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ORIGINAL ARTICLE

Gender Differences in the relationship between carbonated sugar-sweetened beverage intake and the likelihood of hypertension according to obesity

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Abstract
Objectives The aim of the present study was to investigate the association between hypertension and carbonated sugar-sweetened beverages (SSB) intake according to gender and obesity.
Methods The study used data from 2007, 2008 and 2009 Korea National Health and Nutrition Examination Surveys. A total of 9869 subjects (men = 3845 and women = 6024) were included. SSB intakes were calculated from food frequency questionnaires. Odds ratios (ORs) and 95 % confidence interval (CI) for hypertension were assessed using survey logistic regression and multivariable adjusted models.
Results A total of 14.5 % of individuals were classified as having hypertension. The likelihood of hypertension in the third, fourth and fifth quintiles for SSB intake increased to OR 1.00, 1.20 and 1.42 respectively, after adjusting for confounding factors. Compared to the participants in the lowest tertile for SSB intake, participants in the third tertile showed an increased likelihood of hypertension with ORs (CI) of 2.00 (1.21–3.31) and 1.75 (1.23–2.49) for obese women and non-obese men, respectively.
Conclusions The present study showed gender differences in the relationship between carbonated SSB intake and the hypertension according to obesity.

Keywords Hypertension · Sugar-sweetened beverage · Gender · Obesity

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Introduction

Hypertension is an important public health concern, with a global prevalence of 26 % in the adult population (Kearney et al. 2005). It is a major risk factor for vascular mortality including stroke, heart, and renal disease (Chobanian et al. 2003; James et al. 2014; Kalaitzidis and Bakris 2010; Lewington et al. 2002). Well-known risk factors for hypertension include obesity, low physical activity, high consumption of alcohol, high sodium intake, and low potassium intake (Chobanian et al. 2003; James et al. 2014). To reduce hypertension and associated complications, it is important to control the correctable risk factors. Several epidemiologic studies as well as a recent systematic review reported that sugar-sweetened beverage (SSB) consumption was associated with higher blood pressure (BP) (Brown et al. 2011; Kim et al. 2012; Malik et al. 2014). The limitations of previous studies commonly include a lack of randomization and proper identification of causal relationships due to the observational nature of the study designs. The only published clinical trial was a

multicenter randomized study, which reported that reduced consumption of SSBs and sugars were significantly associated with reduced BP levels (Chen et al. 2010). Although the results of previous studies are highly suggestive of an association between SSB consumption and the risk of hypertension, the causality and mechanisms of the association are still unclear. Some animal studies have reported on the role of sex hormones in developing hypertension as a result of SSB consumption (Galipeau et al. 2002; Song et al. 2004; Vasudevan et al. 2005). Furthermore, obesity can influence sex hormone levels (Allan and McLachlan 2010; Quinkler et al. 2004). Therefore, the association between hypertension risk and SSB intake can vary according to gender and obesity.

The aim of the present study was to investigate the presence of any direct, independent association between the prevalence of hypertension and SSB intake and the differences according to gender and obesity using data from the Korea National Health and Nutrition Examination Survey (KNHANES), a nationally representative survey conducted in the Republic of Korea.

Methods

Study population and exclusion criteria

This study was based on the data from the 2007, 2008, and 2009 KNHANES, which together made up the 4th KNHANES database provided by the Korea Centers for Disease Control and Prevention (KCDC) (Kweon et al. 2014). The 4th KNHANES database has been used for previous epidemiologic studies (Choi et al. 2015; Kim et al. 2013; Shin et al. 2013; Song et al. 2014b). Samples for KNHANES were selected using a stratified, multistage, cluster-sampling design with proportional allocation based on the National Census Registry.

The 2007, 2008, and 2009 KNHANES comprised 4594, 9744, and 10,533 individuals, respectively, for a total of 24,871 participants. Subjects aged 19–64 years were included ($n = 14,334$). We excluded participants using the following criteria: (1) pregnant women ($n = 132$), (2) subjects who had a diagnosis of or were receiving treatment for hypertension ($n = 1663$) at the time of the survey, (3) subjects with no blood pressure data ($n = 863$), and (4) subjects with no nutritional data including carbonated SSB intake ($n = 1807$). As a result, a total of 9869 subjects were included in the final analysis (men = 3845, women = 6024). This study's design was similar to our previous study on the association between fruit intake and hypertension (Song et al. 2014b). The study was conducted in accordance with the Ethical Principles for Medical Research Involving Human Subjects, as defined by the Helsinki Declaration. All study subjects provided written informed consent for the survey and de-identified data were used in the study.

