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Association between changes in facial flushing and hypertension across drinking behavior patterns in South Korean adults

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Abstract

Heavy alcohol drinking has been reported to be associated with hypertension. Moreover, when drinking alcohol, individuals may experience symptoms such as facial flushing. Therefore, this study aimed to examine the association between changes in facial flushing and hypertension across different drinking behavior patterns in South Korean adults.

Data from the Korea Community Health Survey conducted in 2019 were used, and 118 129 (51 047 men and 67 082 women) participants were included. The participants were divided into five groups based on the change in facial flushing (non-drinking, non-flushing to non-flushing, flushing to flushing, non-flushing to flushing, flushing to non-flushing). The risk of hypertension in each facial flushing group was analyzed by multiple logistic regression.

Men in the non-flushing to flushing group had a significantly higher association with hypertension than other groups (men: odds ratio (OR) 1.42, confidence interval (CI) 1.14–1.76). According to the level of alcohol use disorder, the non-flushing to flushing group showed a significantly increased odds of hypertension compared to all levels of drinking (men: mild drinking: OR 1.95, CI 1.40–2.71; moderate drinking: OR 2.02, CI 1.41–2.90; women: moderate drinking: OR 1.71, CI 1.16–2.52; heavy drinking: OR 1.90, CI 1.19–3.04).

This study found a significant association between changes in facial flushing and hypertension among adults in South Korea. In particular, individuals who changed from non-flushing to flushing reactions had an increased association with hypertension than the other groups. Compared to people at the same drinking level, people with non-flushing to flushing reactions were highly associated with hypertension at moderate drinking level.

KEYWORDS
alcohol use disorder, Asian flushing, facial flushing, hypertension

1 | INTRODUCTION

Hypertension is a commonly occurring and leading preventable risk factor for cardiovascular disease and a subject of great interest to researchers.[1] The Global Burden of Disease study found that hypertension is at risk of placing an increasing economic burden on societies globally.[2,3,4] In South Korea, neoplasms caused 158.2 deaths per 100 000 in 2019. In comparison, diseases of the circulatory system caused 117.8 deaths. These included cardiovascular diseases (60.4 deaths) and cerebrovascular diseases (40.2 deaths).[5] It is well recognized that hypertension is associated with traditional risk factors such as age, body mass index (BMI), smoking, and family history.[6] Additionally, drinking behavior, especially excessive or frequent drinking, is also a risk factor for hypertension.[7,8]

When drinking alcohol, some people experience facial flushing or palpitations, shortness of breath, headache, and vomiting due to the accumulation of acetaldehyde.[9] In particular, East Asian ethnic groups, such as Korean, Chinese, and Japanese populations, have a higher prevalence of ALDH2 polymorphism than the Western population.[10,11] Ethanol is metabolized by alcohol dehydrogenase (ADH) to acetaldehyde, which is eliminated by aldehyde dehydrogenase (ALDH).[12] Alcohol dependence is associated with the isozymes ADH2*2 and ADH3*1, which oxidize alcohol rapidly and produce high amounts of acetaldehyde.[13] Moreover, the ALDH2 polymorphism encodes an inactive subunit,[14,15] resulting in high acetaldehyde levels in the blood after alcohol intake.[11,16]

A previous study suggested a greater association with hypertension in people who have alcohol-related facial flushing than non-flushers.[17] Moreover, the risk of hypertension in facial flushers is markedly increased with excessive drinking.[18] More research on specific genotypes associated with alcohol metabolism are necessary because the specific genotypes associated with alcohol metabolism are common in South Korean populations. To the best of our knowledge, no study has examined the association between facial flushing and hypertension changes. Therefore, we examined the association between change in facial flushing and hypertension across different drinking behavior patterns, such as alcohol use disorders, to fill this research gap. We focused both on the presence and absence of facial flushing as well as the occurrence or elimination of facial flushing with time in adults.

