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ORIGINAL ARTICLE

Relationship Between Water Intake and Metabolic/Heart Diseases: Based on Korean National Health and Nutrition Examination Survey

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Abstract
Objectives: The aim of this study was to identify the correlation between adequate water intake and the prevalence of metabolic/heart diseases.
Methods: We analyzed the data from the 2012 Korea National Health and Nutrition Examination Survey. All participants were divided into Group Above Adequate Intake (n = 736) and Group Below Adequate Intake (n = 4,819) according to water intake. The thresholds were 1.8 L for men and 1.4 L for women based on the World Health Organization report findings. Logistic regression analyses were performed to verify the correlation between water intake and prevalence of hypertension, diabetes mellitus, dyslipidemia, myocardial infarction, and angina pectoris.
Results: There were significant differences between the two groups in terms of the following variables: age, smoking, alcohol, stress, dietary supplements, body weight, physical activity, total calorie intake, water intakes from food, and sodium intake. Participants in Group Above Adequate Intake showed a higher prevalence of hypertension [odds ratio (OR) = 1.22; 95% confidence interval (CI), 0.58–2.55], diabetes mellitus (OR = 1.38; 95% CI, 0.51–3.73), angina pectoris (OR = 0.94; 95% CI, 0.47–1.86), and myocardial infarction (OR = 5.36; 95% CI, 0.67–43.20) than those in Group Below Adequate Intake, whereas the latter showed a slightly higher prevalence of dyslipidemia (OR = 2.25; 95% CI, 0.88–57.84) than the former.
Conclusion: There was no statistically significant association between water intake and any of the metabolic/heart diseases. However, further studies on water intake are needed to confirm our findings.

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1. Introduction

Water (H_2O), which accounts for approximately 60−70% of the weight of the human body, is essential for digestion, absorption, transfer, excretion, and circulation of biomolecules, as well as regulation of body temperature. If the body's water content decreases by 10%, physiological abnormalities can result, whereas a 20% water loss can result in death [1]. Accordingly, water is very significant, but consensus is lacking about adequate water intake (AI).

Studies have provided different calculations that consider various factors such as sex, age, weight, or climate [2]. Dietary Reference Intakes in the United States and Canada state that AI is 3.7 L/d for men and 2.7 L/d for women [3,4]. Approximately 81% of this fluid intake consists of drinking water, which equates to 3.0 L and 2.2 L for men and women, respectively, whereas the remaining 19% may be provided by food. The 2010 Dietary Reference Intake for Koreans, by contrast, provides lower AI levels, in which men and women are advised to drink 2.1−2.6 L/d and 1.8−2.1 L/d, respectively [5].

The Dietary Reference Intake references of Germany, Austria, and Switzerland depend on calorie consumption and suggest that seniors drink more water than male adults, who consume approximately 1 mL/kcal of water [6]. In fact, Westerterp et al [7] suggest an average AI of 1.14 mL/kcal or a range of 0.83−1.5 mL/kcal for elderly individuals.

A previous study suggested that AI consumption depends on weight, whereas Chernoff [8] argued that an adult should consume 30 mL of water/1 kg of weight or at least 1,500 mL/d. Skipper [9] provides another intake reference based on body weight, suggesting 100 mL/kg for the first 10 kg and 50 mL/kg for the next 10 kg. Beyond this point, an additional 15 mL/kg is suggested.

According to World Health Organization (WHO) reports, various factors such as climate and pregnancy as well as sex and age are considered in calculations of the required amounts of water to maintain hydration. Under standard conditions, the recommended daily AI is 1.0 L for children, 2.9 L for men, and 2.2 L for women. With increased physical activity or in hot temperatures, all lost fluids must be replaced. Approximately one-third of the recommended amount can be consumed through food [2].

The aim of this study is to examine the effectiveness of the daily recommended water intake in prevention of metabolic and heart diseases. We chose to study metabolic and heart diseases because a sufficient water level is known to control arginine vasopressin, a hormone that triggers blood vessel contraction [10]. This study was designed to analyze the projected correlation between the presence of the corresponding disease and a habit of drinking more water than recommended using the Korea National Health and Nutrition Examination Survey (KNHANES).

