





Association between cardiovascular health measured by Life's Essential 8 and depressive symptoms: Results from the 2014, 2016, and 2018 Korea National Health and Nutrition Examination Survey (KNHANES)

Jeong Hyun Ahn

The Graduate School Yonsei University Department of Public Health



Association between cardiovascular health measured by Life's Essential 8 and depressive symptoms: Results from the 2014, 2016, and 2018 Korea National Health and Nutrition Examination Survey (KNHANES)

A Master Thesis

Submitted to the Department of Public Health and the Graduate School of Yonsei University in partial fulfillment of the requirements for the degree of

Master of Public Health

Jeong Hyun Ahn

December 2023



This certifies that the master's thesis of Jeong Hyun Ahn is approved.

Thesis Supervisor: Sun Jae Jung

Thesis Committee Member #1: Hyeon Chang Kim

Thesis Committee Member #2: Hokyou Lee

The Graduate School Yonsei University December 2023



## **TABLE OF CONTENTS**

TABLE INDEX	iii
FIGURE INDEX	iv
APPENDIX INDEX	v
GLOSSARY OF TERMS	vii
ABSTRACT	ix
I. INTRODUCTION	1
II. MATERIAL AND METHODS	6
1. Data source and study population	6
2. Measurement	9
(1) Difference between "Life's Simple 7" and "Life's Essential 8"	9
(2) Assessment of Cardiovascular health by Life's Essential 8	10
(3) Assessment of depressive symptoms	16
(4) Covariates	17
3. Statistical Analysis	19
(1) Main analyses	19
(2) Sensitivity analyses	20
(3) Ethical approval	22
III. RESULTS	23



1. Characteristics of the study population
2. Association between cardiovascular health and depressive symptoms
3. Association between cardiovascular health and depressive symptoms by sex .31
4. Association between cardiovascular health and depressive symptoms by age .35
5. The results of sensitivity analyses40
IV. DISCUSSION
1. Summary of findings
2. Discussion of the previous studies
3. Strengths and Limitations
V. CONCLUSIONS
REFERENCES
ABSTRACT(KOREAN)



## TABLE INDEX

Table 1. General characteristics of the study population by depressive symptoms	24
Table 2. General characteristics of the study population by overall cardiovascular heal	lth
score2	25

Table 3. Association between cardiovascular health scores and depressive symptoms .... 29

# FIGURE INDEX

Figure 1. Assumed structure of the relationship of cardiovascular health (exposure; X) and
depressive symptoms (outcome; Y) with confounders (covariates; C)5
Figure 2. Flow diagram of the study population
Figure 3. Odds ratios (OR) and 95% Confidence Intervals (CI) for the association between
cardiovascular health scores and depressive symptoms
Figure 4. Association between each of cardiovascular health metrics and depressive
symptoms
Figure 5. Odds ratios (OR) and 95% Confidence Intervals (CI) for sex-stratified association
between cardiovascular health metrics and depressive symptoms
Figure 6. Odds ratios (OR) and 95% Confidence Intervals (CI) for sex-stratified association
between each of cardiovascular health metrics and depressive symptoms 34
Figure 7. Odds ratios (OR) and 95% Confidence Intervals (CI) for the age-stratified
association between cardiovascular health scores and depressive symptoms 38
Figure 8. Age-stratified association between each of cardiovascular health metrics and
depressive symptoms

## **APPENDIX INDEX**

연세대학교

Appendix 1. Definition and scoring of Life's Essential 8 based on the American Heart
Association65
Appendix 2. Definition and scoring of Life's Simple 7 based on the American Heart
Association
Appendix 3. The average score for each of 8 metrics by depressive symptoms status 68
Appendix 4. Association between cardiovascular health scores and depressive symptoms
by household income
Appendix 5. Association between cardiovascular health scores and depressive symptoms
by educational attainment71
Appendix 6. Association between cardiovascular health scores and depressive symptoms
by marital status
Appendix 7. Association between cardiovascular health scores and depressive symptoms
using diet metric with KHEI and DASH, respectively (N=8,514)75
Appendix 8. Association between cardiovascular health scores and depressive symptoms
compared to Life's Simple 7 and Life's Essential 876



Appendix 9. Association between cardiovascular health scores and depressive symptoms,
excluding participants who had previously been diagnosed with depression
Appendix 10. Association between cardiovascular health metrics score and depressive
symptoms (PHQ-9≥5)
Appendix 11. Association between cardiovascular health scores and depressive symptoms
(PHQ-9≥15)
Appendix 12. Odds ratios (OR) and 95% Confidence Intervals (CI) for the association
between quartiles of cardiovascular health scores and depressive symptoms
Appendix 13. Association between cardiovascular health scores as continuous variable and
depressive symptoms
Appendix 14. Previous studies on the association between cardiovascular health by Life's
Simple 7 and depressive symptoms



## **GLOSSARY OF TERMS**

- AHA: American Heart Association
- AUC: Area Under the Curve
- BMI: Body mass index
- BP: Blood pressure
- CES-D: Centre of Epidemiological Studies-Depression
- CI: Confidence intervals
- CRP: C-reactive protein
- CVH: Cardiovascular health
- DASH: Dietary Approaches to Stop Hypertension
- DSM-IV: Diagnostic and Statistical Manual of Mental Disorder, Fourth Edition
- DBP: Diastolic blood pressure
- FBG: Fasting blood glucose
- FFQ: Food frequency questionnaire
- GPAQ: Global Physical Activity Questionnaire
- HbA1c: Hemoglobin A1c
- HDL-C: High-density lipoprotein cholesterol
- HEI: Healthy Eating Index
- HPA: Hypothalamic-pituitary-adrenal
- HTN: Hypertension
- IL-6: Interleukin-6
- IRB: Institutional Review Board



- KCDC: Korea Centers for Disease Control and Prevention
- KDRI: Korean Dietary Reference Intake
- KHEI: Korean Healthy Eating Index
- KNHANES: Korea National Health and Nutrition Examination Survey
- LE8: Life's Essential 8
- LS7: Life's Simple 7
- MEC: Mobile examination centre
- NDS: Nicotine delivery system
- OECD: Organization for Economic Cooperation and Development
- OR: Odds ratio
- PHQ-9: Patient Health Questionnaire-9
- PR: Prevalence ratio
- SBP: Systolic blood pressure
- SES: Socioeconomic status
- TC: Total cholesterol
- TNF- $\alpha$ : Tumor necrosis factor- $\alpha$
- WBC: White blood cell
- WHO: World Health Organization



## ABSTRACT

# Association between cardiovascular health measured by Life's Essential 8 and depressive symptoms: Results from the 2014, 2016, and 2018 Korea National Health and Nutrition Examination Survey (KNHANES)

Jeong Hyun Ahn

Department of Public Health The Graduate School of Yonsei University

**Background:** Depression increases the global burden of diseases and is associated with cardiovascular health (CVH). After the American Heart Association (AHA) proposed "Life's Simple 7" (LS7) in 2010, an updated CVH metric called "Life's Essential 8" (LE8) was recently announced. There is a scarcity of research papers examining LE8 utilizing nationally representative data including medical examination, health interviews, and nutrition surveys. Few studies have assessed the association between CVH measured by LE8 and depressive symptoms among Asian populations. Therefore, this study aimed to evaluate the association of CVH



with depressive symptoms and investigate the relationship between each of CVH metrics and depressive symptoms.

Methods: This cross-sectional study included 13,357 adults 19 years or older using data from the Korea National Health and Nutrition Examination Survey (KNHANES) 2014, 2016, and 2018. According to the AHA, the overall CVH is divided into two domains "health behaviors" (diet, physical activity, nicotine exposure, and sleep health) and "health factors" (body mass index, blood lipids, blood glucose, and blood pressure). The overall CVH score by LE8 ranged from 0 to 100 and was categorized into "low" (0-<50), "moderate" (50-<80), and "high" (80-100) by AHA. Depressive symptoms were measured by the Patient Health Questionnaire-9 (PHQ-9). Individuals with a PHQ-9 score of 10 or higher were defined as having depressive symptoms. The covariates are sex, age, socioeconomic status (SES), and current drinking status. After adjusting covariates, a multiple logistic regression analysis was performed to examine the association between CVH (LE8 score, health behavior score, and health factors score) and depressive symptoms. We examined the association between each of CVH metrics and depressive symptoms. Each of CVH metrics defined participants with a score of 100 as 'ideal (=100)', while those not scoring 100 were defined as 'poor (<100)'. The 'poor' serves as the reference in this study. Moreover, sex and age-stratified



analyses were performed. To support the robustness of our main results, this study conducted the six sensitivity analyses as follows: i) additionally stratified analyses by SES ii) redefining the diet metric with Dietary Approaches to Stop Hypertension (DASH) to compare Korean Healthy Eating Index (KHEI), iii) examining the association between CVH and depressive symptoms compared to LS7 and LE8, iv) excluding study participants who had previously been diagnosed with depression by physician, v) redefining depressive symptoms as mild depressive symptoms (PHQ-9 $\geq$ 5) and moderately severe depressive symptoms (PHQ-9 $\geq$ 15), vi) redefining CVH (LE8 score, health behaviors score, and health factors score) as quartiles and continuous variable.

**Results:** Among the 13,357 participants aged 19 and older, 195 men (1.5%) and 541 women (4.1%) indicated having depressive symptoms. When the low CVH was the reference, the odds ratio (OR) for depressive symptoms was 0.60 (95% CI=0.47-0.77) in moderate CVH and 0.33 (95% CI=0.23-0.49) in high CVH. When the low health behaviors score was reference, the OR for depressive symptoms was 0.37 (95% CI=0.26-0.52) in high health behaviors score. However, the health factors score was not associated with depressive symptoms. Furthermore, when poor CVH metrics were the reference, the OR for depressive symptoms was 0.41 (95% CI=0.33-0.52) in ideal nicotine exposure, 0.65 (95% CI=0.54-0.78) in



ideal sleep health, and 0.73 (95% CI=0.58–0.90) in ideal blood glucose. When low CVH was the reference in sex-stratified analyses, the ORs for depressive symptoms were 0.23 (95% CI=0.09–0.59) among men with high CVH and 0.34 (95% CI=0.21–0.55) among women. In age-stratified analyses, the OR for depressive symptoms was 0.24 (95% CI=0.13–0.43) in high CVH among those aged 19–39 years and 0.30 (95% CI=0.14–0.62) in high CVH among those aged 40–59 years. The sensitivity analysis results were similar to the main analysis results.

**Conclusion:** Overall, high CVH and healthy behaviors were inversely associated with depressive symptoms. The findings of this study suggest that individuals with poor CVH or who engage in unhealthy behaviors require monitoring and timely intervention for depressive symptoms. Moreover, adequate sleep and non-smoker may serve as crucial preventive factors for depressive symptoms.

**Keywords:** Cardiovascular Health, Health behaviors, Health factors, Depressive symptoms



## I. INTRODUCTION

#### 1. The burden of depression

Depression is a common mental health problem, a global burden of disease, and a leading cause of death.<sup>1,2</sup> According to the Organization for Economic Cooperation and Development (OECD) 2021 report, Korea had the highest prevalence of depression or depressive symptoms at 37% compared to other countries.<sup>3</sup> As depression is a leading cause of suicide, deaths by suicide also ranked first in the world, with an age-standardized rate of 24.6 per 100,000 population.<sup>3</sup> Therefore, depression is a critical public health issue, and management strategies are needed to prevent the risk factors for depression.<sup>4</sup> Several studies reported that poor lifestyle is related to depressive symptoms. In a study of 2,334 Japanese population, using healthy lifestyles as a reference, inadequate sleep, an unhealthy diet, and insufficient physical activity were associated with depressive symptoms.<sup>5</sup> Individuals with inadequate sleep had the highest odds ratio of depressive symptoms.<sup>5</sup> Not only poor lifestyle habits but also chronic diseases were associated with depressive symptoms. According to a systematic review including eleven studies, type 2 diabetes was associated with depression when excluding individuals with depression at baseline.<sup>6</sup> In Villarreal-Zegarra's study, which included 87,253



from Peru, hypertension (HTN) was related to depressive symptoms compared to those without HTN.<sup>7</sup>

#### 2. Cardiovascular health by the American Heart Association

According to the World Health Organization (WHO), cardiovascular diseases are among the major causes of millions of deaths worldwide.<sup>8</sup> Unhealthy lifestyles, including tobacco use, lack of physical activity, and inadequate diet, are primary risk factors for cardiovascular diseases.<sup>8</sup> Moreover, risk factors for cardiovascular disease were elevated blood pressure (BP), cholesterol levels, and obesity.<sup>8</sup> The American Heart Association (AHA) developed the "Life's Simple 7" (LS7) to measure ideal cardiovascular health (CVH) in 2010.<sup>9</sup> The purpose of LS7 was to establish strategies to improve and promote CVH by the year 2020, to reduce deaths from cardiovascular disease by up to 20%.<sup>9</sup> LS7 consisted of smoking, physical activity, body mass index (BMI), diet, total cholesterol (TC), BP, and glucose.<sup>9</sup> Within LS7, health behaviors were categorized as smoking, physical activity, BMI, and diet, while health factors were classified as TC, BP, and glucose.<sup>9</sup> However, limitations were identified in the quantification of LS7 scoring to evaluate population-level CVH and diet metric which assessed only five food items such as fruits and vegetables, fish, fiber-rich whole grains, sodium, and sugar-sweetened



beverages.<sup>10</sup> Furthermore, sleep, which plays an essential role in life, is confirmed to be associated with CVH through numerous studies and by the AHA.<sup>10,11</sup> For these reasons, in 2022, AHA redefined CVH metrics called "Life's Essential 8" (LE8), including sleep health and providing a more detailed redefinition and quantifiable scoring for each metric.<sup>10</sup> Therefore, within LE8, health behaviors were categorized as diet, physical activity, and sleep health, while health factors were classified as BMI, blood lipids, blood glucose, and BP.

#### 3. Cardiovascular health and depressive symptoms

Numerous studies showed the association between CVH measured by LS7 and depressive symptoms. According to a prospective study including 5,110 US adults, a higher ideal CVH defined by LS7 was associated with decreased odds of depressive symptoms.<sup>12</sup> Another prospective study involving 9,214 Brazilian participants confirmed that a higher optimal CVH score was related to lower odds for depression.<sup>13</sup>

Previous studies showed inverse association between health behaviors or health factors in LS7 and depressive symptoms. In a prospective study including 5,110 US individuals, smoking, BMI, physical activity, and diet were related to lower odds of



depressive symptoms.<sup>12</sup> In a cross-sectional study of 6,851 Chinese adults, participants with ideal smoking, ideal physical activity, and ideal diet intake had a 22%, 33%, and 57% decreased odds of depression, respectively.<sup>14</sup> Additionally, in a cross-sectional study with 14,561 US adults, ideal blood glucose was significantly related to lower prevalence of mild depressive symptoms.<sup>15</sup>

#### 4. Study objectives and hypotheses

However, little is known about the association new definition of LE8 from AHA and depressive symptoms due to scarcity of information about LE8 variables. Few studies assessed this association using nationally representative data among Asian populations. Therefore, this study aims to assess the association between CVH (LE8 score, health behaviors score, and health factors score) and depressive symptoms (Figure 1). Moreover, this study aimed to examine the relationship between each of CVH metrics and depressive symptoms.

