Investigating the Relationship Between Nicotine Dependence and Sleep Quality

Research Question: To what extent does nicotine dependence, as assessed by the Fagerstrom Test, influence sleep quality, as measured by the Pittsburgh Sleep Quality Index (PSQI), in individuals with varying levels of dependency (non-smokers, low dependency, moderate dependency, high dependency)?

Subject: Biology

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1. Introduction

Sleep quality impacts overall health, it influences physical and mental well-being. It is essential to maintain essential processes like memory consolidation, immune system, and emotional regulation. Sleep quality is, however, easily influenced by many factors. These factors include lifestyle habits like smoking, alcohol or caffeine consumption, diet, and irregular sleep timing. Poor quality of sleep leads to the formation of numerous health conditions. Therefore, it is crucial to ensure good quality of sleep in order to get maximum happiness and health.

Smoking remains one of the leading causes of preventable death (Samet, 2013). Beyond its well-documented long-term health risks, such as respiratory and cardiovascular diseases, smoking also affects daily well-being, particularly sleep quality. Studies have shown that smokers tend to sleep fewer hours and experience poorer sleep quality than non-smokers, largely due to the effects of nicotine. As a stimulant, nicotine disrupts sleep by affecting neurotransmitter activity, increasing alertness, and altering sleep architecture (Garcia & Salloum, 2015).

This study investigates whether the extent of nicotine dependency influences sleep quality. To explore this, I conducted a survey incorporating elements from established scientific tools such as the Pittsburgh Sleep Quality Index (PSQI) and the Fagerstrom Test for Nicotine Dependence. By analyzing the relationship between smoking habits and sleep patterns, this research aims to provide insight into how nicotine affects sleep and whether higher dependency worsens sleep quality.

2. Background Information

2.1. Sleep Physiology

Sleep is essential for maintaining physical and mental health, and is regulated by two key mechanisms: the circadian rhythm and the homeostatic sleep drive (Czeisler et al., 1980). The circadian rhythm is controlled by the suprachiasmatic nucleus (SCN) in the hypothalamus. It relies on external cues such as light to regulate the sleep-wake cycle (Klein et al., 1993). Meanwhile, the homeostatic sleep drive builds sleep pressure throughout the day and promotes restorative rest.

Sleep occurs in two main stages: non-rapid eye movement (NREM) and rapid eye movement (REM) sleep. Deep sleep (Stage 3 of NREM) is critical for physical recovery, while REM sleep is essential for cognitive functions such as memory consolidation and emotional regulation (Czeisler et al., 1995; Wright & Czeisler, 2002). Neurotransmitters and hormones like melatonin and adenosine affect the quality of sleep. Melatonin and adenosine stimulate sleep, whereas GABA (gamma-aminobutyric acid) inhibits arousal systems to promote relaxation (Takahashi et al., 2008).

Nicotine interferes with these processes by having a stimulant effect, releasing more acetylcholine and dopamine and inhibiting melatonin release (Chang et al., 2015). This can prolong the onset of sleep, decrease deep sleep, and change REM cycles, resulting in disrupted and lower-quality sleep. Nicotine withdrawal at night can also result in awakenings, further disrupting rest.

2.2. Neurobiological Mechanisms Linking Nicotine to Sleep Disruption

Nicotine affects sleep by altering key neurobiological systems that regulate arousal, neurotransmission, and circadian regulation (Zhou et al., 2021). One of its primary effect is on the mesolimbic dopamine system, which is involved in reward and reinforcement. Nicotine influences nicotinic acetylcholine receptors (nAChRs) in the ventral tegmental area (VTA) to cause release of dopamine in the nucleus accumbens. This enhances arousal and enhances nicotine addiction, contributing to delayed sleep onset and disrupted sleep patterns (D'Souza & Markou, 2018).

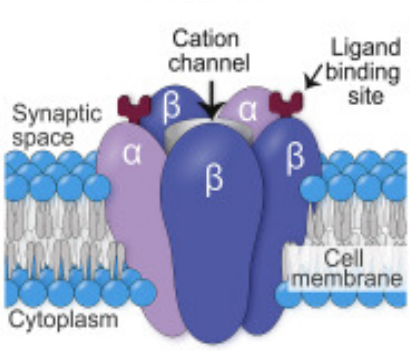


Figure 1: Nicotinic Acetylcholine Receptors Found in the VTA

In addition to dopamine, nicotine also disrupts the balance of neurotransmitters that are required for sleep. It suppresses adenosine, which is a sleep-promoting molecule, and interferes with GABAergic inhibition, leading to increased wakefulness (Santos et al., 2020). Nicotine over-activates nAChRs in the hippocampus, causing disruption in neuron excitability and suppressing REM sleep. Smokers therefore end up with disorganized REM sleep cycles (Feduccia et al., 2012).

The brainstem, responsible for sleep-wake patterns, is targeted by nicotine as well. By stimulating the reticular activating system (RAS), nicotine promotes activity of acetylcholine and norepinephrine, suppressing deep NREM sleep and disrupting sleep architecture overall (Sakurai, 2007). Long-term nicotine exposure is also related to respiratory disturbances, which increase the risk of sleep-disordered breathing disorders such as sleep apnea (Franklin & Lindberg, 2015).

As discussed previously in 2.1., nicotine disturbs circadian rhythm regulation by disrupting the suprachiasmatic nucleus (SCN) of the hypothalamus. By inhibiting melatonin

release, nicotine desynchronizes the sleep-wake cycle, impairing the sleep onset of smokers and reducing total sleeping time. This dysregulation leads to excessive daytime sleepiness (hypersomnolence) and further worsens sleep quality.

2.3. Withdrawal Effects on Sleep Architecture

Nicotine withdrawal significantly disrupts sleep architecture, particularly in heavy smokers who have overnight abstinence or while they are trying to quit. During withdrawal, smokers usually report symptoms such as difficulty in falling asleep, and reduced quality of sleep. These disruptions are caused by the brain's dependence on nicotine to regulate arousal and relaxation processes (Garcia & Salloum, 2015; Jaehne et al., 2009; Siqueira et al., 2017)

One key factor is the heightened activity in stress-related pathways, such as the hypothalamic-pituitary-adrenal (HPA) axis, during withdrawal. Nicotine typically dampens stress responses in habitual users, so its absence triggers an overactive stress response (Bruijnzeel, 2012). Elevated levels of cortisol, the primary stress hormone, are observed during withdrawal periods and promote a state of heightened alertness that makes it difficult to fall and stay asleep (Wong et al, 2014).

