

Effects of exercise intensity on hypertension prevalence in Korean men with high sodium intake

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Abstract. [Purpose] The purpose of present study was to investigate the effects of exercise intensity on hypertension prevalence in Korean men with high sodium intake. [Subjects and Methods] This study was based on the data collected from 2007 to 2013 in the Korean National Health and Nutritional Examination Survey. A total of 8,853 male adults were included in the analysis. The odds ratios for hypertension according to exercise groups were assessed by using logistic regression of each sodium intake group. [Results] Among the 8853 subjects, 6243 had an eating habit of 4000 mg or more sodium consumption per day, and 2619 had less than 4000 mg. Among the 2619 subjects with less than 4000 mg sodium consumption, 16.7% subjects were diagnosed as having hypertension. In the subjects with 4000 mg or more sodium consumption, compared to the no-exercise group, the moderate-exercise group showed a lower likelihood of developing hypertension, with an odds ratio of 0.63 (95% confidence interval, 0.47–0.85) after adjusting for age. In multivariate models 1 and 2, odds ratios for the likelihood of developing hypertension in the moderate-exercise group decreased to 0.63 (0.43–0.91) and 0.66 (0.45–0.96), respectively. [Conclusion] Moderate exercise is significantly associated with a lower likelihood of developing hypertension in cases of high sodium intake.

Key words: Exercise intensity, High sodium intake, Hypertension

(This article was submitted Apr. 30, 2015, and was accepted May 25, 2015)

INTRODUCTION

Hypertension leads to serious and critical public health problems worldwide¹⁾. It is the most general and major risk factor for numerous diseases including cardiovascular disease, stroke, ischemic heart disease, dementia, chronic kidney disease, and heart failure²⁾. Approximately 972 million adults with high blood pressure were distributed widely in 2000, and this number is expected to increase by about 60% to 1.56 billion in 2025³⁾. In Korea 26.9% of the adult population aged 30 years or older had hypertension in 2010⁴⁾. These phenomenon, that the prevalence of hypertension is predicted to increase further, are very critical because blood pressure tends to increase continually throughout life, and the lifespan of population is also increasing gradually^{4, 5)}.

A combination of genetics, complex hemodynamic and metabolic mechanisms, and environmental factors is involved in hypertension⁶⁾. Moreover, various causative elements of hypertension are known to be overweight, lack of physical activity and intake of fruits and vegetables, and excessive alcohol consumption and dietary sodium intake⁷⁾.

Among these high sodium intake has been identified as the major causal factor of hypertension⁸⁾. Excessive salt intake and accumulation can induce an increase in plasma volume in the kidney and high blood pressure²⁾. Recently, it was reported that lower dietary sodium intake reduces the risks of cardiovascular diseases⁹⁾. Nevertheless, because Koreans habitually eat seasoned soups and vegetables pickled with salt, the average consumption of sodium is 5,000 mg per day, which is more than twice the dietary sodium intake goal^{4, 9, 10)}. Therefore, effective methods in many different fields for regulating the increase in blood pressure and decreasing the risk of its related complications are needed.

Lifestyle modifications are recommended as strategies for the prevention, treatment, and control of hypertension, with physical exercise being an integral component^{1, 11)}. Exercise normalizes blood pressure by preventing the development of high and low blood pressure in adults with problems of blood pressure¹¹⁾. In addition, exercise can be effective at decreasing clinical blood pressure¹²⁾. However, different types and intensities of exercise might evoke distinct effects in normal and hypertensive subjects¹³⁾. Some researchers have reported that low rates of participation in exercise programs were due to concerns about the discomfort and risk of vigorous exercise¹¹⁾. Therefore, the purpose of present study was to investigate the effects of exercise intensity on hypertension prevalence in Korean men with high sodium intake.

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SUBJECTS AND METHODS

This study was based on the data collected from 2007, 2008, 2009, 2010, 2011, 2012, and 2013 in the Korean National Health and Nutritional Examination Survey (KNHANES), which was provided by the Korea Centers for Disease Control and Prevention (KCDC). From 2010, KNHANES was conducted throughout the year to reduce seasonal biases in diet. The sample for KNHANES was selected using a stratified, multistage, cluster-sampling design with proportional allocations based on the National Census Registry. The 2007, 2008, 2009, 2010, 2011, 2012, and 2013 KNHANES database holds information on 4594, 9744, 10533, 8958, 8518, 8058, and 8018 individuals, respectively, for a total of 58423 participants. The number of male subjects was 2657, and 22944 male subjects who participated in the Nutritional Survey adults aged 19 to 64 years were selected ($n=11990$). The participants reporting unrealistic daily total energy intakes (<500 kcal or ≥ 6000 kcal) were excluded ($n=472$) and then adults with no blood pressure data ($n=1117$) were excluded. Moreover, adults with no responses to questions about the exercise were excluded ($n=298$). Finally, the subjects who were diagnosed with hypertension or receiving treatment for hypertension ($n=1611$) at the time of the survey were excluded in order to reduce any causal relationship. As a result, 8853 male adults were included in the final analysis. This study was conducted in accordance with the Ethical Principles for Medical Research Involving Human Subjects, as defined by the Helsinki Declaration. All study subjects were provided their written informed consent to the survey. Moreover, anonymous data were used in the study.