This study formulates the following hypotheses. First, a higher CVH score is inversely associated with depressive symptoms. Second, a higher score in health behaviors is inversely related to depressive symptoms.





**Figure 1.** Assumed structure of the relationship of cardiovascular health (exposure; X) and depressive symptoms (outcome; Y) with confounders (covariates; C)



### **II. MATERIAL AND METHODS**

#### 1. Data source and study population

This study utilized data from the Korea National Health and Nutrition Examination Survey (KNHANES) 2014, 2016, and 2018. The reason we used KNHANES data from 2014, 2016, and 2018 is that the Patient Health Questionnaire-9 (PHQ-9) has been administered since 2014 and is surveyed every even-numbered year among adults. Furthermore, data for the Korean Healthy Eating Index (KHEI) was available from 2013 to 2018. The KNHANES has a surveillance system conducted by the Korea Centers for Disease Control and Prevention (KCDC). The KNHANES was designed with multistage stratified cluster sampling to describe nationally representative data with cross-sectional design and calculate accurate estimates.<sup>16</sup> The KNHANES is annually conducted that examine the health and nutritional status of the Korean population aged one and over residing in Korea.<sup>16</sup> The surveys of health interviews, health examinations, and nutrition are carried out by professional examiners such as physicians, medical technicians, health examiners, and dietitians.<sup>16</sup> According to three surveys, professional examiners collect demographic information, socioeconomic status (SES), health behaviors, clinical or laboratory trials, and dietary or nutritional information.<sup>16</sup>



A total of 23,692 participants were included in the KNHANES 2014, 2016, and 2018. Initially, we excluded participants under the age of 19 (n=4,845), pregnant women (n=94), and individuals with fasting blood sugar (n=1,689). Next, among the available 17,064 participants (aged  $\geq$  19 years), we excluded 3,707 participants who had missing information on overall CVH by LE8 (n=2,501) and missing value on the PHQ-9 (n=1,206). Finally, through this process of selecting the study population, a total of 13,357 participants were identified in this analysis (Figure 2).





Figure 2. Flow diagram of the study population



#### 2. Measurement

### (1) Difference between "Life's Simple 7" and "Life's Essential 8"

Overall CVH is divided into two main domains: health behaviors (diet, physical activity, nicotine exposure, and sleep health) and health factors (BMI, blood lipids, blood glucose, and BP).<sup>10</sup> Unlike LS7, BMI is categorized under health factors in LE8.<sup>9,10</sup> Moreover, a new metric of CVH is sleep health.<sup>9,10</sup>

The definitions of diet, nicotine exposure, blood lipids, and blood glucose metrics were updated. The diet metric in LS7 measured five components (fruits and vegetables, fish, fiber-rich whole grains, sodium, sugar-sweetened beverages), while the diet metric in LE8 was updated various dietary assessment methods such as Healthy Eating Index (HEI) or Dietary Approaches to Stop Hypertension (DASH).<sup>9,10</sup> Scoring for nicotine exposure metric considered indoor secondhand smoking.<sup>10</sup> In the case of blood lipids metric, while TC was measured in LS7, LE8 measured non-high-density lipoprotein cholesterol (non-HDL-C).<sup>9,10</sup> Furthermore, scoring for blood glucose metric considered Glycated hemoglobin (HbA1c).<sup>10</sup> The definition of metrics (physical activity, BMI, and BP) remains the same, but the scoring for all metrics has been updated.<sup>10</sup> Details about the definition and scoring of LE8 or LS7 are described in Appendix 1 and Appendix 2.



#### (2) Assessment of Cardiovascular health by Life's Essential 8

We utilized a modified version of the LE8 as defined by the AHA.<sup>10</sup> LE8 is divided into two domains, consisting of health behavior metrics and health factor metrics.<sup>10</sup> The health behavior metrics were diet, physical activity, nicotine exposure, and sleep health.<sup>10</sup> The health factor metrics were BMI, blood lipids, blood glucose, and BP.<sup>10</sup> To measure the CVH metrics included in LE8, KNHANES data were collected as follows. Health behavior metrics were collected with self-reported data. Diet metric was included in a nutrition survey, while physical activity, nicotine exposure, and sleep health were included in a health interview survey.<sup>16</sup> The nutrition survey is carried out through face-to-face interview methods.<sup>16</sup> The health interview surveys are conducted via self-report questionnaires in the mobile examination centre (MEC).<sup>16</sup> Health factor metrics were collected with objective data. According to standardized protocols, BMI, blood lipids, blood glucose, and BP are included in the health examinations survey conducted by measuring and examining in the MEC.<sup>16</sup>

#### 1) Diet

Diet metric was measured by HEI-2015 according to AHA guideline.<sup>10</sup> HEI-2015



consisted of 13 components and assessed the overall dietary quality of Americans.<sup>17</sup> Following the AHA guideline, HEI is suggested to evaluate individual or population-level dietary quality.<sup>10</sup> As this study targeted Koreans, we assessed by diet metric using the KHEI, developed by KCDC.<sup>18</sup> The KHEI evaluates the overall dietary quality among Korean adults and comprises a total of 14 components.<sup>18</sup> These components are categorized into 8 items for adequacy (breakfast, mixed grain, total fruit, fresh fruits, total vegetables, vegetables excluding Kimchi and pickled vegetables, meat/fish/eggs and beans and milk and dairy products), 3 items for moderation (saturated fatty acids, sodium and sweets and beverages) and 3 items for balance of energy (carbohydrates, total fat and energy).<sup>18</sup> The total score of KHEI is 100 points with 10 points assigned to each component.<sup>18</sup> However, mixed grain, total fruit, fresh fruits, total vegetables, vegetables excluding Kimchi and pickled vegetables, and 3 components for balance of energy scored 5 points based on the 2015 Korean Dietary Reference Intake (KDRI) guidelines.<sup>18</sup> The reference population for quantiles of KHEI used KNHANES data from 2016 to 2018. We scored according to quintiles of KHEI by AHA guidelines.

According to AHA guidelines, diet metric could be assessed by DASH.<sup>10</sup> We used modified version of DASH based on Fung's study.<sup>19</sup> DASH consisted of eight components: fruits, vegetables, nuts and legumes, whole grains, low-fat dairy,



sodium, red and processed meats, and sweetened beverages.<sup>19</sup> Each component is scored from 1 point (quintile 1) to 5 point (quintile 5). However, sodium, red and processed meats, and sweetened beverages are scored inversely.<sup>19</sup>

#### 2) Physical activity

Physical activity was assessed using the Global Physical Activity Questionnaire (GPAQ) which consists of 16 questions and is structured into three domains (work, transport, and leisure).<sup>20,21</sup> We used the Korean version of GPAQ which is a translation of the English version of the GPAQ, to measure moderate or vigorous physical activity corresponding to work and leisure activities.<sup>22</sup> Both work and leisure activity had information on the frequency and duration of moderate or vigorous physical activity per week.<sup>20-22</sup> To calculate the total time of moderate or vigorous physical activity, we utilized KNHANES variables. These variables included as presence of moderate or vigorous physical activity at work and leisure activities, as well as the number of days in a week, and the hours and minutes per day. We counted each minute of vigorous activity (work and leisure activity) as two minutes for the weekly total based on AHA guidelines. The total time engaged in moderate or vigorous physical activity per week was calculated in minutes using the frequency and duration of two domains (work and leisure activities). We scored



according to minutes of moderate or vigorous physical activity per week by AHA guidelines.

#### 3) Nicotine exposure

The nicotine exposure metric is determined based on questions regarding current smoking status and is assigned different scores according to never-smokers, past smokers, and current smokers. Moreover, the nicotine delivery system (NDS) and indoor secondhand smoking in the house are taken into account in scoring for the nicotine exposure metric. Never-smokers are defined as individuals who have never smoked cigarettes in their lifetime. Participants who quit smoking were past smokers. The score of past smokers was applied differently based on the duration of quitting cigarettes or current use of NDS. Current smokers are individuals who currently still smoking.

#### 4) Sleep health

Sleep health is defined by the average daily sleep duration. In the 2014 KNHANES survey, the sleep health questionnaire was "How many hours do you usually sleep per day?" In the 2016 and 2018 KNHANES survey, the questions regarding sleep



health were as follows: "What time do you usually go to bed and wake up on weekdays?" and "What time do you usually go to bed and wake up on weekends?" We calculated the weighted average daily sleep duration using the sleep hours on weekdays and weekends. The method for calculating the weighted average daily sleep duration is as follows: (weekday×5 + weekend×2)/7.

#### 5) Body mass index (BMI)

BMI is calculated by dividing weight (kg) by the square of height (m<sup>2</sup>) among individuals who were not pregnant. We scored BMI metric using the definition of BMI based on Koreans.<sup>23</sup> While the WHO defines obesity as  $30 \text{kg/m}^2$  or higher, obesity in Korea is classified into 25.0–29.9, 30.0-34.9 and  $\geq 35.0 \text{ kg/m}^2$ .<sup>23,24</sup> The points of BMI were scored according to the WHO guidelines for the Asian individuals.<sup>10</sup>

#### 6) Blood lipids

TC and HDL-C were measured using Hitachi Automatic Analyzer 7600 (Hitachi, Japan). Blood lipids metric is measured non-HDL cholesterol using HDL-C and TC.



Non-HDL-C is calculated by subtracting HDL-C from TC. The optimal level of non-HDL-C is less than 130 mg/dL.<sup>25,26</sup> The points of blood lipids were scored according to the level of Non-HDL-C by AHA guidelines. Moreover, individuals currently taking medication for dyslipidemia had 20 points subtracted.

#### 7) Blood glucose

Blood samples were collected from individuals fasting for 8 hours. Blood glucose assessed blood sample of fasting blood glucose (FBG) or HbA1c. FBG was examined using Hitachi Automatic Analyzer 7600 (Hitachi, Japan). HbA1c was measured using Tosoh G8 (Tosoh, Japan). Initially, we categorized non-diabetes, prediabetes, and diabetes considering the history of diabetes, FBG (<100, 100–125, and  $\geq$ 126 mg/dL), medication, and insulin injection.<sup>27</sup> Subsequently, scores were given according to HbA1c levels.<sup>10,27</sup>

#### 8) Blood pressure (BP)

BP was measured using a standard mercury sphygmomanometer (Baumanometer; Baum, USA). After sitting in a seated position for 5 minutes during a rest period, blood pressure was measured three times on the right arm. Blood pressure is



automatically calculated by the system as the average of the second and third measurements. The optimal level of blood pressure is systolic blood pressure (SBP) of <120 mmHg and diastolic blood pressure (DBP) of <80 mmHg. The points of BP were scored according to the level of SBP and DBP by AHA guidelines. Moreover, participants presently taking medication for hypertension had 20 points subtracted.

Each of CVH metrics' points ranges from 0 to 100. The overall CVH score was calculated by taking the unweighted average of all metrics scores. The scores of health behaviors and health factors are also calculated using the same method as described above. Following the AHA guidelines, overall CVH score by LE8 including health behaviors score and health factors score are categorized as low (0-<50), moderate (50-<80), and high (80–100).<sup>10</sup> In this study analysis, all CVH scores were examined as both continuous and categorical variables.

#### (3) Assessment of depressive symptoms

Depressive symptoms were assessed using the Korean version of the PHQ-9 which is based on the diagnosis from the Diagnostic and Statistical Manual of Mental



Disorders, Fourth Edition (DSM-IV).<sup>28,29</sup> Depressive symptoms assessed using the PHQ-9 are based on a self-reported questionnaire. Participants conducted a PHQ-9 questionnaire in the MEC. The PHQ-9 includes 9 items and is a questionnaire that asks how often participants experienced depressive symptoms in the past 2 weeks.<sup>28,29</sup> The items are scored on a 4-point scale: 0 = not at all, 1 = several days, 2 = more than half the days, and 3 = nearly every day.<sup>29</sup> The total score of PHQ-9 ranges from 0 to 27 and is categorized into normal, mild, moderate, moderate to severe, and severe depending on the increasing severity of depressive symptoms.<sup>29</sup> The PHQ-9 total score of 10 or higher indicates the presence of depressive symptoms and is validated by a sensitivity of 88% and specificity of 88% among patients who visited general medical clinics or obstetrics-gynecology clinics.<sup>29</sup> Additionally, PHQ-9 was validated in the Korean general population (Cronbach's  $\alpha$ =0.79).<sup>30</sup> We classified participants with PHQ-9 scores of 10 or higher as having depressive symptoms.

#### (4) Covariates

Covariates included sex (men and women), age (19–39, 40–59, and  $\geq$ 60 years), socioeconomic status (household income, educational attainment, and marital status), and current drinking status. Age groups were divided into 19–39 years



(early adulthood), 40–59 years (middle age), and 60 years and older (older age).<sup>10</sup> The household income is divided into quartiles (<17.4, 17.4 to <33.6, 33.6 to <55.0,  $\geq$ 55.0 million Won/month). Questions related to educational attainment are as follows: "How far did you go to school or are currently attending?" and "Have you graduated from that school?" Graduation is included in the current educational level. Completion, dropout, enrollment, or leave of absence belong to previous educational level. Therefore, educational attainment was categorized as  $\leq 6$ (elementary school or less), 7–9 (middle school), 10–12 (high school), and >12 years (college or above). The question "Have you ever been married?" is answered "yes" or "no". Individuals who answered "yes" are categorized as "married," and individuals who answered "no" are categorized as "never married." Individuals categorized as "married" are further asked the following question "What is your current marital status?" The answers to this question are "married-living together," "married-separate," "divorced," and "widowed." Therefore, marital status was grouped into never married, married-living together, married-separate and divorced/widowed. The questions regarding current drinking status are as follows: Have you ever drunk in your lifetime?" and "How often have you drank in a recent year?" Therefore, current drinking status was classified as "yes" for those who drank once or more per month in a recent year and "no" for those who did not.



#### 3. Statistical Analysis

#### (1) Main analyses

The general characteristics of the study population are presented using the chisquare test and t-test. Categorical variables are described number of participants and weighted percentages. Continuous variables are shown as mean and 95% confidence intervals. Multiple logistic regression analyses were used to investigate the association between overall CVH score by LE8 and depressive symptoms. Moreover, we performed multiple logistic regression analyses to examine the association between health behaviors score and depressive symptoms. The association between health factors score and depressive symptoms is also conducted by multiple logistic regression analyses. We analyzed to identify each of CVH metrics (diet, physical activity, nicotine exposure, sleep health, BMI, blood lipids, blood glucose, and BP) and depressive symptoms. Each of CVH metrics defined participants with a score of 100 as 'ideal (=100)', while those not scoring 100 were defined as 'poor (<100)'. The odds ratio (OR) and 95% confidence intervals (CI) were calculated in all logistic models. Model 1 was unadjusted. In model 2, we adjusted for sex and age. In model 3, we additionally adjusted for household income, educational attainment, and marital status. Finally, in model 4, we additionally adjusted for current drinking status.



We conducted stratified analyses by sex and age to examine the association between CVH (LE8 score, health behaviors score, and health factors score) and depressive symptoms. Additionally, we performed these stratified analyses to examine the association between each of CVH metrics and depressive symptoms.