Withdrawal also leads to a change in the balance of neurotransmitters in the brain, and this eventually causes sleep fragmentation. The absence of nicotine causes a temporary reduction in dopamine levels, which affects the brain’s reward and arousal systems, as well as a decrease in acetylcholine, which is critical for the regulation of REM sleep. This leads to shorter REM sleep durations and an increased frequency of transitions between sleep stages. The deep, restorative sleep required for proper cognitive and physical recovery is prevented (Garcia & Salloum, 2015; Siqueira et al., 2017)

The stress and irritability associated with withdrawal can exacerbate these effects, as the discomfort of nicotine cravings often interrupts sleep continuity. Furthermore, smokers

undergoing withdrawal often experience intense dreams or nightmares during the brief periods of REM sleep, which can also contribute to a perception of poor sleep quality.

3. Research Question

To what extent does nicotine dependence, as assessed by the Fagerstrom Test, influence sleep quality, as measured by the Pittsburgh Sleep Quality Index (PSQI), in individuals with varying levels of dependency (non-smokers, low dependency, moderate dependency, high dependency)?

4. Hypothesis

My hypothesis suggests that nicotine dependence has a significant negative impact on sleep quality. Non-smokers are expected to have remarkably better sleep quality than smokers because nicotine has a negative influence on sleep architecture by lowering sleep efficiency, increasing sleep fragmentation, and disorienting REM sleep. In addition, among smokers, those with higher nicotine dependence are expected to report worse sleep quality than those with lower dependence. While some sleeping disruptions may be expected among participants in the low-dependency group, their sleep quality should nonetheless remain better than that of highly dependent smokers.

To formally test this hypothesis, the study will consider the following:

Null Hypothesis (H_0): There is no significant difference in sleep quality between smokers and non-smokers, and nicotine dependence does not significantly impact sleep quality.

Alternative Hypothesis (H_a): Non-smokers have significantly better sleep quality than smokers, and among smokers, those with higher nicotine dependence experience worse sleep quality compared to those with lower dependence.

5. Methodology

5.1. Variables

Independent Variable	Explanation
Nicotine dependence score (Non-smokers, Low Dependency, Moderate Dependency, High Dependency)	The level of nicotine dependence is the main variable influencing sleep quality. It was measured using adequate questions chosen from the *Fagerstrom Nicotine Dependence Test.* The survey was designed to be as practical as possible in order to gain realistic results. If all of the questions from the Fagerstrom test were chosen, the survey would be too long. Hence, only the most essential questions were included in the survey.
Dependent Variable	**Explanation**
Sleep quality score	Sleep quality was measured based on the *PSQI* questionnaire which is used commonly in scientific research. A higher score indicates worse sleep quality. This variable measures the impact of nicotine dependence on sleep.

Table 1: Independent and Dependent Variables Explained with Their Importance to the Exploration

Controlled Variables	Importance to the Exploration	How It Was Controlled
Gender	Sleep quality and nicotine dependence may vary between genders. Keeping a balance prevents gender bias.	An approximately equal distribution of male and female participants was ensured by including a question about gender in the survey.
Chronic health conditions	Conditions like insomnia, anxiety, or depression affect sleep quality. These parameters make it difficult to isolate nicotine's effects.	Participants with confounding factors such as, excessive caffeine/alcohol intake, or chronic health conditions were determined by asking questions assessing these factors in the survey. Then, they were eliminated.
Caffeine and alcohol consumption	Both substances affect sleep quality greatly which makes it important to minimize their influence.	

Table 2: Controlled Variables Explained with Their Importance to the Exploration and Control Methods

5.2.Materials

- Printed surveys
- Excel: used for organizing data
- Online statistical tools: used for conducting ANOVA and Tukey's HSD test

5.3. Survey Design, Sampling & Method Development

Section 1: Participant Demographics & Smoking Habits

1. Age: _____

2. Gender:

- Male
- Female

3. Do you currently smoke?

- Yes
- No

4. How soon after waking up do you smoke your first cigarette?

- After 60 minutes (Score: 1)
- 31-60 minutes (Score: 2)
- 5-30 minutes (Score: 3)
- In 5 minutes (Score: 4)

5. On average, how many cigarettes do you smoke per day?

- 1-5 (Score: 1)
- 6-10 (Score: 2)
- 11-20 (Score: 3)
- More than 20 (Score: 4)

6. Do you consume alcohol or caffeine regularly?

- Yes
- No

Figures 2 & 3: Survey Designed and Used to Assess Nicotine Dependence Levels and Sleep Quality

Section 2: Sleep Quality Assessment (PSQI-Based)

7. On average, how many hours of sleep do you get per night?

- Less than 4 hours (Score: 3)
- 4-6 hours (Score: 2)
- 6-8 hours (Score: 1)
- More than 8 hours (Score: 0)

8. How long does it usually take you to fall asleep at night?

- Less than 15 minutes (Score: 0)
- 15-30 minutes (Score: 1)
- 30-60 minutes (Score: 2)
- More than 60 minutes (Score: 3)

9. How often do you experience interruptions during sleep?

- Never (Score: 0)
- Less than once a week (Score: 1)
- 1-2 times per week (Score: 2)
- 3 or more times per week (Score: 3)

10. What are the most common causes of your sleep interruptions? (You can choose more than 1 option, or not respond at all if it does not apply to you)

- Difficulty breathing
- Coughing or throat irritation
- Need to use the bathroom
- Stress or anxiety
- Noise or other environmental factors

11. How often do you feel tired or drowsy during the day?

- Never (Score: 0)
- Less than once a week (Score: 1)

12. How often do you have difficulty concentrating due to sleep issues?

- Never (Score: 0)
- Rarely (Score: 1)
- Sometimes (Score: 2)
- Often (Score: 3)

13. How would you rate the quality of your sleep overall?

- Very good
- Fairly good
- Fairly bad
- Very bad

Section 3: Perception of Smoking and Sleep

14. Do you believe smoking affects your sleep quality?

- Yes
- No
- Unsure

15. If you answered "yes" to the previous question, what effect have you noticed the most?

- Difficulty falling asleep
- Waking up frequently
- Feeling tired despite sleeping
- No noticeable effects

A self-report questionnaire was chosen as the primary data collection method because it allowed efficient large-scale data collection for sleep quality and nicotine dependence. As sleep is subjective, self-report measures like the Pittsburgh Sleep Quality Index (PSQI) have been widely used in sleep research to assess participants' self-report of sleep quality. Likewise, the Fagerstrom Test for Nicotine Dependence (FTND) is a well-validated measure of classifying smokers according to dependence level and would be a suitable measure for this study.

