

# World Journal of *Psychiatry*

*World J Psychiatr* 2021 December 19; 11(12): 1167-1424



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Editorial Board Member of *World Journal of Psychiatry*, Subho Chakrabarti, MD, FRCP, FAMS, Professor, Department of Psychiatry, Postgraduate Institute of Medical Education and Research, Chandigarh 16002, India. [chakrabarti.subho@pgimer.edu.in](mailto:chakrabarti.subho@pgimer.edu.in)

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The WJP is now abstracted and indexed in Science Citation Index Expanded (SCIE, also known as SciSearch®), Current Contents/Clinical Medicine, Journal Citation Reports/Science Edition, PubMed, and PubMed Central. The 2021 edition of Journal Citation Reports® cites the 2020 impact factor (IF) for WJP as 4.571; IF without journal self cites: 4.429; 5-year IF: 7.697; Journal Citation Indicator: 0.73; Ranking: 46 among 156 journals in psychiatry; and Quartile category: Q2.

**RESPONSIBLE EDITORS FOR THIS ISSUE**

Production Editor: Xu Guo; Production Department Director: Yu-Jie Ma; Editorial Office Director: Jia-Ping Yan.

**NAME OF JOURNAL**

*World Journal of Psychiatry*

**ISSN**

ISSN 2220-3206 (online)

**LAUNCH DATE**

December 31, 2011

**FREQUENCY**

Monthly

**EDITORS-IN-CHIEF**

Rajesh R Tampi

**EDITORIAL BOARD MEMBERS**

<https://www.wjgnet.com/2220-3206/editorialboard.htm>

**PUBLICATION DATE**

December 19, 2021

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<https://www.wjgnet.com/bpg/gerinfo/242>

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**ONLINE SUBMISSION**

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## Case Control Study

# Developing a nomogram for predicting the depression of senior citizens living alone while focusing on perceived social support

Haewon Byeon

**ORCID number:** Haewon Byeon  
0000-0002-3363-390X.

**Author contributions:** Byeon H was designed the study, involved in data interpretation, performed the statistical analysis, and assisted with writing the article.

### Institutional review board

**statement:** The study was approved by the Research Ethics Review Board of the National Biobank of Korea (No. KBN-2019-005) and the H University (No. 20180042).

**Informed consent statement:** All patients gave informed consent.

**Conflict-of-interest statement:** No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

**Data sharing statement:** Technical appendix, statistical code from the corresponding author at [bhwpuma@naver.com](mailto:bhwpuma@naver.com).

**STROBE statement:** The authors have read the STROBE statement—checklist of items, and the manuscript was prepared and revised according to the STROBE statement—checklist of items.

**Haewon Byeon**, Department of Medical Big Data, Inje University, Gimhae, 50834, Gyeongsangnamdo, South Korea

**Corresponding author:** Haewon Byeon, DSc, PhD, Associate Professor, Director, Department of Medical Big Data, Inje University, 197, Inje-ro, Gimhae, 50834, Gyeongsangnamdo, South Korea. [bhwpuma@naver.com](mailto:bhwpuma@naver.com)

## Abstract

### BACKGROUND

Although the number of senior citizens living alone is increasing, only a few studies have identified factors related to the depression characteristics of senior citizens living alone by using epidemiological survey data that can represent a population group.

### AIM

To evaluate prediction performance by building models for predicting the depression of senior citizens living alone that included subjective social isolation and perceived social support as well as personal characteristics such as age and drinking.

### METHODS

This study analyzed 1558 senior citizens (695 males and 863 females) who were 60 years or older and completed an epidemiological survey representing the South Korean population. Depression, an outcome variable, was measured using the short form of the Korean version CES-D (short form of CES-D).

### RESULTS

The prevalence of depression among the senior citizens living alone was 7.7%. The results of multiple logistic regression analysis showed that the experience of suicidal urge over the past year, subjective satisfaction with help from neighbors, subjective loneliness, age, and self-esteem were significantly related to the depression of senior citizens living alone ( $P < 0.05$ ). The results of 10-fold cross validation showed that the area under the curve of the nomogram was 0.96, and the F1 score of it was 0.97.

### CONCLUSION

It is necessary to strengthen the social network of senior citizens living alone with friends and neighbors based on the results of this study to protect them from

**Supported by** Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2018R1D1A1B07041091, NRF-2021S1A5A8062526).

**Country/Territory of origin:** South Korea

**Specialty type:** Psychiatry

**Provenance and peer review:** Invited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review report's scientific quality classification**

Grade A (Excellent): 0  
Grade B (Very good): 0  
Grade C (Good): 0  
Grade D (Fair): 0  
Grade E (Poor): 0

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**Received:** May 23, 2021

**Peer-review started:** May 23, 2021

**First decision:** July 14, 2021

**Revised:** July 18, 2021

**Accepted:** November 3, 2021

**Article in press:** November 3, 2021

**Published online:** December 19, 2021

**P-Reviewer:** Wang Z

**S-Editor:** Wang JJ

**L-Editor:** A

**P-Editor:** Wang JJ



depression.