As we utilized the 2014, 2016, and 2018 KNHANES data, we derived the integrated weight by multiplying one-third of each year's weight. All variables including LE8, depressive symptoms, and covariates were surveyed through health interviews, health examinations, and nutrition surveys. Therefore, we used the corresponding association weights. The method for calculating weight as follows:  $W_{14,16,18} = W_{14} \times (1/3)$ ,  $W_{14,16,18} = W_{16} \times (1/3)$ , and  $W_{14,16,18} = W_{18} \times (1/3)$ . PROC SURVEYFREQ, PROC SURVEYMEANS, and PROC SURVEYLOGISTIC procedures were performed using stratification, clustering, and weighting. A p-value <0.05 was considered statistically significant. Statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

#### (2) Sensitivity analyses

We conducted additional analyses to assess the robustness of our findings. First, we conducted additional stratified analyses by SES to examine the association between


CVH (LE8 score, health behaviors score, and health factors score) and depressive symptoms. Second, to confirm the difference between KHEI and DASH, we remeasured diet metric using DASH instead of KHEI. Due to limitations in the Food Frequency Questionnaire (FFQ) data, we used KNHANES data in 2014 and 2016. To compare KHEI and DASH, the Area Under the Curve (AUC) was described. Third, we examined the association between CVH and depressive symptoms compared to LS7 and LE8. To compare LS7 and LE8, AUC was described. Details about the definition and scoring of LS7 were described in Appendix 2. Fourth, to strengthen the cross-sectional design, which had limitation in demonstrating causal relationships, we excluded individuals who were previously diagnosed with depression by physician. We re-calculated the OR and 95% CI for the association between CVH scores and depressive symptoms. Fifth, we conducted analyses by redefining depressive symptoms as follows: mild depressive symptoms (PHQ- $9\geq 5$ ), and moderately severe depressive symptoms (PHQ-9≥15), respectively.<sup>29</sup> Lastly, we performed analyses by re-measured CVH (LE8 score, health behaviors score, and health factors score) as quartiles and continuous variable. SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) was used for all statistical analyses, and a pvalue <0.05 was considered statistically significant.



## (3) Ethical approval

The second year (2014) of KNHANES VI and the third year (2018) of KNHANES VII were approved by the institutional review board (IRB) of the KCDC (IRB No. 2013–12EXP–03–5C and 2018–01–03–P–A). The first year (2016) of the KNHANES VII obtained data without requiring IRB approval according to Bioethics Act. Informed consent was acquired from all participants. The KNHANES is an open data source and anonymized prior to distribution.



## **III. RESULTS**

## 1. Characteristics of the study population

Table 1 presents the general characteristics of the study population by depressive symptoms. Among the total of 13,357 participants, 736 (5.0%) participants had depressive symptoms. Individuals with depressive symptoms were more likely to be women (67.4%) and had lower household income. Individuals with depressive symptoms had lower overall CVH score than those without depressive symptoms. Among those with depressive symptoms, participants with low CVH, moderate CVH, and high CVH were 142 (19.7%), 532 (71.3%), and 62 (9.0%), respectively. Individuals with depressive symptoms had 61.4 (60.2–62.6) of overall CVH score of 30.6 (26.9–34.4) in physical activity and the highest score of 86.1 (84.0–88.2) in blood glucose (Appendix 3).

Table 2 describes the study population characteristics according to the overall CVH score. Individuals with low CVH were more likely to had lower household income and be current drinker. Individuals with low CVH had the lowest score in physical activity, and the highest score in blood glucose. Individuals with high CVH had the lowest score in diet by KHEI and the highest score in blood glucose.



	No Depressive symptoms	Depressive symptoms	- n value
Variables	$\frac{(\mathbf{HQ} - 9 < 10)}{N - 12.621.(95.5\%)}$	$\frac{(\mathbf{F}\mathbf{H}\mathbf{Q}\mathbf{-9}\mathbf{\leq}10)}{N-736(5.5\%)}$	
<u>variables</u>	N = 12,021(93.5%)	N= 750 (5.570)	p-value $< 0.001$
Mon	5347(50.0)	105 (32 6)	<.0001
Woman	7,347(30.9)	541 (67 A)	
	7,274 (49.1)	541 (07.4)	< 0001
Age(years)	2 552 (26 7)	220(40.6)	<.0001
19-39	3,333 (30.7) 4 915 (41 9)	220(40.0) 211(21.7)	
40-39	4,813 (41.8)	211 (31.7)	
≥00 Manthla hansahald in aana	4,233 (21.3)	303 (27.7)	< 0001
17 4 william Was	2.022(10.4)	256 (42.4)	<.0001
<17.4 million won	2,983 (18.4)	356 (42.4)	
17.4-<33.6 million Won	3,109 (25.0)	150 (20.5)	
33.6-<55.0 million Won	3,073 (26.8)	142 (21.8)	
≥55.0 million Won	3,433 (29.8)	87 (15.3)	. 0001
Educational attainment(year	s)		<.0001
$\leq 6$	2,482 (13.1)	257 (25.4)	
7–9	1,299 (8.5)	83 (9.1)	
10–12	4,184 (37.0)	208 (33.8)	
>12	4,651 (41.4)	188 (31.8)	
Marital status			<.0001
Never married	1,957 (23.3)	140 (27.6)	
Married-living together	9,143 (67.8)	399 (51.1)	
Married-separate	69 (0.5)	6 (0.5)	
Divorced, widowed	1,449 (8.5)	191 (20.8)	
Current drinking status			0.0135
No	5,849 (41.0)	388 (46.6)	
Yes	6,770 (59.0)	348 (53.4)	
CVH metrics score (0–100)			
Overall score (by LE8)	65.7 (65.3–66.1)	61.4 (60.2–62.6)	<.0001
Diet score (by KHEI)	39.8 (39.0-40.6)	31.0 (28.6–33.3)	<.0001
Physical activity score	34.2 (33.0–35.4)	30.6 (26.9–34.4)	<.0001
Nicotine exposure score	71.1 (70.2–72.1)	63.4 (59.6–67.2)	<.0001
Sleep health score	82.3 (81.8-82.7)	70.7 (68.0–73.5)	<.0001
Body mass index score	68.6 (67.8–69.3)	67.8 (64.7–70.9)	<.0001
Blood lipids score	68.0 (67.3–68.7)	68.1 (65.6–70.6)	<.0001
Blood glucose score	89.2 (88.7-89.6)	86.1 (84.0-88.2)	<.0001
Blood pressure score	72.7 (71.9–73.4)	73.4 (70.7–76.1)	<.0001
<b>Overall CVH score (by LE8)</b>		. ,	<.0001
Low CVH	1,610 (13.2)	142 (19.7)	
Moderate CVH	9,047 (70.7)	532 (71.3)	
High CVH	1.964 (16.1)	62 (9.0)	

#### Table 1. General characteristics of the study population by depressive symptoms (N=13,357)

Values are presented as number (weighted %) and mean (95% confidence intervals)

The sum of numbers may not apply to the total number in group due to missing values.

Abbreviations: PHQ-9 = Patient health questionnaire-9; CVH = Cardiovascular health; KHEI = Korean Healthy Eating Index for adults



	Overall CVH score (Life's Essential 8)					
	Low CVH	Moderate CVH	High CVH			
Variables	N=1,752 (13.5%)	N=9,579 (70.7%)	N=2.026 (15.8%)			
Sex						
Men	1,120 (72.8)	3,960 (49.8)	462 (31.2)			
Women	632 (27.2)	5,619 (50.2)	1,564 (68.8)			
Age(years)	· · · ·					
19-39	314 (25.5)	2,596 (36.1)	863 (50.0)			
40-59	696 (48.2)	3,469 (40.2)	861 (40.3)			
>60	742 (26.3)	3,514 (23.7)	302 (9.7)			
Monthly household income						
<17.4 million Won	620 (26.6)	2,489 (20.2)	230 (10.8)			
17.4-<33.6 million Won	439 (26.3)	2,384 (25.3)	436 (21.2)			
33.6-<55.0 million Won	367 (25.4)	2,277 (26.4)	571 (28.3)			
≥55.0 million Won	322 (21.7)	2,409 (28.1)	789 (39.6)			
Educational attainment(vears)			· · · ·			
<6	528 (20.5)	2.114 (14.8)	97 (2.9)			
7-9	242 (12.5)	1,030 (8.7)	110 (4.1)			
10-12	535 (34.8)	3.147 (36.9)	710 (38.6)			
>12	446 (32.2)	3.284 (39.5)	1.109 (54.4)			
Marital status			, , ,			
Never married	215 (18.3)	1,425 (22.6)	457 (32.0)			
Married-living together	1.193 (67.3)	6.886 (67.5)	1.463 (64.0)			
Married-separate	17 (1.0)	51 (0.5)	7 (0.3)			
Divorced, widowed	327 (13.4)	1,215 (9.4)	98 (3.7)			
Current drinking status		, , ,	× ,			
No	711 (35.2)	4,550 (41.6)	976 (45.0)			
Yes	1,040 (64.8)	5,028 (58.4)	1,050 (55.0)			
CVH metrics score	, , ,		, , ,			
Overall score by (LE8)	43.0 (42.7-43.3)	65.3 (65.1–65.5)	85.6 (85.3-85.8)			
Diet score (by KHEI)	23.1 (21.8–24.5)	38.5 (37.7–39.3)	57.3 (55.9–58.7)			
Physical activity score	7.6 (6.1–9.0)	30.0 (28.8–31.2)	74.8 (72.9–76.7)			
Nicotine exposure score	36.9 (34.5-39.2)	72.3 (71.2–73.3)	92.9 (91.8–93.9)			
Sleep health score	69.4 (67.9–70.9)	82.3 (81.7-82.8)	89.7 (88.7–90.6)			
Body mass index score	41.1 (39.7–42.6)	68.7 (67.9–69.5)	91.3 (90.3–92.3)			
Blood lipids score	46.8 (45.4–48.3)	67.9 (67.2–68.7)	86.5 (85.5-87.5)			
Blood glucose score	72.0 (70.3–73.7)	90.1 (89.6–90.6)	98.5 (98.1–98.9)			
Blood pressure score	47.0 (45.5–48.5)	73.0 (72.2–73.7)	93.5 (92.6–94.3)			
Depressive symptoms (by PHO-	.9)					
No depressive symptoms (<10)	1.610 (92.7)	9,047 (95.0)	1.964 (97.2)			
Depressive symptoms (>10)	142 (7.3)	532 (5.0)	62 (2.8)			

 Table 2. General characteristics of the study population by overall cardiovascular health score

 Overall CVH score (Life's Essential 8)

Values are presented as number (weighted %) and mean (95% confidence intervals)

The sum of numbers may not apply to the total number in group due to missing values.

Abbreviations: PHQ-9 = Patient health questionnaire-9; CVH = Cardiovascular health; KHEI = Korean Healthy Eating Index for adults



## 2. Association between cardiovascular health and depressive symptoms

The association between CVH (LE8 score, health behaviors score, and health factors score) and depressive symptoms is shown in Figure 3 and Table 3. Compared to low CVH, participants with high CVH had significantly lower odds of depressive symptoms (OR=0.33, 95% CI=0.23–0.49). Overall CVH is divided into two domains as health behaviors and health factors by AHA. According to the health behaviors score, the ORs for depressive symptoms were 0.53 (95% CI=0.44–0.64) in the moderate health behaviors score and 0.37 (95% CI=0.26–0.52) in the high health behaviors score, respectively. However, moderate and high health factors score were not associated with depressive symptoms compared to low health factors score in overall CVH and health behaviors (p for trend <.0001).

Figure 4 shows the association between each of CVH metrics and depressive symptoms. Compared to individuals with poor diet, the OR for depressive symptoms was 0.89 (95% CI=0.56–1.42) in diet metric. However, the diet metric was not statistically significant for depressive symptoms. Individuals with ideal nicotine exposure were associated with lower odds of depressive symptoms (OR=0.41, 95 % CI=0.33–0.52) compared to individuals with poor nicotine exposure. Participants with ideal sleep health were related to lower odds of



depressive symptoms (OR=0.65, 95% CI=0.54–0.78) compared to individuals with poor sleep health. Compared to poor blood glucose, the OR for depressive symptoms was 0.73 (95% CI=0.58–0.90) in ideal blood glucose. However, BMI, blood lipids, and BP were not associated with lower depressive symptoms.





Odds ratio for depressive symptoms

**Figure 3.** Odds ratios (OR) and 95% Confidence Intervals (CI) for the association between cardiovascular health scores and depressive symptoms (PHQ-9, cut-off=10, N=13,357)

Adjusted for sex, age, household income, educational attainment, marital status, and current drinking status

Abbreviations: Cardiovascular health = CVH;



Table 3. Association between cardiovascular health scores and depressive symptoms

			Model 1	Model 2	Model 3	Model 4	
	Ν	Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	p for trend
Overall CVH score (by LE8)							<.0001
Low CVH	1,752	142 (8.1)	Reference	Reference	Reference	Reference	
Moderate CVH	9,579	532 (5.6)	0.67 (0.53-0.85)	0.51 (0.41-0.65)	0.60 (0.47-0.77)	0.60 (0.47-0.77)	
High CVH	2,026	62 (3.1)	0.37 (0.26-0.54)	0.24 (0.17-0.35)	0.33 (0.23-0.49)	0.33 (0.23-0.49)	
Health behaviors score							<.0001
Low	4,116	338 (8.2)	Reference	Reference	Reference	Reference	
Moderate	7,507	346 (4.6)	0.58 (0.49-0.70)	0.47 (0.39-0.57)	0.53 (0.44-0.64)	0.53 (0.44-0.64)	
High	1,734	52 (3.0)	0.34 (0.24-0.48)	0.28 (0.20-0.40)	0.37 (0.26-0.52)	0.37 (0.26-0.52)	
Health factors score							0.3895
Low	1,388	83 (6.0)	Reference	Reference	Reference	Reference	
Moderate	6,411	358 (5.6)	0.89 (0.66-1.19)	0.86 (0.64-1.15)	0.95 (0.71-1.27)	0.94 (0.70-1.27)	
High	5,558	295 (5.3)	0.91 (0.68–1.23)	0.74 (0.54–1.01)	0.88 (0.64–1.21)	0.88 (0.63-1.21)	

Model 1: Unadjusted model

Model 2: Adjusted for age and sex

Model 3: Model 2 + Adjusted for household income, educational attainment, and marital status.

Model 4: Model 3 + Adjusted for current drinking status

Overall CVH score, health behaviors score, and health factors score are categorized as low (0-<50), moderate (50-<80), and high (80-<100).

Overall CVH (by LE8) is divided into two domains: health behaviors (diet, physical activity, nicotine exposure, and sleep health), and health factors (body mass index, blood lipids, blood glucose, and blood pressure)

Abbreviations: Cardiovascular health = CVH;

29





odds fatto for depressive symptoms



Adjusted for sex, age, household income, educational attainment, marital status, and current drinking status

Abbreviations: Cardiovascular health = CVH;



# **3.** Association between cardiovascular health and depressive symptoms by sex

Figure 5 presents the sex-stratified association between CVH (LE8, health behaviors score, and health factors score) and depressive symptoms. Compared to low CVH, the ORs for depressive symptoms were 0.67 (95% CI=0.46–0.97) among men with moderate CVH and 0.56 (95% CI=0.41–0.77) among women with moderate CVH. The ORs for depressive symptoms were 0.23 (95% CI=0.09–0.59) among men with high CVH and 0.34 (95% CI=0.21–0.55) among women with high CVH compared to low CVH. Compared to low health behaviors score, moderate score in health behaviors were associated with lower odds of depressive symptoms among both men and women (men, OR=0.65, 95% CI=0.45–0.92; women, OR=0.49, 95% CI=0.28–0.63). Moreover, both men and women with high score in health behaviors score (men, OR=0.17, 95% CI=0.06–0.43; women, OR=0.42, 95% CI=0.28–0.63). However, moderate or high score in health factors were not associated with depressive symptoms among both men and women compared to low score in health factors.