By incorporating elements of these validated tools, the survey collected both quantitative data for statistical analysis and qualitative data regarding individual variation. As opposed to laboratory-based sleeping studies (e.g., polysomnography), a survey was a more feasible and ethical way of assessing real-world sleeping habits in smokers. It also allowed for a heterogeneous sample in natural sleeping environments rather than experimental settings.

The sample included both smokers and non-smokers to allow for comparative analysis. Among smokers, participants varied in nicotine dependence levels. Non-smokers served as a control group to assess baseline sleep quality without nicotine influence.

Survey responses were collected in print and later digitalized for analysis to ensure accuracy through manual verification. A total of 234 results were obtained. Only 125 of them were used in the analysis since the rest of them were outliers (they either indicated confounding factors such as alcohol/caffeine consumption or chronic illnesses or they were incomplete).

5.4. Statistical Methods

In order to examine the association between nicotine dependence and sleep quality, a one-way ANOVA (Analysis of Variance) was used to compare sleep quality scores for various levels of nicotine dependence. ANOVA was selected since it can compare more than two groups. Following ANOVA, Tukey's HSD post hoc analysis was employed to identify

specifically which groups of nicotine dependence were significantly different from each other in terms of sleep quality. The post hoc analysis was needed to clarify further the ANOVA result by detailing where the differences occurred. Being able to better determine the impact of escalating nicotine dependence on sleep quality was perceived in this manner.

5.5. Procedure

1. Survey Preparation: A structured survey was developed to assess the relationship between nicotine dependence and sleep quality. A total of 300 copies were printed for distribution.
2. Ethical Approval & Collaboration: Official permission was obtained from a hospital to conduct the survey in a clinical setting. Discussions were held with doctors, who agreed to assist with the distribution of the surveys to patients.
3. Survey Distribution & Collection: Surveys were handed out directly to patients, while assistant doctors facilitated further distribution. Participants completed the survey and returned them to their respective doctors. After one week, all completed surveys were collected from the doctors.
4. Data Entry & Screening: Survey responses were manually transferred to an Excel sheet for analysis. Incomplete surveys were excluded. Additionally, participants who reported confounding factors such as alcohol or caffeine consumption, chronic illnesses, or irregular work hours were removed from the dataset.
5. Data Processing:

- Nicotine dependence scores and levels were calculated based on participants' responses.
- Sleep quality scores were computed using established scoring criteria.

6. Statistical Analysis: An ANOVA test was conducted to determine whether there were significant differences in sleep quality between groups. Post-hoc tests were performed

to further analyze pairwise comparisons between different levels of nicotine dependence.

5.6. Ethical Considerations

Participants were recruited from A**** Ş**** Hospital, with ethical considerations prioritized. Anonymity was ensured by not requesting personal identifying details, and all participants provided consent after being presented with a clear explanation of the study purpose. Official permission was obtained from the hospital before data collection. The survey method was also the most convenient and ethical method in a hospital setting, with the least burden to participants and ease of recruitment.

6. Results

6.1. Survey Results for Each Question

Gender	**Male**	**Female**
Number of Respondents	74	51
%	59.20	40.80
Do you currently smoke?	**Yes**	**No**
Number of Respondents	110	15
%	88.00	12.00

Table 3: Survey Results – Participant Demographics and Smoking Status

Percentage of number of respondents was found by:

$$\%Number\ of\ Respondents = \frac{Number\ of\ Respondents}{Total\ Number\ of\ Participants} \times 100$$

E.g. for percentage of male respondents:

$$\%Number\ of\ Male\ Respondents = \frac{74}{125} \times 100 = 59.20$$

Scores from Questions 4 & 5 Added	Nicotine Dependence Group
0	Non-smokers
2-3	Low Dependency
4-6	Moderate Dependency
7-8	High Dependency

Table 4: Scores for Arranging the Nicotine Dependence Groups

Nicotine dependence was found by adding up the scores obtained from questions 4 and 5. The maximum obtainable nicotine dependence score is 8, and the minimum is 0. 1 is not an obtainable score since if a participant smokes, he/she would have to answer both questions 4 and 5, which both have minimum obtainable scores as 1.

Nicotine Dependence Group	Non-smokers	Low Dependency	Moderate Dependency	High Dependency
Number of Respondents	15	16	57	37
%	12.00	12.80	45.60	29.60

Table 5: Survey Results – Number of Participants in Each Dependence Group

4- How soon after waking up do you have your first cigarette?		Low Dependency	Moderate Dependency	High Dependency
After 60 minutes (1)	Number	10	7	0
	%	62.50	12.28	0
31-60 minutes (2)	Number	6	14	0
	%	27.50	24.56	0
5-30 minutes (3)	Number	0	28	2
	%	0	49.12	5.41
In 5 minutes (4)	Number	0	8	35
	%	0	14.04	94.59
5- On average, how many cigarettes do you smoke per day?		**Low Dependency**	**Moderate Dependency**	**High Dependency**
1-5 (1)	Number	9	11	0
	%	56.25	19.30	0
6-10 (2)	Number	7	25	0
	%	43.75	43.86	0
11-20 (3)	Number	0	19	15
	%	0	33.33	40.54
More than 20 (4)	Number	0	2	22
	%	0	3.51	59.46

Table 6: Survey Results – Questions for Assessing Nicotine Dependence

7- On average, how many hours of sleep do you get per night?		Non-smokers	Low Dependency	Moderate Dependency	High Dependency
Less than 4 hours (3)	**Number**	0	0	6	22
	%	0	0	10.53	59.46
4-6 hours (2)	**Number**	2	4	18	12
	%	13.33	25.00	31.58	32.43
6-8 hours (1)	**Number**	3	9	22	3
	%	20.00	56.25	38.60	8.11
More than 8 hours (0)	**Number**	10	3	11	0
	%	66.67	18.75	19.30	0
8- How long does it usually take you to fall asleep at night?		**Non-smokers**	**Low Dependency**	**Moderate Dependency**	**High Dependency**
More than 60 minutes (3)	**Number**	1	2	7	19
	%	6.67	12.50	12.28	51.35
30-60 minutes (2)	**Number**	3	2	17	11
	%	20.00	12.50	29.82	29.73
15-30 minutes (1)	**Number**	5	7	21	6
	%	33.33	43.75	36.84	16.22
Less than 15 minutes (0)	**Number**	6	5	12	1
	%	40.00	31.25	21.05	2.70