2. Materials and methods

2.1. Study participants

This study used materials from the 3rd year of the fifth KNHANES project, which included the full months of January to December 2012. Among the 10,069 persons included in the 2012 KNHANES, 8,058 participated in at least two surveys (among national health, physical examination, and/or nutritional); of this total, 6,293 who were aged ≥19 years were selected as study participants.

2.2. Adequate water intake

This study used the reference of the report on Domestic Water Quantity, Service Level and Health by the WHO to determine AI. According to the WHO report, AI under standard conditions was 2.9 L/d for men and 2.2 L/d for women. One-third of water intake was consumed via food; thus, the remaining daily AI was 1,933.3 mL for men and 1,467.7 mL for women.

Water intake of the KNHANES was based on metering of 1 cup (200 mL). Therefore, this study assigned individuals aged ≥19 years who consumed >9 cups (1,800 mL) and >7 cups (1,400 mL) of water for men and women, respectively, into Group Above AI, and those who consumed <9 cups (1,800 mL) and <7 cups (1,400 mL) for men and women, respectively, into Group Below AI.

2.3. Study variables

The study aimed to examine the difference in prevalence between metabolic and heart diseases of Group Above AI and Group Below AI. The 2012 KNHANES included hypertension, dyslipidemia, diabetes mellitus, myocardial infarction, and angina pectoris. Prior to the prevalence examination, this study examined intergroup differences in factors that could potentially affect water intake, such as alcohol consumption, smoking, and physical activity. Logistic regression analysis was then used to investigate whether water intake affects the prevalence of metabolic and heart diseases.

Figure 1 shows an overview of the study.

2.4. Statistical analyses

The chi-square test was used to examine the following variables: age groups, sex, smoking, alcohol, stress, dietary supplements, hypertension, diabetes mellitus, dyslipidemia, myocardial infarction, and angina pectoris. The *t* test was used to examine weight, sleeping hours, severe physical activity, moderate physical activity, total calorie intake, water intake (cup), water intakes from food, and sodium intake.

A three-step logistic regression analysis model was used to examine the correlation between water intake with ailments such as hypertension, dyslipidemia, diabetes mellitus, myocardial infarction, and angina

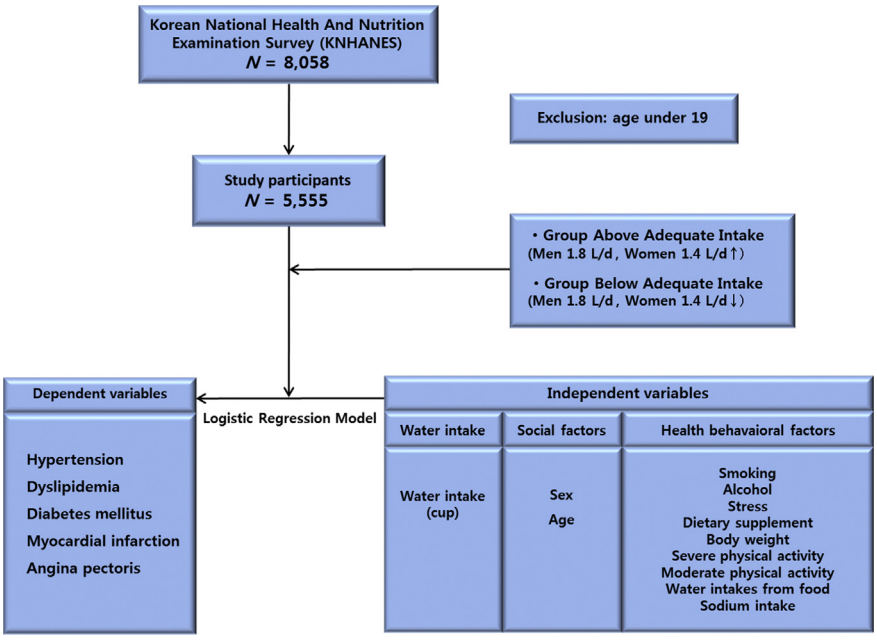

Figure 1. Study design.

pectoris after gradually adjusting for confounding factors affecting water intake.

