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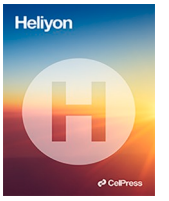

Research article

Factors associated with suboptimal adherence to antihypertensive medication: Cross-sectional study using nationally representative databases

Sangyong Jo [a,1], Taegyu Um [b,1], Jihye Shin [b], Dongchan Lee [c], Kyungil Park [a,**], Minkook Son [b,d,*]

[a] Division of Cardiology, Department of Internal Medicine, Dong-A University College of Medicine, Busan, Republic of Korea
[b] Department of Physiology, Dong-A University College of Medicine, Busan, Republic of Korea
[c] New York Institute of Technology College of Osteopathic Medicine, Old Westbury, NY, United States
[d] Department of Data Sciences Convergence, Dong-A University Interdisciplinary Program, Busan, Republic of Korea

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ABSTRACT

Suboptimal adherence to antihypertensive medication is a major challenge in controlling blood pressure. However, limited studies exist on suboptimal adherence to hypertension, especially in Korea. This study investigates factors associated with suboptimal adherence, including non-treatment and non-adherence. Study populations were collected from the Korea National Health and Nutrition Examination Survey (KNHANES) from 2007 to 2021. Participants were classified into three groups based on treatment and adherence to antihypertensive medication using a self-reported questionnaire. Multivariable adjusted logistic regression analysis was performed using KNHANES data to investigate associations for suboptimal adherence with covariates. In KNHANES, the adherent, non-adherent, and non-treatment groups consisted of 13,831 (92.8 %), 460 (3.1 %), and 612 (4.1 %) subjects, respectively. In the adjusted model, age, hypertension diagnosis duration, diabetes, dyslipidemia, and high hemoglobin levels were associated with receiving treatment. Older age, longer hypertension diagnosis duration, comorbid diabetes mellitus, and ischemic heart disease were associated with adherence. This study showed the characteristics of non-adherent and non-treatment hypertensive patient groups in Korea. Based on this study, further individualized health interventions are required.

1. Introduction

Hypertension is a critical modifiable risk factor, posing a significant threat to public health [1,2]. It is strongly linked to the development of cerebro-cardiovascular diseases, among the leading causes of death worldwide [3,4]. Despite medical advances, hypertension remains largely uncontrolled in the twenty-first century and has become one of the biggest contributors to non-infectious

* Corresponding author. Department of Physiology, Dong-A University College of Medicine, Department of Data Sciences Convergence, Dong-A University Interdisciplinary Program, 32 Daeshingongwon-ro, Seo-gu, Busan, 49315, Republic of Korea.
** Corresponding author. Regional Cardiovascular Center, Dong-A University Hospital, Division of Cardiology, Department of Internal Medicine, Dong-A University College of Medicine, 26 Daesingongwon-ro, Seo-gu, Busan, 49201, Republic of Korea.
E-mail addresses: cardiopark@gmail.com (K. Park), physionet@dau.ac.kr (M. Son).
[1] Sangyong Jo and Taegyu Um contributed equally to this work.

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disease-related deaths globally [5]. While the mortality rate for cerebro-cardiovascular diseases has decreased in Korea [6], cerebro-cardiovascular diseases and hypertensive disorders continue to be the major causes of death [7]. The medical cost of treating hypertension in Korea is estimated at 4.3 trillion won, accounting for 4.5 % of all medical expenses or 10.9 % of medical costs for chronic diseases as of 2022 [8]. Given these alarming statistics, controlling blood pressure is crucial for reducing the societal burden of disease and improving the quality of life of individuals [9]. However, achieving optimal blood pressure control is challenging as several factors contribute to poor control in hypertensive patients [10]. One of the challenges is suboptimal adherence, which includes failure to initiate drug therapy, inadequate adherence to prescribed medications, and premature discontinuation of treatment [11]. Several clinical factors are associated with non-adherence; their understanding is critical for effectively managing non-adherence [12]. With decreased development and approval of novel antihypertensive medications [13], healthcare providers should try optimizing medication adherence. One solution is to increase the availability of more accurate adherence measures, which can help identify patients who are non-adherent to medication [14]. Moreover, healthcare providers can collaborate with patients to develop personalized medication plans tailored to their needs and preferences [15]. Overall, it is evident that medication adherence is a substantial challenge that needs to be addressed in managing hypertension. Therefore, recent guidelines highlight the importance of medication adherence and urge healthcare providers to take steps to improve adherence [16,17]. Despite this recognition, there are limited studies on suboptimal adherence to medication in hypertension, especially in Korea. Therefore, we aim to investigate factors associated with suboptimal adherence, including non-treatment and non-adherence, using the Korea National Health and Nutrition Examination Survey (KNHANES) with nationally representative samples of Korea.