Table 7: Survey Results – Questions 7 and 8

9- How often do you experience interruptions during sleep?		Non-smokers	Low Dependency	Moderate Dependency	High Dependency
3 or more times per week (3)	Number	0	0	8	20
	%	0	0	14.04	54.05
1-2 times per week (2)	Number	2	5	23	9
	%	13.33	31.25	40.35	24.32
Less than once a week (1)	Number	7	6	17	5
	%	46.67	37.50	29.82	13.51
Never (0)	Number	6	5	9	3
	%	40.00	31.25	15.79	8.12
10- What are the most common causes of your sleep interruptions?		**Non-smokers**	**Low Dependency**	**Moderate Dependency**	**High Dependency**
Difficulty breathing	Number	0	3	6	6
	%	0	18.75	10.52	16.22
Coughing or throat irritation	Number	1	2	12	11
	%	6.67	12.50	21.05	29.72
Need to use the bathroom	Number	1	1	4	3
	%	6.67	6.25	7.02	8.12
Stress or anxiety	Number	1	4	8	5
	%	6.67	25.00	14.04	13.51
Noise or other environmental factors	Number	2	3	4	3
	%	13.33	18.75	7.02	8.11

Table 8: Survey Results – Questions 9 and 10

11-How often do you feel tired or drowsy during the day?		Non-smokers	Low Dependency	Moderate Dependency	High Dependency
3 or more times per week (3)	Number	2	2	9	15
	%	13.33	12.50	15.79	40.54
1-2 times per week (2)	Number	2	2	23	14
	%	13.33	12.50	40.35	37.84
Less than once a week (1)	Number	5	8	17	5
	%	33.33	50.00	29.82	13.51
Never (0)	Number	6	4	8	3
	%	40.00	25.00	14.04	8.11
12-How often do you feel tired or drowsy during the day?		**Non-smokers**	**Low Dependency**	**Moderate Dependency**	**High Dependency**
Often (3)	Number	0	1	7	17
	%	0	6.25	12.28	45.95
Sometimes (2)	Number	2	1	24	14
	%	13.33	6.25	42.11	37.84
Rarely (1)	Number	6	8	22	6
	%	40.00	50.00	38.60	16.22
Never (0)	Number	7	6	4	0
	%	46.67	37.50	7.02	0

Table 9: Survey Results – Questions 11 and 12

13-How would you rate the quality of your sleep overall?		Non-smokers	Low Dependency	Moderate Dependency	High Dependency
Very good	**Number**	8	6	3	2
	%	53.33	37.50	5.26	5.41
Fairly good	**Number**	4	7	10	4
	%	26.67	43.75	17.54	10.81
Fairly bad	**Number**	3	2	28	12
	%	20.00	12.50	49.12	32.43
Very bad	**Number**	0	1	16	19
	%	0	6.25	28.07	51.35

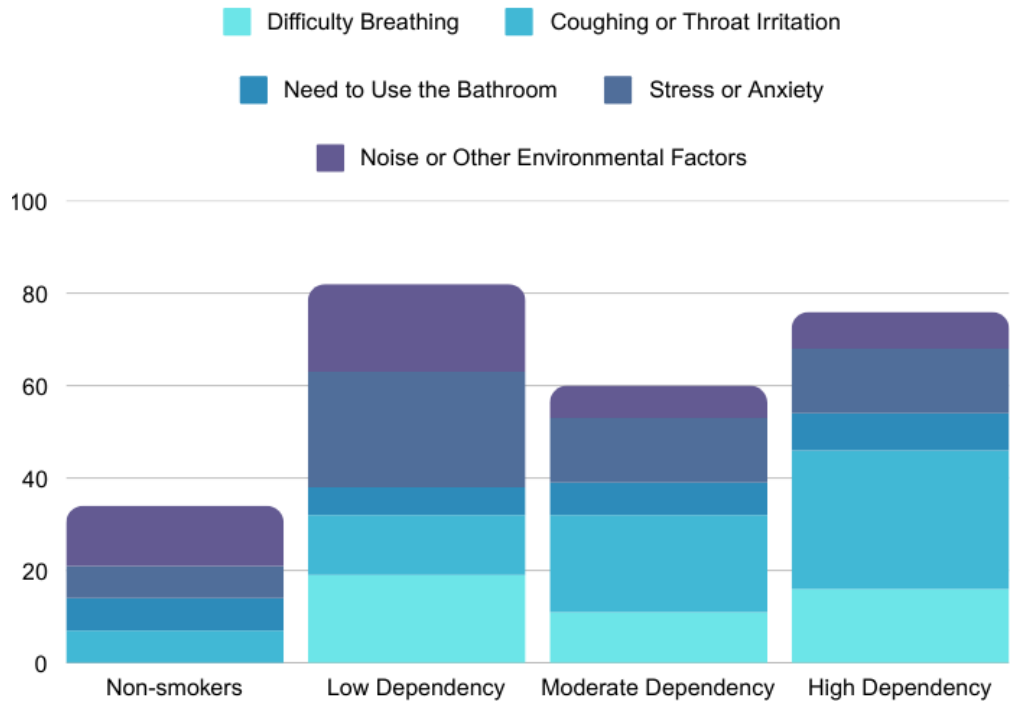
14- Do you believe smoking affects your sleep quality		Low Dependency	Moderate Dependency	High Dependency
Yes	**Number**	10	33	28
	%	62.50	57.89	75.68
No	**Number**	4	9	6
	%	25.00	15.79	16.22
Unsure	**Number**	2	15	3
	%	12.5	26.32	8.11

Table 10: Survey Results – Questions 13 and 14

15- (If you answered "yes" to question 14) What effect have you noticed the most?		Low Dependency	Moderate Dependency	High Dependency
Difficulty falling asleep	**Number**	5	19	14
	%	50.00	57.58	50.00
Waking up frequently	**Number**	1	5	6
	%	10.00	15.15	21.43
Feeling tired despite sleeping	**Number**	2	6	4
	%	20.00	18.18	14.29
No noticeable effects	**Number**	2	3	2
	%	20.00	9.09	7.14