Figure 6 shows the sex-stratified association between each of CVH metrics and depressive symptoms. Compared to poor nicotine exposure, both men and women



with ideal nicotine exposure were associated with lower odds of depressive symptoms (men, OR=0.43, 95% CI=0.25–0.76; women, OR=0.41, 95% CI=0.32–0.51). Both men and women with ideal sleep health were related to lower odds of depressive symptoms compared to poor sleep health (men, OR=0.60, 95% CI=0.41–0.87; women, OR=0.68, 95% CI=0.55–0.84). Compared to poor blood glucose, men with ideal blood glucose were associated with lower odds of depressive symptoms, but not observed in women (OR=0.66, 95% CI=0.46–0.95).





Figure 5. Odds ratios (OR) and 95% Confidence Intervals (CI) for sex-stratified association between cardiovascular health metrics and depressive symptoms

Adjusted for age, household income, educational attainment, marital status, and current drinking status

Abbreviations: Cardiovascular health = CVH;





Figure 6. Odds ratios (OR) and 95% Confidence Intervals (CI) for sex-stratified association between each of cardiovascular health metrics and depressive symptoms

Adjusted for age, household income, educational attainment, marital status, and current drinking status

Abbreviations: Cardiovascular health = CVH;



# 4. Association between cardiovascular health and depressive symptoms by age

Figure 7 presents the age-stratified association between CVH (LE8 score, health behaviors score, and health factors score) and depressive symptoms. Figure 7 (A) was the results among the age range of 19-39 years. The ORs for depressive symptoms decreased from 0.52 (moderate CVH, 95% CI=0.32-0.84) to 0.24 (high CVH, 95% CI=0.13-0.43) compared to low CVH. Moreover, the ORs for depressive symptoms were 0.49 (95% CI=0.35-0.69) in moderate health behaviors score and 0.20 (95% CI=0.11-0.39) in high health behaviors score compared to low health behaviors score. Figure 7 (B) was the results among the age range of 40–59 years. As the low CVH was reference, the ORs for depressive symptoms were 0.59 (95% CI=0.39-0.90) in moderate CVH and 0.30 (0.14-0.62) in high CVH, respectively. Additionally, the ORs for depressive symptoms were 0.56 (95% CI=0.39-0.81) in moderate health behaviors score and 0.42 (95% CI=0.23-0.78) in high health behaviors score compared to low health behaviors score. Figure 7 (C) was the results among those older than 60 years. As the low CVH was reference, the ORs for depressive symptoms were 0.58 (95% CI=0.44-0.77) in moderate health behaviors score, respectively. However, moderate or high CVH and high health behaviors score were not significantly associated with depressive symptoms



compared to low score. In all age groups, health factors score was not statistically significant association with depressive symptoms.

Figure 8 shows the age-stratified association between each of CVH metrics and depressive symptoms. Figure 8 (A), Figure 8 (B), and Figure 8 (C) represent results for ages 19–39, 40–59, and 60 and over, respectively. Ideal nicotine exposure was associated with lower odds of depressive symptoms compared to poor nicotine exposure among all age groups. Compared to poor nicotine exposure, the OR for depressive symptoms was 0.30 (95% CI=0.21-0.43) in ideal nicotine exposure among those aged 19-39 years. The OR for depressive symptoms was 0.49 (95% CI=0.32-0.74) in ideal nicotine exposure compared to poor nicotine exposure among 40-59 years. Compared to poor nicotine exposure among those aged 60 and over, the OR for depressive symptoms was 0.67 (95% CI=0.46-0.98) in ideal nicotine exposure. Furthermore, ideal sleep health was related to lower odds of depressive symptoms compared to poor sleep health among all age groups. The OR for depressive symptoms was 0.64 (95% CI=0.47-0.89) in ideal sleep health compared to poor sleep health among 19-39 years. Among participants aged 40-59 years, the OR for depressive symptoms was 0.58 (95% CI=0.41-0.81) in ideal sleep health compared to poor sleep health. The OR for depressive symptoms was 0.72



(95% CI=0.54–0.97) in ideal sleep health compared to poor sleep health among participants aged 60 and over.





Figure 7. Odds ratios (OR) and 95% Confidence Intervals (CI) for the age-stratified association between cardiovascular health scores and depressive symptoms

Adjusted for sex, household income, educational attainment, marital status, and current drinking status Abbreviations: Cardiovascular health = CVH;

38





Figure 8. Age-stratified association between each of cardiovascular health metrics and depressive symptoms

Adjusted for sex, household income, educational attainment, marital status, and current drinking status Abbreviations: Cardiovascular health = CVH;

39



## 5. The results of sensitivity analyses

The six sensitivity analysis conducted to verify the robustness of the study results is as follows. First, we performed additional stratified analyses according to socioeconomic status (household income, educational attainment, and marital status) to examine the association between CVH and depressive symptoms (Appendix 4, Appendix 5, and Appendix 6). According to household income in Q4 ( $\geq$  55.0 million Won), the OR for depressive symptoms was 0.30 (95% CI=0.11-0.82) in high CVH compared to low CVH. According to educational attainment, the OR for depressive symptoms was 0.25 (95% CI=0.14-0.44) in high CVH compared to low CVH among those with more than 12 years of educational attainment. According to marital status, the OR for depressive symptoms was 0.34 (95% CI=0.21-0.57) in high CVH compared to low CVH among those who are married and living together. Second, to compare the diet metric measured by KHEI, we re-measured diet metric by the DASH using KNHANES data for 2014 and 2016 (Appendix 7). According to the diet metric defined by KHEI, the OR for depressive symptoms was 0.34 (95% CI=0.22–0.52) in high CVH compared to low CVH. According to the diet metric defined by DASH, the OR for depressive symptoms was 0.30 (95% CI=0.19–0.46) in high CVH compared to low CVH. The AUC value of these two models was 0.72. In case of the overall CVH score as continuous variable, the OR for depressive



symptoms was 0.74 (95% CI=0.68-0.81) in model defined by diet metric with KHEI. The OR for depressive symptoms was 0.74 (95% CI=0.68–0.81) in model defined by diet metric with DASH. The AUC value of these two models was 0.73. Third, we identified the association between CVH and depressive symptoms compared to LS7 and LE8 (Appendix 8). In LS7 model, the OR for depressive symptoms was 0.35 (95% CI=0.21-0.57) in high CVH compared to low CVH. In LE8 model, the OR for depressive symptoms was 0.33 (95% CI=0.23-0.49) in high CVH compared to low CVH. The AUC value of these two models was 0.72. In case of the overall CVH score (per 10-point increment) as continuous variable, the OR for depressive symptoms was 0.22 (95% CI=0.14-0.35) in LS7 model. In LE8 model, the OR for depressive symptoms was 0.75 (95% CI=0.69-0.80). The AUC values for LS7 and LE8 were 0.71 and 0.73, respectively. Fourth, we excluded participants who had previously been diagnosed with depressive symptoms by physician (Appendix 9). Compared to low CVH, participants with high CVH had 63% (OR=0.37, 95% CI=0.24-0.57) decreased odds of depressive symptoms. Compared to low health behaviors score, participants with high health behaviors score had 62% (OR=0.38, 95% CI=0.26-0.55) decreased odds of depressive symptoms. Fifth, we defined depressive symptoms using cut-off PHQ-9 score of 5 and 15. In the results with a PHQ-9 score cut-off of 5, the ORs for depressive symptoms were 0.80 (95% CI=0.68-0.94) in moderate CVH and 0.59 (95%



CI=0.47-0.73) in high CVH. Moreover, the ORs for depressive symptoms were 0.68 (95% CI=0.61-0.76) in moderate health behaviors score and 0.53 (95% CI=0.44–0.63) in high health behaviors score (Appendix 10). As we defined by a PHQ-9 score of 15 or higher for depressive symptoms, it showed lower depressive symptoms compared to the PHQ-9 cut-off of 5. A high CVH showed 71% (OR=0.29, 95% CI=0.14-0.57) decreased odds of depressive symptoms compared to low CVH. A high health behaviors score described 70% (OR=0.30, 95% CI=0.15-0.61) decreased odds of depressive symptoms compared to low health behaviors score (Appendix 11). Lastly, we redefined CVH (LE8 score, health behaviors score, and health factors score) as quartiles (Appendix 12) and continuous variable (Appendix 13). According to the overall CVH score as quartiles, the OR for depressive symptoms was significantly lower in Q4 (OR=0.34, 95% CI=0.25-0.46), compared to Q1. As the quartiles of health behaviors score increased, the ORs for depressive symptoms decreased by 0.59 (95% CI=0.46-0.76), 0.39 (95% CI=0.30-0.51), and 0.35 (95% CI=0.27–0.46) when we compared to the lowest quartile. However, quantiles of health factors score were not associated with lower odds of depressive symptoms. We assessed the ORs for depressive symptoms per 10-point increment in overall CVH by LE8 score, health behaviors score, and health factors score. The ORs for depressive symptoms were 0.75 (95% CI=0.69-0.80) in the overall CVH



score by LE8 and 0.78 (95% CI=0.73–0.82) in health behaviors score. However, health factors score was not associated with lower odds of depressive symptoms.



## **IV. DISCUSSION**

## 1. Summary of findings

This study examined the association between CVH measured by LE8 and depressive symptoms. Compared to low CVH, high CVH was inversely associated with depressive symptoms. Health behaviors showed similar results to overall CVH by LE8, while health factors were not statistically associated with depressive symptoms. Additionally, we assessed the association between each of CVH metrics and depressive symptoms. As poor health behavior metrics were reference, ideal nicotine exposure, and ideal sleep health were related to lower odds of depressive symptoms. According to health factor metrics, ideal blood glucose was associated with lower odds of depressive symptoms compared to individuals with poor blood glucose. According to the results of sex-stratified analyses, overall CVH by LE8 and health behaviors were related to lower odds of depressive symptoms among both men and women. Among both men and women, ideal nicotine exposure and ideal sleep health were associated with lower odds of depressive symptoms compared to poor metrics. Moreover, as poor blood glucose was reference among men, ideal blood glucose was related to lower odds of depressive symptoms. According to the results of age-stratified analyses, overall CVH by LE8 and health behaviors were associated with lower odds of depressive symptoms in early



adulthood and middle age, whereas health factors were not. In all age groups, ideal nicotine exposure and ideal sleep health were associated with lower odds of depressive symptoms compared to poor metrics.



### 2. Discussion of the previous studies

### 1) Cardiovascular health and depressive symptoms, using Life's Simple 7

Prior to the updating of LE8, AHA assessed CVH using LS7.<sup>9</sup> In the health behavior domain of LS7, while sleep health was not included, but BMI was incorporated.<sup>9,10</sup> The health factors domain of LS7 included TC, blood glucose, and BP.<sup>9</sup> In this study, CVH was measured using the recently announced LE8 by AHA. The results of this study showed that a moderate or high CVH was associated with lower depressive symptoms compared to low CVH. According to the systematic review published in 2022, it reported on the association between CVH measured by LS7 and depressive symptoms up to May 2021.<sup>31</sup> Out of total of 132 papers, duplicates, review articles, and those with mismatched variables were excluded, resulting in the selection of 11 studies.<sup>31</sup> Among the 11 studies, five studies were consistent with our findings due to the same exposure and outcome (Appendix 14).<sup>31</sup>

First, in a study of 5,110 US adults, an increasing number of ideal CVH components was linearly associated with lower odds for depressive symptoms.<sup>12</sup> In the fully adjusted model, individuals with 5–7 ideal CVH components were associated with lower odds for depressive symptoms compared to those with 0–2 ideal CVH components.<sup>12</sup> Second, according to a study involving a total of 9,962 Chinese participants, an increase in the number of ideal CVH components was inversely



associated with depression.<sup>32</sup> Third, in a study involving 6,851 Chinese individuals aged 20 and above, CVH score was divided into quartiles.<sup>14</sup> Quartile 3 and 4 were associated with lower odds of depression compared to Quartile 1, consistent with our study's findings.<sup>14</sup> Fourth, a prospective cohort study including 9,214 Brazilian individuals demonstrated that an increasing number of ideal CVH components was associated with decreased odds of depression.<sup>13</sup> Fifth, a cross-sectional study involving 14,561 US individuals aged 20 and older investigated the association between CVH and depression using optimal CVH as the reference.<sup>15</sup> Compared to optimal CVH scoring 10–14 points, inadequate CVH scoring 0–4 points was associated with mild and moderate or severe depression, respectively.<sup>15</sup> After the publication of this systematic review, a recent prospective study involving 6,980 French individuals was published in 2023.<sup>33</sup> This prospective study confirmed that increasing number of CVH metrics was associated with decreased OR for depressive symptoms when compared to those with 0–1 intermediate or ideal metrics.<sup>33</sup>

## 2) "Health behaviors" and depressive symptoms

CVH is divided into two domains by AHA: health behaviors and health factors.<sup>10</sup> In our study, compared to those with a low health behaviors score, those with



moderate or high health behaviors score were related to lower odds of depressive symptoms. Our findings align with previous studies that examined the association between health behaviors belonging to LS7 and depressive symptoms. In the study of US adults without mental disorder at baseline, individuals with a higher number of health behavior metrics were related to lower odds of depressive symptoms compared to those with the lowest number of health behavior metrics.<sup>12</sup> In a study of US adults aged 20 and older, the OR for depression was higher in individuals with inadequate health behaviors than those with average health behaviors when compared to individuals with 3–4 optimal health behaviors.<sup>15</sup>

In this study, we examined the association between each of health behavior metrics (diet, physical activity, nicotine exposure, and sleep health), and depressive symptoms. Several studies confirmed that healthy lifestyles are associated with lower depressive symptoms in agreement with the results of our study. Our study found that ideal diet showed inverse linear trend with depressive symptoms. However, this association was not statistically significant. In a prospective study including 5,110 participants, individuals satisfying 3–4 diet components were associated with lower odds of depressive symptoms compared to those satisfying 0–1 diet components.<sup>12</sup> Furthermore, when comparing poor diet metric, intermediate diet or ideal diet were associated with lower odds of depression.<sup>14</sup> The



reason for different results may be attributed to the different assessment of diet metric. Previous studies mentioned measured diet metrics belonging to LS7, such as fruits and vegetables, fish, fiber-rich whole grains, sodium, and sugar-sweetened beverages. Therefore, further research is needed to examine the association between various diet metric measurements and depressive symptoms, depending on the population.