2. Methods

2.1. Data source & study population

Study populations were collected from the KNHANES from 2007 to 2021. Data were fully anonymized and contained no identifiable information. This study was approved, and informed consent was waived by the Institutional Review Board of the Dong-A University (2-1040709-AB-N-01-202303-HR-007-02).

The KNHANES is a nationwide cross-sectional survey of the Korean population conducted by the Korea Centers for Disease Control and Prevention [18]. This survey consists of health interviews and health examinations. Further information on the KNHANES is summarized on the relevant website (https://knhanes.kdca.go.kr/knhanes/eng/index.do). This study used KNHANES data from 2007 to 2021 and recruited 115,587 subjects. The study excluded 100,684 subjects using the following exclusion criteria: (1) subjects under 20 years; (2) subjects with pregnancy or cancer; (3) subjects with missing values in any variables; (4) subjects without hypertension diagnosis. Finally, the study included 14,903 subjects. The flow of the study population is shown in Fig. 1.

Hypertension was defined as systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, or antihypertensive medication use [19,20]. In KNHANES, blood pressure was measured three times on the arm of the subject in the sitting position after 5 min of rest using a mercury sphygmomanometer (Baumanometer; Baum, Copiague, NY, USA) by a trained nurse (measured thrice and averaged the second and third measurements). Blood pressure measurements were performed for quality assurance and control in academic societies. Antihypertensive medication use was checked using a self-reported questionnaire.

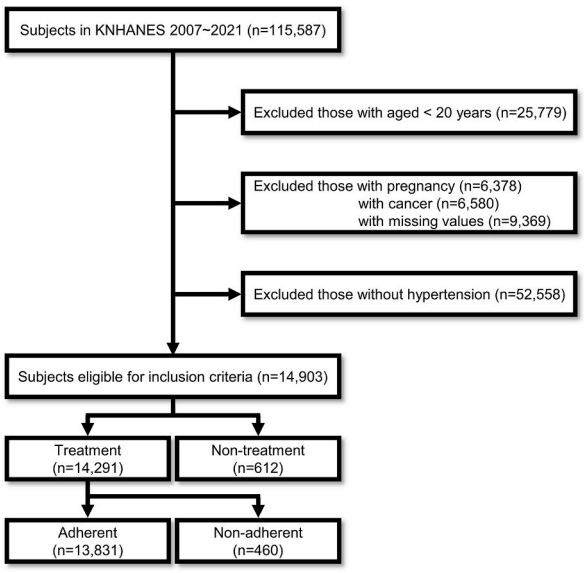

Fig. 1. The flowchart of study population in the Korea National Health and Nutrition Examination Survey.

2.2. Operational definitions for treatment and adherence to antihypertensive medication

In KNHANES, we evaluated treatment and adherence to antihypertensive medication using a self-reported questionnaire. The answers to the questionnaire on antihypertensive medication use are as follows: (1) taken daily; (2) taken more than 20 days per month; (3) taken more than 15 days per month; (4) taken less than 15 days per month; (5) no treatment. In this study, the subjects were divided into two groups according to their answers to the questionnaire: a treatment group (1–4) and a non-treatment group (5). Next, in the treatment group, the subjects were further classified into two groups: an adherent group with a daily dose (1) and a non-adherent group without a non-daily dose (2–4). The treatment and non-treatment groups included 14,291 and 612 subjects, respectively. The adherent and non-adherent groups included 13,831 and 460 subjects, respectively. The proportion of each group in KNHANES is shown in Fig. 2.