**Key Words:** Senior citizens living alone; Nomogram; Depression; Risk factor; Perceived social support; Subjective social isolation

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**Core Tip:** In this study, the significant predictors of depression of the senior citizens living alone were the experiences of suicidal urge over the past year, dissatisfaction with help from neighbors, subjective loneliness, age, and low self-esteem. The results of this study implied that it is necessary to develop a support system customized for subjects to strengthen the relation network for preventing depression in senior citizens living alone so that they can receive actual support (reinforced qualitative network) from acquaintances such as neighbors rather than the frequency of physical contact (reinforced quantitative network).

**Citation:** Byeon H. Developing a nomogram for predicting the depression of senior citizens living alone while focusing on perceived social support. *World J Psychiatr* 2021; 11(12): 1314-1327

**URL:** <https://www.wjgnet.com/2220-3206/full/v11/i12/1314.htm>

**DOI:** <https://dx.doi.org/10.5498/wjp.v11.i12.1314>

## INTRODUCTION

The incidence of diseases involving senile dementia is rapidly increasing globally due to a rapid increase in the aging population[1]. One of the outcomes of these diseases, depression, is an important and frequent psychiatric disorder in the senile stage, and it is predicted to become the second most important factor in the global disease burden [1]. Since depression can be treated through drug and psychosocial therapy, it is very important to diagnose and treat it as soon as possible. Nevertheless, it is difficult to diagnose depression in the senile stage in good time because it is often erroneously confused with physical symptoms (*e.g.*, a headache, dizziness, *etc.*) by other family members (senior citizens complain about these more often than younger people), while cognitive decline due to depression is often obscured by the normal aging process[2,3]. Thus, it tends to be neglected without receiving appropriate attention, diagnosis, and/or treatment[2,3]. Hence, many senior citizens living in the community may be suffering from depression even if they have not been clinically diagnosed with it by medical personnel[4].

Although detecting depression in good time is an important requirement for the aged, depression tends to be discovered late or not treated adequately due to various reasons, such as a lack of awareness of one's depression, the complex manifestation of depression, and a decrease in the interest of close acquaintances and family members. However, if geriatric depression is neglected without being properly treated, the individual will suffer from unnecessary mental and social pain, which can lead to serious outcomes such as suicidal ideation[5,6]. Consequently, it is very important to accurately diagnose and detect geriatric depression when treating diseases involving senility[5,6].

The proportion of the elderly population who are living with and/or supported by their children continues to decrease in South Korea in concert with a rapid increase in the number of elderly people living alone[7]. As of 2015, the number of senior citizens living alone in South Korea was 1379000, which is a 1.8-fold increase (777000 people) compared to 2005[7], and is expected to increase to 3.43 million by 2035[7]. Moreover, the proportion of senior citizens living alone is expected to increase to 23.2% in 2035 from 17.8% in 2020. Senior citizens living alone must handle everything that arises in their daily lives, and they exist in poorer environments than those supported by their children not only from economic (income and consumption) and welfare perspectives but also concerning their mental health. The findings from the Survey of Living Conditions and Welfare Needs of Korean Older Persons[7] show that senior citizens living alone are usually old and poorly educated, while the proportion of female senior

citizens living alone is five times higher than those living with their families. Pogön Sahoe Yöngu[8] reported that senior citizens living alone had poorer subjective health and were more likely to suffer from a disease such as depression than those living with their families. Thus, the mental health of senior citizens living alone is poorer than those living with their families and the causes of depression in the former are many rather than singular[8,9].

Although the number of senior citizens living alone is increasing, few researchers have identified factors related to the characteristics of depression in these individuals by using epidemiological survey data representative of this population group. Although epidemiological surveys on the prevalence of depression in the senile stage have been actively conducted in many countries[10-13], the prevalence of depression varied between them due to differences in the survey sampling methods, depression testing tools, and evaluation methodology. Researchers usually use two-phase designs in psychiatric epidemiological studies to classify subjects into a depression-positive group and a depression-negative group quickly and economically by using a simple standardized screening test in the first phase followed by conducting a robust diagnostic test in the second phase to save on the labor and economic burden[14]. Therefore, in the first phase, we used the Center for Epidemiological Studies Depression Scale (CES-D)[15], a widely used standardized screening test, to identify the prevalence of depression in senior citizens living alone. Second, we evaluated the prediction performance [area under the curve (AUC) for the receiver operating characteristic, general accuracy, balanced accuracy, F1 score, sensitivity, and specificity] by building models for predicting depression in senior citizens living alone, which included subjective social isolation and perceived social support as well as personal characteristics such as age and alcohol consumption. Last, we developed a nomogram that allows practitioners to check multiple risk factors for depression in senior citizens living alone using visual graphs and to calculate the prevalence of depression while considering the personal characteristics of the subjects based on these results.