Blood pressure, anthropometric and biochemical measurements

Well-trained observers manually measured BP with a mercury sphygmomanometer (Baumanometer; Baum, Copiague, NY, USA) using a standard protocol. After participants sat quietly for 5 min, the observer measured BP in the right arm with an appropriately sized cuff. For this analysis, the values of BP were calculated by taking the mean of a set of two BP measurements. The height and weight of the subjects were measured and body mass index (BMI) was calculated as weight (in kilograms) divided by the square of height (in meters). Fasting blood glucose, triglyceride, total cholesterol, and high-density lipoprotein (HDL) cholesterol were measured after a 12-h overnight fast.

Case definition

Hypertension was defined as having a systolic BP of 140 mmHg or higher or a diastolic BP of 90 mmHg or higher.

Dietary assessment

Dietary assessments consisted of a food frequency questionnaire (FFQ) for the past year and a 24-h recall. A total 91.7 % of participants did not consume any kind of carbonated SSB in a day. The mean intake of carbonated SSB was 21.8 g/day (28.9 g for men and 17.2 g for women) for Korean adults. Therefore, we calculated the frequency of carbonated SSB intake using the FFQ for habitual intake. The FFQ consisted of 63 commonly consumed food items in Korea with a frequency of food intake in ten categories (almost never, 6–11 times/year, 1 time/month, 2–3 times/month, 1 time/week, 4–6 times/week, 2–3 times/week, 1 time/day, 2 times/day, and 3 times/day). We converted the frequency of 10 categories to times per week. Therefore, SSB intake frequency was shown from 0 to 21 times/week. That is, the numbers by category were 3721 for almost no intake, 1019 for 0.15,385 times/week, 1353 for 0.25 times/week, 1089 for 0.625 times/week, 1278 for 1 time/week, 944 for 2.3 times/week, 261 for 5 times/week, 175 for 7 times/week, 22 for 14 times/week, and 7 for 21 times/week. In order to generate a similar number per category, we automatically created quintiles of SSB frequency in a statistical program. Daily energy and sodium intake were calculated by a 24-h recall method.

Assessment of other covariates

The assessments of other covariates, such as age, gender, alcohol consumption, smoking, education, annual income, physical activity, survey year, menopause, were collected from health interview. Education level was categorized into four groups: less than middle school education, middle school graduate, high school graduate, and college and/or higher degree graduate. Income was categorized into quartiles (lowest, low, high, and highest, as defined by the KCDC). Household income was assessed according to self-report. Income was measured as the average total monthly income of all family members living together or sharing living-related expenditures. The equivalent income was calculated as income divided by the square root of family number, and the equivalent income level was created by quartile. Alcohol consumption was categorized into four groups: non-drinker, less than once a month, once a month and less than heavy drinker, and heavy drinker. "Heavy drinker" was defined as someone consuming alcohol twice or more per week and having at least seven drinks per occasion for men and five drinks per occasion for women, which was provided by KCDC. Smoking status was categorized into nonsmokers and past smokers, and two groups of current smokers (less than 2 packs per day, 2 packs or more per day). Packs per day were measured by asking: "How many cigarettes do you smoke per day?"; 20 cigarettes were converted into 1 pack. Physical activity was categorized into four groups: no exercise with irregular walking, regular walking, regular moderate activity, and regular vigorous activity. Menopausal status in women subjects was categorized as either "yes" or "no." Comorbidities included diabetes, cerebrovascular disease, acute coronary syndrome, chronic renal failure, lung cancer, gastric cancer, liver cancer, colon cancer, breast cancer, and uterine or cervical cancer. The information about comorbidities was obtained from the past medical history section of the questionnaire.