We confirmed that non-smoking and sleep health were associated with lower odds of depressive symptoms. In stratified analyses by sex and age, non-smoking and sleep health were associated with lower odds of depressive symptoms in all groups. Previous studies had reported on the relationship between smoking and depressive symptoms. According to the Espana-Romero study, compared to current smokers, former smokers and non-smokers had 27% and 25% lower odds of depressive symptoms, respectively.<sup>12</sup> In Li's study, ideal level of smoking was related to decreased odds of depression when compared to poor CVH metrics.<sup>14</sup> According to Zhang's study with optimal CVH components as the reference, poor level of smoking was associated with mild and moderate or severe depression.<sup>15</sup> In a study involving 1,190 Norwegian population, current smokers who consumed more than eleven cigarettes per day were associated with the onset of depressive events compared to those who never smoked.<sup>34</sup> In prospective cohort study of the Danish



population without depression at baseline, both men and women who smoked tobacco per day were related to risk of depression.<sup>35</sup>

Similar to nicotine exposure, sleep health was associated with a lower odds of depressive symptoms. In Patterson's study, using the scoring system of LS7 and definition of LE8, optimal levels of sleep health were associated with a lower prevalence ratio (PR) of moderate to severe depression.<sup>36</sup> Previous studies had consistently indicated that sleep health problems are known risk factors for depressive symptoms. In a study involving 2,532 Japanese adults, individuals who slept less than 6 hours showed an association with depressive symptoms.<sup>37</sup> In prospective study of 3,806 US women at baseline, early mid-sleep time, and short or long sleep hours were related to depressive symptoms.<sup>38</sup> After a 6-year followup study, individuals who slept less than 7 hours were associated with depressive symptoms.<sup>38</sup> In a prospective study including 10,704 participants at baseline, both men and women who slept short durations (<5 hours or 5-6 hours) were associated with depression compared with normal sleep duration (7-8 hours).<sup>39</sup> In a prospective study involving 11,052 Chinese population, individuals who slept less than 6 hours were associated with depressive symptoms among those aged 45-65 or 65 and over.40

The possible mechanisms for the association between nicotine exposure, sleep



health, and depressive symptoms are as follows. Smoking elevated inflammatory response that increased levels of CRP, IL-6, and WBC, potentially heightening the risk of depression.<sup>41</sup> When compared to non-smokers, individuals who had quit smoking for less than 20 years maintained significantly elevated levels of CRP and WBC.<sup>42</sup> It took more than 20 years of smoking cessation for their inflammatory markers to improve the levels observed in non-smokers.<sup>42</sup> Persistent sleep restriction or limited sleep duration could lead to changes in neuroendocrine stress system such as autonomic sympathetic-adrenal system, and hypothalamic-pituitary-adrenal (HPA) axis.<sup>43</sup> Changes like decreased serotonin receptor and the control of the HPA axis are identified in depression<sup>43</sup>.

## 3) "Health factors" and depressive symptoms

Previous studies measuring CVH using LS7 reported that higher number of health factors are not associated with lower depressive symptoms.<sup>12,15</sup> However, when examining CVH metrics individually, previous study observed the association between blood glucose and depressive symptoms. In Zhang's study, which measured CVH using LS7, ideal health factors served as the reference.<sup>15</sup> poor blood glucose were associated with mild depression.<sup>15</sup> Similar to previous studies, this study confirmed the association between blood glucose and depressive symptoms.



Additionally, as this study conducted sex-stratified analyses, this association was found to be significant in men.

A prospective study involving 4,388 participants from England examined the association between HbA1c levels, FBG, and depressive symptoms during a 2-year follow-up period.<sup>44</sup> An increase of 1 unit in HbA1c was related to depressive symptoms after adjusting for age and baseline Centre of Epidemiological Studies-Depression (CES-D) score ( $\geq$ 4).<sup>44</sup> As individuals with normal blood glucose were reference group, those who self-reported a diabetes diagnosis or had increased FBG levels were associated with depressive symptoms.<sup>44</sup> Five longitudinal studies confirmed the association between HbA1c and depressive symptoms.<sup>45</sup> According to previous studies, individuals who were undiagnosed with diabetes had a lower risk of depressive symptoms compared to those with type 2 diabetes.<sup>46,47</sup> Individuals diagnosed with diabetes were associated with depressive symptoms due to the psychological burden of managing complications arising from diabetes.<sup>46,48</sup> In a previous study including 5,462 men aged 70–89, men with the longest duration since diabetes diagnosis were associated with depression.<sup>49</sup> The diagnosis of diabetes additionally showed a direct effect on depression, and frailty played the role of mediator in the association between diagnosis of diabetes and depression.<sup>49</sup> The possible mechanisms for the association between blood glucose and depressive



symptoms were lifestyle factors, adherence, diagnosed diabetes with complications, and HPA axis dysfunction.<sup>48</sup> Blood glucose and depressive symptoms still exhibit a bidirectional relationship. Further, longitudinal studies are needed to investigate the association between blood glucose and depressive symptoms.

#### 4) Manage health behaviors in early adulthood and middle age

Our study found that participants aged 19–39 (early adulthood) and 40–59 (middle age) with a moderate or high CVH were associated with lower odds for depressive symptoms compared to those with a low CVH. However, among those aged 60 or higher, the association with lower odds of depressive symptoms was not statistically significant. Our stratified analysis by age yielded similar results to previous study. Age-stratified analyses revealed that intermediate and poor CVH were associated with mild depression in all age groups.<sup>15</sup> However, while individuals aged 20–44 and 45–64 with intermediate and poor CVH were related to moderate or severe depression, those aged 65 and above were not statistically significant.<sup>15</sup> Age-related differences in the results may be attributed to health issues and individual and social-environmental factors. Older adults are exposed to negative environments where depressive symptoms are more likely to occur than in younger adults. With aging, older adults had numerous chronic diseases such as hearing loss of vision,



stroke, cardiac disease, and chronic lung disease.<sup>50</sup> In a meta-analysis including 24 cross-sectional and 7 prospective studies, chronic diseases were associated with depression in older adults.<sup>50</sup> Additionally, financial difficulties, loneliness, and spousal loss are all associated with depressive symptoms among older adults.<sup>51-53</sup> In a longitudinal study involving individuals aged more than 75 years in Germany, individuals who lost their spouse were associated with mild to moderate and severe depressive symptoms.<sup>52</sup> For these reasons, older adults are more likely to face challenging circumstances in overcoming depressive symptoms. Therefore, managing healthy behaviors from early adulthood is preventive for depressive symptoms. Nevertheless, according to the association between each of CVH metrics and depressive symptoms, sleep health and nicotine exposure were associated with lower odds of depressive symptoms in all age groups. Several previous studies confirmed the association between nicotine exposure or sleep health and depressive symptoms. Therefore, healthy behaviors in early adulthood and middle age act as preventive factors for depressive symptoms. Moreover, in all ages, non-smoking and sleep health serve as preventive factors for depressive symptoms.



## 3. Strengths and Limitations

The strengths of this study are as follows. First, we utilized nationally representative data, which had strength to provide precision in statistical analyses due to complex sampling design and potential for generalization to the entire Korean adults. Second, we measured overall CVH which was defined and scored based on AHA guidelines. Furthermore, we conducted sensitivity analyses considering not only the KHEI diet but also the DASH. Third, objective metrics such as BMI, blood lipids, blood glucose, and BP were measured according to standardized protocol. Fourth, our findings provide robust and powerful evidence of association between cardiovascular health measured by LE8 and depressive symptoms.

However, this study had several limitations that should be considered for future research and interpretation of the results. First, as this study is a cross-sectional design, a causal relationship cannot be explained. However, to address this limitation, we excluded individuals with a history of diagnosed depression by physicians and conducted sensitivity analyses. After excluding these individuals in sensitivity analysis, overall CVH by LE8 and health behaviors were associated with lower odds of depressive symptoms, but health factors were not statistically significant associations, which aligns with the main analyses. Future research should consider conducting longitudinal studies targeting individuals without



baseline depression. Second, the health behavior metrics are self-reported data. Third, there may be unmeasured confounding variables. However, we adjusted for covariates comprising demographic variables, socioeconomic status, and current drinking status. Future investigations should take into account other potential confounders on the association between CVH and depressive symptoms.


# **V. CONCLUSIONS**

The findings of this study evaluated the association between CVH measured by LE8 and depressive symptoms in the Korean population. Overall, higher scores of CVH or health behaviors were inversely associated with depressive symptoms. Ideal sleep health and non-smokers were protective factors for depressive symptoms. Among both men and women, ideal sleep health and non-smokers were protective factors for depressive symptoms. Moreover, ideal blood glucose was preventive factor for depressive symptoms among men. To prevent individuals with depressive symptoms, CVH requires timely attention and management depending on early adulthood, middle age, and older age.

### 연세대학교 YONSEI UNIVERSITY

### REFERENCES

- Lépine J-P, Briley M. The increasing burden of depression. Neuropsychiatric disease and treatment 2011;7:3-7.
- 2. Prince M, Patel V, Saxena S, Maj M, Maselko J, Phillips MR, et al. No health without mental health. The lancet 2007;370:859-77.
- 3. OECD. Health at a Glance 2021; 2021.
- 4. Cassano P, Fava M. Depression and public health: an overview. Journal of psychosomatic research 2002;53:849-57.
- Furihata R, Konno C, Suzuki M, Takahashi S, Kaneita Y, Ohida T, et al. Unhealthy lifestyle factors and depressive symptoms: A Japanese general adult population survey. Journal of Affective Disorders 2018;234:156-61.
- Nouwen A, Winkley K, Twisk J, Lloyd CE, Peyrot M, Ismail K, et al. Type
  2 diabetes mellitus as a risk factor for the onset of depression: a systematic review and meta-analysis. Diabetologia 2010;53:2480-6.
- 7. Villarreal-Zegarra D, Bernabe-Ortiz A. Association between arterial hypertension and depressive symptoms: results from population-based surveys in Peru. Asia-Pacific Psychiatry 2020;12:e12385.
- Organization WH. Global status report on noncommunicable diseases 2010: World Health Organization; 2011.
- Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. Circulation 2010;121:586-613.
- Lloyd-Jones DM, Allen NB, Anderson CA, Black T, Brewer LC, Foraker RE, et al. Life's essential 8: updating and enhancing the American Heart



Association's construct of cardiovascular health: a presidential advisory from the American Heart Association. Circulation 2022;146:e18-e43.

- Itani O, Jike M, Watanabe N, Kaneita Y. Short sleep duration and health outcomes: a systematic review, meta-analysis, and meta-regression. Sleep medicine 2017;32:246-56.
- España-Romero V, Artero EG, Lee D-c, Sui X, Baruth M, Ruiz JR, et al. A prospective study of ideal cardiovascular health and depressive symptoms. Psychosomatics 2013;54:525-35.
- Brunoni AR, Szlejf C, Suemoto CK, Santos IdS, Goulart AC, Viana M, et al. Association between ideal cardiovascular health and depression incidence: a longitudinal analysis of ELSA-Brasil. Acta Psychiatrica Scandinavica 2019;140:552-62.
- Li Z, Yang X, Wang A, Qiu J, Wang W, Song Q, et al. Association between ideal cardiovascular health metrics and depression in Chinese population: a cross-sectional study. Scientific reports 2015;5:11564.
- Zhang Z, Jackson S, Merritt R, Gillespie C, Yang Q. Association between cardiovascular health metrics and depression among US adults: National Health and Nutrition Examination Survey, 2007–2014. Annals of epidemiology 2019;31:49-56. e2.
- Kweon S, Kim Y, Jang M-j, Kim Y, Kim K, Choi S, et al. Data resource profile: the Korea national health and nutrition examination survey (KNHANES). International journal of epidemiology 2014;43:69-77.
- Krebs-Smith SM, Pannucci TE, Subar AF, Kirkpatrick SI, Lerman JL, Tooze JA, et al. Update of the healthy eating index: HEI-2015. Journal of the Academy of Nutrition and Dietetics 2018;118:1591-602.
- 18. Yun S, Park S, Yook S-M, Kim K, Shim JE, Hwang J-Y, et al. Development



of the Korean healthy eating index for adults, based on the Korea National Health and Nutrition Examination Survey. Nutrition Research and Practice 2022;16:233-47.

- Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Archives of internal medicine 2008;168:713-20.
- 20. Armstrong T, Bull F. Development of the world health organization global physical activity questionnaire (GPAQ). Journal of Public Health 2006;14:66-70.
- 21. Organization WH. WHO STEPS surveillance manual: the WHO STEPwise approach to chronic disease risk factor surveillance. World Health Organization; 2005.
- Lee J, Lee C, Min J, Kang D-W, Kim J-Y, Yang HI, et al. Development of the Korean Global Physical Activity Questionnaire: reliability and validity study. Global health promotion 2020;27:44-55.
- Yang YS, Han B-D, Han K, Jung J-H, Son JW. Obesity Fact Sheet in Korea,
  2021: Trends in obesity prevalence and obesity-related comorbidity incidence stratified by age from 2009 to 2019. Journal of Obesity & Metabolic Syndrome 2022;31:169.
- Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obesity reviews 2002;3:141-6.
- 25. Zelber-Sagi S, Salomone F, Yeshua H, Lotan R, Webb M, Halpern Z, et al. Non-high-density lipoprotein cholesterol independently predicts new onset of non-alcoholic fatty liver disease. Liver International 2014;34:e128-e35.
- 26. Detection NCEPEPo, Adults ToHBCi. Third report of the National



Cholesterol Education Program (NCEP) Expert Panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III): The Program; 2002.

- 27. Bae JH, Han K-D, Ko S-H, Yang YS, Choi JH, Choi KM, et al. Diabetes fact sheet in Korea 2021. Diabetes & Metabolism Journal 2022;46:417-26.
- 28. Han C, Jo SA, Kwak J-H, Pae C-U, Steffens D, Jo I, et al. Validation of the Patient Health Questionnaire-9 Korean version in the elderly population: the Ansan Geriatric study. Comprehensive psychiatry 2008;49:218-23.
- 29. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. Journal of general internal medicine 2001;16:606-13.
- 30. Shin C, Ko Y-H, An H, Yoon H-K, Han C. Normative data and psychometric properties of the Patient Health Questionnaire-9 in a nationally representative Korean population. BMC psychiatry 2020;20:1-10.
- Ogunmoroti O, Osibogun O, Spatz ES, Okunrintemi V, Mathews L, Ndumele CE, et al. A systematic review of the bidirectional relationship between depressive symptoms and cardiovascular health. Preventive medicine 2022;154:106891.
- Zeng Q, Dong S-Y, Song Z-Y, Zheng Y-S, Wu H-Y, Mao L-N. Ideal cardiovascular health in Chinese urban population. International journal of cardiology 2013;167:2311-7.
- 33. van Sloten TT, Valentin E, Climie RE, Jouven X, Lemogne C, Goldberg M, et al. Association of Cardiovascular Health With Risk of Clinically Relevant Depressive Symptoms. JAMA psychiatry 2023;80:342-9.
- 34. Klungsøyr O, Nygård JF, Sørensen T, Sandanger I. Cigarette smoking and incidence of first depressive episode: an 11-year, population-based follow-



up study. American journal of epidemiology 2006;163:421-32.

