Associations between Nicotine Dependence, Smartphone Usage Patterns, and Expected Compliance with a Smoking Cessation Application among Smokers

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Objectives: Smoking remains the leading cause of preventable disease. However, smokers have shown poor compliance with smoking cessation clinics. Smartphone applications present a promising opportunity to improve this compliance. This study aimed to explore the relationship between nicotine dependence, smartphone usage patterns, and anticipated compliance with a smoking cessation application among smokers, with the goal of informing future development of such applications.

Methods: A total of 53 current smokers were surveyed using a questionnaire. Nicotine dependence was assessed using the Fagerstrom Test for Nicotine Dependence (FTND). Variables included the number of hours spent using a phone, willingness to quit smoking, number of previous quit attempts, desired number of text messages about smoking cessation, expected duration of application usage, and FTND scores. Kendall’s partial correlation, adjusted for age, was employed for the analysis.

Results: The amount of time smokers spent on their mobile devices was negatively correlated with the number of smoking cessation text messages they wanted to receive (τ coefficient = –0.210, p = 0.026) and the duration they intended to use the cessation application (τ coefficient = –0.260, p = 0.006). Conversely, the number of desired text messages was positively correlated with the intended duration of application usage (τ coefficient = 0.366, p = 0.00012).

Conclusions: Smokers who spent more time on their mobile devices tended to prefer using the cessation application for shorter periods, whereas those who desired more text messages about smoking cessation were more inclined to use the application for longer durations.

Keywords: Tobacco Use Disorder, Surveys and Questionnaires, Smoking Cessation, Smartphone, Mobile Applications
I. Introduction

Smoking is one of the leading causes of preventable diseases and death in the United States, accounting for over 480,000 deaths annually between 2005 and 2009 [1]. In 2019, there were 1.14 billion smokers worldwide [2], and tobacco-related deaths exceeded 8 million globally [3]. Efforts to reduce tobacco use have been successful on a global scale; the prevalence of current tobacco use dropped from 32.7% in 2000 to 22.3% in 2020 [4]. In the United States, 68% of smokers have expressed a desire to quit completely, and 55.1% of adult smokers reported attempting to quit in the previous year [5]. However, nicotine, a component of tobacco, has addictive properties that are a major reason for the failure of smoking cessation efforts [6].

Nicotine acts on nicotinic cholinergic receptors in the brain, releasing neurotransmitters that play a crucial role in nicotine dependence and withdrawal symptoms. Addiction to nicotine develops when smokers depend on smoking to regulate their mood or alleviate withdrawal symptoms [7]. Varenicline, a partial agonist of the nicotine cholinergic receptor, prevents full receptor activation and has proven effective in aiding smoking cessation [8]. However, approximately 25% of patients attempting to quit smoking do not adhere to their medication regimen as prescribed [9,10]. Yu et al. [11] suggested that higher medication compliance was linked to a lower risk of failing to quit smoking, yet more than half of all individuals registered at smoking cessation clinics drop out after one or two visits [12]. Digital health solutions, including smartphone applications, have been proposed to address these adherence issues [10,13]. In the United States, 75.9% of smokers own smartphones, and those motivated to quit are more likely to download such applications [14]. Individual, group, and telephone counseling have been effective, and their effectiveness increases with the intensity of the treatments [15]. If smokers were to use smoking cessation applications in conjunction with these counseling programs, the treatment outcomes could be significantly enhanced.

Smokers who fully adhered to using a smartphone application were four times more likely to quit smoking, although only 24% of users achieved full adherence [16]. Among users of a smartphone application designed to support drug adherence, 29% used the application at least once a week for a minimum of 4 weeks [17]. To address these high attrition rates, a new smartphone application for smoking cessation was developed, adhering strictly to the US Clinical Practice Guideline (USCPG). On average, participants engaged with the application 100.6 times over the 8-week study, and 26.2% reported 30 days of smoking cessation after 8 weeks [10]. Therefore, exploring methods to increase compliance with smoking cessation applications is crucial. The Fagerstrom Test for Nicotine Dependence (FTND) is widely used to assess the intensity of a smoker’s nicotine dependence [18]. The success of a smoker’s cessation efforts has been linked to the severity of their nicotine dependence [19]. Thus, it is essential to consider the severity of nicotine dependence when counseling smokers. Before developing a smartphone application for smoking cessation, we conducted a survey to gather data on smokers’ mobile usage patterns, smoking habits, and nicotine dependence.