Statistical analysis

The sample weights were applied in all analysis to reflect population estimates. Means and standard errors (SEs) of continuous variables were calculated in both the hypertension and non-hypertension groups according to gender. The proportions of each covariate in categorical variables were calculated for each group. P value was calculated using SURVEYREG for continuous variables and SURVEYFREQ with the Rao-Scott's χ^2 for categorical variables in SAS procedures. We conducted survey logistic regression to assess the association between SSB intake and hypertension prevalence by gender and further gender and obesity. Obesity was defined as BMI $\geq$25 kg/m^2. We categorized SSB intake frequency into tertiles in each gender group. All models were adjusted for age and gender. We conducted multivariable survey logistic regression analyses for the association using sampling weight provided by the KNHANES survey. In the subgroup analysis, domain code was used to preserve the complex sampling design of KNHANES. The well-known confounding factors such as age, sex, social demographic characteristics, smoking, alcohol consumption, physical activity, menopause in relation to hypertension were used in multivariate model. The blood glucose and lipids were used because these were correlated with blood pressure ($P < 0.05$). Therefore, the covariates included education, income, smoking, alcohol consumption, physical activity, menopause, comorbidities, body mass index, blood glucose, triglycerides, total cholesterol, HDL cholesterol, and total energy intake. Sodium intake is a potential risk factor for hypertension (Chobanian et al. 2003; James et al. 2014), so we added sodium intake as a continuous variable in the multivariate model.

The multivariate model is as follows:

$$\begin{aligned} Y = {} & \text{intercept} + \beta_1\,\text{age}\dagger + \beta_2\,\text{gender} + \beta_3\,\text{SSB} \\ & + \beta_4\,\text{income} + \beta_5\,\text{education} + \beta_6\,\text{smoking} \\ & + \beta_7\,\text{alcohol drinking} + \beta_8\,\text{menopause (in women only)} \\ & + \beta_9\,\text{physical activity} + \beta_{10}\,\text{comorbidities} + \beta_{11}\,\text{BMI}\dagger \\ & + \beta_{12}\,\text{blood glucose}\dagger + \beta_{13}\,\text{blood triglycerides}\dagger \\ & + \beta_{14}\,\text{blood total cholesterol}\dagger + \beta_{15}\,\text{blood HDL}\dagger \\ & + \beta_{16}\,\text{total energy intake}\dagger + \beta_{17}\,\text{survey years} \end{aligned}$$

where † is the continuous; categories of other covariables were described in the measurements of covariates above.

The multivariate model was additionally adjusted for these factors as well as sodium intake. Linear trends across SSB categories were tested by using the median intake frequency within SSB category in logistic regression analysis. The overall interaction of SSB and obesity and gender was tested in a multivariate model.

All $P < 0.05$ were considered to be statistically significant. The statistical analyses were performed using SAS statistical software (version 9.3; SAS Institute Inc., Cary, NC, USA).

Results

Of 9869 total participants, 14.5 % were classified as newly diagnosed with hypertension. The mean or proportion of BMI, alcohol consumption, physical activity, education, income, and survey year for men and women, and the energy intake and menopausal status for women, were different in the hypertension and non-hypertension groups ($P < 0.05$). There was a significant difference in the

distribution of prevalence of hypertension and carbonated SSB intake between men and women. Therefore, we analyzed the data in subgroups by gender. Compared with the non-hypertension group, participants presenting with hypertension were generally older, had a higher prevalence of alcohol consumption, and lower mean education and income levels. Despite higher reported rates of vigorous exercise and lower daily total energy intake, the hypertension group was also more likely to be obese (Table 1).

In the entire population, the likelihood of hypertension in the third, fourth, and fifth quintiles of carbonated SSB intake increased to 1.03, 1.20, and 1.42, respectively, compared to participants in the lowest quintile, after adjusting for age, sex, smoking, alcohol consumption, physical activity, income, education, survey year, comorbidities, body mass index, blood glucose, triglycerides, total cholesterol, HDL, total energy intake, menopausal status (not applicable to men), and sodium intake. Although the 95 % confidence interval [CI] of odds ratio for the third and fourth quintile was not significant, there was a significant positive trend (P value for trend = 0.0086) (Table 2). Participants in the fifth quintiles for men and women showed an increased likelihood of hypertension, with ORs of 1.41 (95 % CI, 1.01–1.96) and 1.45 (95 % CI, 1.02–2.07), respectively. Although the confidence intervals of the OR for the third and fourth quintiles were not significant, the trend for increased likelihood of hypertension according to carbonated SSB intake was significant for both sexes (P value for trend <0.05) (Table 2).