## MATERIALS AND METHODS

### *Data source*

This study is a secondary data based on the Korean Psychosocial Anxiety (KPA) survey, an epidemiological survey representing the South Korean population. KPA-survey was conducted from August to September 2015 by the Korea Institute for Health and Social Affairs. The study stratified the population, obtained from the Residence Registration Data (complete enumeration) conducted by the Ministry of Security and Public Administration as of June 2015, into 17 cities and provinces (*i.e.*, Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Sejong, Gyeonggi-do, Gangwon-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollanam-do, Gyeongsangbuk-do, Gyeongsangnam-do, and Jeju-do). Afterward, this study extracted samples using the quota sampling method with considering the gender, age, and residential area ratios. This study selected 200 eups, myeons, and dongs from 3552 eups, myeons, and dongs in South Korea using the probabilities proportional to size (PPS) method. In order to secure randomness when extracting sampling sites, the PPS was applied after sorting the districts in the order of city, county, and district based on the administrative district code. After selecting 200 sampling sites, the 5<sup>th</sup> household from the Community Service Center of each selected eup, myeon, or dong was chosen as the sampling household by visiting the selected sampling site, and finally, 7000 adults (19 years or older) were surveyed. This study conducted an in-person survey by having trained surveyors who received survey training visit the sample households using the computer assisted personal interview method. This study was approved by H University's Clinical Research Ethics Committee (No. 20180042). This study analyzed 1558 senior citizens (695 males and 863 females) who were 60 years or older and completed the KPA-survey.

### *Measurement*

Depression, an outcome variable, was measured using the short form of the Korean version CES-D (short form of CES-D)[16]. CES-D[15] is a standardized self-report depression test that is used most commonly in the world and can measure depression in healthy people easily. This test was developed by the National Institute of Mental Health for investigating the epidemiological status of depression in a community and has been widely used in many countries in various languages as a screening instrument for depression[16]. Many previous studies have proven the high internal

consistency and validity of CES-D[17,18]. More recently, the scale of short form of CES-D, which has secured good reliability and validity, has also been developed and used for subjects who have difficulties in responding to the 20 items of the original CES-D (e.g., senior citizens, those with dyslexia, or illiterates)[19-23]. Short form of CES-D has been continuously used in epidemiological surveys because it reduces the response burden of the participants and it has the advantage that it can be easily used for the elderly who suffer from many physical symptoms and have difficulties in answering a long item due to a decrease in concentration[24]. The KPA-survey, the data source of this study, used standardized short form CES-D consisting of 11 items. This test classified depression into four levels based on the frequency of depression symptoms experienced by the subject over the past week. Moreover, the severity of symptoms was classified into four classes using a Likert scale (0 points = rare or 1 d or fewer per week; 1 point = occasional or 1 to 2 d per week; 2 points = often or 3 to 4 d per week; and 3 points = mostly or 5 d or more per week). A higher total score means more depression symptoms. This study defined the threshold of depression as 16 points based on the previous study[22] on the elderly in South Korea.

Explanatory variables were age (continuous variable), alcohol consumption (abstainers or normal drinkers, high-risk drinkers, and those with alcohol use disorder), self-esteem, suicidal ideation over the past year (yes or no), subjective social isolation (rarely, occasionally, often, or usually lonely), frequency of communication with other family members (a 10-point scale with a higher score infers more frequent communication), interaction with neighbors and friends [regular club activities (yes or no), perceived social support (a 10-point scale), trust neighbors (yes or no), and satisfied with help (support) from neighbors (yes or no)], satisfaction with the neighborhood environment (yes or no), satisfaction with the safety level of the neighborhood (yes or no), and satisfaction with the medical services in the region (yes or no) [25]. The self-esteem item was measured by using the Self-Esteem Scale (SES) comprising 10 items (a total score of 40 points)[26]: A low score (15 or less) indicates poor self-esteem. The Alcohol Use Disorders Identification Test (AUDIT)[27] developed by the World Health Organization for the preliminary screening of high-risk drinkers comprises 10 items with a total score of 40 points: 0-15 points identify abstainers and normal drinkers, 16-19 points identify high-risk drinkers, and  $\geq 20$  points identify individuals with alcohol use disorder.

### ***Developing a model to predict the depression of senior citizens living alone***

The general characteristics and depression prevalence of the subjects were presented/ present in percentages. The effects of depression were examined by Chi-square test. This study built a depression prediction model using logistic regression analysis to find out the effect of each variable on depression. This study selected variables using step-forward regression analysis. Moreover, this study presented an unadjusted crude model, which was not adjusted with confounding factors, and an adjusted model, which was adjusted with confounding factors.

The developed depression prediction model contained a nomogram to make it possible for clinicians to interpret the prediction results (prediction probability) easily. The nomogram was composed of 4 elements. The first was a point line. It was the line located at the top of the nomogram to indicate the score corresponding to the risk range of a factor. In the case of a logistic nomogram, it ranged from 0 to 100 points. The second was a risk factor line. This line indicates the score range of a risk factor influencing the occurrence of an event. The number of risk factor lines was equal to the number of risk factors. The third was a probability line. The probability line was the sum of finally calculated nomogram scores and it was placed at the bottom of the nomogram to derive the probability (risk) of depression. The fourth is a total point line. It was constructed by calculating it based on a statistical model.