Thus, this study aimed to investigate the association between smartphone application usage patterns, smoking habits, nicotine dependence, and expected compliance with a smoking cessation application among smokers. The goal is to inform the development of a future smartphone application for smoking cessation.

II. Methods

1. Participants

A total of 53 current smokers who visited the pulmonology outpatient department at Kangwon National University Hospital between September 2023 and October 2023 were enrolled in this study. The application developed by the Ministry of Health and Welfare of Korea had been downloaded over 100,000 times. Based on this figure, we assumed the population size to be 100,000. With a confidence level of 85% and a margin of error of 10%, the sample size was estimated to be 52. Only participants who used smartphones and provided written informed consent were included in this study. Out of 67 candidates, 53 smokers agreed to participate, resulting in a response rate of 79.10%. Smokers who did not use smartphones were excluded from the study.

2. Questionnaire and Variable Definitions

A cross-sectional, questionnaire-based study was conducted. The questionnaire included questions about patient characteristics, mobile phone usage patterns, smoking habits, and nicotine dependence. The questions related to mobile phone usage patterns were adapted from a design originally created by Nazari et al. [20], while those concerning smoking habits were based on a design by Jafari et al. [21]. The FTND, which comprises six items, was employed to assess nicotine dependence (see Supplementary Table S1). The Heaviness of Smoking Index (HSI), a significant predictor of smoking cessation [22], was calculated using the first and fourth
questions of the FTND. The questionnaire was developed by three pulmonologists and one psychiatrist. It underwent a pretest in a small group of smokers through a pilot study, which led to minor modifications. Following these revisions, the final version of the questionnaire was completed (see Supplementary Table S2). The final questionnaire comprised 17 questions across three themes: characteristics of the participants, mobile phone usage patterns, and smoking habits.

The first five questions (Q) collected information on the participants’ characteristics. Q1 and Q2 asked about the participants’ age and gender. Q3 inquired about the frequency of mobile phone usage, with a scoring scale that ranged from 0 to 4 points based on the number of hours the participants used their mobile phones. Q4 required participants to rate their likelihood of successfully quitting smoking on a 5-point Likert scale, from very likely to not at all likely, reflecting their level of motivation. Q5 asked participants if they were aware of the harmful effects of smoking, as this knowledge can influence motivation levels. Motivated participants tended to visit more health-related websites than their unmotivated counterparts [14]. Therefore, questions to assess the motivation level of the participants were included in the questionnaire.

The next six questions, Q6 to Q11, collected data on mobile phone usage patterns and expected compliance with the smoking cessation application. The questions about mobile phone usage patterns were divided into two parts. The first part, questions Q6 to Q8, asked whether the participant would seek social support to help them quit smoking, as social support is known to be effective in smoking cessation [15]. The second part, questions Q9 and Q10, focused on text messages. Previous studies have demonstrated that short text messages are effective in smoking cessation, particularly those that highlight the health benefits of quitting [5,23]. Q9 asked how many text messages the participants wanted to receive, while Q10 inquired about the content of these messages. Q11 sought to determine how long the participant would use the application, serving as a measure of expected compliance with the smoking cessation application.

Q12 to Q17 focused on previous smoking cessation attempts and smoking habits. Q12 and Q13 asked whether the participant had made any previous attempts to quit smoking and how many attempts they had made. These questions were included because strategies for quitting are tailored based on an individual's history of quit attempts [15]. Q14 to Q17 pertained to smoking habits linked to the risk of relapse. Certain circumstances and withdrawal symptoms serve as triggers for relapse [24]. Q14 asked the participant to specify the reasons they failed to quit smoking. Q15 and Q16 addressed how participants manage withdrawal symptoms and tobacco cravings. Finally, Q17 explored the specific circumstances that act as triggers.