2 | METHODS

We used data from the Korea Community Health Survey (KCHS) conducted by the Korea Center for Disease Control and Prevention (KCDC) in 2019. The KCHS is a cross-sectional, nationally representative survey that has been conducted regularly since 2008 to gather regional data for planning, monitoring, and evaluating community health services. The data for providing country-level health indicators is made using a large population-based National Census Registry and a systematic, stratified, and multistage cluster sampling method. The weights allocated to each participant's data were calculated based on geographic and demographic distributions to generalize the entire population of Korea.

2.1 | Participants

The 2019 survey included 229 099 individuals, and the analysis excluded individuals who were younger than 19 years of age (n = 2200) and pregnant (n = 641). In addition, we excluded individuals who had been undergoing anti-hypertensive drug treatment were excluded (n = 62 286). Some anti-hypertensive drugs cause facial flushing.[19,20] Finally, after excluding those with missing data (n = 45 843), 118 129 healthy participants were included in this study.

Our study did not require approval from the Institutional Review Board or informed consent because the KCHS is a secondary dataset available in the public domain and does not contain private information.

2.2 | Variables

The dependent variable of this study was the risk of hypertension. Blood pressure was measured thrice with intervals of 1 minute for stabilization, and the final blood pressure was the average of the three measurements. Hypertension was classified as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg.[21] We classified those who met the hypertension criteria and those who did not meet the hypertension criteria when measuring blood pressure, except for taking anti-hypertensive drugs.

Facial flushing reaction was the primary independent variable of interest. The following question assessed past facial flushing reaction: "In the past year or two, did you experience a quick facial flushing reaction when drinking a small glass of beer?" A current facial flushing reaction was assessed by asking the following question: "Do you currently experience a facial flushing reaction when drinking a small amount of beer?" The data on past and present facial flushing reactions were self-reported.

We divided the study population into five categories: people who have never drunk alcohol (ND, non-drinking); people who never had facial flushing reaction (NN, non-flushing→ non-flushing); people who had facial flushing reaction in the past and present (FF, flushing→ flushing); people who had facial flushing reaction in the past but not in the present (FN, flushing→ non-flushing); and people who did not have facial flushing reaction in the past but did in the present (NF, non-flushing→ flushing). Furthermore, we analyzed each group stratified by variables such as alcohol use.

We controlled for covariates such as sociodemographic and socioeconomic factors, health behaviors, and health conditions of the participants. The sociodemographic factors were age (19–29, 30–39, 40–49, 50–59, and ≥60 years) and sex (men and women). The socioeconomic factors were education level (below middle school, high school, and college or higher), region (city and rural areas), marital status (yes and no), occupation (white-collar, pink collar, blue-collar, and unemployed),

and household income (high, middle high, middle-low, and low). Health behavior factors included smoking status (non-smoker, past smoker, and current smoker), BMI (non-obese and obese), diagnosis of diabetes (yes and no), and physical activity assessed to walking practice rate (yes and no). In the female group, menopause status was added (yes and no). Additionally, we used the Alcohol Use Disorder Identification Test Score (AUDIT-C) to assess the pattern of alcohol use. Cut-off scores of AUDIT-C for heavy alcohol drinking were 7 for men and 6 for women, and mild alcohol drinking were 3 for both men and women.[22]

2.3 | Statistical analysis

Independent variables were compared using the chi-squared test to identify the association between changes in facial flushing and hypertension. After adjusting for sociodemographic, economic, and health-related variables, we used a multiple logistic regression analysis to evaluate the association between the change of facial flushing and hypertension. The results were reported using odds ratios (ORs) and confidence intervals (CIs). Moreover, we performed a subgroup analysis stratified by sex and multiple logistic regression analysis was used to examine the associations with change in facial flushing in persons with hypertension according to the level of alcohol use disorder. Differences were considered significant at *P*-values of <.05 as well as at *P*-values for trends <.05. Data were analyzed using SAS 9.4 (SAS Institute Inc; Cary, North Carolina, USA) and a *P* value <.05 was considered to be statistically significant.