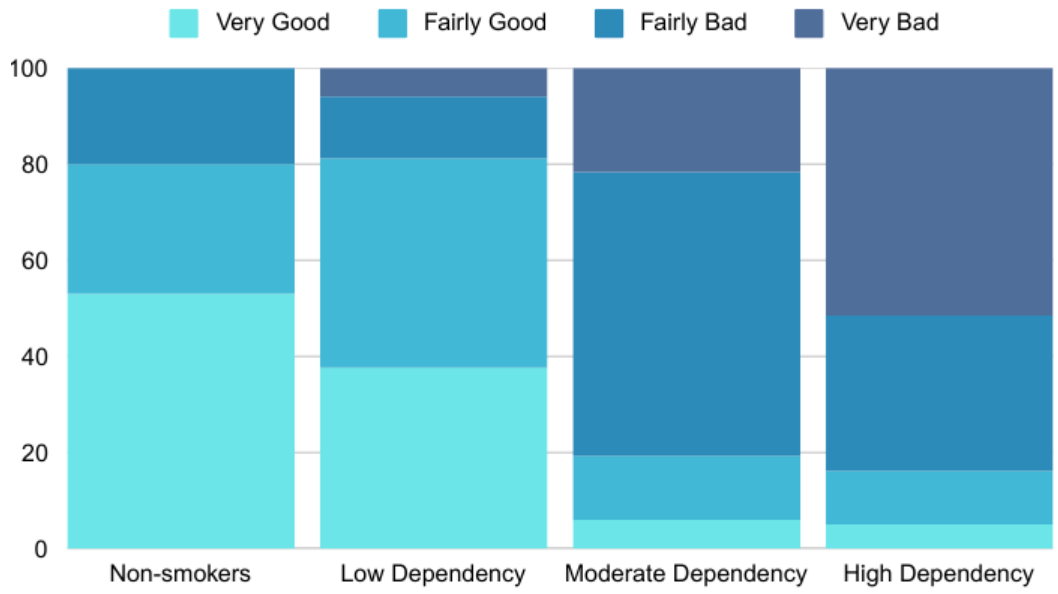
Table 11: Survey Results – Question 15

6.2. Qualitative Analysis



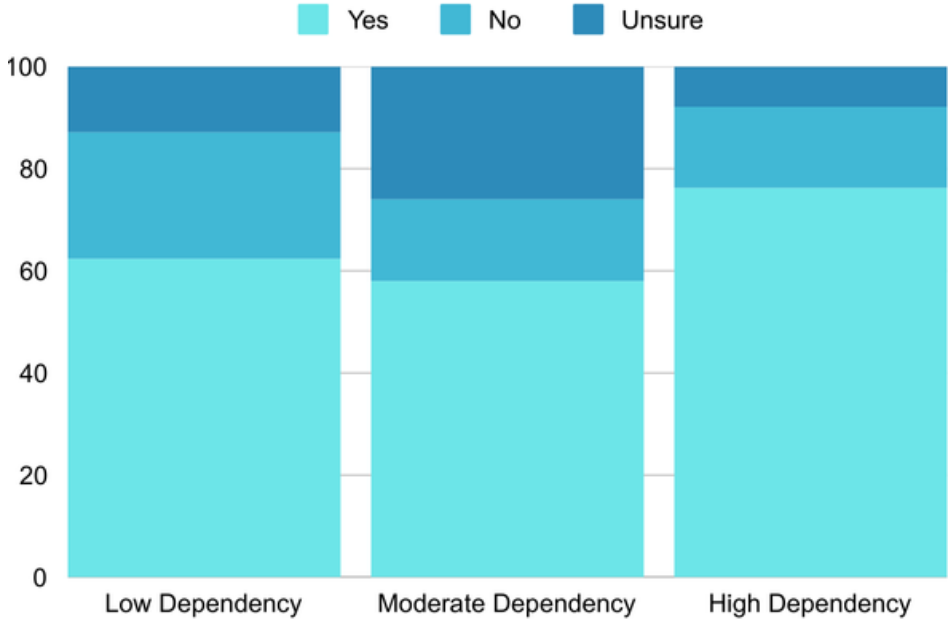
Graph 1: Survey Results – Question 10: Most Common Causes for Sleep Interruptions

Graph-1 shows that sleep disturbance increases with nicotine dependence. Non-smokers experience fewer symptoms, while low and high dependence smokers experience larger quantities of coughing, throat irritation, and breathlessness, especially the high dependence group. This trend shows that physical symptoms play a significant role in sleep disturbance.

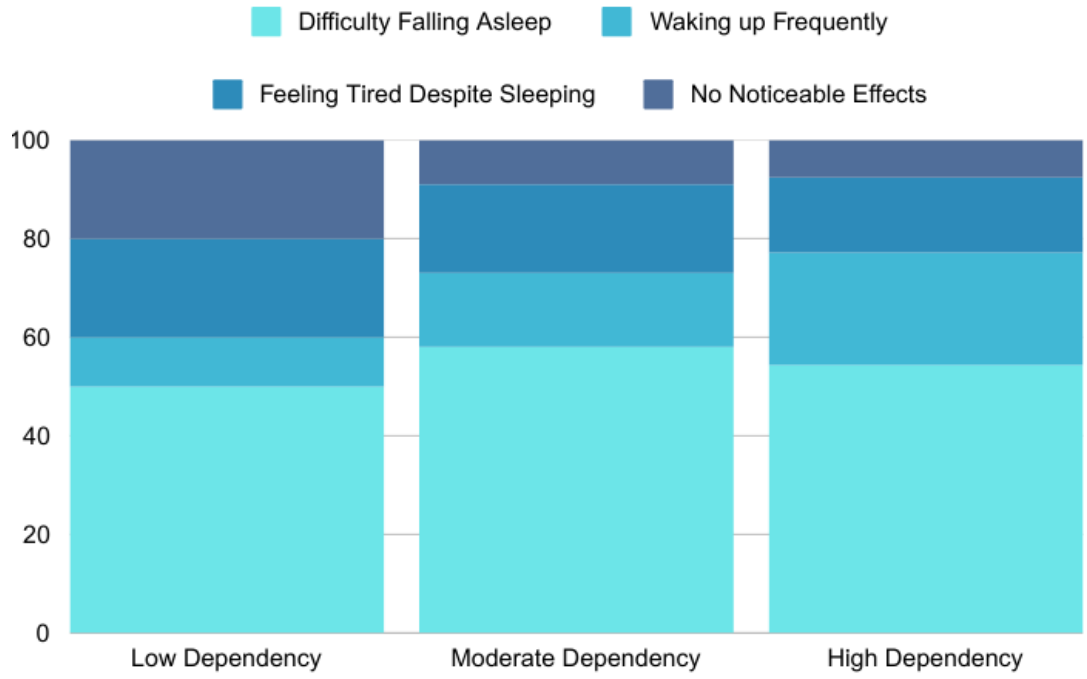


Graph 2: Survey Results – Question 13: Participants' Own Rating of Their Overall Sleep Quality