### ***Evaluating the prediction performance of a model for predicting the depression of senior citizens living alone***

The sample size of this study was small ( $n = 1558$ ). Therefore, when the prediction performance of the model is validated using a held-out validation method (i.e., a validation method that divides the dataset into a training dataset and a validation dataset at a 7:3 ratio), it poses a risk of overfitting. Consequently, it is more likely to decrease the reliability of prediction results. As a result, this study used 10-fold cross-validation to validate the prediction performance of the developed depression prediction model (nomogram). AUC, general accuracy, balanced accuracy, F1 score, sensitivity, specificity and calibration plot were presented. The calibration plot is a graph for visually confirming the degree of agreement (y, Calibration curve and x,



predicted probability) between the predicted probability and the observed probability. Sensitivity indicates the ratio of true positives: The ratio of the developed model to predict the senior citizen living alone with depression as depression. Specificity indicates the ratio of true negatives: The ratio of the developed model to predict the senior citizen living alone without depression as no-depression accurately. R version 4.0.3 (Foundation for Statistical Computing, Vienna, Austria) was used for analyses and significance level was 0.05 in two-tailed test.

## RESULTS

### **General characteristics of subjects**

General characteristics of all subjects (1558 subjects) are presented in [Table 1](#). The mean age was  $67.9 \pm 5.5$  years old: 55.4% of them were women and 44.6% of them were men. The results of the AUDIT showed that most of the subjects were normal (52.4%), no suicidal urge over the past one year (91.0%), very rare subjective loneliness (44.1%), and homemaker (35.5%). The prevalence of depression among the senior citizens living alone in the community, measured by short form of CES-D was 7.7%.

### **Characteristics of the subject according to the prevalence of depression**

The characteristics of the subjects according to the prevalence of depression are presented in [Table 2](#). The results of chi-square test showed that depression was significantly ( $P < 0.05$ ) affected by age, self-esteem, subjective frequency of communication with other family members, alcohol use disorder, the experience of suicidal urge over the past year, subjective trust satisfaction with neighbors, subjective satisfaction with help (support) from neighbors, subjective satisfaction of the safety level of the neighborhood, subjective satisfaction of the medical service of the region, regular club activities, and subjective loneliness.

### **Developing a model for predicting depression of senior citizens living alone**

[Table 3](#) shows a model for predicting the depression of senior citizens living alone. The results of univariate logistic regression analysis (crude model) showed that all variables (age, self-esteem, alcohol use disorder, the experience of suicidal urge over the past year, subjective trust satisfaction with neighbors, subjective satisfaction of the living environment of the neighborhood, subjective satisfaction of the safety level of the neighborhood, subjective satisfaction of the medical service of the region, regular club activities, subjective loneliness, subjective frequency of communication with other family members, and subjective frequency of communication with neighbors/friends) were significantly ( $P < 0.05$ ) related to the depression of senior citizens living alone. However, the results of the adjusted model revealed that the depression of senior citizens living alone was independently associated only with the experience of suicidal urge over the past year [odds ratio (OR): 3.57, 95% cumulative incidence (CI): 1.55-8.22], subjective satisfaction with help (support) from neighbors (OR: 0.29, 95%CI: 0.13-0.66), subjective loneliness (occasionally lonely: OR: 5.04, 95%CI: 1.00-4.65; often lonely: OR: 187.19, 95%CI: 23.17-1512.13; mostly lonely: OR: 758.12, 95%CI: 56.44-10183.32), age (OR: 1.17, 95%CI: 1.07-1.26), and self-esteem (OR: 0.81, 95%CI: 0.72-0.91).

### **Developing a nomogram to predict the depression of senior citizens living alone based on multiple risk factors**

A nomogram for predicting the depression of elderly living alone based on multiple risk factors is presented in [Figure 1](#). Among the risk factors of depression of senior citizens living alone, subjective loneliness had the greatest influence, and the senior citizens living alone who responded that they felt lonely showed the highest risk of depression. For example, the nomogram for predicting depression predicted that the depression risk of senior citizens who had suicidal urge over the past year, were not satisfied with subjective help (support) with neighbors, thought that they were mostly lonely, had 15 points in Rosenberg SES scale (self-esteem), and were 80 years or older was 99.8% ([Figure 2](#)).

### **Validating a nomogram for predicting the depression of senior citizens living alone**

The developed nomogram for predicting the depression of senior citizens living alone was validated by using AUC, general accuracy, balanced accuracy, F1 score, sensitivity, and specificity ([Table 4](#)). The results of 10-fold cross validation showed that the AUC of the nomogram was 0.96, the general accuracy of it was 0.95, the balanced

**Table 1 General characteristics of subjects**

Characteristics	n (%)
Age, mean $\pm$ SD	67.9 $\pm$ 5.5
Gender	
Male	695 (44.6)
Female	863 (55.4)
Occupation (ISCO)	
Managers	20 (1.3)
Professional	12 (0.8)
Clerical support workers	6 (0.4)
Service workers	97 (6.2)
Sales workers	166 (10.7)
Skilled agricultural, forestry and fishery workers	88 (5.6)
Craft and related trades workers	77 (4.9)
Plant and machine operators, and assemblers	9 (0.6)
Elementary occupations	130 (8.3)
Housewives	553 (35.5)
Unemployed persons	399 (25.6)
Alcohol use disorder (AUDIT)	
Normal drinker	817 (52.4)
High-risk drinker	278 (17.8)
Alcohol use disorder	13 (0.8)
Self-esteem, the experience of suicidal urge over the past year	
No	1418 (91.0)
Yes	140 (9.0)
Subjective loneliness	
Very rare	687 (44.1)
Occasionally lonely	639 (41.0)
Often lonely	210 (13.5)
Mostly lonely	22 (1.4)
Self-esteem scale, mean $\pm$ SD	28.7 $\pm$ 3.4
Depression	
No	1438 (92.3)
Yes	120 (7.7)

ISCO: International Standard Classification of Occupations; ADUIT: Alcohol Use Disorders Identification Test.

accuracy of it was 0.80, the sensitivity of it was 0.98, the specificity of it was 0.62, and the F1 score of it was 0.97. The equation of the calibration plot was drawn along the ideal line; coefficient of determination (R square) was 0.853 (Figure 3). The AUC of the developed nomogram for predicting the depression of senior citizens living alone is presented in Figure 4.