Table 3 shows the association between SSB intake and hypertension prevalence according to obesity in the stratified group by sex. The P value of the overall interaction between SSB and sex and obesity was 0.043. In the group of obese men, the observed increased likelihood of hypertension by carbonated SSB intake was not significant. In the group of non-obese men, compared to the participants in the lowest tertile of carbonated SSB intake, participants in the second and third tertiles showed an increased likelihood of hypertension, with OR of 1.36 (95 % CI, 0.93–2.00) and 1.75 (95 % CI 1.23–2.49), respectively. The trend for the increased likelihood of hypertension according to carbonated SSB intake was significant (P value for trend = 0.0074). In the group of obese women, the likelihood of hypertension in the second and third tertile for carbonated SSB intake increased to 1.18 and 2.00, respectively. Although the CI for the OR of the second tertile was not significant, there was a significant trend (P value for trend = 0.0067). However, no association between carbonated SSB intake and the likelihood of hypertension was observed in non-obese women.

Discussion

The present study documents the independent relationship between carbonated SSB intake and the likelihood of hypertension in an Asian population, and the gender differences of the relationship according to obesity. Even though recent studies have reported associations between hypertension and high consumption of SSBs (Brown et al. 2011; Kim et al. 2012; Malik et al. 2014), it is unclear whether the association between SSB consumption and risk of hypertension is caused by the SSBs per se, or through some other mechanism. It has been suggested that increased salt consumption, which was accompanied by increased SSB consumption, was one of the mechanisms for the relationship between hypertension and high consumption of SSBs (Grimes et al. 2013; He et al. 2008). However, after we adjusted for sodium intake, the independent relationship between carbonated SSB intake and the likelihood of hypertension remained unaffected and significant. Another proposed mechanism for the independent relationship between carbonated SSB consumption and the likelihood of hypertension was that high carbonated SSB consumption led to obesity and metabolic syndrome, and secondarily raised BP level (Barrio-Lopez et al. 2013). However, the results of subgroup analysis according to obesity and gender, in our study were notable (Table 3). No association between carbonated SSB consumption and the likelihood of hypertension was shown in non-obese women; on the other hand, in obese women, the likelihood of hypertension in the second and third tertile for carbonated SSB consumption increased to 1.2 and 1.79, respectively. Although the CI for the OR of the second tertile was not significant, there was a significant positive trend (P value for trend = 0.0051) for obese women. As shown in previous animal studies, females, unlike males, did not develop fructose-induced hypertension (Kamari et al. 2012). A positive association between testosterone levels and risk of hypertension in women has been reported (Klein et al. 2013; Ziemens et al. 2013). Active androgen synthesis in adipose tissue of obese women might contribute to the positive trend of the increased risk of association between carbonated SSB consumption and the likelihood of hypertension in obese women (Quinkler et al. 2004).

In contrast, non-obese men in the third tertile for carbonated SSB consumption showed a 50 % increase in the likelihood of hypertension compared to non-obese men in the lowest tertile. However, in obese men, the increased likelihood of hypertension by carbonated SSB consumption was only marginally significant. Gonadectomy was shown to prevent mRNA overexpression of vascular cyclooxygenase-2 and hypertension in fructose-fed male rats, which suggests that androgens are needed for the development of

Table 1 Baseline characteristics of adults participated in the Korea Health and Examination Survey (KNHANES) 2007–2009

