpose that it was provide for.

5.2 Impact on Society, Environment and Sustainability

In order to understand the impact of insomnia and this study, we'll have to consider how it makes individual suffer also a society suffers on a long run. This section will shed light to the impact of this study on life and society while describing ethical aspects of this study.

5.2.1 Impact on Life

Insomnia is a condition that, if goes untreated for a very long period of time, may lead to cognitive deterioration, and memory loss, and hinder the decision-making capability of individuals. It can disrupt individuals' day-to-day activities. Sleep deprivation caused by insomnia can lead individuals to develop mental health disorders like depression and anxiety, which will affect their lives as a result. The findings from this exploratory analysis targets to provide a better understanding of insomnia's effects on different parts of the brain, enabling individuals to seek customized and timely treatment and as a result, it'll help improve their lives.

5.2.2 Impact on Society

Impact of insomnia extends beyond individual health. Individuals who are suffering from insomnia usually experience reduced productivity, and, in result it can affect work places, offices, institutions and even social functioning. Fatigue from insomnia, contributes to adverse effects like daytime sleepiness, which in results may cause accidents and many societal problems. Moreover, insomnia creates significant health care costs on society as individuals suffering from insomnia often requires prolonged medical care, psychotherapy/psychological support and medications, which usually have withdrawal effects too. This study will enable experts in researching and identifying the alternatives of traditional treatments based on the parts of the brain effected to manage insomnia effectively.

5.2.3 Ethical Aspects

Researching insomnia must take into account, ethical guidelines for confidentiality and informed consent. All participants were made anonymous and all data were collected anonymously, and, used ethically as part of this investigation. Moreover, this study informs the principle of beneficence by improving the understanding and treatment option for insomnia to minimize harm, thereby promoting public health.

5.3 Project Management and Financial Analysis

In order to collect data, we travelled to different university which cost us transport fare and lunch. We collected data through an online questionnaire therefore on most occasions we had to provide internet to the participants which cost us for mobile data and an internet range extender. Apart from those we had to print some QR codes and a few more papers to conduct this study. However, using open-source software and libraries saved us some money. Besides we used the Sci-hub website for downloading books, journals and research articles which saved us from buying subscriptions.

Table 5.1: Management and financial analysis

Expense Category	**Estimated Cost (BDT)**	**Description**
Data Collection	3,500/-	Travel, participant incentives, and survey logistics.
Software & Tools	0/-	Used Opensource Software.
Equipment	2,500/-	Internet range extender.
Research and Literature	0/-	Travel, Books, Journals, Research Articles.
Miscellaneous	3,000/-	Internet package, Hard Copy, Photocopy, Bindings, etc.
Total	9,000/-	

5.4 Complex Engineering Problem

This section will discuss on the Complex engineering problems that we addressed during the research.

5.4.1 Complex Problem Solving

Table 5.2: Mapping with complex problem solving.

EP1 Dept of Knowledge	EP2 Range of Conflicting Requirements	EP3 Depth of Analysis	EP4 Familiarity of Issues	EP5 Extent of Applicable Codes	EP6 Extent of Stakeholder Involvement	EP7 Interdependence
√			√		√	√

EP4 Familiarity of issues: In this thesis, we worked on exploratory analysis of insomnia disorder. It was a challenging task for us to work on since we are students of computer science background and we didn't have deep knowledge in the field of neuroscience. However, with the guidance of our supervisor Dr. Mohammad Taimur Ahad, a doctor of philosophy in biomedical engineering and his friend Dr. Ahmad Mustafa, a mental health and data analytics at Bond University, Australia, we managed to do this work. To conduct this study, we had to study numerous research papers of neuroscience describing brain functionalities affected by insomnia as well as brain anatomy [24, 25, 26, 27, 50]. We also discussed our work with a psychologist and got a positive response from him.

EP6 Extent of Stakeholder Involvement: The stakeholders of our work are psychologists, psychiatrists, neurologists, data scientists and so on. Therefore, we discussed our questionnaire and variables with psychiatrists and to understand the effects of insomnia on brain functionality we conversed with a renowned neurologist too. They refined our understanding of the brain and habits and provided links to relevant sources too.

EP7 Interdependence: The methodology for insomnia analysis is highly interdependent, meaning that each step in the process—data collection, hypothesis testing, conclusions—relies on the success of its predecessor. The collection of data, whether it consists of surveys or interview responses, has to provide accurate and consistent information so that effective feature extraction can take place, thereby impacting the accuracy of data analysis and hypothesis testing. Hypothesis testing helps inform the results and findings that lead to actionable conclusions and recommendations. This interdependent workflow calls for a holistic system in which all of the stages are integrated and where each step feeds into the next.

Mapping with Knowledge Profile for EP1

This table (5.3) is designed to map the EP1 to the Knowledge Profile.

Table 5.3: Mapping with knowledge Profile.