3 | RESULTS

Table 1 shows the general characteristics of the participants. There were 51 047 men and 67 082 women in this study, and 11 234 (22%) men and 10 406 (15.5%) women had a risk of hypertension. Participants were grouped into five categories based on the change in facial flushing reaction. Of the men, 5798 (11.4%) reported they have never drunk alcohol, 29 044 (56.9%) reported non-flushing to alcohol, 11 592 (22.7%) reported flushing in the past and present, 3711 (7.3%) reported facial flushing reaction in the past but not in the present, and 902 (1.8%) reported facial flushing reaction in the present but not in the past. Of the women, 18 060 (26.9%) reported they have never drunk alcohol, 32 616 (48.6%) reported non-flushing to alcohol, 11 476 (17.1%) reported flushing in the past and present, 3958 (5.9%) reported facial flushing reaction in the past but not in the present, and 972 (1.4%) reported facial flushing reaction in the present but not in the past.

Table 2 reports the findings of logistic regression analysis for the association between change in facial flushing and hypertension stratified by sex. Men in the NF group had a higher OR of hypertension than other groups (men: OR 1.42, CI 1.14–1.76); among women, there was no statistically significant relationship between change in facial flushing and hypertension. Additionally, participants who drink moderately (men: OR 1.20, CI 1.11–1.30, women: OR 1.16, CI 1.07–1.27) and heavily (men: OR 1.83, CI 1.69–1.98, women: OR 1.93, CI 1.76–2.13) were strongly associated with an increased risk for hypertension.

Figure 1 shows the results of stratified analyses of the association of the changes in facial flushing on hypertension according to alcohol consumption. Overall, taking the non-drinking group as the reference category, the OR of the NF was high in mild and moderate drinking levels among men. (mild drinking: OR 1.95, CI 1.40–2.71; moderate drinking: OR 2.02 CI, 1.41–2.90). Also, the OR of the NF was high in moderate and heavy drinking levels among women. (moderate drinking: OR 1.71, CI 1.16–2.52; heavy drinking: OR 1.90 CI, 1.19–3.04)

Finally, Table 3 reports the subgroup analysis stratified by independent variables. Men diagnosed with diabetes had an increased association with hypertension in the NF group (OR 2.24, CI 1.22–4.11). Additionally, men who did not exercise had an increased risk of hypertension in the NF group (OR 1.68, CI 1.26–2.25).

4 | DISCUSSION

We found that change in facial flushing reaction was associated with a higher risk of hypertension. Especially, individuals with facial flushing reaction in the present but not in the past increased the likelihood of hypertension, and we also examined individuals who consumed similar alcohol levels. The association between flushing changes and hypertension was different for each alcohol consumption level. Among those who drink mild or moderate, men who did not have facial flushing reaction in the past but did in the present were the highest likelihood of hypertension. And women who did not have facial flushing reaction in the past but did in the present were the highest likelihood of hypertension among moderate drinking group.

Some studies link hypertension and alcohol-induced facial flushing.[17,23] The likelihood of hypertension was higher in people with facial flushing than in those without facial flushing in previous study. In the result of our study, the difference between the two group was not significant. Since previous studies considered only current facial flushing, different results may have been derived from our study. While polymorphisms partly explained the association in alcohol metabolism genes,[24] these studies did not find any evidence that facial flushing reaction is associated with the risk of hypertension.[25,26] Therefore, further studies are necessary.

In this study, we assessed the association between the presence of facial flushing and alcohol consumption. The reasons for the change in facial flushing can be explained as follows. Facial flushing is a well-known symptom of acetaldehyde accumulation and intolerance to alcohol.[9] Some studies showed that the genotype of ADH and ALDH was associated with liver disease.[27,28–30] Chronic alcoholics have a higher tolerance to alcohol than others because of the metabolic adaptation of the central nervous system and increased ethanol elimination rate.[31] Increased ethanol elimination increases both blood and tissue acetaldehyde levels in chronic alcoholics.[32] People with liver injury experience decreasing activities of ADH and proportionally low-K ALDH (ALDH2).[33] It is speculated that the decrease in ADH could be due to centrilobular cell necrosis.[33,34] Thus, decrease in liver