- 35. Flensborg-Madsen T, von Scholten MB, Flachs EM, Mortensen EL, Prescott E, Tolstrup JS. Tobacco smoking as a risk factor for depression. A 26-year population-based follow-up study. Journal of psychiatric research 2011;45:143-9.
- 36. Patterson SL, Marcus M, Goetz M, Vaccarino V, Gooding HC. Depression and anxiety are associated with cardiovascular health in young adults. Journal of the American Heart Association 2022;11:e027610.
- Furihata R, Uchiyama M, Suzuki M, Konno C, Konno M, Takahashi S, et al. Association of short sleep duration and short time in bed with depression:
  AJ apanese general population survey. Sleep and Biological Rhythms 2015;13:136-45.
- 38. Furihata R, Hall MH, Stone KL, Ancoli-Israel S, Smagula SF, Cauley JA, et al. An aggregate measure of sleep health is associated with prevalent and incident clinically significant depression symptoms among communitydwelling older women. Sleep 2017;40:zsw075.
- 39. Sun Y, Shi L, Bao Y, Sun Y, Shi J, Lu L. The bidirectional relationship between sleep duration and depression in community-dwelling middle-aged and elderly individuals: evidence from a longitudinal study. Sleep medicine 2018;52:221-9.
- Li Y, Wu Y, Zhai L, Wang T, Sun Y, Zhang D. Longitudinal association of sleep duration with depressive symptoms among middle-aged and older Chinese. Scientific reports 2017;7:11794.
- Yanbaeva DG, Dentener MA, Creutzberg EC, Wesseling G, Wouters EF. Systemic effects of smoking. Chest 2007;131:1557-66.
- 42. Wannamethee SG, Lowe GD, Shaper AG, Rumley A, Lennon L, Whincup



PH. Associations between cigarette smoking, pipe/cigar smoking, and smoking cessation, and haemostatic and inflammatory markers for cardiovascular disease. European heart journal 2005;26:1765-73.

- Meerlo P, Sgoifo A, Suchecki D. Restricted and disrupted sleep: effects on autonomic function, neuroendocrine stress systems and stress responsivity. Sleep medicine reviews 2008;12:197-210.
- 44. Hamer M, Batty G, Kivimaki M. Haemoglobin A1c, fasting glucose and future risk of elevated depressive symptoms over 2 years of follow-up in the English Longitudinal Study of Ageing. Psychological medicine 2011;41:1889-96.
- 45. Beran M, Muzambi R, Geraets A, Albertorio-Diaz JR, Adriaanse MC, Iversen MM, et al. The bidirectional longitudinal association between depressive symptoms and HbA1c: A systematic review and meta-analysis. Diabetic Medicine 2022;39:e14671.
- 46. Nouwen A, Nefs G, Caramlau I, Connock M, Winkley K, Lloyd CE, et al. Prevalence of depression in individuals with impaired glucose metabolism or undiagnosed diabetes: a systematic review and meta-analysis of the European Depression in Diabetes (EDID) Research Consortium. Diabetes care 2011;34:752-62.
- 47. Chireh B, Li M, D'Arcy C. Diabetes increases the risk of depression: A systematic review, meta-analysis and estimates of population attributable fractions based on prospective studies. Preventive medicine reports 2019;14:100822.
- 48. Holt RI, De Groot M, Golden SH. Diabetes and depression. Current diabetes reports 2014;14:1-9.
- 49. Almeida OP, McCaul K, Hankey GJ, Yeap BB, Golledge J, Norman PE, et



al. Duration of diabetes and its association with depression in later life: The Health In Men Study (HIMS). Maturitas 2016;86:3-9.

- 50. Huang C-Q, Dong B-R, Lu Z-C, Yue J-R, Liu Q-X. Chronic diseases and risk for depression in old age: a meta-analysis of published literature. Ageing research reviews 2010;9:131-41.
- 51. Van As BAL, Imbimbo E, Franceschi A, Menesini E, Nocentini A. The longitudinal association between loneliness and depressive symptoms in the elderly: a systematic review. International Psychogeriatrics 2022;34:657-69.
- 52. Sikorski C, Luppa M, Heser K, Ernst A, Lange C, Werle J, et al. The role of spousal loss in the development of depressive symptoms in the elderly implications for diagnostic systems. Journal of affective disorders 2014;161:97-103.
- 53. Baiyewu O, Yusuf AJ, Ogundele A. Depression in elderly people living in rural Nigeria and its association with perceived health, poverty, and social network. International Psychogeriatrics 2015;27:2009-15.



				~
Domain	CVH metric	Definition and details	Points	Status
Health	1. Diet	KHEI: 24-hour recall, reference	100	≥95th percentile
behaviors		population in KNHANES from	80	75 <sup>th</sup> -<95th percentile
		2014, 2016 and 2018	50	50th-<75th percentile
			25	25th-<50th percentile
			0	1st-<25th percentile
	2. Physical	Moderate or vigorous intensity	100	≥150 minutes
	activity	activity (work and leisure) per	90	120-<150 minutes
		week	80	90-<120 minutes
		: one minute of moderate PA	60	60-<90 minutes
		per minute	40	30-<60 minutes
		and two minutes of vigorous	20	1-<30 minutes
		PA per minute	0	0
	3. Nicotine	Self-reported use of cigarettes	100	Never smoker
	exposure	(tobacco), NDS and secondhand	75	Former smoker, quit ≥5 y
		smoke exposure: minus 20	50	Former smoker, quit 1-<5 y
		points for living with active indoor smoker in home	25	Former smoker, quit <1 y, or currently using inhaled NDS
			0	Current smoker
	4. Sleep health	Self-reported average hours of	100	7-<9 hours
		sleep duration	90	9-<10 hours
			70	6-<7 hours
			40	5-<6 or $\geq 10$ hours
			20	4-<5 hours
			0	<4 hours

Appendix 1. Definition and scoring of Life's Essential 8 based on the American Heart Association (continued)



Domain	CVH metric	Definition and details	Points	Status
Health	5. Body mass	Body mass index $(kg/m^2) =$	100	$<23 \text{ kg/m}^2$
factors	index	body weight (kg) / height	70	$23.0 - 25.0 \text{ kg/m}^2$
		squared (m <sup>2</sup> )	30	$25.0 - <30.0 \text{ kg/m}^2$
			15	$30.0 - <35.0 \text{ kg/m}^2$
			0	$\geq$ 35.0 kg/m <sup>2</sup>
	6. Blood lipids	Non-HDL cholesterol	100	<130 mg/dL
		(mg/dL) = TC - HDL-C	60	130-<160 mg/dL
			40	160-<190 mg/dL
			20	190-220 mg/dL
			0	≥220 mg/dL
	7. Blood	Fasting blood glucose	100	No history of diabetes and FBG
	glucose	(mg/dL) and HbA1c (%)	100	<100 (or HbA1c <5.7)
			60	No diabetes and FBG 100–125
			00	(or HbA1c 5.7-<6.5)
			40	Diabetes with HbA1c 6.5-<7.0
			30	Diabetes with HbA1c 7.0-<8.0
			20	Diabetes with HbA1c 8.0-<9.0
			10	Diabetes with HbA1c 9.0-<10.0
	-		0	Diabetes with HbA1c ≥10.0
	8. Blood	Systolic and diastolic blood	100	<120/<80 mmHg
	pressure	pressure (mmHg)	75	120-<130/<80 mmHg
			50	130-<140 or 80-<90 mmHg
			25	140-<160 or 90-<100 mmHg
			0	≥160 or ≥100 mmHg

Appendix	1. Definition	and scoring	of Life's	Essential 8	based on th	he American	Heart Association
----------	---------------	-------------	-----------	-------------	-------------	-------------	-------------------

Abbreviations: CVH = Cardiovascular health; KHEI = Korean Healthy Eating Index for adults; PA = Physical activity; NDS = Nicotine delivery system; TC = Total cholesterol; HDL = High-density lipoprotein



Domain	Metrics	Definition and details	Points
Health	1. Diet	0-<50	0 (Poor)
behavior		50-<80	1 (Intermediate)
		≥80	2 (Ideal)
	2. Physical	No physical activity	0 (Poor)
	activity	Moderate intensity (1-<150 min/wk)	1 (Intermediate)
		or vigorous intensity (1-<75 min/wk)	
		or moderate to vigorous (1-<150 min/wk)	
		Moderate intensity (≥150 min/wk)	2 (Ideal)
		or vigorous intensity (≥75min/wk)	
		or moderate to vigorous (≥150 min/wk)	
	<ol><li>Smoking</li></ol>	Current smoker	0 (Poor)
		Former smoker, quit≤12 month	1 (Intermediate)
		Never smoker or quit>12 month	2 (Ideal)
	4. Body	≥30 kg/m2	0 (Poor)
	mass index	25-<30kg/m2	1 (Intermediate)
		<25 kg/m2	2 (Ideal)
Health	5. Total	$\geq 240 \text{ mg/dL}$	0 (Poor)
factor	cholesterol	200-239 mg/dL or treated to goal	1 (Intermediate)
		<200 mg/dL	2 (Ideal)
	<ol><li>Fasting</li></ol>	$\geq$ 126 mg/dL	0 (Poor)
	plasma	100-<126 mg/dL or treated to goal	1 (Intermediate)
	glucose	<100 mg/dL	2 (Ideal)
	7. Blood	SBP≥140 or DBP≥90 mmHg	0 (Poor)
	pressure	SBP 120-<140 or DBP 80-<90 mmHg or treated to goal	1 (Intermediate)
		<120 / <80 mmHg	2 (Ideal)
dana e			, ,

Appendix 2. Definition and scoring of	Life's Simple 7 based	on the American Heart A	Association
---------------------------------------	-----------------------	-------------------------	-------------

<sup>†</sup>Diet were assessed using the Korean Healthy Eating Index for adults (KHEI).

Life's Simple 7 score is the sum of the two domains of health behaviors (diet, physical activity, smoking, and body mass index) and health factors (total cholesterol, fasting plasma glucose, and blood pressure) Abbreviations: LS7 = Life's Simple 7; SBP = Systolic Blood pressure; DBP = Diastolic Blood Pressure





### Appendix 3. The average score for each of 8 metrics by depressive symptoms status



	N	Case (%)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	p for trend
Q1, <17.4 million Won (N=3,33	<b>69</b> )						
<b>Overall CVH score (by LE8)</b>							0.0006
Low CVH	620	91 (14.7)	Reference	Reference	Reference	Reference	
Moderate CVH	2,489	249 (10.0)	0.58 (0.42-0.80)	0.53 (0.39-0.74)	0.58 (0.42-0.82)	0.58 (0.41-0.82)	
High CVH	230	16 (7.0)	0.37 (0.19-0.71)	0.32 (0.17-0.61)	0.38 (0.20-0.73)	0.38 (0.20-0.74)	
Health behaviors score							0.0008
Low	1,247	173 (13.9)	Reference	Reference	Reference	Reference	
Moderate	1,847	160 (8.7)	0.58 (0.44–0.77)	0.51 (0.38-0.70)	0.54 (0.40-0.74)	0.54 (0.40-0.75)	
High	245	23 (9.4)	0.58 (0.33-1.02)	0.50 (0.29-0.89)	0.56 (0.32-0.98)	0.56 (0.32-0.98)	
Health factors score							0.0908
Low	491	60 (12.2)	Reference	Reference	Reference	Reference	
Moderate	1,850	205 (11.1)	0.86 (0.61-1.22)	0.88 (0.62-1.24)	0.88 (0.62-1.25)	0.88 (0.62-1.25)	
High	998	91 (9.1)	0.67 (0.45–1.01)	0.64 (0.42-0.98)	0.70 (0.46-1.08)	0.70 (0.46-1.08)	
Q2, 17.4-<33.6 million Won (Na	=3,259)						
<b>Overall CVH score (by LE8)</b>							0.0033
Low CVH	439	20 (4.6)	Reference	Reference	Reference	Reference	
Moderate CVH	2,384	118 (4.9)	1.27 (0.74–2.17)	0.88 (0.51-1.53)	0.91 (0.52-1.59)	0.91 (0.52-1.59)	
High CVH	436	12 (2.8)	0.57 (0.25–1.32)	0.29 (0.12-0.71)	0.31 (0.12-0.76)	0.31 (0.12-0.76)	
Health behaviors score							<.0001
Low	1,081	71 (6.6)	Reference	Reference	Reference	Reference	
Moderate	1,781	69 (3.9)	0.66 (0.46-0.96)	0.51 (0.35-0.75)	0.53 (0.36-0.78)	0.53 (0.36-0.78)	
High	397	10 (2.5)	0.39 (0.18–0.86)	0.28 (0.13-0.62)	0.30 (0.14-0.65)	0.30 (0.14-0.65)	
Health factors score							0.4674
Low	328	6 (1.8)	Reference	Reference	Reference	Reference	
Moderate	1,640	73 (4.5)	2.44 (0.97-6.14)	2.28 (0.91-5.71)	2.35 (0.93-5.93)	2.34 (0.93-5.90)	
High	1,291	71 (5.5)	2.96 (1.19-7.35)	1.97 (0.77-5.05)	2.11 (0.81-5.47)	2.10 (0.81-5.44)	

Appendix 4. Association between cardiovascular health scores and depressive symptoms by household income. *(continued)* 



		~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	Model 1	Model 2	Model 3	Model 4	<i>p</i> for trend
00 00 ( <b>55</b> 0 '''''' 'W' 'A'		Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	-
Q3, 33.6-<55.0 million Won (N	=3,215)						0.01.10
Overall CVH score (by LE8)							0.0148
Low CVH	367	21 (5.7)	Reference	Reference	Reference	Reference	
Moderate CVH	2,277	100 (4.4)	0.71 (0.41–1.24)	0.44 (0.24–0.80)	0.45 (0.24–0.81)	0.45 (0.24–0.82)	
High CVH	571	21 (3.7)	0.69 (0.35–1.36)	0.32 (0.15–0.68)	0.33 (0.15–0.71)	0.33 (0.15-0.72)	
Health behaviors score							0.0057
Low	933	56 (6.0)	Reference	Reference	Reference	Reference	
Moderate	1,816	73 (4.0)	0.74 (0.48–1.15)	0.55 (0.35-0.87)	0.56 (0.36-0.88)	0.57 (0.36-0.89)	
High	466	13 (2.8)	0.58 (0.30-1.11)	0.43 (0.22-0.83)	0.45 (0.23-0.86)	0.45 (0.23-0.87)	
Health factors score							0.9762
Low	285	12 (4.2)	Reference	Reference	Reference	Reference	
Moderate	1,416	51 (3.6)	0.77 (0.35-1.71)	0.69 (0.31-1.51)	0.69 (0.32-1.49)	0.69 (0.32-1.48)	
High	1,514	79 (5.2)	1.33 (0.62–2.84)	0.80 (0.35-1.86)	0.81 (0.36-1.83)	0.80 (0.35-1.83)	
Q4, ≥55.0 million Won (N=3,52	0)						
<b>Overall CVH score (by LE8)</b>							0.0049
Low CVH	322	10 (3.1)	Reference	Reference	Reference	Reference	
Moderate CVH	2,409	64 (2.7)	0.89 (0.41–1.93)	0.68 (0.29–1.58)	0.70 (0.30-1.63)	0.71 (0.31-1.63)	
High CVH	789	13 (1.6)	0.47 (0.18–1.18)	0.28 (0.10-0.79)	0.30 (0.11-0.82)	0.30 (0.11-0.82)	
Health behaviors score							<.0001
Low	846	38 (4.5)	Reference	Reference	Reference	Reference	
Moderate	2,048	43 (2.1)	0.50 (0.30-0.84)	0.46 (0.27-0.80)	0.47 (0.27-0.81)	0.47 (0.28-0.81)	
High	626	6 (1.0)	0.13 (0.05-0.33)	0.13 (0.05–0.32)	0.14 (0.06–0.35)	0.14 (0.06–0.35)	
Health factors score							0.6205
Low	280	5 (1.8)	Reference	Reference	Reference	Reference	
Moderate	1,494	29 (1.9)	0.93 (0.31-2.78)	0.88 (0.29-2.68)	0.92 (0.31-2.72)	0.91 (0.31-2.71)	
High	1,746	53 (3.0)	1.28 (0.46–3.55)	0.78 (0.25-2.40)	0.81 (0.28-2.33)	0.81 (0.28-2.33)	

Appendix 4. Association between cardiovascular health scores and depressive symptoms by household income.