2.3. Covariates in the Korea National Health and Nutrition Examination Survey

To investigate associations between adherence to antihypertensive medication and various covariates, we extracted multiple variables, including demographic, comorbidity, lifestyle, anthropometric, and laboratory data. The residential area was classified by residential administrative district. Education level was divided into four groups: elementary school or lower, middle school, high school, and college or higher. The income level was divided into quartile groups. We assessed comorbidities, including diabetes, dyslipidemia, cerebrovascular disease, or ischemic heart disease. Diabetes status was divided into 3 groups: (1) “normal” for fasting blood glucose <100 mg/dL, (2) “pre-diabetes” for fasting blood glucose between 100 mg/dL to 125 mg/dL, and (3) “diabetes” for fasting blood glucose ≥126 mg/dL or anti-diabetic medication usage or diabetes diagnosis by a physician. Dyslipidemia was defined as total cholesterol ≥240 mg/dL or dyslipidemia medication usage [21,22]. The comorbidities for stroke and ischemic heart disease were evaluated using a questionnaire.

Lifestyle choices, including smoking, alcohol drinking, and regular exercise, were evaluated by a self-reported questionnaire. The answers were classified as categorical variables, as follows: smoking (non-smoker, ex-smoker, and current smoker); alcohol drinking (≤1/week, 2–3/week, and ≥4/week); regular exercise (group with activity in ≥150 min of moderately hard exercise within a week or in ≥75 min of hard exercise within a week or mixed exercise equivalent to the above level, and group with activity less than levels mentioned above). Body mass index was calculated by dividing body weight (kg) by the square of height (m^2). Laboratory covariates, including triglyceride, high-density lipoprotein cholesterol (HDL-C), hemoglobin, and creatinine, were also extracted. Blood samples were collected after 8 h of fasting and analyzed at NeoDin Medical Institute (Seoul, South Korea). Estimated glomerular filtration rates were calculated using the Modification of Diet in Renal Disease equation [23].

2.4. Statistical analysis

Continuous variables are presented as means with standard deviation, and categorical variables are presented as the number of cases with a percentage. Baseline characteristics between the three groups were compared using a one-way analysis of variance for continuous variables and a Chi-square test for categorical variables. Multivariable adjusted logistic regression analysis was used to investigate associations for treatment and adherence to antihypertensive medication with covariates. This model was evaluated for

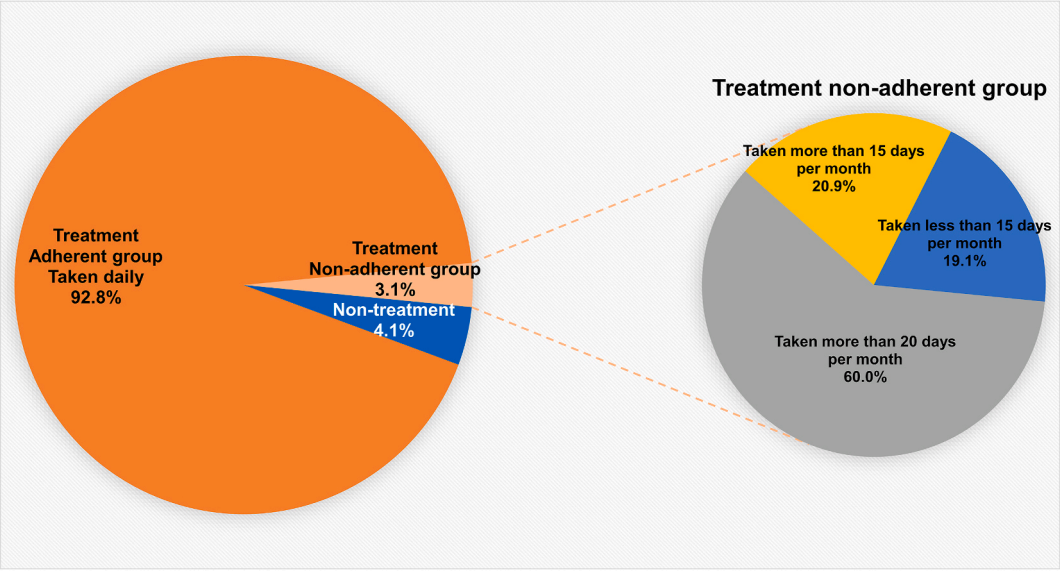

Fig. 2. The proportion of treatment and adherence to antihypertensive medication in the Korea National Health and Nutrition Examination Survey.