KNHANES includes well-established questions to determine the demographic and socioeconomic characteristics of the subjects. Questions on age, gender, physical exercise, and the other health values are incorporated. Daily energy and nutrient intakes are assessed using one day 24-hour recall. The height and weight of subjects were measured with the participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as weight (in kilograms) divided by height (in meters) squared. Well-trained observers manually measured blood pressure using a mercury sphygmomanometer (Baumanometer; Baum, Copiague, NY, USA). Hypertension was defined as having a systolic pressure of 140 mmHg (or higher) or a diastolic pressure of 90 mmHg (or higher) following the standard established by the KCDC. Physical exercise was categorized into three groups: no exercise (Non-exe), moderate exercise (Mod-exe), and vigorous exercise (Vig-exe). The subjects were divided on the basis of sodium intake into 'high' (≥ 4000 mg/day) and 'moderate' (<4000 mg/day) groups.

Means and standard errors (SEs) of continuous variables were calculated according to physical exercise groups for the high and moderate sodium intake groups. The proportions of each covariate in categorical variables were calculated for each group. The difference between groups was tested using ANOVA and Duncan test for continuous variables, and the χ^2 test for categorical variables. The odds ratios for hypertension according to physical exercise groups were assessed using logistic regression for each of the sodium intake groups. Multivariate model 1 was adjusted for age, BMI, fasting

glucose, triglycerides, low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C), energy, and sodium intake. Multivariate model 2 was adjusted for education, income, smoking, alcohol consumption, receiving education for hypertension, survey year, chronic disease status (those diagnosed with or taking medication(s) for the management of diabetes, stroke, myocardial infarction, angina pectoris, chronic renal failure, and cancers vs. those not) in addition to the factors of multivariate model 1. All analyses were performed using SAS statistical software (version 9.2; SAS Institute Inc., Cary, NC, USA).

RESULTS

Baseline characteristics according to exercise intensity (Non-exe, Mod-exe, and Vig-exe groups) by sodium consumption are presented in Table 1. Among the 8853 subjects, 6243 (70.5%) habitually consumed 4000 mg or more sodium per day, and 2619 (29.5%) habitually consumed less than 4000 mg. Among the subjects with 4000 mg or more sodium consumption, there were significant differences in systolic and diastolic blood pressure, BMI, fasting glucose, HDL-C, and energy consumption among the exercise groups. In subjects with less than 4000 mg sodium consumption, there were no significant differences, except the value of HDL-C, among the exercise groups.

Frequencies of hypertension prevalence in the different exercise intensity groups according to sodium intake are shown in Table 2. Out of 6243 subjects with 4000 mg or more sodium consumption, 1128 (18.1%) were newly diagnosed as having hypertension. According to exercise intensity, 4565 (73.1%) subjects with 4000 mg or more sodium consumption per day scarcely performed exercise, whereas 414 (6.6%) and 1264 (20.3%) performed moderate and vigorous exercise, respectively. Among the 2619 subjects with less than 4000 mg sodium consumption, 436 (16.7%) subjects were diagnosed as having hypertension. According to exercise intensity, 1958 (75.0%) subjects with less than 4000 mg sodium consumption per day seldom performed exercise, whereas 151 (5.8%) and 501 (19.2%) performed moderate and vigorous exercise, respectively.

Table 3 presents the odds ratio of hypertension according to exercise intensity by sodium consumption. In the subjects with 4000 mg or more sodium consumption, compared to the Non-exe group, the Mod-exe group showed a lower likelihood of developing hypertension, with an odds ratio of 0.63 (95% confidence interval, 0.47–0.85) after adjusting for age. In multivariate models 1 and 2, the odds ratios for the likelihood of developing hypertension in the Mod-exe group decreased to 0.63 (95% confidence interval, 0.43–0.91) and 0.66 (95% confidence interval, 0.45–0.96), respectively. Although the confidence intervals of the odds ratio for the Mod-exe group subjects with less than 4000 mg sodium consumption were not significant, there was a trend of decrease. There were no significant results for the Vig-exe group.