Questions that were on a 5-point scale (Q3, Q4, Q9, Q11, and Q13) and the total FTND score were used as the main variables. The variables corresponding to Q3, Q4, Q9, Q11, and Q13 were redefined as “P_freq,” “Q_chance,” “M_text,” “A_comp,” and “P_attempt.”

### 3. Statistical Analysis

Continuous variables were expressed as mean ± standard deviation. The responses to the questionnaire were presented as numbers and percentages. The relationships between the variables P_freq, Q_chance, M_text, A_comp, P_attempt, and the total FTND score were analyzed to assess the association between smartphone usage patterns, nicotine dependence, and expected compliance with the smoking cessation application. Due to the small sample size and the presence of many tied ranks among the variables, Kendall’s partial correlation, adjusted for age, was used to analyze these relationships. p-values less than 0.05 were considered statistically significant. Statistical analyses were conducted using Rex Pro (version 3.6.0; RexSoft, Seoul, Korea) and R (version 4.0.2; The R Foundation, Vienna, Austria).

### 4. Ethics Statement

This study was approved by the Institutional Review Board of Kangwon National University Hospital (No. KNUH-2023-08-002-001). Informed consent was obtained from all participants involved in the study.

### III. Results

#### 1. Participant Characteristics

The demographics of the participants are shown in Table 1. The average age was 52 ± 18.06 years, and 52 participants (98.11%) were men. The majority of the participants (90.57%) knew the harmful effects of smoking.

#### 2. Main Variables

The values of the main variables are presented in Table 2. Eighteen participants (33.96%) reported using a mobile device for 1–2 hours daily, while 22 participants (41.51%) rated their chances of quitting smoking as neutral. Thirty-eight participants (71.70%) preferred to receive no more than five text messages per day. Twenty-five participants (47.17%) indicated they would use the smartphone application for less
than a week. Forty-three participants (81.13%) had previously attempted to quit smoking, with 13 of these (30.23%) having made more than three attempts. As shown in Table 3, the overall FTND score was 3.79 ± 2.51.

3. Categorical Variables
The results of categorical variables are presented in Tables 3–5. Table 3 displays the outcomes of the FTND questionnaire, including the distribution of participants’ FTND scores, which are illustrated in Figure 1. Among the participants, 29 (54.72%) exhibited low nicotine dependence, 12 (22.64%) displayed medium nicotine dependence, and another 12 (22.64%) showed high nicotine dependence. The average score of the HSI, calculated as the sum of the first and fourth FTND questions, was 2.70 ± 1.60 points. Table 4 details responses concerning social network service (SNS) and text messages. A majority of 66.04% of participants preferred not to inform their families or friends about their intention to quit smoking, and 52.83% believed that sharing their plans would not enhance their chances of quitting. Additionally, 37.74% of participants felt that receiving text messages highlighting the harmful effects of smoking would be the most effective strategy. Responses related to smoking habits are summarized in Table 5. Eighteen participants (33.96%) attributed their failure to quit smoking to stress, and the majority (67.92%) lacked a method to manage withdrawal symptoms. Post-meal cravings were reported by 24 participants (45.28%), while 12 (22.64%) felt the urge to smoke upon waking. To cope with tobacco cravings, 20 participants (37.74%) used self-suggestion, and 12 (22.64%) resorted to drinking water.

4. Correlation among Variables
The correlations among FTND and the main variables are presented in Table 6. Statistically significant correlations were found between P_freq and M_text (τ coefficient = −0.210, p = 0.026), P_freq and A_comp (τ coefficient = −0.260, p = 0.006), and M_text and A_comp (τ coefficient = 0.366, p = 0.00012).
IV. Discussion

Among the 53 participants with nicotine use disorder who visited Kangwon National University Hospital’s pulmonology outpatient department, the average FTND score was 3.79 ± 2.51 points, with 24 smokers (45.28%) exhibiting medium or high nicotine dependence. Given that smokers with high nicotine dependence are less likely to attempt quitting [25], it is essential to assess their level of dependence and provide appropriate treatment. In our study, the majority (90.57%) of participants were aware of the harmful effects of tobacco, and 43 participants (81.13%) had previously attempted to quit smoking. Kim et al. [26] have demonstrated that smokers who failed to quit had higher stress levels. Since 18 participants (33.96%) reported that mental stress had caused their previous cessation attempts to fail, clinicians at the smoking cessation clinic should assess the smoker’s stress level and determine if there are any underlying mental health issues.