**Table 2** The characteristics of the subjects according to the prevalence of depression, *n* (%)

Variables	Depression		<i>P</i>
	No ( <i>n</i> = 1438)	Yes ( <i>n</i> = 120)	
Age, mean ± SD	67.75 ± 5.53	70.95 ± 4.99	< 0.0001
Self-esteem scale, mean ± SD	29.06 ± 3.26	25.01 ± 3.43	< 0.0001
Subjective frequency of communication with other family members, mean ± SD	2.54 ± 0.95	2.05 ± 0.94	< 0.0001
Subjective frequency of communication with neighbors and friends, mean ± SD	2.25 ± 1.05	2.05 ± 1.11	0.05
Alcohol use disorder			< 0.001
Normal drinker	766 (93.8)	51 (6.2)	
High-risk drinker	258 (92.8)	20 (7.2)	
Alcohol use disorder	6 (46.2)	7 (53.8)	
Self-esteem, the experience of suicidal urge over the past year			< 0.001
No	1349 (95.1)	69 (4.9)	
Yes	89 (63.6)	51 (36.4)	
Subjective trust satisfaction with neighbors			< 0.001
No	163 (76.9)	49 (23.1)	
Yes	1275 (94.7)	71 (5.3)	
Subjective satisfaction with help from neighbors			< 0.001
No	420 (85.7)	70 (14.3)	
Yes	1018 (95.3)	50 (4.7)	
Subjective satisfaction of the living environment of the neighborhood			0.08
No	245 (89.7)	28 (10.3)	
Yes	1193 (92.8)	92 (7.2)	
Subjective satisfaction of the safety level of the neighborhood			< 0.001
No	230 (84.3)	43 (15.7)	
Yes	1208(94.0)	77 (6.0)	
Subjective satisfaction of the medical service of the region			< 0.001
No	386 (88.5)	50 (11.5)	
Yes	1,438 (92.3)	120(7.7)	
Regular club activities			< 0.001
No	975 (90.5)	103(9.5)	
Yes	463 (96.5)	17(3.5)	
Subjective loneliness			< 0.001
Very rare	685 (99.7)	2 (0.3)	
Occasionally lonely	617 (96.6)	22 (3.44)	
Often lonely	131 (62.4)	79(37.6)	
Mostly lonely	5 (22.7)	17(77.3)	

## DISCUSSION

The prevalence of depression in senior citizens living alone in the community measured using the short form of the CES-D was 7.7%, which is 2-4 times higher than reported in previous studies (1%-4%)[28-31]. In particular, after combining the results from 16 studies, Beekman *et al*[32] reported that the weighted mean prevalence of depression in the elderly living alone in the community was 1.77%. In contrast, Park *et al*[33] identified the prevalence of depression in 6018 senior citizens who participated

**Table 3 A model for predicting the depression of senior citizens living alone: Odds ratio and 95% confidence interval**

Variables	Crude model	Adjusted model	VIF
Alcohol use disorder			
Normal drinker	1.00	1.00	
High-risk drinker	1.16 (0.68, 1.99)	1.08 (0.45, 2.59)	1.14
Alcohol use disorder	17.52 (5.67, 54.06) <sup>a</sup>	1.54 (0.16, 14.80)	1.20
Self-esteem, the experience of suicidal urge over the past year			
No (Ref)			
Yes	12.83 (7.74, 21.26) <sup>a</sup>	3.57 (1.55, 8.22) <sup>a</sup>	1.27
Subjective trust satisfaction with neighbors			
No (Ref)	1.00	1.00	
Yes	0.20 (0.12, 0.32) <sup>a</sup>	1.02 (0.43, 2.40)	1.37
Subjective satisfaction with help from neighbors			
No (Ref)	1.00	1.00	
Yes	0.24 (0.15, 0.39) <sup>a</sup>	0.29 (0.13, 0.66) <sup>a</sup>	1.40
Subjective satisfaction of the living environment of the neighborhood			
No (Ref)	1.00	1.00	
Yes	0.41 (0.25, 0.66) <sup>a</sup>	0.51 (0.23, 1.10)	1.19
Subjective satisfaction of the safety level of the neighborhood			
No (Ref)	1.00	1.00	
Yes	0.32 (0.20, 0.53) <sup>a</sup>	0.46 (0.21, 1.04)	1.19
Subjective satisfaction of the medical service of the region			
No (Ref)	1.00	1.00	
Yes	0.46 (0.28, 0.73) <sup>a</sup>	0.56 (0.26, 1.20)	1.19
Regular club activities			
No (Ref)	1.00	1.00	
Yes	0.38 (0.20, 0.70) <sup>a</sup>	2.04 (0.81, 5.15)	1.31
Subjective loneliness			
Very rare (Ref)	1.00	1.00	
Occasionally lonely	12.21 (2.86, 52.14) <sup>a</sup>	5.04 (0.58, 43.39)	6.87
Often lonely	206.54 (50.13, 850.86) <sup>a</sup>	187.19 (23.17, 1512.13) <sup>a</sup>	7.89
Mostly lonely	1164.50 (210.83, 6431.88) <sup>a</sup>	758.12 (56.44, 10183.32) <sup>a</sup>	3.10
Subjective frequency of communication with other family members	0.55 (0.49, 0.61) <sup>a</sup>	0.95 (0.71, 1.27)	2.16
Subjective frequency of communication with neighbors and friends	0.59 (0.53, 0.66) <sup>a</sup>	1.10 (0.81, 1.48)	2.12
Age	0.89 (0.85, 0.93) <sup>a</sup>	1.17 (1.07, 1.26) <sup>a</sup>	1.42
Self-esteem scale	0.70 (0.65, 0.74) <sup>a</sup>	0.81 (0.72, 0.91) <sup>a</sup>	1.33