Adjusted for sex, age, educational attainment, marital status, and current drinking status by monthly household income



			Model 1	Model 2	Model 3	Model 4	
	Ν	Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	p for trend
≤6 years (N=2,739)		<u> </u>	· · ·			<u> </u>	•
<b>Overall CVH score (by LE8)</b>							0.2310
Low CVH	528	59 (11.2)	Reference	Reference	Reference	Reference	
Moderate CVH	2,114	187 (8.8)	0.74 (0.53-1.02)	0.68 (0.49-0.93)	0.75 (0.54-1.05)	0.75 (0.54-1.04)	
High CVH	97	11 (11.3)	0.84 (0.39–1.77)	0.75 (0.36-1.60)	1.03 (0.47-2.27)	1.02 (0.46-2.25)	
Health behaviors score							0.0150
Low	1,002	123 (12.3)	Reference	Reference	Reference	Reference	
Moderate	1,581	119 (7.5)	0.61 (0.44–0.85)	0.51 (0.36-0.72)	0.55 (0.39-0.78)	0.55 (0.39-0.78)	
High	156	15 (9.6)	0.77 (0.38-1.55)	0.65 (0.32-1.30)	0.78 (0.40-1.54)	0.78 (0.39–1.53)	
Health factors score							0.6095
Low	455	48 (10.5)	Reference	Reference	Reference	Reference	
Moderate	1,704	148 (8.7)	0.71 (0.46–1.09)	0.72 (0.47-1.12)	0.73 (0.47-1.13)	0.74 (0.47–1.14)	
High	580	61 (10.5)	0.76 (0.49–1.19)	0.80 (0.50-1.29)	0.87 (0.53-1.42)	0.86 (0.52-1.41)	
7–9 years (N=1,382)							
<b>Overall CVH score (by LE8)</b>							0.0015
Low CVH	242	22 (9.1)	Reference	Reference	Reference	Reference	
Moderate CVH	1,030	57 (5.5)	0.63 (0.34-1.18)	0.43 (0.23–0.82)	0.41 (0.21–0.83)	0.41 (0.20-0.83)	
High CVH	110	4 (3.6)	0.35 (0.12-1.05)	0.21 (0.07–0.64)	0.17 (0.05–0.55)	0.17 (0.05-0.56)	
Health behaviors score							0.0149
Low	474	40 (8.4)	Reference	Reference	Reference	Reference	
Moderate	764	38 (5.0)	0.77 (0.45–1.31)	0.54 (0.32-0.93)	0.60 (0.34-1.06)	0.58 (0.33-1.03)	
High	144	5 (3.5)	0.45 (0.17-1.20)	0.29 (0.11-0.79)	0.31 (0.11–0.84)	0.31 (0.11-0.87)	
Health factors score							0.6882
Low	188	9 (4.8)	Reference	Reference	Reference	Reference	
Moderate	793	50 (6.3)	1.03 (0.43–2.44)	0.89 (0.37-2.11)	0.84 (0.34-2.05)	0.86 (0.36-2.07)	
High	401	24 (6.0)	1.07 (0.42-2.72)	0.87 (0.33-2.27)	0.81 (0.30-2.20)	0.81 (0.30-2.17)	

Appendix 5. Association between cardiovascular health scores and depressive symptoms by educational attainment *(continued)* 



			Model 1	Model 2	Model 3	Model 4	
	Ν	Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	p for trend
10-12 years (N=4,392)							
<b>Overall CVH score (by LE8)</b>							0.0033
Low CVH	535	32 (6.0)	Reference	Reference	Reference	Reference	
Moderate CVH	3,147	156 (5.0)	0.86 (0.55-1.33)	0.62 (0.39-0.99)	0.67 (0.41-1.07)	0.68 (0.42-1.10)	
High CVH	710	20 (2.8)	0.49 (0.26-0.92)	0.30 (0.15-0.59)	0.36 (0.18-0.71)	0.37 (0.19-0.74)	
Health behaviors score							<.0001
Low	1,414	94 (6.6)	Reference	Reference	Reference	Reference	
Moderate	2,378	99 (4.2)	0.61 (0.44–0.85)	0.53 (0.38-0.75)	0.55 (0.39-0.79)	0.57 (0.40-0.81)	
High	600	15 (2.5)	0.31 (0.16-0.59)	0.28 (0.15-0.54)	0.33 (0.17-0.62)	0.34 (0.18-0.66)	
Health factors score							0.8664
Low	396	15 (3.8)	Reference	Reference	Reference	Reference	
Moderate	2,001	91 (4.5)	1.40 (0.77–2.56)	1.31 (0.72–2.38)	1.43 (0.77–2.65)	1.42 (0.76–2.66)	
High	1,995	102 (5.1)	1.66 (0.88–3.12)	1.12 (0.57-2.20)	1.24 (0.62–2.49)	1.20 (0.59–2.44)	
>12 years (N=4,839)							
<b>Overall CVH score (by LE8)</b>							<.0001
Low CVH	446	29 (6.5)	Reference	Reference	Reference	Reference	
Moderate CVH	3,284	132 (4.0)	0.59 (0.38-0.92)	0.42 (0.26-0.66)	0.47 (0.29-0.75)	0.47 (0.29-0.75)	
High CVH	1,109	27 (2.4)	0.38 (0.21-0.66)	0.21 (0.12-0.36)	0.25 (0.14-0.44)	0.25 (0.14-0.44)	
Health behaviors score							<.0001
Low	1,224	81 (6.6)	Reference	Reference	Reference	Reference	
Moderate	2,781	90 (3.2)	0.52 (0.36-0.74)	0.44 (0.30-0.65)	0.48 (0.33-0.70)	0.48 (0.32-0.70)	
High	834	17 (2.0)	0.33 (0.19–0.58)	0.27 (0.16-0.48)	0.31 (0.18-0.55)	0.31 (0.18-0.55)	
Health factors score							0.5917
Low	349	11 (3.2)	Reference	Reference	Reference	Reference	
Moderate	1,910	69 (3.6)	1.00 (0.51-1.97)	0.89 (0.45-1.76)	0.98 (0.50-1.89)	0.98 (0.50-1.90)	
High	2,580	108 (4.2)	1.26 (0.62–2.54)	0.79 (0.38–1.61)	0.88 (0.44-1.78)	0.88 (0.44-1.79)	

Appendix 5. Association between cardiovascular health scores and depressive symptoms by educational attainment

Adjusted for sex, age, monthly household income, marital status, and current drinking status



			Model 1	Model 2	Model 3	Model 4	
	Ν	Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	p for trend
Never married (N=2,097)							
<b>Overall CVH score (by LE8)</b>							0.0010
Low CVH	215	21 (9.8)	Reference	Reference	Reference	Reference	
Moderate CVH	1,425	99 (6.9)	0.71 (0.42-1.20)	0.54 (0.30-0.95)	0.59 (0.33-1.04)	0.59 (0.33-1.05)	
High CVH	457	20 (4.4)	0.37 (0.19-0.75)	0.25 (0.12-0.53)	0.29 (0.14-0.62)	0.30 (0.14-0.63)	
Health behaviors score							<.0001
Low	716	68 (9.5)	Reference	Reference	Reference	Reference	
Moderate	1,136	66 (5.8)	0.59 (0.39–0.87)	0.50 (0.33-0.78)	0.49 (0.32-0.76)	0.50 (0.32-0.77)	
High	245	6 (2.5)	0.18 (0.08-0.44)	0.16 (0.07-0.39)	0.17 (0.07-0.41)	0.17 (0.07-0.42)	
Health factors score							0.8325
Low	113	7 (6.2)	Reference	Reference	Reference	Reference	
Moderate	619	38 (6.1)	0.83 (0.34-1.99)	0.81 (0.34-1.94)	0.89 (0.36-2.20)	0.87 (0.36-2.14)	
High	1,365	95 (7.0)	1.00 (0.42-2.38)	0.80 (0.33-1.96)	0.89 (0.36-2.20)	0.87 (0.35-2.14)	
Married-living together (N=9,5	(42)						
<b>Overall CVH score (by LE8)</b>							<.0001
Low CVH	1,193	69 (5.8)	Reference	Reference	Reference	Reference	
Moderate CVH	6,886	295 (4.3)	0.67 (0.48-0.92)	0.50 (0.36-0.69)	0.55 (0.40-0.77)	0.55 (0.40-0.77)	
High CVH	1,463	35 (2.4)	0.43 (0.27-0.70)	0.27 (0.16-0.44)	0.34 (0.21-0.57)	0.34 (0.21–0.57)	
Health behaviors score							<.0001
Low	2,766	177 (6.4)	Reference	Reference	Reference	Reference	
Moderate	5,419	189 (3.5)	0.58 (0.46-0.74)	0.47 (0.36-0.60)	0.52 (0.40-0.67)	0.52 (0.40-0.67)	
High	1,357	33 (2.4)	0.38 (0.25-0.60)	0.31 (0.20-0.48)	0.38 (0.25-0.59)	0.38 (0.24-0.59)	
Health factors score							0.4117
Low	1,004	44 (4.4)	Reference	Reference	Reference	Reference	
Moderate	4,781	201 (4.2)	0.89 (0.60–1.31)	0.83 (0.56-1.22)	0.90 (0.61-1.33)	0.90 (0.61-1.33)	
High	3,757	154 (4.1)	0.96 (0.64-1.45)	0.72 (0.46-1.11)	0.83 (0.54-1.29)	0.83 (0.54-1.28)	

Appendix 6. Association between cardiovascular health scores and depressive symptoms by marital status *(continued)* 



			Model 1	Model 2	Model 3	Model 4	
	Ν	Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	p for trend
Separate, divorced, widowed (N	N=1,715)						
<b>Overall CVH score (by LE8)</b>							0.0356
Low CVH	344	52 (15.1)	Reference	Reference	Reference	Reference	
Moderate CVH	1,266	138 (10.9)	0.77 (0.52-1.13)	0.71 (0.47-1.05)	0.82 (0.55-1.21)	0.81 (0.55-1.21)	
High CVH	105	7 (6.7)	0.28 (0.12-0.67)	0.22 (0.09-0.55)	0.30 (0.12-0.80)	0.30 (0.11-0.80)	
Health behaviors score							0.1097
Low	633	93 (14.7)	Reference	Reference	Reference	Reference	
Moderate	951	91 (9.6)	0.65 (0.44-0.96)	0.57 (0.38-0.86)	0.63 (0.42-0.95)	0.63 (0.42-0.95)	
High	131	13 (9.9)	0.75 (0.36-1.58)	0.61 (0.28–1.35)	0.77 (0.34-1.72)	0.76 (0.34–1.71)	
Health factors score							0.5753
Low	271	32 (11.8)	Reference	Reference	Reference	Reference	
Moderate	1,010	119 (11.8)	0.98 (0.59–1.61)	0.98 (0.59–1.62)	1.07 (0.65–1.77)	1.07 (0.65–1.77)	
High	434	46 (10.6)	0.78 (0.45–1.35)	0.75 (0.42–1.33)	0.88 (0.49–1.57)	0.88 (0.49–1.57)	

Appendix 6. Association between cardiovascular health scores and depressive symptoms by marital status

Adjusted for sex, age, monthly household income, educational attainment, and current drinking status



	Depress	sive sympton	ns (PHQ-9≥10)	
—	Diet metric with	KHEI	Diet metric with I	DASH
	OR (95% CI)	AUC	OR (95% CI)	AUC
	Categorical vari	able		
Overall CVH score (by LE8)				
Low CVH	Reference		Reference	
Moderate CVH	0.66 (0.49-0.88)	0.72	0.70 (0.52-0.94)	0.72
High CVH	0.34 (0.22-0.52)		0.30 (0.19-0.46)	
Health behaviors score				
Low	Reference		Reference	
Moderate	0.58 (0.46-0.74)	0.72	0.55 (0.43-0.71)	0.73
High	0.38 (0.26-0.57)		0.35 (0.24–0.51)	
Health factors score				
Low	Reference		Reference	
Moderate	0.95 (0.68–1.34)	0.71	0.95 (0.68–1.34)	0.71
High	0.82 (0.55-1.21)		0.82 (0.55-1.21)	
	Continuous vari	able		
Overall CVH score (by LE8)	0.74 (0.68–0.81)	0.73	0.74 (0.68–0.81)	0.73
Health behaviors score	0.79 (0.74–0.84)	0.73	0.78 (0.73-0.83)	0.73
Health factors score	0.94 (0.88–1.00)	0.71	0.94 (0.88-1.00)	0.71

Appendix 7. Association between cardiovascular health scores and depressive symptoms using diet metric with KHEI and DASH, respectively (N=8,514)

Adjusted for sex, age, monthly household income, educational attainment, marital status, and current drinking status

Overall CVH score, health behaviors score, and health factors score are categorized as low (0-<50), moderate (50-<80), and high (80-<100).

Overall CVH (by LE8) is divided into two domains: health behaviors (diet, physical activity, nicotine exposure, and sleep health), and health factors (body mass index, blood lipids, blood glucose, and blood pressure)



	Depressive symptoms (PHQ-9≥10)					
	Life's Simple	e 7	Life' Essentia	18		
	OR (95% CI)	OR (95% CI) AUC		AUC		
Catego	orical variable					
Overall CVH score						
Low CVH	Reference		Reference			
Moderate CVH	0.68 (0.43-1.09)	0.72	0.60 (0.47-0.77)	0.72		
High CVH	0.35 (0.21-0.57)		0.33 (0.23-0.49)			
Contin	uous variable					
Overall CVH score*	0.86 (0.82-0.90)	0.71	0.75 (0.69–0.80)	0.73		
Overall CVH score (no sleep health in model)	0.86 (0.82–0.90)	0.71	0.82 (0.77–0.87)	0.71		

**Appendix 8.** Association between cardiovascular health scores and depressive symptoms compared to Life's Simple 7 and Life's Essential 8.

Adjusted for sex, age, household income, educational attainment, marital status, and current drinking status

Life's Simple 7 is categorized as low (0–4), moderate (5–9), and high (10–14).

Life's Essential 8 is categorized as low (0-<50), moderate (50-<80), and high (80-<100).