DISCUSSION

Hypertension is currently an important public health problem, because it is a major risk factor of cardiovascular

Table 1. General and clinical characteristics of hypertension in the Non-exe, Mod-exe, and Vig-exe groups according to sodium intake

Variables	Sodium intake \geq 4000 mg/day			Sodium intake <4000 mg/day		
	Non-exe	Mod-exe	Vig-exe	Non-exe	Mod-exe	Vig-exe
Intensity of exercise						
Number	4565	414	1264	1958	151	501
Age (years)	42.0 \pm 0.2	42.6 \pm 0.6	41.5 \pm 0.3	42.7 \pm 0.3	42.5 \pm 1.1	41.5 \pm 0.6
Systolic blood pressure (mmHg)	118.1 \pm 0.2	116.7 \pm 0.7*	118.5 \pm 0.4#	117.4 \pm 0.3	117.3 \pm 1.0	117.2 \pm 0.6
Diastolic blood pressure (mmHg)	79.6 \pm 0.2	77.6 \pm 0.5*	79.6 \pm 0.3#	78.5 \pm 0.2	77.5 \pm 0.8	78.0 \pm 0.5
Body mass index (kg/m ²)	24.1 \pm 0.1	23.6 \pm 0.2*	24.4 \pm 0.1#	23.8 \pm 0.1	23.7 \pm 0.2	24.1 \pm 0.1
Fasting glucose (mg/dL)	97.0 \pm 0.3	98.8 \pm 1.4	96.4 \pm 0.6#	98.6 \pm 0.6	95.7 \pm 1.5	96.6 \pm 0.9
Triglycerides (mg/dL)	160.4 \pm 2.0	156.0 \pm 8.8	147.6 \pm 3.4	155.6 \pm 2.7	138.5 \pm 9.4	143.3 \pm 4.9
HDL-C (mg/dL)	45.7 \pm 0.2	45.6 \pm 0.6	46.6 \pm 0.4#	45.2 \pm 0.3	46.4 \pm 1.1*	45.8 \pm 0.6#
LDL-C (mg/dL)	110.7 \pm 0.6	107.5 \pm 2.1	111.8 \pm 1.1	111.6 \pm 0.9	115.8 \pm 3.5	107.4 \pm 1.7
Energy (kcal/day)	2626.5 \pm 12.7	2626.7 \pm 43.2	2728.0 \pm 25.2*#	1831.0 \pm 13.9	1872.4 \pm 48.6	1902.6 \pm 30.4
Sodium (mg/day)	7270.1 \pm 45.8	7322.1 \pm 152.7	7290.4 \pm 86.4	2865.3 \pm 18.3	2833.9 \pm 65.4	2902.9 \pm 37.4

Characteristics of the study population were investigated using disease related data. Each value represents the mean \pm SD of the values measured during the survey. Means in a row without a common letter are significantly different. * $p < 0.05$ versus Non-exe; # $p < 0.05$ versus Mod-exe

Table 2. Frequency of hypertension in the Non-exe, Mod-exe, and Vig-exe groups according to sodium intake

Groups	Sodium intake \geq 4000 mg/day			Sodium intake <4000 mg/day		
	Yes (%)	No (%)	Total (%)	Yes (%)	No (%)	Total
Non-exe	829 (13.3)	3736 (60.0)	4565 (73.1)	329 (12.6)	1629 (62.4)	1958 (75.0)
Mod-exe	52 (0.8)	362 (5.8)	414 (6.6)	20 (0.8)	131 (5.0)	151 (5.8)
Vig-exe	247 (4.0)	1017 (16.3)	1264 (20.3)	87 (3.3)	414 (15.9)	501 (19.2)
Total	1128 (18.1)	5115 (81.9)	6243 (100.0)	436 (16.7)	2174 (83.3)	2610 (100.0)

The frequency of hypertension in the Non-exe, Mod-exe, and Vig-exe groups according to sodium intake was analyzed. Each value represents the number and percentages of subjects according to exercise intensity groups and sodium intake.

Table 3. Odds ratios of hypertension in the Non-exe, Mod-exe, and Vig-exe groups according to sodium intake

Groups	Age-adjusted Model		Multivariate Model 1		Multivariate Model 2	
	OR	95% CI	OR	95% CI	OR	95% CI
Sodium intake \geq 4000 mg/day						
Non-exe	Reference		Reference		Reference	
Mod-exe	0.63	0.47–0.85	0.63	0.43–0.91	0.66	0.45–0.96
Vig-exe	1.11	0.95–1.30	1.22	0.99–1.50	1.22	0.98–1.51
Sodium intake <4000 mg/day						
Non-exe	Reference		Reference		Reference	
Mod-exe	0.75	0.46–1.23	0.76	0.41–1.39	0.90	0.48–1.68
Vig-exe	1.07	0.82–1.39	1.29	0.91–1.83	1.33	0.92–1.92