<sup>a</sup> $P < 0.05$ .

VIF: Variance Inflation Factor.

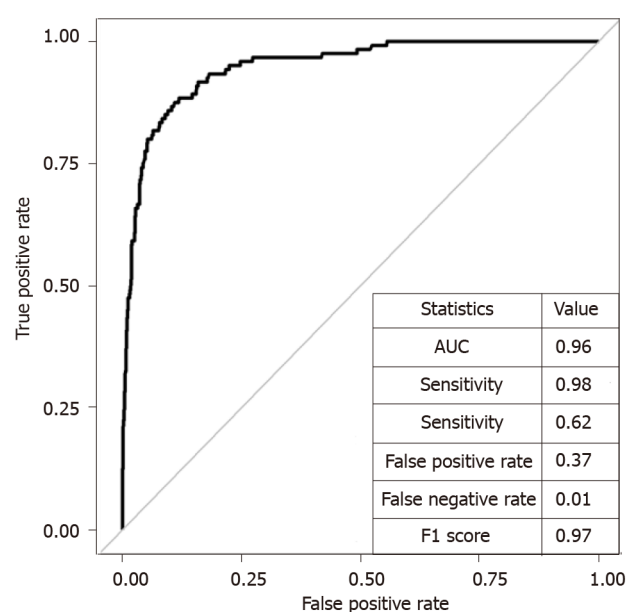
in the Nationwide survey on dementia in Korea that was 17.5% higher than in the present study. The differences in the reported prevalence of depression suggest that the number of senior citizens at a high risk of depression (even if not yet clinically diagnosed) may actually be higher than the reported number. Therefore, the development of a customized prediction model that can screen this high risk of depression group based on the results of the present study is needed.



**Table 4** Validating a nomogram for predicting the depression of senior citizens living alone

Measure	Description	Value
TP		1012
TN		49
FP		29
FN		18
AUC		0.96
Accuracy	$(TP + TN)/(TP + TN + FP + FN)$	0.95
Balanced accuracy	$[TP/(TP + FN) + TN/(TN + FP)]/2$	0.80
Sens	$TP/(TP + FN)$	0.98
Spec	$TN/(TN + FP)$	0.62
FPR	$FP/(TN + FP)$	0.37
FNR	$FN/(TP + FN)$	0.01
F1 score	$2/(1/Sens + 1/PPV)$	0.97

TP: True positive; TN: True negative; FP: False positive; FN: False negative; AUC: Area under the curve; FPR: False positive rate; FNR: False negative rate; PPV: Potential path volume; Sens: Sensitivity; Spec: Specificity.



**Figure 1** The area under the curve of the developed nomogram for predicting the depression of senior citizens living alone. AUC: Area under the curve.

In the present study, the significant predictors of depression in senior citizens living alone were suicidal ideation over the past year, dissatisfaction with help (support) from neighbors, subjective loneliness, age, and low self-esteem. It is known that the prevalence of depression in the elderly increases with age[34,35] and low self-esteem [36,37]. Many studies have reported that old people show a high risk of depression regardless of gender because they are more likely to lose their spouses, become physically weaker, have fewer opportunities to participate in social activities, become more susceptible to disease, and suffer from physical dysfunction[38,39]. Nevertheless, researchers have mainly tried to identify individual risk factors for depression using regression analysis[40-43], which negates discovering multiple risk factors for depression. In the present epidemiologic study, multiple risk factors for depression in senior citizens living alone were identified based on a nomogram. Moreover, the risk of depression in senior citizens living alone who had experienced suicidal ideation