age, sex, residential region, education level, income level, hypertension diagnosis duration, diabetes, dyslipidemia, cerebrovascular disease, ischemic heart disease, smoking, alcohol drinking, exercise status, body mass index, waist circumference, hemoglobin, and glomerular filtration rate. The results were presented as odds ratio (OR) and 95 % confidence intervals (CIs) for each covariate. All statistical analyses were performed using R 4.2.1 (https://www.r-project.org/). The p-value <0.05 was considered statistically significant.

3. Results

3.1. Baseline characteristics of the study population according to suboptimal adherence

Table 1 shows the baseline characteristics of the study population according to antihypertensive medication treatment and adherence. There were significant differences among the three groups (adherent, non-adherent, and non-treatment) regarding age, sex, residential region, and education level. Hypertension diagnosis duration was lowest in the non-treatment group. There were significant differences among groups for all comorbidities and lifestyle choices, including smoking and alcohol drinking. The non-treatment group had higher blood pressure, total cholesterol, triglyceride, hemoglobin, and glomerular filtration rates among the three groups.

Table 1
Baseline characteristics of subjects according to antihypertensive medication treatment and adherence.

Total subjects (n = 14,903)	Treatment (n = 14,291)		Non-treatment (n = 612)	P-value
	Adherent (n = 13,831)	Non-adherent (n = 460)		
Age (years)	65.5 ± 10.2	62.1 ± 10.8	56.5 ± 13.6	<0.001
Sex (%)				<0.001
Male	5580 (40.3)	198 (43.0)	335 (54.7)	
Female	8251 (59.7)	262 (57.0)	277 (45.3)	
Residential region (%)				0.02
Rural	4760 (34.4)	168 (36.5)	180 (29.4)	
Urban	9071 (65.6)	292 (63.5)	432 (70.6)	
Education level (%)				<0.001
Elementary school or lower	6633 (48.0)	194 (42.2)	177 (28.9)	
Middle school	2085 (15.1)	75 (16.3)	92 (15.0)	
High school	3267 (23.6)	115 (25.0)	179 (29.3)	
College or higher	1846 (13.3)	76 (16.5)	164 (26.8)	
Income level (quartile, %)				0.2
1st	3444 (24.9)	117 (25.4)	172 (28.1)	
2nd	3549 (25.7)	133 (28.9)	139 (22.7)	
3rd	3463 (25.0)	109 (23.7)	159 (26.0)	
4th	3375 (24.4)	101 (22.0)	142 (23.2)	
Hypertension diagnosis duration (years)	9.7 ± 8.3	6.6 ± 6.7	6.1 ± 7.1	<0.001
Diabetes (%)				<0.001
Normal	4884 (35.3)	225 (48.9)	298 (48.7)	
Pre-diabetes	4767 (34.5)	139 (30.2)	203 (33.2)	
Diabetes	4180 (30.2)	96 (20.9)	111 (18.1)	
Dyslipidemia (%)	5334 (38.6)	147 (32.0)	129 (21.1)	<0.001
Cerebrovascular disease (%)	675 (4.9)	11 (2.4)	11 (1.8)	<0.001
Ischemic heart disease (%)	897 (6.5)	11 (2.4)	14 (2.3)	<0.001
Smoking (%)				<0.001
Non-smoker	8615 (62.3)	270 (58.7)	316 (51.6)	
Ex-smoker	3621 (26.2)	119 (25.9)	179 (29.2)	
Current smoker	1595 (11.5)	71 (15.4)	117 (19.2)	
Alcohol drinking (%)				<0.001
≤1/week	11,019 (79.7)	356 (77.4)	448 (73.2)	
2–3/week	1686 (12.2)	47 (10.2)	105 (17.2)	
≥4/week	1126 (8.1)	57 (12.4)	59 (9.6)	
Regular exercise (%)	3885 (28.1)	140 (30.4)	186 (30.4)	0.3
Systolic blood pressure (mmHg)	130.1 ± 16.0	132.8 ± 17.6	150.2 ± 16.6	<0.001
Diastolic blood pressure (mmHg)	76.6 ± 10.4	80.4 ± 11.4	93.0 ± 12.4	<0.001
Body mass index (kg/m^2)	25.3 ± 3.4	24.9 ± 3.5	24.9 ± 3.9	0.01
Waist circumference (cm)	87.4 ± 9.2	85.8 ± 9.3	86.0 ± 10.5	<0.001
Fasting blood glucose (mg/dL)	109.6 ± 27.0	107.5 ± 32.4	106.6 ± 29.1	0.008
Total cholesterol (mg/dL)	183.1 ± 38.3	191.9 ± 37.4	200.7 ± 39.1	<0.001
Triglyceride (mg/dL)	149.1 ± 105.9	150.7 ± 112.1	163.4 ± 127.3	0.005
High-density lipoprotein cholesterol (mg/dL)	47.8 ± 11.7	48.1 ± 11.7	49.0 ± 12.2	0.05
Hemoglobin (g/dL)	13.7 ± 1.5	13.9 ± 1.6	14.5 ± 1.6	<0.001
Glomerular filtration rate (mL/min/1.73 m^2)	80.5 ± 19.4	82.3 ± 19.1	84.8 ± 16.5	<0.001