\*Overall CVH score by LE8: per 10 increase

Abbreviations: Cardiovascular health = CVH;



			Model 1	Model 2	Model 3	Model 4	p for
	Ν	Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	trend
Overall CVH score (by LE8)						<.0001	
Low CVH	1,652	102 (6.2)	Reference	Reference	Reference	Reference	
Moderate CVH	9,107	415 (4.6)	0.67 (0.51-0.87)	0.53 (0.40-0.69)	0.60 (0.45-0.79)	0.60 (0.45-0.79)	
High CVH	1,955	51 (2.6)	0.42 (0.28-0.63)	0.28 (0.19-0.43)	0.37 (0.24–0.57)	0.37 (0.24–0.57)	
Health behaviors	score						<.0001
Low	3,897	256 (6.6)	Reference	Reference	Reference	Reference	
Moderate	7,153	271 (3.8)	0.59 (0.48-0.72)	0.48 (0.39-0.60)	0.53 (0.42-0.66)	0.53 (0.43-0.66)	
High	1,664	41 (2.5)	0.36 (0.24–0.52)	0.30 (0.21-0.44)	0.37 (0.26-0.55)	0.38 (0.26-0.55)	
Health factors sco	ore						0.6565
Low	1,313	60 (4.6)	Reference	Reference	Reference	Reference	
Moderate	6,067	275 (4.5)	1.01 (0.71–1.42)	0.98 (0.69–1.38)	1.06 (0.75-1.50)	1.06 (0.75–1.49)	
High	5,334	233 (4.4)	1.02 (0.73–1.42)	0.84 (0.59–1.20)	0.98 (0.68–1.40)	0.97 (0.67-1.40)	

Appendix 9. Association between cardiovascular health scores and depressive symptoms, excluding participants who had previously been diagnosed with depression

Model 1: Unadjusted model

Model 2: Adjusted for sex and age

Model 3: Model 2 + Adjusted for household income, educational attainment, and marital status. Model 4: Model 3 + Adjusted for current drinking status

Overall CVH score, health behaviors score, and health factors score are categorized as low (0-<50), moderate (50-<80), and high (80-<100).

Overall CVH (by LE8) is divided into two domains: health behaviors (diet, physical activity, nicotine exposure, and sleep health), and health factors (body mass index, blood lipids, blood glucose, and blood pressure) Abbreviations: Cardiovascular health = CVH; Life's essential 8 = LE8

Model 1 Model 2 Model 3 Model 4 p for OR (95% CI) OR (95% CI) OR (95% CI) OR (95% CI) N Case (%) trend **Overall CVH score (by LE8)** <.0001 Low CVH 390 (22.3) 1,752 Reference Reference Reference Reference 1900 (19.8) 0.92 (0.79–1.07) 0.73 (0.62–0.85) 0.80 (0.68-0.94) 0.80 (0.68-0.94) Moderate CVH 9,579 High CVH 2,026 323 (15.9) 0.74 (0.60-0.90) 0.48 (0.39-0.60) 0.58 (0.47-0.73) 0.59 (0.47-0.73) Health behaviors score <.0001 4,116 985 (23.9) Reference Low Reference Reference Reference 0.75 (0.68–0.83) 0.63 (0.57–0.70) 0.68 (0.61-0.76) 0.68 (0.61-0.76) Moderate 7.507 1388 (18.5) High 1,734 240 (13.8) 0.54 (0.45-0.64) 0.45 (0.37-0.54) 0.52 (0.44-0.63) 0.53 (0.44-0.63) Health factors score 0.7416 1,388 263 (18.9) Reference Reference Reference Low Reference Moderate 6,411 1206 (18.8)  $0.97\ (0.82{-}1.16)\quad 0.93\ (0.78{-}1.11)$ 0.99 (0.82–1.18) 0.98 (0.82-1.18) 1144 (20.6) 1.16 (0.97-1.39) 0.89 (0.74–1.06) 0.97 (0.81-1.18) High 5,558 0.97 (0.80-1.17)

Appendix 10. Association between cardiovascular health metrics score and depressive symptoms

Model 1: Unadjusted model

(PHQ-9≥5)

Model 2: Adjusted for sex and age

Model 3: Model 2 + Adjusted for household income, educational attainment, and marital status.

Model 4: Model 3 + Adjusted for current drinking status

Overall CVH score, health behaviors score, and health factors score are categorized as low (0-<50), moderate (50-<80), and high (80-<100).

Overall CVH (by LE8) is divided into two domains: health behaviors (diet, physical activity, nicotine exposure, and sleep health), and health factors (body mass index, blood lipids, blood glucose, and blood pressure)

Abbreviations: Cardiovascular health = CVH;



Appendix 11. Association between cardiovascular health scores and depressive symptoms (PHQ-9≥15)

			Model 1	Model 2	Model 3	Model 4	p for
	Ν	Case (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	trend
<b>Overall CVH</b>	l score (l	oy LE8)					0.0004
Low CVH	1,752	56 (3.2)	Reference	Reference	Reference	Reference	
Moderate CV	H9,579	184 (1.9)	0.68 (0.46-0.99)	0.53 (0.35-0.79)	0.67 (0.44-1.02)	0.67 (0.44-1.02)	
High CVH	2,026	15 (0.7)	0.25 (0.13-0.47)	0.18 (0.09-0.35)	0.29 (0.15-0.57)	0.29 (0.14-0.57)	
Health beha	viors sco	ore					<.0001
Low	4,116	129 (3.1)	Reference	Reference	Reference	Reference	
Moderate	7,507	113 (1.5)	0.50 (0.36-0.69)	0.38 (0.27-0.54)	0.45 (0.31-0.65)	0.45 (0.31-0.65)	
High	1,734	13 (0.7)	0.25 (0.13-0.49)	0.20 (0.10-0.40)	0.30 (0.15-0.61)	0.30 (0.15-0.61)	
Health facto	ors score						0.6717
Low	1,388	34 (2.4)	Reference	Reference	Reference	Reference	
Moderate	6,411	131 (2.0)	0.76 (0.47-1.25)	0.76 (0.46-1.26)	0.86 (0.52-1.43)	0.86 (0.52-1.42)	
High	5,558	90 (1.6)	0.69 (0.41-1.16)	0.68 (0.39-1.19)	0.86 (0.49-1.51)	0.86 (0.49–1.51)	

Model 1: Unadjusted model

Model 2: Adjusted for sex and age Model 3: Model 2 + Adjusted for household income, educational attainment, and marital status.

Model 4: Model 3 + Adjusted for current drinking status

Overall CVH score, health behaviors score, and health factors score are categorized as low (0-<50), moderate (50-<80), and high (80-<100).

Overall CVH (by LE8) is divided into two domains: health behaviors (diet, physical activity, nicotine exposure, and sleep health), and health factors (body mass index, blood lipids, blood glucose, and blood pressure) Abbreviations: Cardiovascular health = CVH; Life's essential 8 = LE8





**Appendix 12.** Odds ratios (OR) and 95% Confidence Intervals (CI) for the association between quartiles of cardiovascular health scores and depressive symptoms (PHQ-9, cut-off=10, N=13,357)

Adjusted for sex, age, household income, educational attainment, marital status, and current drinking status



	Model 1	Model 2	Model 3	Model 4	
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	
Overall CVH score	0.80 (0.75-0.85)	0.69 (0.64–0.75)	0.75 (0.69-0.80)	0.75 (0.69-0.80)	
Health behaviors score	0.80 (0.76-0.84)	0.74 (0.70-0.78)	0.78 (0.73-0.82)	0.78 (0.73-0.82)	
Health factors score	0.98 (0.93-1.03)	0.92 (0.88–0.97)	0.95 (0.90-1.00)	0.95 (0.90-1.00)	

Appendix 13. Association between cardiovascular health scores as continuous variable and depressive symptoms

Model 1: Unadjusted model

Model 2: Adjusted for sex and age

Model 3: Model 2 + Adjusted for household income, educational attainment, and marital status.

Model 4: Model 3 + Adjusted for current drinking status

Overall CVH score, health behaviors score, and health factors score are categorized as low (0-<50), moderate (50-<80), and high (80-<100).

Overall CVH (by LE8) is divided into two domains: health behaviors (diet, physical activity, nicotine exposure, and sleep health), and health factors (body mass index, blood lipids, blood glucose, and blood pressure)

Abbreviations: Cardiovascular health = CVH; Life's essential 8 = LE8



	1.		<b>D</b> '		. 1	• •	1 .	1.	1	1 1.	1 1	T ' C	• • •	1 .	7 1	1 .	
A 1	nnondiv	1/1	Previous	ctudiec	on the	acconstion	hetween	cordiova	coulor	healt	h hv	1 110	6 V1m	mla	/ and (	lonroccive	symptome
	DUCHULA		I ICVIOUS	studios	UII UIIC	association	DULWUUII	Caruiova	Sourai	ncan			- 5 - 5 - 11 - 1	inne -	/ and u		symptoms.
																	- /

No.	Author	Year	Study design	Population	Sample size	Exposure	Outcome				
The systematic review of the association between CVH measured by LS7 and depressive symptoms											
1	España-Romero et al.	2013	Prospective study	United States	5,110	No. of CVH metrics	Depression (CES-D)				
2	Zeng et al	2013	Cross-sectional study	China	9,962	No. of CVH metrics	Depression (DASS-21)				
3	Li et al	2015	Cross-sectional study	China	6,851	CVH score	Depression (CES-D)				
4	Brunoni et al	2019	Prospective study	Brazil	9,214	CVH score	Depression (CIS-R)				
5	Zhang et al	2019	Cross-sectional study	United States	14,561	CVH score	Depression (PHQ-9)				
A re	A recent study of the association between CVH measured by LS7 and depressive symptoms										

6 van Sloten et al 2023 Prospective study United States 6,980 No. of CVH metrics Depressive symptoms (CES-D)

Abbreviations: CVH = Cardiovascular health; LS7 = Life's Simple 7; CESD = Center for Epidemiologic Studies Depression; DASS-21 = Depression Anxiety Stress Scales-21; CIS-R = Clinical interview schedule-revised; PHQ-9 = Patient health questionnaire-9;



## **ABSTRACT(KOREAN)**

#### 8대 심장 건강 필수 지침으로 측정된 심혈관계 건강과 우울증상 사이의 연관성

연세대학교 대학원 보건학과

안정현

#### 배경 및 목적:

우울증은 세계적으로 질병 부담을 증가시키며 심혈관계 건강과 관련이 있다. 미국 심 장 협회가 2010년에 "Life's Simple 7 (LS7)"을 제안한 이후, 최근에는 "Life's Essential 8 "(LE8)로 업데이트된 심혈관계 건강 지표가 발표되었다. 검진, 건강 설문 및 영양 조사 가 포함된 전국적 대표 데이터를 활용한 LE8을 조사한 연구논문이 부족하다. 아시아 인구를 대상으로 하여 LE8으로 측정된 심혈관계 건강과 우울증상 사이의 연관성을 평 가한 연구는 거의 없다. 따라서, 본 연구는 심혈관계 건강과 우울증상 사이의 연관성 을 규명하고, 심혈관계 건강의 어떤 지표가 우울증상과 관련이 있는 지 확인 하는 것 이다.

#### 연구 방법:

본 연구는 2014년, 2016년 및 2018년 국민건강영양조사 자료를 활용하여 19세 이상 의 성인 13,357명이 포함된 단면연구이다. 미국심장협회에 따르면, LE8은 "건강 행동" (식단, 신체활동, 니코틴 노출 및 수면 건강)과 "건강 요인" (체질량 지수, 혈중 지질, 혈당 및 혈압) 두 가지 영역으로 나뉜다. LE8으로 측정된 심혈관계 건강 점수는 0부터



100까지 범위이며, 미국심장협회에 따라 낮음 (0-<50), 중증도 (50-<80), 높음 (80-100) 으로 분류된다. 우울증상은 우울증 선별 도구에 의해 측정된다. 우울증 선별 도구 점 수가 10점 이상인 사람들은 우울증상으로 정의된다. 공변량은 성별, 연령, 사회경제적 지위 및 현재 음주상태이다. 모든 공변량을 보정한 후, 심혈관계 건강 지표 (LE8 점수, 건강 행동 점수 및 건강 요인 점수)와 우울증상 사이의 연관성을 조사하기 위해 다중 로지스틱 회귀 분석을 시행했다. 각각의 심혈관계 건강 지표(식단, 신체활동, 니코틴 노출, 수면건강, 체질량 지수, 혈중 지질, 혈당 및 혈압)와 우울 증상 사이의 연관성에 대해 조사했다. 각 심혈관계 건강 지표 점수가 100점인 사람은 '이상적'으로 정의하고, 100점 이하인 사람은 '좋지 않은'으로 정의했다. 또한, 성별 및 연령에 대한 층화분석 도 수행했다. 주요 결과의 견고성을 확립하기 위해, 본 연구는 다음과 같은 여섯 가지 민감도 분석을 시행했다: i) 추가적으로 사회경제적상태로 층화 분석 ii) 한국인 식생활 평가 지수와 비교하기 위해 고혈압 예방을 위한 식단으로 재정의 iii) LE8과 LS7을 비 교하기 위해 심혈관계 건강과 우울 증상 사이의 연관성 조사 iv) 의사에게 우울증을 진단 받은 대상자를 제외 v) 우울증상을 경증 우울 증상 및 중증고도 우울증상으로 재정의 vi) 심혈관계 건강 지표 (LE8점수, 건강 행동 점수 및 건강 요인 점수)를 사분 위수와 연속형 변수로 재정의

#### 연구 결과:

19세 이상의 13,357명 참가자 중, 195명의 남성 (1.5%)과 541명의 여성 (4.1%)이 우울 증상을 보였다. 낮은 수준의 심혈관계 건강이 기준일 때, 우울증상에 대한 오즈비는 중증도 수준의 심혈관계 건강에서 0.60 (95% CI=0.47-0.77), 높은 수준의 심혈관계 건 강에서 0.33 (95% CI=0.23-0.49)이다. 낮은 수준의 건강 행동 점수가 기준일 때, 우울 증상에 대한 오즈비는 높은 수준의 건강 행동 점수에서 0.37 (95% CI=0.26-0.52)이다. 그러나, 건강 요인 점수는 우울 증상과 유의한 연관성을 나타내지 않았다. 게다가, 좋 지 않은 심혈관계 건강지표를 기준으로 하였을 때, 우울증상에 대한 오즈비는 이상적 니코틴 노출에서 0.41 (95% CI=0.33-0.52), 이상적 수면 건강에서는 0.65 (95% CI=0.54-



0.78), 이상적 혈당에서는 0.73 (95% CI=0.58-0.90)이다. 성별 층화분석에서 낮은 수준 의 심혈관계 건강이 기준일 때, 우울증상에 대한 오즈비는 높은 수준의 심혈관계 건 강인 남성에서 0.23 (95% CI=0.09-0.59), 높은 수준의 심혈관계 건강인 여성에서 0.34 (95% CI=0.21-0.55)이다. 나이 층화분석에서, 우울증상에 대한 오즈비는 높은 수준의 심혈관계 건강인 19-39세인 사람들 중에서 0.24 (95% CI=0.13-0.43), 높은 수준의 심 혈관계 건강인 40-59세인 사람들 중에서 0.30 (95% CI=0.14-0.62)이다. 민감도 분석 결과는 주요 분석 결과와 유사했다.

#### 결론 및 고찰:

전반적으로, 높은 수준의 심혈관계 건강과 건강한 행동은 우울 증상과 역의 연관성을 나타냈다. 본 연구 결과는 심혈관계 건강이 좋지 않거나 건강하지 않은 행동을 하는 사람들은 우울 증상에 대한 모니터링과 시기 적절한 개입이 필요함을 시사한다. 또한, 적절한 수면과 흡연을 하지 않는 것은 우울 증상의 예방요인으로서 중요하게 작용할 수 있음을 시사한다.

핵심어: 심혈관계 건강, 건강 행동, 건강 요인, 우울 증상