Model 1: Adjusted for water intake
Model 2: Adjusted for water intake, sex, and age
Model 3: Adjusted for water intake, sex, age, smoking, alcohol, stress, dietary supplements, body weight, severe physical activity, moderate physical activity, total calorie intake, water intakes from food, and sodium intake

The data analysis was performed using IBM SPSS Statistics 21 (IBM Co., Armonk, NY, USA) at a significance level of $p = 0.05$.

3. Results

3.1. Amount of water intake

In this study, 293 men and 374 women had daily water intakes that exceeded the recommended water amount. The maximum value was 6,000 mL (30 cups) in one man and 4,000 mL (20 cups) in three women. Ten men and 22 women indicated that their daily water intake was < 200 mL. The ratio of Group Above AI and Group Below AI was 1:6.6 in men and 1:7.9 in women. Figure 2 shows the distribution of daily drinking water amount.

3.2. Health behaviors between Group Above AI and Group Below AI

Among the 6,293 participants in the survey, 5,555 remained after excluding missing data, 40.1% of whom were men (2,227 persons) and 59.9% of whom were women (3,328 persons).

Table 1 summarizes the group distributions by sex, age, smoking, alcohol, stress, dietary supplements, hypertension, diabetes mellitus, dyslipidemia, myocardial infarction, angina pectoris, body weight, sleeping hours, severe physical activity, moderate physical activity, total calorie intake, water intakes from food, sodium intake, and water intake.

Items with a statistically significant intergroup difference ($p < 0.05$) were age, smoking, alcohol, stress, dietary supplements, body weight, severe physical activity, moderate physical activity, total calorie intake, water intakes from food, sodium intake, and water intake (Table 1).

3.3. Odds ratios of metabolic diseases and heart diseases associated with water intake

To examine the presence of metabolic and heart diseases according to water intake, logistic regression analysis was performed. Using Group Below AI as a reference, three regression analysis models were used to examine the odds ratio (OR) of metabolic and heart diseases associated with water intake (Table 2).

The OR of hypertension in Models 1, 2, and 3 were 0.85 [95% confidence interval (CI), 0.71−1.02)], 1.25 (95% CI, 1.02−1.53), and 1.22 (95% CI, 0.58−2.55), respectively. The OR of diabetes mellitus in Models 1, 2, and 3 were 1.13 (95% CI, 0.87−1.47), 1.55 (95% CI, 1.17−2.05), and 1.38 (95% CI, 0.51−3.73), respectively. The OR of dyslipidemia in Models 1, 2, and 3 were 1.02 (95% CI, 0.84−1.23), 1.19 (95% CI, 0.98−1.45), and 0.94 (95% CI, 0.47−1.86),