Data are expressed as mean ± standard deviation or number (%).

3.2. Association between hypertension treatment and covariates

Table 2 shows the results of crude and multivariable adjusted logistic regression analysis between hypertension treatment and covariates. In the adjusted logistic model, older age (per 10 years) was associated with treatment (adjusted OR 0.56, 95 % CIs 0.51 to 0.62). Longer duration after diagnosis of hypertension was associated with treatment (adjusted OR 0.97, 95 % CIs 0.95 to 0.98). Regarding comorbidities, diabetes mellitus and dyslipidemia were associated with treatment. Higher hemoglobin level was associated with non-treatment (adjusted OR 1.33, 95 % CIs 1.23 to 1.43).

3.3. Association between antihypertensive medication adherence and covariates

Table 3 shows the results of crude and multivariable adjusted logistic regression analysis between antihypertensive medication adherence and covariates. In the adjusted logistic model, older age (per 10 years) was associated with adherence (adjusted OR 0.81, 95 % CIs 0.73 to 0.91). Longer duration after hypertension diagnosis was associated with adherence (adjusted OR 0.96, 95 % CIs 0.94 to 0.97). Regarding comorbidities, diabetes mellitus and ischemic heart disease were associated with adherence. Also, alcohol drinking 2–3/week was associated with adherence (adjusted OR 0.71, 95 % CIs 0.50 to 0.97).

4. Discussion

Improving treatment and adherence rates in hypertensive patients is crucial to maximizing the effect of antihypertensive pharmacotherapy and enhancing clinical outcomes [24]. Identifying individual characteristics of non-treatment and non-adherent hypertensive patients can help healthcare providers recognize patients at risk, thus enabling rapid clinical intervention in advance to ensure the best medication compliance in patients.

Previous studies reporting factors correlated with antihypertension medication adherence in Korea had limited study populations insufficient to represent the overall patients. Moreover, these studies failed to identify different characteristics between non-adherent

Table 2
Odds ratios with 95 % confidence intervals for the association between antihypertensive medication treatment and covariates.