Withdrawal symptoms, cravings, and exposure to smoking triggers such as alcohol consumption and peer pressure were the primary reasons for relapse [24]. In our study, the triggers identified for smoking included meals, waking up, drinking alcohol, and peer pressure, aligning with findings from previous research. When these situations occur repeatedly, they become cues that trigger the urge to smoke. The pleasurable effects of smoking or the unpleasant moods associated with not smoking serve as further incentives to smoke [7]. However, as indicated in Table 3, 36 participants (67.92%) lacked a structured approach to manage these cravings. Twenty participants (37.74%) reported using self-suggestion as a strategy to cope with tobacco cravings. Therefore, it is essential to establish effective methods for managing cravings and withdrawal symptoms to prevent relapse.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
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<tbody>
<tr>
<td>How soon after waking up do you smoke your first cigarette?</td>
<td></td>
</tr>
<tr>
<td>&lt;5 min</td>
<td>16 (30.19)</td>
</tr>
<tr>
<td>6–30 min</td>
<td>19 (35.85)</td>
</tr>
<tr>
<td>31–60 min</td>
<td>10 (18.87)</td>
</tr>
<tr>
<td>60 min</td>
<td>8 (15.09)</td>
</tr>
<tr>
<td>Do you find it difficult to refrain from smoking in places where it is forbidden?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9 (16.98)</td>
</tr>
<tr>
<td>No</td>
<td>44 (83.02)</td>
</tr>
<tr>
<td>Which cigarette would you hate most to give up?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>19 (35.85)</td>
</tr>
<tr>
<td>No</td>
<td>34 (64.15)</td>
</tr>
<tr>
<td>How many cigarettes per day do you smoke?</td>
<td></td>
</tr>
<tr>
<td>≤10</td>
<td>18 (33.96)</td>
</tr>
<tr>
<td>11–20</td>
<td>27 (50.94)</td>
</tr>
<tr>
<td>21–30</td>
<td>4 (7.55)</td>
</tr>
<tr>
<td>≥30</td>
<td>4 (7.55)</td>
</tr>
<tr>
<td>Do you smoke more frequently during the first hours after waking than during the rest of the day?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>13 (24.53)</td>
</tr>
<tr>
<td>No</td>
<td>40 (75.47)</td>
</tr>
<tr>
<td>Do you smoke if you are so ill that you are in bed most of the day?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>17 (32.08)</td>
</tr>
<tr>
<td>No</td>
<td>36 (67.92)</td>
</tr>
<tr>
<td>Overall points</td>
<td>3.79 ± 2.51</td>
</tr>
<tr>
<td>Heaviness of Smoking Index</td>
<td>2.70 ± 1.60</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or mean ± standard deviation.

Table 3. Fagerstrom Test for Nicotine Dependence
Shankar et al. [23] demonstrated that a text message program was effective in motivating smokers with opioid use disorder to quit smoking. Participants reported that text messages highlighting the health benefits of quitting and providing positive encouragement were helpful. The preferences for text content among participants were similar to those in our study. Specifically, 20 participants (37.74%) indicated that messages emphasizing the harmful effects of smoking were useful, while 12 participants (22.64%) found texts promoting a positive mindset helpful. However, participants also noted that receiving too many texts could be annoying [27]. In our study, 22 participants (41.51%) preferred to receive one text message per day, and 16 participants (30.19%) wanted to receive between two to five messages daily. Although text messages can be effective, it is important to limit their number to avoid causing annoyance.