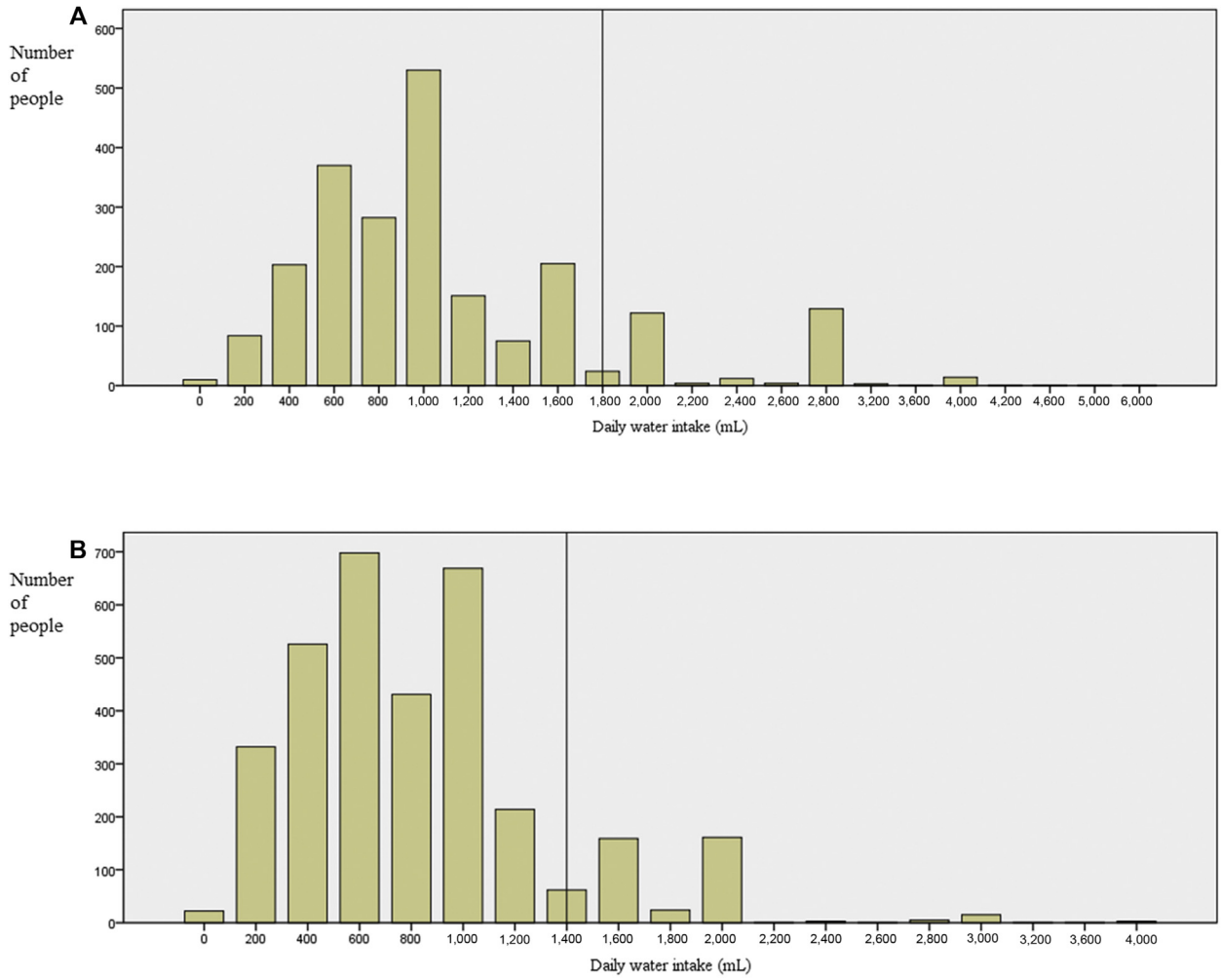

Figure 2. Distribution of daily water intake. (A) In men. (B) In women.

respectively. The OR of myocardial infarction in Models 1, 2, and 3 were 0.60 (95% CI, 0.22−1.69), 0.84 (95% CI, 0.30−2.37), and 5.36 (95% CI: 0.67−43.20), respectively. The OR of angina pectoris in Models 1, 2, and 3 were 0.68 (95% CI, 0.34−1.35), 1.02 (95% CI, 0.51−2.07), and 2.25 (95% CI, 0.88−57.84), respectively.

On the logistic regression analysis, none of the three metabolic diseases or two heart diseases showed a significant difference in prevalence according to water intake.

4. Discussion

This study analyzed the correlation between water intake and the prevalence of metabolic/heart diseases using logistic regression analyses. The distributions of daily water intake were similar in men and women. Both graphs were right-skewed, which shows that the majority of Korean people drink less than the recommended daily intake of water (Figure 2). Few men and women in this study achieved the target daily water intake.