TABLE 1 General characteristics of the study population

	Hypertension													
	Men							Women						
	TOTAL		Yes		No			TOTAL		Yes		No		
Variables	No.	%	No.	%	No.	%	*P*	No.	%	No.	%	No.	%	*P*
Total 118 129	51,047	100.0	11 234	22.0	39 813	78.0		67 082	100.0	10 406	15.5	56 676	84.5	
Facial flushing change														
non-drinking	5798	11.4	1142	19.7	4656	80.3	<.0001	18 060	26.9	3789	21.0	14 271	79.0	<.0001
non-flushing →non-flushing	29 044	56.9	6530	22.5	22 514	77.5		32 616	48.6	4271	13.1	28 345	86.9	
flushing →flushing	11 592	22.7	2414	20.8	9178	79.2		11 476	17.1	1560	13.6	9916	86.4	
non-flushing →flushing	902	1.8	255	28.3	647	71.7		972	1.4	201	20.7	771	79.3	
flushing →non-flushing	3711	7.3	893	24.1	2818	75.9		3958	5.9	585	14.8	3373	85.2	
Age (years)														
19-29	8467	16.6	816	9.6	7651	90.4	<.0001	8966	13.4	242	2.7	8724	97.3	<.0001
30-39	9619	18.8	1818	18.9	7801	81.1		10 200	15.2	714	7.0	9486	93.0	
40-49	10 865	21.3	2699	24.8	8166	75.2		13 644	20.3	1683	12.3	11 961	87.7	
50-59	9859	19.3	2560	26.0	7299	74.0		14 468	21.6	2513	17.4	11 955	82.6	
≥60	12 237	24.0	3341	27.3	8896	72.7		19 804	29.5	5254	26.5	14 550	73.5	
Marital Status														
Living w/ spouse	33 383	65.4	7703	23.1	25 680	76.9	<.0001	44 096	65.7	6883	15.6	37 213	84.4	.3433
Living w/o spouse	17 664	34.6	3531	20.0	14 133	80.0		22 986	34.3	3523	15.3	19 463	84.7	
Region														
City	16 621	32.6	3565	21.4	13056	78.6	0.035	22 173	33.1	3047	13.7	19 126	86.3	<.0001
Rural	34 426	67.4	7669	22.3	26757	77.7		44 909	66.9	7359	16.4	37 550	83.6	
Educational level														
Middle school or less	7795	15.3	2147	27.5	5648	72.5	<.0001	18 886	28.2	5098	27.0	13 788	73.0	<.0001
High school	15 344	30.1	3830	25.0	11514	75.0		20 188	30.1	3155	15.6	17 033	84.4	
College or over	27 908	54.7	5257		22651			28 008	41.8	2153		25 855		
Household Income														
Low	8740	17.1	2225	25.5	6515	74.5	<.0001	15 401	23.0	3760	24.4	11 641	75.6	<.0001
Mid-low	8574	16.8	2083	24.3	6491	75.7		11 184	16.7	1918	17.1	9266	82.9	
Mid-high	15 395	30.2	3407		11 988			18 056	26.9	2405		15 651		
High	18 338	35.9	3519	19.2	14819	80.8		22 441	33.5	2323	10.4	20 118	89.6	

(Continues)

TABLE 1 (Continued)