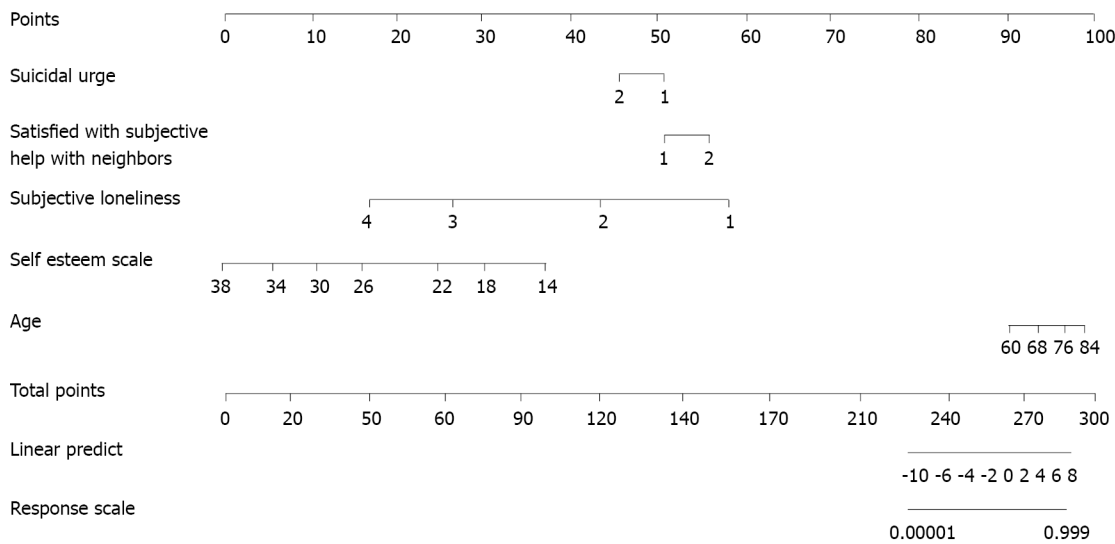


Figure 2 A nomogram for predicting the depression of elderly living alone.

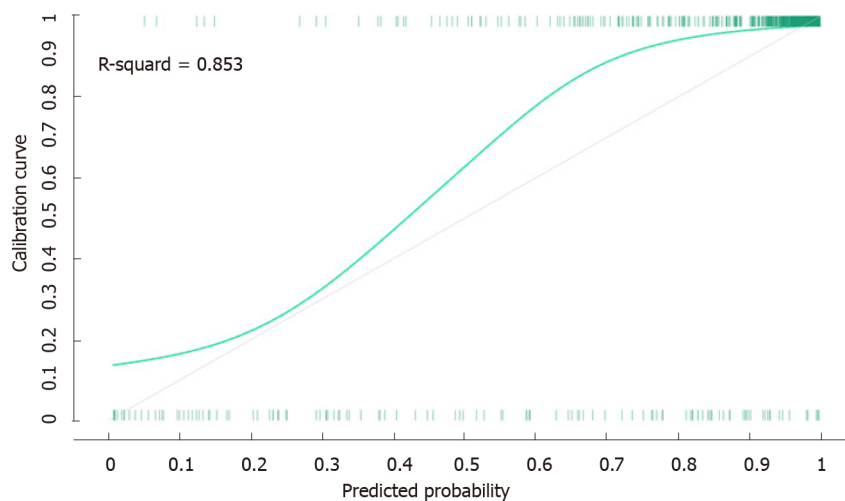
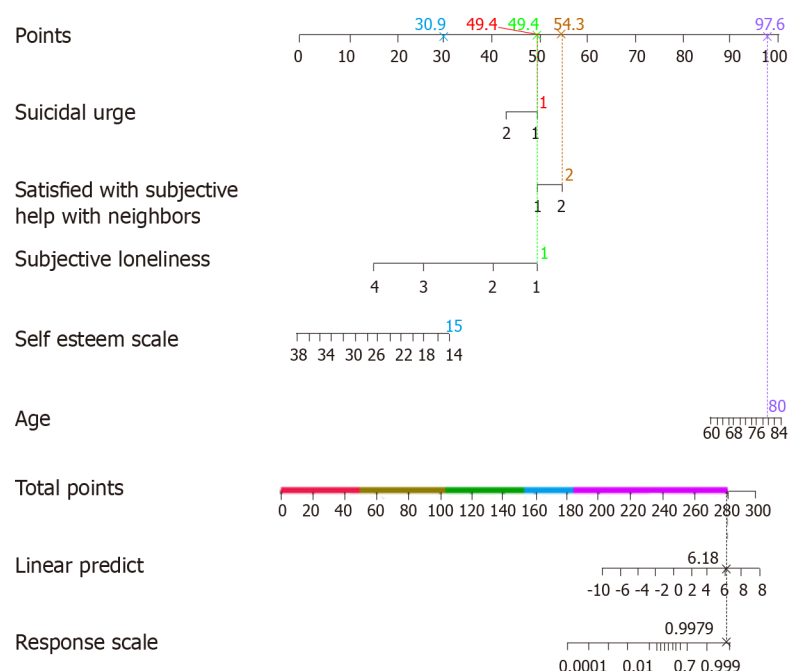


Figure 3 Calibration plot for nomogram model.

over the past year, were not satisfied with help (support) from neighbors, felt lonely, had low self-esteem ( $\leq 15$  on the Rosenberg SES scale), and were  $\geq 80$  years old was 99.8%, which is very high. Therefore, screening this high-risk group for multiple risk factors and continuously monitoring them from a community perspective to prevent depression in the senile stage is urgently required.