Variables	Men			Women		
	Hypertension[a] ($n = 639$)	Non-Hypertension ($n = 3206$)	*P* value	Hypertension[a] ($n = 398$)	Non-Hypertension ($n = 5626$)	*P* value
Age (year)	42.5 ± 0.5	37.8 ± 0.3	<.0001	47.4 ± 0.6	38.5 ± 0.2	<.0001
SBP (mmHg)	134.6 ± 0.6	112.9 ± 0.2	<.0001	139.7 ± 0.9	106.4 ± 0.2	<.0001
DBP (mmHg)	94.6 ± 0.3	75.8 ± 0.2	<.0001	92.5 ± 0.4	70.7 ± 0.2	<.0001
Body mass index (kg/m^2)	25.3 ± 0.2	23.8 ± 0.1	<.0001	25.0 ± 0.2	22.5 ± 0.1	<.0001
Blood glucose (mg/dl)	101.0 ± 1.1	94.7 ± 0.4	<.0001	98.8 ± 1.3	91.6 ± 0.3	<.0001
Blood triglyceride (mg/dl)	193.3 ± 6.7	143.8 ± 2.2	0.0481	136.1 ± 5.5	97.4 ± 1.0	<.0001
Blood total cholesterol (mg/dl)	199.3 ± 1.7	183.6 ± 0.7	0.2384	203.4 ± 2.0	180.7 ± 0.6	<.0001
High-density lipoprotein (mg/dl)	48.5 ± 0.6	47.4 ± 0.3	0.0679	53.8 ± 0.8	54.1 ± 0.3	0.0256
Carbonated SSB (times/week)	1.1 ± 0.1	1.2 ± 0.0	0.0511	0.5 ± 0.1	0.7 ± 0.0	0.0108
Energy intake (Kcal/day)	2329.6 ± 36.6	2320.3 ± 20.9	0.8219	1601.6 ± 37.1	1651.1 ± 11.3	0.0146
Sodium intake (mg/day)	6102.1 ± 138.2	6033.5 ± 66.1	0.6510	4122.4 ± 139.8	4248.7 ± 45.2	0.3858
Smoking (%)						
Non-smoker	119 (19.1)	636 (20.7)	0.1233	358 (89.5)	4945 (85.9)	0.0296
Past smoker	222 (32.8)	970 (28.3)		11 (2.6)	328 (7.1)	
Current, 1 ≤ 2 packs per day	139 (25.0)	807 (27.4)		20 (5.8)	283 (6.2)	
Current, more than 2 packs per day	152 (23.1)	776(23.6)		5 (2.1)	46 (0.9)	
Alcohol intake (%)						
Non-drinker	19 (2.9)	133(3.6)	<.0001	74(16.3)	729(12.2)	0.0002
Less than once a month	84 (12.4)	682 (20.5)		142 (35.5)	2309 (39.6)	
Once a month—less than heavy drinker[b]	327 (50.9)	1697 (54.2)		136 (37.4)	2287 (42.6)	
Heavy drinker	200 (33.9)	675 (21.6)		42 (10.7)	268 (5.6)	
Physical activity (%)						
Do not exercise/walk sometimes	262 (41.8)	1271 (40.5)	0.0480	160 (42.2)	2547 (46.1)	0.0373
Regularly walk	165 (26.8)	945 (31.0)		111 (27.0)	1630 (30.3)	
Regular moderate-level activity	44 (7.2)	299 (8.4)		50 (10.9)	522 (8.5)	
Regular vigorous-level activity	157 (24.3)	651 (20.1)		70 (20.0)	856 (15.2)	
Education (%)						
Less than middle school	95 (12.9)	308 (6.7)	<.0001	136 (26.5)	792 (10.7)	<.0001
Middle school	83 (10.6)	338 (8.5)		69 (19.6)	605 (9.9)	
High school	193 (29.7)	970 (29.8)		146 (40.4)	2023 (36.8)	
College or higher degree	259 (46.9)	1572 (55.0)		43 (13.5)	2175 (42.6)	
Income quartile (%)						
1st (lowest)	187 (28.8)	753 (23.3)	0.0021	117 (27.2)	1309 (22.7)	0.0152
2nd	159 (25.5)	787 (24.0)		108 (26.4)	1326 (23.9)	
3rd	158 (25.5)	788(24.3)		89 (22.5)	1448 (25.9)	
4th (highest)	127 (18.8)	811(25.8)		80 (22.5)	1429 (25.0)	
Survey year (%)						
2007	87 (13.9)	578 (21.3)	<.0001	39 (11.5)	1002 (20.2)	<.0001
2008	176 (30.0)	1294 (41.6)		120 (31.4)	2270 (40.4)	
2009	376 (56.1)	1334 (37.0)		239 (57.1)	2354 (39.4)	
Menopause (%)						
No	–	–		203(56.7)	4276(80.5)	<.0001
Yes	–	–		195(43.3)	1350(19.5)	

Table 1 continued

Variables	Men			Women		
	Hypertension[a] ($n = 639$)	Non-Hypertension ($n = 3206$)	*P* value	Hypertension[a] ($n = 398$)	Non-Hypertension ($n = 5626$)	*P* value
Comorbidity[c] (%)						
No	599 (94.3)	3004 (95.1)	0.4127	369 (93.7)	5320 (95.3)	0.1918
Yes	40 (5.7)	202 (4.9)		29 (6.3)	306 (4.7)	