	Hypertension												
	Men							Women					
	TOTAL		Yes		No			TOTAL		Yes		No		
Variables	No.	%	No.	%	No.	%	*P*	No.	%	No.	%	No.	%	*P*
Occupational categories[a]														
White	14 534	28.5	2932	20.2	11 602	79.8	<.0001	15 564	23.2	1270	8.2	14 294	91.8	<.0001
Pink	6192	12.1	1270	20.5	4922	79.5		12 044	18.0	1775	14.7	10 269	85.3	
Blue	20 477	40.1	4929	24.1	15 548			12 620	18.8	2730	21.6	9890		
Inoccupation	9844	19.3	2103	21.4	7741	78.6		26 854	40.0	4631	17.2	22 223	82.8	
Smoking														
Non smoker	15 180	29.7	2666	17.6	12 514	82.4	<.0001	63 027	94.0	9673	15.3	53 354	84.7	<.0001
past smoker	17 362	34.0	4218	24.3	13 144	75.7		1998	3.0	331	16.6	1667	83.4	
smoker	18 505	36.3	4350	23.5	14 155	76.5		2057	3.1	402	19.5	1655	80.5	
BMI														
Non-obesity	48 115	94.3	10 145	21.1	37 970	78.9	<.0001	64 865	96.7	9725	15.0	55 140	85.0	<.0001
Obesity	2932	5.7	1089	37.1	1843	62.9		2217	3.3	681	30.7	1536	69.3	
Diagnose of diabetes														
Yes	3152	6.2	794	25.2	2358	74.8	<.0001	3323	5.0	749	22.5	2574	77.5	<.0001
No	47 895	93.8	10 440	21.8	37 455	78.2		63 759	95.0	9657	15.1	54 102	84.9	
Physical activity-walk														
Yes	28 240	55.3	6226	22.0	2 2014	78.0	0.810	40 054	59.7	6323	15.8	33 731	84.2	0.017
No	22 807	44.7	5008	22.0	17 799	78.0		27 028	40.3	4083	15.1	22 945	84.9	
Menopausal status														
Yes								32 882	49.0	7576	23.0	25 306	77.0	<.0001
No								34 200	51.0	2830	8.3	31 370	91.7	
Alcohol use disorder														
Mild drinking & Non-drinking	16 560	32.4	3153	19.0	13 407	81.0		44 918	67.0	7512	16.7	37 406	83.3	
Moderate drinking	15 746	30.8	3174	20.2	12 572	79.8	<.0001	12 595	18.8	1497	11.9	11 098	88.1	<.0001
Heavy drinking	18 741	36.7	4907	26.2	13 834	73.8		9569	14.3	1397	14.6	8172	85.4	

[a]Three groups(White, Pink, Blue) based on International Standard Classification Occupations codes. Inoccupation group includes housewife

TABLE 2 Results of factors associated with hypertension

	Hypertension			
	Men		Women	
Variables	OR	95% CI	OR	95% CI
Facial flushing change				
Non-drinking	1.00		1.00	
non-flushing →non-flushing	1.11	(0.99 - 1.25)	0.93	(0.86 - 1.01)
flushing →flushing	1.09	(0.97 - 1.22)	1.03	(0.94 - 1.13)
non-flushing →flushing	1.42	(1.14 - 1.76)	1.11	(0.90 - 1.37)
flushing →non-flushing	1.08	(0.93 - 1.24)	0.93	(0.81 - 1.06)
Age (years)				
19-29	1.00		1.00	
30-39	2.48	(2.22 - 2.77)	2.98	(2.50 - 3.56)
40-49	3.79	(3.38 - 4.24)	5.71	(4.82 - 6.77)
50-59	4.35	(3.87 - 4.90)	6.98	(5.68 - 8.57)
≥60	5.21	(4.57 - 5.94)	9.28	(7.47 - 11.54)
Marital Status				
Living wtih spouse	1.00		1.00	
Living without spouse	1.32	(1.23 - 1.42)	1.09	(1.01 - 1.16)
Region				
City	1.00		1.00	
Rural	0.99	(0.94 - 1.05)	1.01	(0.96 - 1.08)
Occupational categories[a]				
White	1.00		1.00	
Pink	0.95	(0.86 - 1.04)	1.06	(0.95 - 1.17)
Blue	1.04	(0.97 - 1.12)	1.12	(1.00 - 1.25)
Inoccupation	1.05	(0.95 - 1.15)	1.11	(1.01 - 1.22)
Educational level				
Middle shool or less	1.33	(1.20 - 1.47)	1.72	(1.54 - 1.92)
High school	1.22	(1.14 - 1.30)	1.31	(1.20 - 1.42)
College or over	1.00		1.00	
Household income				
Low	1.12	(1.02 - 1.22)	1.25	(1.14 - 1.37)
Mid-low	1.17	(1.08 - 1.28)	1.20	(1.10 - 1.32)
Mid-high	1.11	(1.04 - 1.19)	1.13	(1.05 - 1.23)
High	1.00		1.00	
Smoking				
Non smoker	1.00		1.00	
Past smoker	1.06	(0.98 - 1.14)	1.36	(1.16 - 1.61)
smoker	1.04	(0.97 - 1.12)	1.28	(1.10 - 1.48)
BMI				
Non-obesity	1.00		1.00	
Obesity	3.25	(2.94 - 3.59)	3.57	(3.08 - 4.14)
Diagnose of diabetes				
Yes	1.00		1.00	
No	1.17	(1.05 - 1.31)	1.06	(0.94 - 1.20)