Total subjects (n = 14,903)		Antihypertensive medication treatment					
		Crude OR	95 % CIs	P-value	Adjusted OR[a]	95 % CIs	P-value
Age (per 10 years)		0.50	0.47, 0.53	<0.001	0.56	0.51, 0.62	<0.001
Sex	Male	1	Reference		1	Reference	
	Female	0.56	0.48, 0.66	<0.001	0.93	0.69, 1.27	0.66
Residential region	Rural	1	Reference		1	Reference	
	Urban	1.26	1.06, 1.51	0.010	1.12	0.93, 1.36	0.22
Education level	Elementary school or lower	1	Reference		1	Reference	
	Middle school	1.64	1.27, 2.12	<0.001	1.03	0.78, 1.35	0.82
	High school	2.04	1.65, 2.52	<0.001	0.87	0.67, 1.12	0.28
	College or higher	3.29	2.64, 4.09	<0.001	1.07	0.80, 1.44	0.63
Income level	1st	1	Reference		1	Reference	
	2nd	0.78	0.62, 0.98	0.03	0.80	0.63, 1.01	0.06
	3rd	0.92	0.74, 1.15	0.47	0.88	0.70, 1.11	0.28
	4th	0.85	0.67, 1.06	0.15	0.82	0.64, 1.05	0.12
Hypertension diagnosis duration		0.93	0.92, 0.94	<0.001	0.97	0.95, 0.98	<0.001
Diabetes	Normal	1	Reference		1	Reference	
	Pre-diabetes	0.71	0.59, 0.85	<0.001	0.81	0.67, 0.98	0.03
	Diabetes	0.45	0.36, 0.55	<0.001	0.65	0.51, 0.83	<0.001
Dyslipidemia		0.43	0.35, 0.52	<0.001	0.50	0.41, 0.61	<0.001
Cerebrovascular disease		0.36	0.19, 0.63	<0.001	0.55	0.28, 0.97	0.06
Ischemic heart disease		0.35	0.19, 0.57	<0.001	0.66	0.37, 1.10	0.14
Smoking	Non-smoker	1	Reference		1	Reference	
	Ex-smoker	1.35	1.11, 1.62	0.002	0.93	0.71, 1.21	0.58
	Current smoker	1.97	1.58, 2.45	<0.001	0.94	0.70, 1.27	0.69
Alcohol drinking	≤1/week	1	Reference		1	Reference	
	2-3/week	1.54	1.23, 1.91	<0.001	0.86	0.67, 1.09	0.22
	≥4/week	1.27	0.95, 1.66	0.10	0.82	0.59, 1.10	0.20
Regular exercise		1.11	0.93, 1.33	0.23	0.91	0.76, 1.10	0.33
Body mass index		0.97	0.95, 1.00	0.04	0.96	0.91, 1.00	0.08
Waist circumference		0.98	0.98, 0.99	<0.001	0.99	0.97, 1.01	0.18
Hemoglobin		1.41	1.34, 1.49	<0.001	1.33	1.23, 1.43	<0.001
Glomerular filtration rate		1.11	1.06, 1.15	<0.001	0.99	0.94, 1.04	0.78

OR, odds ratio; CI, confidence interval.

[a] Logistic model was evaluated for age, sex, residential region, education level, income level, hypertension diagnosis duration, diabetes, dyslipidemia, cerebrovascular disease, ischemic heart disease, smoking, alcohol drinking, exercise status, body mass index, waist circumference, hemoglobin, and glomerular filtration rate.

Table 3
Odds ratios with 95 % confidence intervals for the association between antihypertensive medication adherence and covariates.