All data represent mean ± standard error or number (%) of participants

SBP systolic blood pressure, *DBP* diastolic blood pressure, *SSB* sugar-sweetened beverages

[a] Hypertension was defined as having a systolic blood pressure of 140 mmHg or higher, or a diastolic blood pressure of 90 mmHg or higher

[b] Heavy drinker was defined as consuming alcohol twice or more per week and having at least seven drinks/occasion for men and five drinks/occasion for women

[c] Comorbidities included the diagnosis of diabetes, cerebrovascular disease, acute coronary syndrome, chronic renal failure, lung cancer, gastric cancer, liver cancer, colon cancer, breast cancer, and uterine and cervical or cancer

Table 2 Odds ratio (95 % confidence interval) of the likelihood of hypertension according to carbonated sugar-sweetened beverage intake among the adults in the Korea Health and Examination Survey (KNHANES) 2007–2009

Category	No. of participants	Range of total carbonated SSB intake (times/week)	Median of total carbonated SSB intake (times/week)	No. of cases	Age and sex adjusted ORs (95 % CI)	Multivariate-adjusted ORs[a] (95 % CI)	Multivariate + sodium intake-adjusted ORs[b] (95 % CI)
Total							
Q1	3721	0	0	392	Reference	Reference	Reference
Q2							
Q3	2372	0.15–0.25	0.25	236	1.10 (0.9–1.33)	1.03 (0.84–1.28)	1.03 (0.84–1.28)
Q4	2367	0.63–1.00	1.5	245	1.17 (0.94–1.45)	1.19 (0.95–1.49)	1.20 (0.96–1.49)
Q5	1409	2.3–21.00	2.3	164	1.41 (1.08–1.84)	1.42 (1.06–1.89)	1.42 (1.06–1.89)
			P value for trend[c]		0.0137	0.0086	0.0086
Men							
Q1	1081	0	0	198	Reference	Reference	Reference
Q2	320	0.15–0.15	0.15	47	0.87 (0.61–1.26)	0.75 (0.50–1.12)	0.75 (0.51–1.12)
Q3	979	0.25–0.63	0.25	164	1.13 (0.88–1.46)	1.12 (0.84–1.48)	1.12 (0.84–1.47)
Q4	652	1.00–1.00	1.00	98	1.04 (0.76–1.42)	1.16 (0.83–1.62)	1.16 (0.83–1.62)
Q5	813	2.30–21.00	2.30	132	1.25 (0.92–1.70)	1.41 (1.01–1.97)	1.41 (1.01–1.96)
			P value for trend[c]		0.0890	0.0246	0. 0249
Women							
Q1	2640	0	0	194	Reference	Reference	Reference
Q2							
Q3	699	0.15–0.15	0.15	43	1.09 (0.73–1.60)	1.00 (0.67–1.49)	1.00 (0.67–1.49)
Q4	1463	0.25–0.63	0.25	89	1.33 (0.97–1.82)	1.25 (0.89–1.75)	1.25 (0.89–1.75)
Q5	1222	1.00–21.00	1	72	1.67 (1.18–2.37)	1.45 (1.02–2.06)	1.45 (1.02–2.07)
			P value for trend[c]		0.0035	0.0365	0. 0376

SSB sugar-sweetened beverages, *CI* confidence interval, *ORs* odds ratios, *Q* quintile

[a] Multivariate-adjusted models were adjusted for age, sex, smoking, alcohol intake, physical activity, income, education, survey year, comorbidities, body mass index, blood glucose, triglycerides, total cholesterol, HDL, total energy intake and menopausal state(not applicable to men)

[b] Multivariate + sodium intake-adjusted models: sodium intake was additionally adjusted in multivariate model

[c] Tests for linear trends across categories were conducted by using the median intake frequency within SSB category in survey logistic regression analysis

Table 3 Odds ratio (95 % confidence interval) of the likelihood of hypertension according to carbonated sugar-sweetened beverage intake among the adults in the Korea Health and Examination Survey (KNHANES) 2007–2009