Regarding smartphone applications, 25 participants (47.17%) reported that they would use an app for less than 1 week. To address this low engagement, a previous study suggested incorporating game elements [13]. When developing digital health solutions, it is crucial to consider methods that enhance compliance with the applications. Social connections can have powerful influences on health behavior [28] and social support. As shown in Table 4, 35 participants (66.04%) preferred not to inform their families and friends about their plans to quit smoking, and 28 participants (52.83%) believed that sharing their intentions would not enhance their chances of quitting. Additionally, 31 participants (58.49%) indicated they would not seek help from others when facing difficulties in quitting smoking. These attitudes may be influenced by cultural factors. Previous research has suggested that South Koreans often prioritize maintaining face and are highly sensitive to others’ evaluations [29]. This cultural context can make it challenging for smokers to seek support, as they may fear negative judgments. Therefore, when considering social connections, including SNS, as a potential aid for smoking cessation, it is important to take cultural considerations into account.

The partial correlation matrix between FTND and the main variables, adjusted for age, is presented in Table 6. P_freq and M_text were negatively correlated, indicating that the more time smokers spent on their mobile devices, the fewer text messages they preferred to receive. Similarly, P_freq and A_comp showed a negative correlation, suggesting that the more time smokers spent on their mobile devices, the shorter the duration they desired to use smartphone applications for smoking cessation. This suggests that heavy smartphone users may have lower compliance with smoking cessation apps. Excessive use of mobile phones can lead to smartphone addiction [30]. Individuals addicted to mobile phones are likely to spend more time on the applications they use. Therefore, it is important to inquire about the

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
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<tbody>
<tr>
<td>Do you want to tell your family members or friends that you are going to quit smoking via SNS?</td>
<td>Yes 18 (33.96) No 35 (66.04)</td>
</tr>
<tr>
<td>Do you think that if you tell other that you are going to quit smoking via SNS, your chances of quit smoking will be higher?</td>
<td>Yes 25 (47.17) No 28 (52.83)</td>
</tr>
<tr>
<td>If you think that your chances of quit smoking is low, do you want to seek helps from your family or friends?</td>
<td>Yes 22 (41.51) No 31 (58.49)</td>
</tr>
<tr>
<td>Which text message content do you think is most effective to encourage you to quit smoking?</td>
<td>Benefits to quit smoking 7 (13.21) Emphasizing the harmful effects of smoking 20 (37.74) Positive mindset that I can quit smoking 12 (22.64) Encouraging phrases 8 (15.09) Thinking about my family and friends 6 (11.32)</td>
</tr>
</tbody>
</table>

Values are presented as number (%). SNS: social network service.
amount of time smokers spend on their smartphones and develop strategies to encourage the use of smoking cessation applications. Previous studies have demonstrated that a combination of methods, including personalized messaging, social engagement, and completing missions, can enhance compliance with applications [10]. Behavioral counseling or cognitive behavioral therapy (CBT) can be employed to address tobacco cravings and manage situations that trigger smoking. M_text and A_comp were positively correlated, indicating that the fewer text messages smokers wished to receive, the shorter the duration they wanted to use the smartphone application. This suggests that smokers who are disinterested in using smartphone applications as a quitting tool will likely exhibit poor compliance. It is crucial to carefully select smokers who could benefit from using smart-
phone applications. The correlations between FTND and other main variables were not statistically significant.

Our study has identified a relationship between smartphone usage patterns and anticipated compliance with a smoking cessation application. The findings can inform the design of the application to improve user compliance based on these patterns. However, this study has several limitations. First, it depended on patients’ responses to questionnaires, which necessitates caution. Second, it utilized cross-sectional data, precluding any determination of causality. Third, the number of patients enrolled in this study was relatively small. Future longitudinal studies with larger sample sizes are needed.

In conclusion, smokers who spent more time on their mobile devices expressed a preference for receiving fewer text messages about smoking cessation, and they anticipated lower compliance with the smoking cessation application. Conversely, smokers who were open to receiving more text messages about smoking cessation were also inclined to use the smoking cessation application for a longer period. When developing smoking cessation applications, it may be beneficial to inquire about the user’s preferred frequency of text messages and their smartphone usage patterns to increase compliance with the application. Further research is needed to confirm this relationship in practical settings.

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

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Supplementary Materials
Supplementary materials can be found via https://doi.org/10.4258/hir.2024.30.3.224.

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