Graph-2 shows that sleep quality worsens as nicotine dependence increases. Non-smokers sleep best, with most rating their sleep as very good or fairly good. Moderate and heavy dependency smokers sleep considerably worse, with many rating their sleep as fairly bad or very bad. This pattern verifies a strong inverse relationship between nicotine dependence and subjective sleep quality.



Graph 3: Survey Results – Question 14: Perception on Whether Smoking Affects Sleep Quality Among Participants Who Smoke



Graph 4: Survey Results – Question 15: The Most Noticed Effect of Smoking on Sleep Quality Among Participants Who Answered "Yes" to Question 14

Graph-3 shows that the majority of the respondents in each level of nicotine dependency believe that smoking affects the quality of their sleep, and this rate is highest among those with

high dependency. However, a clear trend towards doubt and disagreement with lesser dependency exists, suggesting that the less dependent smokers may be less aware of the effect of smoking on their sleep.

Graph-4 indicates that at all dependency levels, difficulty falling asleep is the most common reported problem, followed closely by frequent awakenings. It is seen that increased dependency correlates with increased daytime fatigue, suggesting the idea that nicotine affects sleep quality and depth too, and not just sleep onset. The proportion of participants with no reported effects is lowest among highly dependent smokers, further supporting the hypothesis that awareness of nicotine's impact increases with dependency.

6.3. Quantitative Analysis

Nicotine Dependence Group	N (Sample Size)	Range	Mean Sleep Quality Score	SD (Standard Deviation)
Non-smokers (0)	15	8	3.67	2.13
Low Dependency (2-3)	16	7	4.88	2.03
Moderate Dependency (4-6)	57	12	7.40	2.83
High Dependency (7-8)	37	6	11.46	1.71

Table 12: Sample Sizes for Each Dependence Group & Range, Mean Sleep Quality Score and Standard Deviation in the Sleep Quality Scores

Nicotine dependence and PSQI scores were calculated using the following:

$$Nicotine\ Dependence = Score\ from\ Q4 + Score\ from\ Q5$$

$$PSQI\ Sleep\ Quality\ Score = Q7 + Q8 + Q9 + Q11 + Q12$$

E.g. for a male 44-year-old participant with the following results:

Questions	Q4	Q5	Q7	Q8	Q9	Q11	Q12
Obtained Scores	3	1	1	3	1	2	2

Table 13: A Participant's Scores from the Survey to Demonstrate How the Calculations Were Done

$Nicotine\ Dependence = 3 + 1 = 4$, therefore the participant is grouped in the moderate nicotine dependency level.

$$PSQI\ Sleep\ Quality\ Score = 1 + 3 + 1 + 2 + 2 = 9$$

Range, which demonstrates the variability of sleep quality within each group, is calculated by:

$$Range = (Max\ Sleep\ Quality\ Score\ in\ the\ Group) - (Min\ Sleep\ Quality\ Score\ in\ the\ Group)$$

Mean sleep quality score and standard deviation for sleep quality scores for each nicotine dependence group were calculated because they are essential for conducting the one-way ANOVA test. They are given by:

$$Mean\ Sleep\ Quality\ Score = \frac{\sum Sleep\ Quality\ Scores\ from\ Each\ Participant\ in\ the\ Nicotine\ Dependence\ Group}{Sample\ Size\ of\ the\ Group}$$

$$SD = \sqrt{\frac{\sum(Sleep\ Quality\ Score\ From\ Each\ Participant - Mean\ Sleep\ Quality\ Score\ of\ the\ Group)^2}{(Sample\ Size) - 1}}$$

E.g. for the "non-smokers" group with the participants' sleep quality scores as given below:

$$2, 2, 6, 3, 3, 6, 3, 5, 2, 1, 3, 5, 3, 2, 9$$

$$Range = 9 - 1 = 8$$

$$Mean\ Sleep\ Quality\ Score = \frac{2 + 2 + 6 + 3 + 3 + 6 + 3 + 5 + 2 + 1 + 3 + 5 + 3 + 2 + 9}{15} \approx 3.67$$

$$SD = \sqrt{\frac{(2-3.67)^2 + \cdots + (9-3.67)^2}{14}} \approx 2.13$$

Graph 5: Nicotine Dependency Against Mean Sleep Quality Score

The sleep quality scores show a very distinct rise as smoking dependency increases, indicating deteriorating sleep quality. The lowest sleep quality scores are seen in non-smokers with significantly better sleep and the highest scores in highly smoking-dependent individuals with poorer sleep.

The standard deviations are helpful in indicating the difference between each group. Surprisingly, moderate-dependency smokers and non-smokers are more variable in their sleep scores compared to low and high-dependency smokers. This suggests that apart from smoking, some other variables are accountable for the quality of sleep in these two groups. The values range also highlights that while moderate-dependency smokers and non-smokers do possess greater score dispersion, the high-dependency category does possess a relatively more compressed range, potentially indicating a more consistently poor sleeping pattern in heavy smokers.

Mean scores already suggest dose-response where the greater the dependence on nicotine, the poorer the sleep is. But in order to find if the differences were significant or not, statistical testing was performed.