(Continues)

TABLE 2 (Continued)

Variables	Hypertension			
	Men		Women	
	OR	95% CI	OR	95% CI
Physical activity-walk				
Yes	1.00		1.00	
No	0.91	(0.87 - 0.97)	0.96	(0.90 - 1.01)
Menopausal status				
Yes			1.17	(1.03 - 1.34)
No			1.00	
Alcohol use disorder				
mild drinking & non-drinking	1.00		1.00	
moderate drinking	1.20	(1.11 - 1.30)	1.16	(1.07 - 1.27)
heavy drinking	1.83	(1.69 - 1.98)	1.93	(1.76 - 2.13)

[a](White, Pink, Blue) based on International Standard Classification Occupations codes. Inoccupation group includes housewife

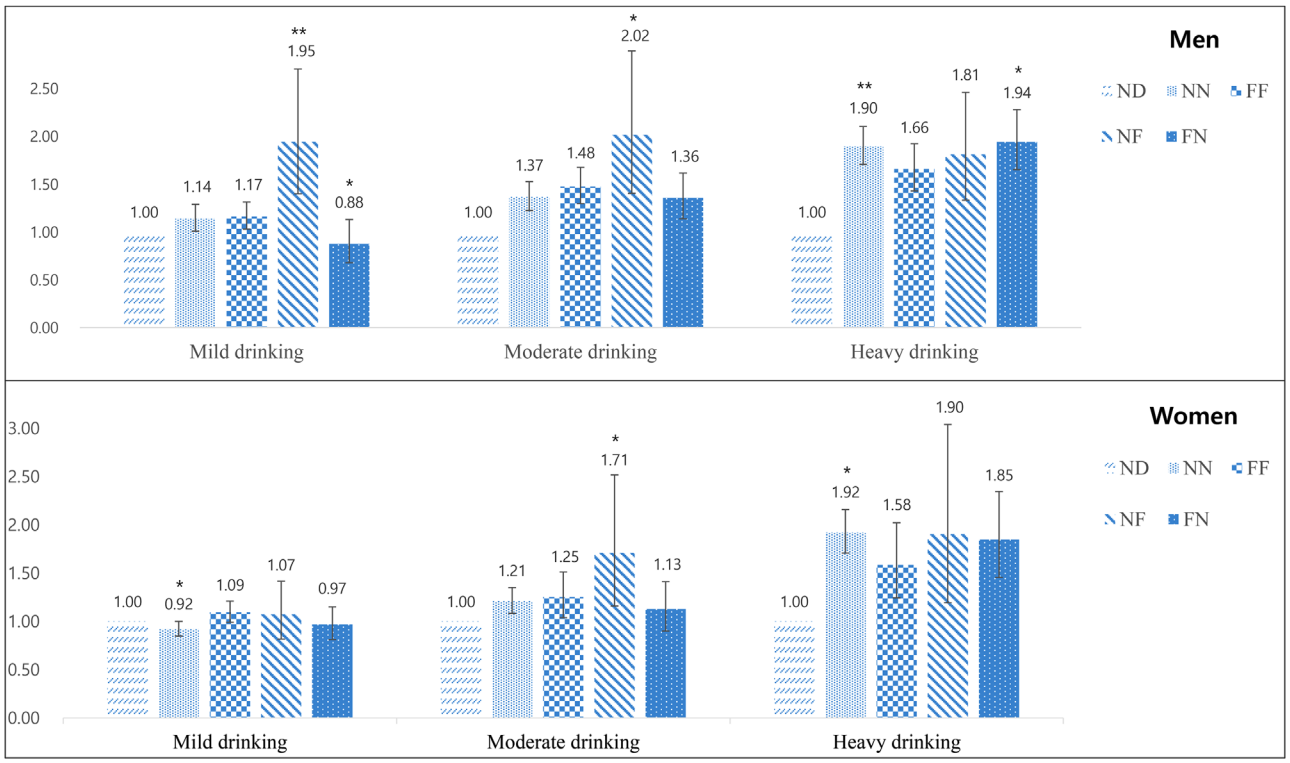

FIGURE 1 Stratified analysis of the changes in facial flushing with respect to hypertension by alcohol consumption

function may be associated with a decrease in the activity of the enzyme that metabolizes alcohol. This, in turn, leads to the accumulation of alcohol and acetaldehyde in the body and induces symptoms such as facial flushing.[9] Therefore, people who have liver disease with non-facial flushing in the past may develop a facial flushing reaction later.

In our study, people who did not have a facial flushing reaction in the past but did in the present were significantly associated with the risk of hypertension among those who were diagnosed with diabetes or did not exercise. Although the mechanism causing flushing is unknown, it is clear that this is not a good indication or reaction in the body. Research findings have indicated that ALDH2 polymorphism that causes facial flushing is related to cancer risk incidence according to alcohol intake. It is noteworthy that these studies mainly focused on upper oral pharyngeal and laryngeal cancer and esophageal squamous cell carcinoma.[35,36,37] Thus, if people have never had facial flushing to

TABLE 3 The results of subgroup analysis stratified by independent variables

	Hypertension								
	Facial flushing change								
	No-drinking	non-flushing → non-flushing		flushing → flushing		non-flushing → flushing		flushing → non-flushing	
Variables	OR	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Men									
Age									