K1 Natural Sciences	K4 Specialist Knowledge	K5 Engineering Design	K6 Engineering Practice	K8 Research Literature
√	√			√

K1 Natural Sciences: For this study, we had to gather knowledge on how the effects or symptoms of insomnia affect brain functionality. Therefore, we had to study literature of neuroscience which is a branch of natural science.

K4 Specialist Knowledge: Insomnia and its neuro-scientific comprehension: Essentially, the research approach deals with insomnia, its psycho-physio-environment behavior causal factors, and their neuro-scientific understanding. Such expertise is critical to ensure that the underlying contributors to insomnia are correctly identified, and that their effects are appropriately interpreted against cognitive and neurological health. Clustering, A/B testing and hypothesis validation, etc., are other advanced techniques that require specialized expertise in data science and health related domains.
K8 Research Literature: For this study, we reviewed different types of works conducted on insomnia. We have reviewed quantitative, qualitative, cross-sectional studies, exploratory studies, epidemiological studies, longitudinal studies, validation studies on our way of working in this thesis.

5.4.2 Engineering Activities

Table 5.4: Mapping with complex engineering activities.

EA1 Range of resources	EA2 Level of Interaction	EA3 Innovation	EA4 Consequences for society and environment	EA5 Familiarity
√				√

EA1 Range of resources: In this study, we have collected survey data from young adults, especially from university the students. We collected data from different places in Dhaka which cost us transport fares. We also used digital equipment like laptops, mobile phones, internet range extenders and so on. We also used other resources like literature, google form, Jupyter Notebook and so on in our pathway of exploratory research.
EA5 Familiarity: We have conducted an exploratory analysis on insomnia disorder. Here we have contributed in the health sector through a combination of the knowledge of computer science and neuroscience. We got the knowledge of computer science from our university courses and we gathered knowledge on neuroscience through studying literature.

5.5 Summary

In our thesis, we followed ethical standards for data collection and handling as well as the standards of literature writing was also followed. The impacts of our work on public life and society were described and how our work is contributing for the betterment of people was also demonstrated. Eventually, the complex engineering problems that our study solved was addressed.

Chapter 6

Conclusion

The chapter will provide with a comprehensive summary regarding the findings from the study we did, the limitations we encountered and will highlight the potential directions for the planned future work. The goal of this chapter includes blending the insights that we gained through this study and proposing recommendations regarding the understanding and management of insomnia.

6.1 Summary

The study/research explored the complex relationship between insomnia and its effects on the brain by analyzing sleep related problems that individuals reported by themselves. The research work leveraged the techniques such as clustering analysis, hypothesis testing, and data visualization to gain insights and identify significant factors contributing to insomnia, including poor sleep quality, variable bedtime, restless sleep.
The findings focus on the multi-dimensional impact of insomnia on the regular brain function and mental health. It also shows evidences on its broader societal and environmental implications. K-Means Clustering and PCA were applied in this analysis to successfully visualize patterns among insomnia symptoms, creating actionable insights for healthcare providers. Furthermore, this study highlighted the need for alternative, non-medicinal and customized treatment approach for insomnia.

6.2 Limitation

Despite its contributions, the research has some limitations. They are:

Self-reported data: Data used in this research are self-reported and reliance on self-reported data can introduce biases, as the participants can underassess or misinterpret their symptoms.
Lack of brain imagery data: The study lacked neuropsychological/imaging data. Getting these data could provide deeper insights regarding the specific areas of the brain that

gets affected due to insomnia.

Cross-sectional nature: The cross-sectional nature of this research limits the ability to establish casual relationships between insomnia and its effects.

6.3 Future Work

Combining the findings and the limitations, the research can be seen going to the following directions:

Incorporating prolonged studies: Insomnia symptoms should be tracked overtime to establish casual relationship and symptoms should be assessed for prolonged period of time to find effects on mental health in future.

Including brain imagery techniques for better understanding: Brain imaging techniques like fMRI or EEG should be integrated in this research as this would provide more detailed insights of how insomnia affects brain activity.

Developing Machine Learning models to predict severity of insomnia: Based on behavioral and physiological data, advanced machine learning models can be deployed which will predict individuals at a high risk of developing insomnia.

Examine Comorbid Conditions: Based on insomnia's overlaying with other illnesses like anxiety, depression, chronic pain, etc., will provide a more holistic view of the problem of sleep disorders.

Studying for non-pharmacological alternatives: Future studies should assess the utility of CBT-I, mindfulness and lifestyle interventions.

Expanding dataset: Future studies should expand the dataset to get diverse demographics and objective measures. It would enhance the reliability and applicability of the findings.

Finally, it can be said that, this study provides some very important insights regarding insomnia and its impacts on society as a whole. The findings not only point to important challenges which are correlated with insomnia, but also shows the path for creative ways to think about and treat this complex disorder.

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