The odds ratios for hypertension according to exercise groups were estimated by using logistic regression for both sodium intake groups. Multivariate model 1 was adjusted for age, BMI, fasting glucose, triglycerides, LDL-C, HDL-C, energy, and sodium intakes. Multivariate model 2 was adjusted for education, income, smoking, alcohol consumption, receiving education for hypertension, survey year, chronic disease status (those diagnosed with or taking medication(s) for the management of diabetes, stroke, myocardial infarction, angina pectoris, chronic renal failure, and cancers vs. those not) in addition to the factors of multivariate model 1. Odds ratios for each factor in each model were calculated with 95% Wald's confidence intervals.

diseases related to stroke and ischemic heart diseases. High sodium intake is identified as the major causal factor of hypertension. Korean average consumption of sodium is too high, and is more than twice the dietary sodium intake goal because of traditional eating habits. Exercise can be effective at decreasing clinical blood pressure. Therefore,

the purpose of present study was to investigate the effects of exercise intensity on hypertension prevalence in Korean men with high sodium intake.

It was recently reported that the average sodium intake of Koreans was more than 5000 mg per day, making them one of the highest intake groups in the world¹⁰. In the pres-

ent study, among 8853 subjects, 6243 (70.5%) habitually consumed of 4000 mg or more sodium per day, and 2619 (29.5%) habitually consumed less than 4000 mg. These facts might be associated with traditional Korean foods, including seasoned soups, soybean paste, and salt-fermented fishes and vegetables. In our results, 18.1% of subjects with 4000 mg or more sodium consumption were newly diagnosed as having hypertension as were 16.7% of subjects less than 4000 mg of sodium consumption. High sodium intake contributes to high blood pressure⁸⁾. The physiological mechanism of sodium intake in the prevalence of hypertension is associated with dysfunction of the kidney in excreting sodium completely and the impact on vascular smooth muscle cells of excessive sodium intake²⁾.

Exercise is a general lifestyle modification strategy for the prevention, treatment, and control of hypertension. It induces ordinary blood pressure by preventing the development of high blood pressure¹¹⁾. Nevertheless, 73.1% of subject with 4000 mg or more sodium consumption per day and 75.0% of subjects with less than 4000 mg seldom performed exercise according to the results of our study. These facts mean that Koreans need to be highly encouraged to exercise to prevent and reduce hypertension.

A number of previous studies have reported that the differences in exercise intensity could be confirmed by the different groups of metabolic, hemodynamic, cardiorespiratory stress, and blood pressure. Piepoli et al. demonstrated that only maximal exercise was effective at reducing diastolic blood pressure compared to moderate and control exercise¹⁴⁾. Karoline de Morais et al. reported that the maximum exercise elicited a reduction in blood pressure and produced a significant reduction in pressure variation during sleep compared to the non-exercise and moderate exercise¹⁵⁾. Its finding was explained that the maximum exercise regulates neural and humoral factors influencing blood pressure group by decreasing of peripheral resistance^{15, 16)}.

Meanwhile, our results presented that in the subjects with 4000 mg or more sodium consumption, compared to the Non-exe group, the Mod-exe group showed a lower likelihood of developing hypertension after adjusting for age, multivariate models, respectively. Although the confidence intervals of the odds ratio for the Mod-exe group in subjects with less than 4000 mg sodium consumption were not significant, there was a trend of decrease. No significant results were found for the Vig-exe group. Majeed et al. demonstrated that intense exercise may have significant deleterious cardiovascular effects. Intensive exercise might promote exercise-induced hypertension that is also associated with endothelial dysfunction, progressive atherosclerosis, and increased cardiovascular mortality¹⁷⁾. Schultz et al. reported that excessive exercise can have deleterious effects on cardiac function and accelerate the progression to heart failure in the untreated hypertensive state because it becomes a pathologic overloading stimulus rather than a physiological stimulus¹⁸⁾. Moreover, it was reported that moderate exercise induced the stabilization of heart rate variability to enhance the activity of peripheral nervous system control¹⁹⁾. These facts imply that moderate exercise has the positive effects on cardiovascular function, including blood pressure, compared to vigorous exercise.

Physical exercise has many beneficial effects. Especially, it prevents the development of high blood pressure. However, the exercise intensity plays a role in determining the pathological or physiological responses of the body, which depend on health condition, training group, living habits, gender, age, and so on. Moderate exercise is associated with a lower likelihood of developing hypertension in cares with high sodium intake. More studies about the related mechanisms of hypertension and the detailed exercise intensity are needed of populations with high sodium intake.

ACKNOWLEDGEMENT

This work was supported by Rural Development Administration R&D (PJ01009002), Suwon, Republic of Korea.

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