Category	No. of participants	Range of total carbonated SSB intake (times/week)	Median of total carbonated SSB intake (times/week)	No. of cases	Age and sexadjusted ORs (95 % CI)	Multivariate-adjusted ORs[a] (95 % CI)	Multivariate + sodium intake-adjusted ORs[b] (95 % CI)
Men							
Obese							
T1	499	0.00–0.15	0	121	Reference	Reference	Reference
T2	330	0.25–0.63	0.25	83	1.03 (0.72–1.49)	1.06 (0.72–1.56)	1.06 (0.72–1.55)
T3	511	1.00–14.00	2.3	118	1.01 (0.71–1.43)	1.15 (0.78–1.69)	1.15 (0.78–1.70)
			P value for trend[c]		0.9735	0.6199	0.6049
Non-obese							
T1	893	0	0	123	Reference	Reference	Reference
T2	647	0.25-0.63	0.25	80	1.29 (0.92–1.80)	1.36 (0.92–1.99)	1.36 (0.93–2.00)
T3	951	0.23–14.00	2.3	111	1.32 (0.95–1.82)	1.75 (1.23–2.48)	1.75 (1.23–2.49)
			P value for trend[c]		0.2396	0.0074	0.0074
Women							
Obese							
T1	599	0	0	81	Reference	Reference	Reference
T2	340	0.15–0.25	0.25	43	1.31 (0.84–2.04)	1.19 (0.72–1.95)	1.18 (0.71–1.94)
T3	415	0.63–21.00	1	60	2.06 (1.31–3.23)	1.98 (1.2–3.27)	2.00 (1.21–3.31)
			P value for trend[c]		0.0015	0.0079	0.0067
Non-obese							
T1	2031	0	0	110	Reference	Reference	Reference
T2	1161	0.15-0.25	0.25	48	1.00 (0.68–1.49)	0.90 (0.59–1.37)	0.91 (0.60–1.39)
T3	1463	0.63–21.00	1	52	1.30 (0.86–1.96)	1.20 (0.78–1.84)	1.20 (0.79–1.85)
			P value for trend[c]		0.2012	0.3742	0.3725

SSB sugar-sweetened beverages, *CI* confidence interval, *ORs* odds ratios, *T* tertile

[a] Multivariate-adjusted models were adjusted for age, sex, smoking, alcohol intake, physical activity, income, education, survey year, comorbidities, body mass index, blood glucose, triglycerides, total cholesterol, HDL, total energy intake and menopausal state(not applicable to men)

[b] Multivariate + sodium intake-adjusted models: sodium intake was additionally adjusted in multivariate models

[c] Tests for linear trends across categories were conducted by using the median intake frequency within SSB category in survey logistic regression analysis

fructose-induced hypertension (Song et al. 2004). Furthermore, studies have reported sex differences in the development of hypertension in fructose-fed rats (Galipeau et al. 2002; Song et al. 2004; Vasudevan et al. 2005). Population and interventional data suggested that a bidirectional relationship exists between testosterone levels and obesity in men, with lower total testosterone levels and sex hormone binding globulin levels than their non-obese counterparts (Allan and McLachlan 2010). Studies on chronic, non-communicable diseases have reported sex-specific differences (Song et al. 2014a, b; Vlassoff 2007; Wang et al. 2014). According to the results of our study, we suggested that obesity could interfere in the independent relationship between carbonated SSB consumption and the likelihood of hypertension.

Our study had several limitations. First, with a cross-sectional design, causal relationships cannot be confirmed. To reduce the influence of this limitation on the results, we excluded data from those who were diagnosed with or had received treatment for hypertension. However, a randomized controlled trial design would have provided more reliable evidence. The second limitation was that we did not have measured values for estrogen and testosterone. Even though data for sex hormones was needed to clarify their effect on the association between SSB consumption and the likelihood of hypertension, the 4th KNHANES data did not have data on sex hormones. The third limitation of our research was the diagnosis of hypertension. We could not obtain three measurements of blood pressure in different weeks. Therefore, the number of patients with

hypertension could be overestimated. Lastly, the majority of the study subjects were Asian. Our results need to be further validated using different ethnic groups.

In conclusion, the present study showed a clear sex difference in the relationship between carbonated SSB intake and the likelihood of hypertension according to obesity. Interventions to reduce intake of carbonated SSB should be an important part of public health strategy to reduce the incidence and prevalence of hypertension, especially in non-obese men and obese women.

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