Another finding of this study was that poor perceived social support or a weakened social network (social bonds and meaningful social contact[44]) was identified as a risk factor for depression in senior citizens living alone. A social network is a multidimensional concept that encompasses social relationships and factors such as the frequency of contact with family members, friends, and spouses; the degree of mutual assistance; and satisfaction with social relationships can be used to measure it[45]. Previously, several research groups have also reported that the lack of a social network is a major risk factor for depression in the elderly[41,43], which is in agreement with our results.

It has been reported that the reinforcement of a social network (such as support from acquaintances) can alleviate depression (*i.e.*, it is a preventative factor)[46]. In the case of senior citizens living alone, support from acquaintances such as neighbors can complement a lack of support from immediate family members and/or relatives. Senior citizens living alone and interacting with neighbors on equal terms is considered to be a very important element in their social networks. Park[47] reported that senior citizens who frequently met friends or neighbors had a significantly lower risk of depression and explained that this was because they received more social support when they met acquaintances more frequently. However, the results of the present



**Figure 4** Application example of depression prediction nomogram for elderly living alone: Senior citizens who had suicidal urge over the past year, were not satisfied with subjective help with neighbors, thought that they were mostly lonely, had 15 points in the Self-Esteem Scale, and were 80 years or older.

study show that the frequency of contact with friends and neighbors (a quantitative factor) did not significantly affect the relationships in the social network whereas actual help (a qualitative factor) did significantly. Thus, this qualitative aspect of support that positively supported the emotional or economic problems of senior citizens living alone was more important than the number of meetings in the social network.

In summary, the results of the present study reveal that living alone due to the loss of a spouse and/or breakdown of the family network are more likely to cause emotional disorders such as depression. Moreover, strengthening qualitative aspects such as direct support from neighbors could more effectively lower the risk of depression than quantitative aspects such as the frequency of communication with family members or neighbors.

We identified factors related to depression in the elderly living alone using representative epidemiologic data and developed a nomogram that can help clinicians visually and conveniently identify the risk factors of depression, including social networks as well as demographic factors, which are the advantages of the study.

The limitations of this study are as follows: (1) We could not identify the severity of depression because we only analyzed the prevalence of depression in senior citizens living alone using a depression screening test, further studies are required to prove the risk factors of depression by identifying the severity of depression based on medical diagnosis; (2) We only used a self-report survey on the social isolation or social network of senior citizens living alone; a self-report survey poses the risk of recall bias, so in future studies, we will mitigate this by using interviews with social workers who regularly visit the homes of the senior citizens living alone and collecting data by using the Internet of Things; and (3) Since this is a cross-sectional study, it is impossible to determine causal relationships between the risk factors for depression in senior citizens living alone, and thus, a longitudinal study should be conducted in the future to achieve this.

## CONCLUSION

The results of the present study imply that it is necessary to develop a support system customized for each senior citizen living alone by strengthening his/her relationship network for preventing depression. Actual support from acquaintances such as neighbors (reinforcement of the qualitative aspect of the network) rather than the

frequency of physical contact (reinforcement of the quantitative aspect of the network) is key for protecting them from depression. Furthermore, establishing an improved mental health policy that identifies and continually manages groups of senior citizens living alone with a high risk of developing depression based on multiple risk factors is needed.

## ARTICLE HIGHLIGHTS

### **Research background**

Senile diseases are rapidly increasing globally due to the rapid aging of the population. Among these diseases, depression is an important and frequent psychiatric disorder in the senile stage, and it is predicted to be the second major factor in the global burden of disease.

### **Research motivation**

Although the number of senior citizens living alone is increasing, only a few studies have identified factors related to the depression characteristics of senior citizens living alone by using epidemiological survey data that can represent a population group.

### **Research objectives**

This study developed a nomogram that allows physicians to check the multiple risk factors of depression of senior citizens living alone using visual graphs and to calculate the prevalence probability of depression while considering the personal characteristics of a subject based on these results.

### **Research methods**

This study analyzed 1558 senior citizens (695 males and 863 females) who were 60 years or older. Depression, an outcome variable, was measured using the short form of the Korean version CES-D (short form of CES-D). This study built a depression prediction model using logistic regression analysis to find out the effect of each variable on depression. The developed depression prediction model contained a nomogram to make it possible for clinicians to interpret the prediction results easily.

### **Research results**

In this study, the significant predictors of depression of the senior citizens living alone were the experiences of suicidal urge over the past year, dissatisfaction with help (support) from neighbors, subjective loneliness, age, and low self-esteem.

### **Research conclusions**

The results of this study implied that it is necessary to develop a support system customized for subjects to strengthen the relation network for preventing depression in senior citizens living alone so that they can receive actual support from acquaintances such as neighbors rather than the frequency of physical contact.

### **Research perspectives**

It is needed to establish an improved mental health policy that identifies high depression risk groups among senior citizens living alone based on multiple risk factors and continuously manages them.

## ACKNOWLEDGEMENTS

The authors wish to thank the Korea Institute for Health and Social Affairs that provided the raw data for analysis.

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