During aging, water consumption decreases as a result of reduced metabolic activities [11]. These findings correspond with the results of another study using National Health and Nutrition Examination Survey (NHANES) data [12]. In addition, the groups of the current study showed significant differences in factors such as smoking, alcohol, stress, dietary supplements, body weight, physical activity, total calorie intake, water intake, and sodium intake (Table 1). Group Above AI included more current smokers and fewer nonsmokers than Group Below AI. Smoking dries out the mouth, increases the mouth's temperature, and results in water loss via the saliva [13]. Drinking alcohol triggers a diuretic effect and dehydration due to the degradation of ethanol, inevitably increasing water intake [14].

There was no statistically significant difference in the OR of the five diseases examined in Group Above AI

Table 1. Health behaviors between Group Above AI and Group Below AI.

		Group Above AI		Group Below AI		
		n	%	*n*	%	*p*
Sex	Male	315	42.8	1,912	39.7	0.107
	Female	421	57.2	2,907	60.3	
		736	100.0	4,819	100.0	
Age (y)	19−29	92	12.5	487	10.1	0.000
	30−39	158	21.5	776	16.1	
	40−49	148	20.1	751	15.6	
	50−59	143	19.4	888	18.4	
	60−69	125	17.0	885	18.4	
	70−79	64	8.7	826	17.1	
	≥ 80	6	0.8	206	4.3	
			100.0		100.0	
Smoking	Currently smoking	178	26.9	659	15.4	0.000
	Previously smoking	110	16.6	891	20.8	
	Nonsmoking	373	56.4	2,734	63.8	
			100.0		100.0	
Alcohol	More than 2−3 times/wk	161	24.4	738	17.2	0.000
	1−4 times/mo	208	31.5	1,280	29.9	
	Less than one time	126	19.1	857	20.0	
	No drink for the latest 1 y	166	25.1	1,409	32.9	
			100.0		100.0	
Stress	Feel stress under pressure	28	4.2	166	3.9	0.015
	Feel stress a lot	160	24.2	855	20.0	
	Feel stress a little	386	58.4	2,529	59.1	
	Hardly feel stress	87	13.2	730	17.1	
			100.0		100.0	
Dietary supplements	Yes (2 wk/1 mo)	363	49.3	1,991	41.3	0.000
	No	373	50.7	2,828	58.7	
			100.0		100.0	
		Mean (SD)		Mean (SD)		*p*
Body weight	kg	65.43 (12.48)		61.27 (11.29)		0.001
Sleeping hours	h/d	6.74 (1.36)		6.78 (1.43)		0.333
Severe physical activity	min/wk	117.13 (320.28)		70.80 (244.08)		0.000
Moderate physical activity	min/wk	139.84 (365.58)		88.23 (273.62)		0.000
Total calorie intake	kcal/d	2,088.92 (1,009.56)		1,892.36 (796.69)		0.000
Water intakes from food	g/d	1,132.98 (751.47)		926.27 (594.15)		0.000
Sodium intake	mg/d	5,287.78 (3,765.54)		4,566.42 (3,251.83)		0.000
Water intake	cup/d (1 cup = 200 mL)	9.97 (2.73)		3.69 (1.71)		0.034

Group Above AI = group above adequate intake; Group Below AI = group below adequate intake; SD = standard deviation.

and Group Below AI. The correlation between water intake and these five diseases (Table 2) can be explained as follows.

Diabetes mellitus is a metabolic disorder caused by abnormal insulin secretion, and patients with uncontrolled diabetes mellitus would suffer thirst and drink increased amounts of water to compensate [15]. Because of this, the higher OR of diabetes mellitus in the logistic regression analysis (Model 2) should not be interpreted to mean that drinking more water is a risk factor for diabetes mellitus. However, hypertension and dyslipidemia commonly accompany diabetes mellitus. They are due to fatty acid secretion by adipose cells being triggered by insulin resistance of diabetes mellitus, which increases low-density lipoprotein and triglyceride levels in the liver, causing dyslipidemia [16,17].

Angina pectoris tends to be accompanied by thrombosis [18]. Therefore, drinking an adequate amount of water may help reduce blood coagulation and result in a lower OR for angina pectoris. In addition, heart failure has symptoms related to salt and water retention; therefore, its management includes restricted water intake. This factor should be considered in the interpretation of the OR of heart diseases [19].