6.4. One- Way ANOVA and Tukey's HSD Test Results

Source	DF	SS	MS	F-Stat	P-Value
Between Groups	3	897.48	299.16	53.39	0.00
Within Groups	121	677.99	5.60		
Total	124	1575.47			

Table 14: One-Way ANOVA Test Summary

A one-way ANOVA test was performed to determine whether the observed differences in sleep quality scores between the four groups were statistically significant. Since p-value< 0.005, H_0, which suggests that there is no correlation between nicotine dependence and sleep quality, is rejected and H_a is accepted. This means that the results showed a highly significant effect of smoking dependency on sleep quality, and at least one group differs significantly from the others. To further explore these differences, a post-hoc analysis was conducted. The pairwise comparisons are given below:

Treatments Pair	Tukey HSD Q Statistic	Tukey HSD P-Value	Tukey HSD Interference
Non-smokers vs Low Dependency	2.01	0.49	insignificant
Non-smokers vs Moderate Dependency	7.69	0.00	p<0.01
Non-smokers vs High Dependency	15.21	0.00	p<0.01
Low vs Moderate Dependency	5.34	0.00	p<0.01
Low vs High Dependency	13.15	0.00	p<0.01
Moderate vs High Dependency	11.48	0.00	p<0.01

Table 15: Tukey's HSD Post-Hoc Analysis Test Summary

These findings indicate a non-linear relationship between nicotine dependence and sleep quality. The reduction in sleep quality is most pronounced in progressing from non-smoker to moderate dependence, yet the decline diminishes between moderate and high dependence. This is consistent with findings that nicotine interferes with sleep architecture by shortening sleep efficiency, increasing wakefulness, and suppressing REM sleep. But at high levels of dependency, the deteriorating effect will plateau by physiological adaptations or chronic tolerance to nicotine's stimulatory effects.

Reduced sleep score variability among high-dependency smokers suggests that chronic nicotine exposure results in a consistently disrupted sleep pattern with reduced variability in heavy smokers. This can be further explored using individual variability analysis or other covariates such as stress levels, caffeine consumption, or genetic vulnerability to sleep disturbance.

Statistical tests validate significant correlation between nicotine dependence and sleep quality disturbance. The results affirm existing evidence of the stimulant effect of nicotine on the nervous system and confirm the hypothesis of smoking heaviness heightening sleep disturbance. Future research may use other lifestyle factors (e.g., alcohol use, exercise, or mental health) as intervening variables.

7. Conclusion

This study examined the effects of nicotine dependence on sleep quality using the Pittsburgh Sleep Quality Index (PSQI), and Fagerstrom Test for Nicotine Dependence to categorize participants based on nicotine dependence. The findings conclusively support the hypothesis that greater nicotine dependence is associated with poorer sleep quality.

A clear pattern emerged in the findings: non-smokers have the best sleep quality, and sleep quality worsens as nicotine dependence increases. The most significant deterioraton was observed between non-smokers and moderate-dependence smokers, and high-dependence smokers gave persistently worse sleep. Participants with greater nicotine dependence reported reduced sleep duration, increased sleep onset latency, increased night-time awakenings, and increased daytime fatigue. These results align with known neurobiological mechanisms because nicotine's stimulant action interferes with sleep architecture by decreasing slow-wave sleep, inhibiting REM sleep, and heightening sleep fragmentation.

The results have important implications for public health. Because nicotine dependence disrupts sleep—a fundamental physiological process necessary for cognitive function, emotional stability, and immune health—smokers may be at greater risk of long-term health consequences beyond those already associated with tobacco smoking. Poor sleep quality has been linked to increased stress, cardiovascular disease, and metabolic disorders, suggesting that sleep disturbances in smokers could be a key step in harm reduction strategies. The results also reveal that a large number of smokers, particularly less dependent smokers, underestimate the extent to which nicotine affects their sleep. This necessitates greater awareness and education about nicotine's effects on sleep quality.

While this study provides significant results, there are limitations to be acknowledged. The sample size imbalance, particularly in the smaller non-smoker and low-dependence samples, may have affected comparative statistical power. Also, reliance on self-reported data has the potential for recall bias, and stress, caffeine consumption, and prior sleep disorders are potential external sources of variability in sleep quality.

Generally, this study reinforces what has been documented so far about the negative impact of nicotine on sleep and highlights the importance of considering sleep health when conducting smoking cessation interventions.

8. Evaluation

8.1. Strengths of the Research

This study properly measured the relationship between nicotine dependence and sleep quality utilizing validated scales, which ensured the reliability of the data during collection. The Pittsburgh Sleep Quality Index (PSQI) and Fagerstrom Test for Nicotine Dependence are scales validated scientifically, and their results are comparable with those of existing studies. The use of a survey method enabled efficient data collection from a heterogeneous sample of people since it reflected true sleeping habits compared to controlled experiments. Secondly, use of statistical analyses like ANOVA and Tukey's HSD post-hoc analysis provided the results with credibility since it showed significant differences in the quality of sleep across levels of nicotine dependence.

Another strength of the study was that it separated smokers of varying levels of dependence, instead of combining them together. This helped to clarify more precisely how nicotine affects sleep quality at varying levels of dependence.

8.2. Limitations & Their Impact

While it was overall well-conceived, the study also had a number of limitations that can potentially affect the validity of its findings. One of these limitations involved sample size imbalance, especially non-smokers and low-dependency smokers were underrepresented compared to their moderate- and high-dependency counterparts. This can potentially bias

comparative statistical tests into being more challenging to find differences in sleep quality even at low levels of nicotine dependency.

Another limitation of this study was the broad age range of the participants. Although age was recorded on the questionnaire, it was not used as a control variable, meaning that changes in sleep quality could be influenced by age rather than nicotine dependence alone. Sleep patterns change with increasing age, and older individuals experience lighter and more fragmented sleep. This could have introduced variability in the results. Therefore, isolating the specific effects of nicotine dependence on sleep quality is difficult.

Additionally, self-report data provided a window for recall bias and subjectivity. Respondents may have over-reported or under-reported their sleep disturbances, and thus answers might have been unreliable. The study also lacked objective sleep measures, i.e., actigraphy or polysomnography, which would have provided a more realistic picture of the quality of sleep. Furthermore, although the study attempted to hold confounding variables like alcohol and caffeine intake at a steady level, variables like stress levels, diet, physical activity, and underlying sleep disorder were not regulated and could have affected the seen sleep patterns.

8.3. Discussion

The findings of this study are in agreement with existing research on nicotine's negative impact on sleep. Prior studies have consistently demonstrated that nicotine disrupts sleep architecture by reducing deep sleep, delaying sleep onset, and increasing night-time awakenings. Polysomnographic data from a large cohort study found that current smokers experience longer sleep onset latency, reduced total sleep time, increased stage 1 sleep, and decreased slow-wave sleep compared to non-smokers (Zhang et al., 2006). Similarly, Jaehne et al. (2009) observed that smokers with higher nicotine dependence report significantly greater

sleep disturbances, including prolonged sleep latency and reduced sleep efficiency, which supports the dose-response relationship observed in this study.