19-29	1.00	1.17	(0.77 - 1.77)	1.11	(0.72 - 1.72)	1.16	(0.49 - 2.75)	1.11	(0.64 - 1.91)
30-39	1.00	1.16	(0.83 - 1.63)	0.95	(0.67 - 1.34)	1.52	(0.84 - 2.76)	1.05	(0.69 - 1.58)
40-49	1.00	1.29	(0.98 - 1.71)	1.22	(0.93 - 1.62)	1.61	(1.00 - 2.60)	1.17	(0.85 - 1.61)
50-59	1.00	0.96	(0.74 - 1.24)	1.10	(0.85 - 1.42)	1.40	(0.86 - 2.28)	1.00	(0.74 - 1.36)
≥60	1.00	1.04	(0.88 - 1.24)	1.14	(0.97 - 1.35)	1.39	(1.00 - 1.94)	1.13	(0.90 - 1.43)
Diagnose of diabetes									
Yes	1.00	0.97	(0.67 - 1.40)	0.97	(0.66 - 1.43)	2.24	(1.22 - 4.11)	0.68	(0.42 - 1.13)
No	1.00	1.13	(1.01 - 1.28)	1.11	(0.98 - 1.25)	1.35	(1.07 - 1.70)	1.12	(0.96 - 1.29)
BMI									
non-obesity	1.00	1.13	(1.01 - 1.27)	1.10	(0.98 - 1.24)	1.40	(1.11 - 1.76)	1.10	(0.95 - 1.28)
Obesity	1.00	0.91	(0.62 - 1.35)	1.00	(0.68 - 1.48)	1.58	(0.73 - 3.41)	0.80	(0.48 - 1.34)
Physical activity									
Yes	1.00	1.01	(0.86 - 1.20)	0.97	(0.82 - 1.14)	1.18	(0.85 - 1.63)	0.91	(0.73 - 1.13)
No	1.00	1.21	(1.03 - 1.42)	1.22	(1.04 - 1.42)	1.68	(1.26 - 2.25)	1.25	(1.04 - 1.52)
Women									
Age									
19-29	1.00	1.25	(0.68 - 2.29)	1.28	(0.66 - 2.46)	0.45	(0.09 - 2.14)	0.69	(0.29 - 1.63)
30-39	1.00	1.03	(0.71 - 1.51)	0.93	(0.61 - 1.41)	0.65	(0.28 - 1.48)	1.23	(0.75 - 2.04)
40-49	1.00	1.39	(1.10 - 1.76)	1.56	(1.21 - 2.01)	0.97	(0.56 - 1.69)	1.28	(0.94 - 1.75)
50-59	1.00	0.96	(0.82 - 1.12)	1.14	(0.96 - 1.35)	1.79	(1.26 - 2.56)	1.00	(0.78 - 1.28)
≥60	1.00	0.82	(0.73 - 0.91)	0.92	(0.80 - 1.07)	1.13	(0.79 - 1.62)	0.89	(0.71 - 1.11)
Diagnose of diabetes									
Yes	1.00	1.07	(0.82 - 1.39)	1.11	(0.79 - 1.56)	0.69	(0.35 - 1.38)	0.76	(0.44 - 1.33)
No	1.00	0.93	(0.86 - 1.01)	1.02	(0.93 - 1.12)	1.14	(0.92 - 1.42)	0.93	(0.81 - 1.07)
BMI									
Non-obesity	1.00	0.91	(0.84 - 0.99)	1.01	(0.92 - 1.12)	1.12	(0.88 - 1.43)	0.93	(0.81 - 1.07)
Obesity	1.00	1.47	(1.02 - 2.12)	1.43	(0.96 - 2.13)	1.17	(0.53 - 2.58)	1.08	(0.56 - 2.08)
Physical activity									
Yes	1.00	0.92	(0.82 - 1.04)	1.03	(0.90 - 1.19)	1.15	(0.82 - 1.61)	0.87	(0.71 - 1.06)
No	1.00	0.94	(0.85 - 1.04)	1.03	(0.91 - 1.16)	1.07	(0.82 - 1.40)	0.99	(0.83 - 1.18)