Total subjects (n = 14,291)		Antihypertensive medication adherence					
		Crude OR	95 % CIs	P-value	Adjusted OR[a]	95 % CIs	P-value
Age (per 10 years)		0.74	0.68, 0.81	<0.001	0.81	0.73, 0.91	<0.001
Sex	Male	1	Reference		1	Reference	
	Female	0.89	0.74, 1.08	0.25	0.93	0.66, 1.31	0.66
Residential region	Rural	1	Reference		1	Reference	
	Urban	0.91	0.75, 1.11	0.35	0.88	0.72, 1.08	0.21
Education level	Elementary school or lower	1	Reference		1	Reference	
	Middle school	1.23	0.93, 1.61	0.13	1.07	0.80, 1.42	0.66
	High school	1.20	0.95, 1.52	0.12	0.92	0.69, 1.21	0.54
	College or higher	1.41	1.07, 1.84	0.01	1.02	0.72, 1.43	0.91
Income level	1st	1	Reference		1	Reference	
	2nd	1.10	0.86, 1.42	0.45	1.12	0.87, 1.45	0.37
	3rd	0.93	0.71, 1.21	0.57	0.93	0.71, 1.21	0.58
	4th	0.88	0.67, 1.15	0.36	0.92	0.69, 1.22	0.54
Hypertension diagnosis duration		0.94	0.93, 0.96	<0.001	0.96	0.94, 0.97	<0.001
Diabetes	Normal	1	Reference		1	Reference	
	Pre-diabetes	0.63	0.51, 0.78	<0.001	0.70	0.56, 0.87	0.001
	Diabetes	0.50	0.39, 0.63	<0.001	0.63	0.48, 0.80	<0.001
Dyslipidemia		0.75	0.61, 0.91	0.004	0.87	0.71, 1.06	0.18
Cerebrovascular disease		0.48	0.25, 0.83	0.02	0.61	0.31, 1.06	0.11
Ischemic heart disease		0.35	0.18, 0.61	<0.001	0.48	0.25, 0.84	0.02
Smoking	Non-smoker	1	Reference		1	Reference	
	Ex-smoker	1.05	0.84, 1.30	0.67	1.10	0.80, 1.52	0.56
	Current smoker	1.42	1.08, 1.84	0.01	1.23	0.86, 1.76	0.25
Alcohol drinking	≤1/week	1	Reference		1	Reference	
	2-3/week	0.86	0.63, 1.16	0.35	0.71	0.50, 0.97	0.04
	≥4/week	1.57	1.17, 2.07	0.002	1.35	0.97, 1.84	0.07
Regular exercise		1.12	0.91, 1.37	0.27	1.05	0.85, 1.29	0.62
Body mass index		0.97	0.94, 1.00	0.03	1.01	0.95, 1.07	0.76
Waist circumference		0.98	0.97, 0.99	<0.001	0.98	0.96, 1.00	0.10
Hemoglobin		1.05	0.99, 1.12	0.12	1.01	0.94, 1.10	0.72
Glomerular filtration rate		1.05	1.00, 1.09	0.05	0.98	0.93, 1.03	0.47

OR, odds ratio; CI, confidence interval.
[a] Logistic model was evaluated for age, sex, residential region, education level, income level, hypertension diagnosis duration, diabetes, dyslipidemia, cerebrovascular disease, ischemic heart disease, smoking, alcohol drinking, exercise status, body mass index, waist circumference, hemoglobin, and glomerular filtration rate.

and non-treated patient groups among hypertensive patients [25–27]. This study is the first to subdivide non-adherent patients into a "treated-but-non-adherent group (non-adherent group)" and a "non-treated group" and investigate factors that are correlated with each group through large-scale nationwide data from 2007 to 2021. Moreover, we suggest a more patient-specific strategy to improve adherence and treatment rates among hypertensive patients.

The results analyzing the treatment group versus the non-treatment group demonstrated that older age was related to receiving treatment, which is consistent with results from previous studies [26,27]. Younger age was related to increased participation in labor and economic activities, in which daily labor is more important than daily medicine use, resulting in a low treatment rate [28]. Longer duration after hypertension diagnosis was also related to receiving treatment. Interestingly, patients with diabetes mellitus or dyslipidemia were more inclined to get treated than those without comorbidities. This finding can be explained with a psychological health-belief model of medication compliance, according to which the high severity of an illness or many comorbid diseases affects the patient's belief in the potential risk of not being treated and the benefit of taking medicines for managing health [27,29]. Of note, high blood hemoglobin level was associated with non-treatment. Given that high hemoglobin level is one of the well-known factors associated with high blood pressure, the non-treatment group showed higher blood pressure and subsequently showed high hemoglobin levels in this group. Although the mechanism underlying the phenomenon is unclear, it could be a noteworthy factor in clinical practice.