Neurobiologically, this study aligns with earlier research regarding how nicotine impacts the neurotransmitter system. Nicotine impacts dopamine as well as acetylcholine, both of which which significantly influence sleep regulation and arousal. Markou (2008) suggested that nicotine alters reward processes by altering the neurotransmitters so that sleep was disrupted within ongoing smoking as well as during the withdrawal process. Apart from that, Pidoplichko et al. (1997) found nicotine to initially stimulate but ultimately desensitize the midbrain dopamine neurons, the reason smokers' sleep quality varies. Apart from that, it has been found that nicotine is likely to suppress melatonin release at night, and melatonin is vital in controlling sleep, thereby increasing disturbed sleep cycles (Gnight et al., 2000).

Overall, the results of this study confirm previous evidence that nicotine dependence is strongly associated with poor sleep quality, and that this association is through disruption of the balance of neurotransmitters and sleep architecture. However, while the adverse effect of nicotine on sleep has been determined through previous studies, more research is needed in order to determine whether chronic smokers develop tolerance for nicotine's sleep-disrupting effects over time, as suggested by the plateau in this study's highest dependence group.

8.4. Suggestions for Future Research

To improve the reliability and depth of understanding in this field, future research should address the current study’s limitations through the following recommendations:

1. Expanding Sample Size and Diversity – A more balanced sample, with equal representation of non-smokers and different smoking dependence levels, would strengthen statistical comparisons and reduce bias. Including participants from a wider

age range and different demographic backgrounds could further improve generalizability.

2. Incorporating Objective Sleep Measurements – Future studies should utilize wearable sleep trackers, actigraphy, or polysomnography to obtain accurate, real-time data on sleep architecture, rather than relying solely on self-reported measures.
3. Controlling Additional Lifestyle Factors – Collecting data on stress levels, physical activity, and diet would help isolate nicotine's effects from other variables that influence sleep.
4. Conducting Longitudinal Studies – Instead of a single-point survey, future research should follow participants over time to assess how changes in smoking habits (e.g., quitting, relapse, or increased dependence) impact sleep quality over weeks or months.
5. Examining Withdrawal Effects – Since nicotine withdrawal also affects sleep, future studies could investigate how sleep disturbances evolve in smokers attempting to quit and whether interventions (such as nicotine replacement therapy) improve sleep outcomes.

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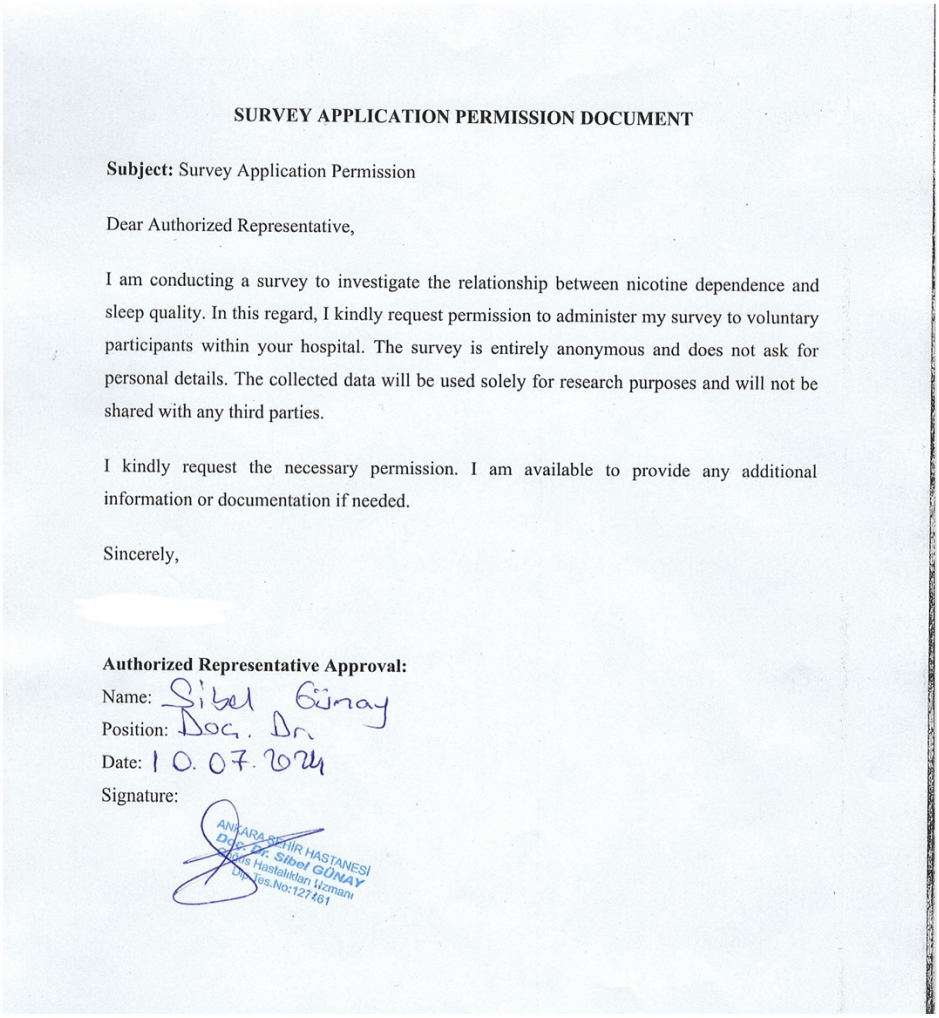
10. Appendix



SURVEY APPLICATION PERMISSION DOCUMENT

Subject: Survey Application Permission

Dear Authorized Representative,

I am conducting a survey to investigate the relationship between nicotine dependence and sleep quality. In this regard, I kindly request permission to administer my survey to voluntary participants within your hospital. The survey is entirely anonymous and does not ask for personal details. The collected data will be used solely for research purposes and will not be shared with any third parties.

I kindly request the necessary permission. I am available to provide any additional information or documentation if needed.

Sincerely,

Authorized Representative Approval:

Name: Sibel Günay

Position: Doç. Dr.

Date: 10.07.2024

Signature:

ANKARA ŞEHİR HASTANESİ
Doç. Dr. Sibel GÜNAY
Göğüs Hastalıkları Uzmanı
Diş Tes.No:127161

Appendix I: Document of Survey Application Permission