There is little evidence that clearly reveals any correlation between water consumption and metabolic/heart diseases. In a U.S. cohort study on risk levels of heart disease involving approximately 20,000 participants, a

Table 2. Odds ratio of metabolic diseases and heart diseases associated with water intake.

		1 (Above AI)		
Disease	0 (Below AI)	OR	(95% CI)	*p*
Hypertension				
Model 1[a]	1.0 (ref.)	0.85	(0.71−1.02)	0.076
Model 2[b]	1.0 (ref.)	1.25	(1.02−1.53)	0.032
Model 3[c]	1.0 (ref.)	1.22	(0.58−2.55)	0.599
Diabetes mellitus				
Model 1	1.0 (ref.)	1.13	(0.87−1.47)	0.370
Model 2	1.0 (ref.)	1.55	(1.17−2.05)	0.002
Model 3	1.0 (ref.)	1.38	(0.51−3.73)	0.384
Dyslipidemia				
Model 1	1.0 (ref.)	1.02	(0.84−1.23)	0.866
Model 2	1.0 (ref.)	1.19	(0.98−1.45)	0.082
Model 3	1.0 (ref.)	0.94	(0.47−1.86)	0.853
Myocardial infarction				
Model 1	1.0 (ref.)	0.60	(0.22−1.69)	0.603
Model 2	1.0 (ref.)	0.84	(0.30−2.37)	0.737
Model 3	1.0 (ref.)	5.36	(0.67−43.20)	0.115
Angina pectoris				
Model 1	1.0 (ref.)	0.68	(0.34−1.35)	0.268
Model 2	1.0 (ref.)	1.02	(0.51−2.07)	0.952
Model 3	1.0 (ref.)	2.25	(0.88−57.84)	0.624

[a]Model 1: adjusted for water intake; [b]Model 2: adjusted for water intake, sex, and age; [c]Model 3: adjusted for water intake, sex, age, smoking, alcohol, stress, dietary supplements, body weight, severe physical activity, moderate physical activity, total calorie intake, water intakes from food, sodium intake. CI = confidence interval; OR = odds ratio; ref. = Group Below AI.

group of individuals drinking 4 cups of water daily showed a significantly lower risk of heart disease compared to a group drinking < 2 cups of water daily [20]. Other studies found that drinking water prior to meals affected weight loss and fat reduction [21,22].

One cross-sectional study examined the correlation between water intake and cardiovascular disorders based on the NHANES publications [23]. The study divided the participants into three groups according to water intake, and the group with the highest intake showed a low prevalence of heart diseases such as coronary artery disease and angina pectoris, although there was no significant correlation with OR. Likewise, our study failed to reveal a correlation between water intake and metabolic/heart diseases.

This study has several limitations. First, the daily water intake reference has not been verified because the WHO references serve as a recommendation that is not based on clinical experiments. Moreover, water intake has a variety of standards, each of which has a different calculation method. Second, there are various kinds of drinking water, for example, tap water, bottled water, and mineral-rich water. Mineral-rich water contains antioxidants that could protect against metabolic syndromes [24]. Hard water can also reduce the prevalence of cardiovascular diseases [25]. However, this type of association could not be considered because the KHNANES does not investigate water type or hardness. Third, the study failed to consider water intake from food as well as beverages and alcohol. Metabolic water generated by the oxidation of carbohydrate, protein, and fat was also ignored in the calculation of daily water intake [26]. This may have induced error to the study results. Finally, other possible confounding factors between water intake and cardiovascular disorders were limited [27].

In conclusion, this study revealed no statistically significant differences in the prevalence of hypertension, diabetes mellitus, dyslipidemia, myocardial infarction, and angina pectoris between people drinking or not drinking more water than the daily recommended amount. Even though interest in the effects of water has only recently increased, related studies are still insufficient. Therefore, this study can be used as a reference in future studies, including clinical trials to determine the ideal daily water intake and its associated effects on the human body.

Conflicts of interest

The authors declare that they have no conflicts of interest concerning this article.

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