The results comparing the adherent and non-adherent groups revealed that older age and longer duration after diagnosis were related to adherence, which is in agreement with the result obtained from the comparison between treatment and non-treatment groups. As for comorbidities, diabetes mellitus or ischemic heart disease were associated with adherence. Notably, diabetes mellitus was the common factor that positively affected adherence and treatment. Some research indicates that diabetes mellitus may negatively affect adherence to antihypertensive medications among hypertensive patients [30,31]. Our research, however, aligns with studies that report a positive correlation between comorbid diabetes mellitus and improved adherence to antihypertensive therapy [27,32]. We propose that these discrepancies in findings may be attributed to differences in the health-belief models among individuals participating in studies. Consequently, future research should focus on incorporating how variations in individuals' health beliefs impact medication adherence, providing a more nuanced understanding of this relationship. In addition, drinking alcohol 2–3 times a

week was associated with adherence. Many studies have shown that alcohol consumption, especially heavy consumption, is associated with non-adherence to medication [33]. Further research is warranted to clarify whether moderate or social-level drinking can positively influence medication adherence.

According to the World Health Organization, five categories (health system factors, social and economic factors, therapy-related factors, patient-related factors, and condition-related factors) affect non-adherence [34]. Among these, patient-related factors, such as patients' knowledge and beliefs about their illness, motivation to manage the disease, expectations regarding treatment outcomes, consequences of poor adherence, anxieties about side effects, and forgetfulness, are highly modifiable. From our study's results, professionals should establish a patient-specific approach for each group to improve adherence.

Our study should be interpreted in the context of several limitations. First, given the long duration of data collection spanning from 2007 to 2021, the study was susceptible to external factors such as the temporal change in hypertensive patients' overall health beliefs, especially their perceptions of the importance of receiving treatment or medication adherence. Moreover, changes in hypertension treatment guidelines or real-world prescription trends of antihypertensive regimens could also have influenced patient adherence. Second, although we demonstrated several factors that correlate with adherence and treatment rate, the results do not guarantee causality since our study was methodologically cross-sectional research. Further research should use cohort data to strengthen causality from the results. Another concern was the possibility of recall bias and memory decay bias because some patient data to assess adherence was derived from a self-reported questionnaire based on patients' memory. Studies that use different methods to assess adherence via strategies, such as medication possession ratio or detecting medication from urine or blood samples, can result in a discrepancy in adherence rates [14,35,36]. For instance, research done by the Korean Health Insurance Review & Assessment Service in 2019 used the medication possession ratio method to report that the overall adherence rate was 85 % (compared to 92.4 % in our study) [14]. Lastly, since the KNHANES data was not originally designed to investigate factors related to medication adherence, real-world factors that may impact medication compliance were not considered and included in the original data. For example, data on regimen switches or medication costs were unavailable. Moreover, specific types and the number of medications prescribed were also unavailable. Provided that dual therapy (43.6 %) is now more prescribed than monotherapy (40.1 %) for hypertension control as of 2020 [37], additional research is warranted to incorporate real-world factors that may influence patients' adherence.

Our study is the first large-scale cross-sectional research to identify the characteristics of non-adherent and non-treatment hypertensive patient groups in Korea. Older age, longer duration after diagnosis, and comorbidities, including diabetes mellitus and dyslipidemia, were reliably associated with receiving antihypertension medication treatment, while high hemoglobin level was related to non-treatment. Older age, longer duration after diagnosis, comorbid diabetes mellitus and ischemic heart diseases, and alcohol consumption 2–3 times a week were associated with medication adherence.

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Data availability statement

Further information on the KNHANES is summarized on the relevant website (https://knhanes.kdca.go.kr/knhanes/eng/index.do).

Ethics declarations

KNHANES data were fully anonymized and contained no identifiable information. This study was approved, and informed consent was waived by the Institutional Review Board of the Dong-A University (2-1040709-AB-N-01-202303-HR-007-02).

CRediT authorship contribution statement

Sangyong Jo: Writing – review & editing, Writing – original draft, Resources, Investigation, Conceptualization. **Taegyu Um:** Writing – original draft, Methodology, Conceptualization. **Jihye Shin:** Validation, Formal analysis, Data curation, Conceptualization. **Dongchan Lee:** Writing – review & editing, Resources, Methodology, Investigation, Conceptualization. **Kyungil Park:** Writing – review & editing, Supervision, Project administration, Methodology. **Minkook Son:** Writing – review & editing, Visualization, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e38531.

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