*Adjusted for other covariates

alcohol before but experience facial flushing now, people need to exercise caution with their alcohol intake. However, as there are no studies in the literature supporting this result, it is difficult to determine an absolute judgment.

This study has some limitations. First, this study was based on data from a cross-sectional survey. Therefore, although the association could be confirmed, the causality could not be evaluated. Second, our data were self-reported; thus, it is subject to recall bias and underreporting of drinking habits or experience of facial flushing. Therefore, the association of facial flushing with drinking may not be accurate. Moreover, we do not know how long it has been since changes in facial flushing were observed by participants. Third, although the cut-off points used for facial flushing are in accordance with KCHS, it may be difficult to compare our findings in different settings or populations.[38] Fourth, residual confounding factors may exit because taking some medication like steroid that cause facial flushing have not

been identified due to data limitation. These factors should be considered in future studies. Finally, due to lack of similar studies, it is difficult to explain all the findings in this study. Therefore, it is necessary to perform precise measurements of facial flushing in further studies.

Despite these limitations, this study has several strengths. We used the most recent nationally representative database to determine the association between facial flushing and hypertension. Therefore, the results obtained are highly representative of adults in South Korea. Furthermore, in our analysis, we adjusted for several social factors that are known potential confounders for facial flushing pattern or hypertension, including sex, socioeconomic status, and health behaviors, to appropriately estimate the associations across different drinking behavior patterns.

In conclusion, this study found a significant association between change in facial flushing and hypertension among adults in South Korea. In particular, individuals who changed from non-flushing to flushing reactions had an increased association with hypertension than those in the other groups. Compared to people at the same drinking level, people with non-flushing to flushing reactions were highly associated with hypertension at moderate drinking level.

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CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

Soo Hyun Kang conceived of the presented idea. Yu Shin Park and Soo Hyun Kang developed the theory and performed the computations. Yu Shin Park and Soo Hyun Kang verified the analytical methods. Eun Cheol Park and Suk Yong Jang encouraged Yu Shin Park to investigate facial flushing mechanism and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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SUPPORTING INFORMATION

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