Detrimental Effects of Higher Body Mass Index and Smoking Habits on Menstrual Cycles in Korean Women

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Abstract

Background: Alteration of menstrual cycle by individual lifestyles and unfavorable habits may cause menstrual irregularity. We aimed to investigate the relationship between lifestyle factors and menstrual irregularity in Korean women using data from the Fifth Korea National Health and Nutrition Examination Survey (KNHANES) 2010–2012.

Materials and Methods: This cross-sectional study included 3779 nondiabetic Korean women aged 19–49 years who did not take any oral contraceptives or sex hormonal compounds. We examined the association of menstrual irregularity with age, body mass index (BMI), drinking experience, and smoking habits.

Results: Age, Asian BMI, marriage status, age at menarche, and smoking habits were significantly associated with menstrual cycle irregularity ($p < 0.01$). The prevalence of menstrual irregularity was significantly increased at younger ages: 18.4%, 10.3%, and 10.5% at 19–29, 30–39, and 40–49 years, respectively. Moreover, obesity groups, defined as per Asian BMI using modified WHO criteria, were strongly associated with menstrual irregularity. BMI 25.0–29.9 [obesity class I] (adjusted odds ratios [OR], 1.94; 95% confidence intervals [CI], 1.37–2.74) and ≥ 30.0 [obesity class II] (adjusted OR, 2.18; 95% CI, 1.22–3.91) presented significantly higher risk of menstrual irregularity compared with BMI 18.5–22.9 [normal weight]. Multivariable analysis revealed that high BMI in younger women aged 19–29 years ($p < 0.001$) and smoking habits in middle-aged women aged 30–39 years ($p < 0.005$) significantly predicted menstrual irregularity.

Conclusion: This study substantiated that menstrual irregularity was closely associated with higher BMI and smoking habits in nondiabetic Korean women. Weight loss and smoking cessation should be recommended to promote women's reproductive health.

Keywords: menstrual cycle, KNHANES, body mass index, smoking, reproductive health

Introduction

REGULARITY OF THE MENSTRUAL cycle is related to a woman's reproductive health. A variety of endogenous and exogenous factors such as hormonal imbalance, nutrient deficiency, obesity, excessive exercise, mental or physical stress, and increased sex hormones could affect the hypothalamic-pituitary-ovarian axis.^{1,2} It has been reported that individual lifestyle factors such as obesity, exercise,

smoking, alcohol drinking, physical activity, and physical stress are related to menstrual irregularity,^{3–7} and it has been consistently reported that a woman's general physiology and function were related to an irregular menstrual cycle due to changes in hormone levels associated with lifestyle factors.

In particular, obesity affects various pregnancy complications, such as gestational diabetes, miscarriage-induced labor, preeclampsia, congenital anomalies, and fetal macrosomia.^{8,9} Obesity may disturb reproductive capacity through

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the influence of oocyte maturation, control of ovulation, endometrial development, embryonic development, and even pregnancy and maintenance of implantation.¹⁰ In a mouse model, obesity affected ovarian inflammation and steroidogenic pathway genes, thus inducing extensive ovarian dysfunction.¹¹ In addition, body mass index (BMI) is associated with higher miscarriage and hormonally related cancers; overweight before the first pregnancy is particularly important in the risk of ovarian cancer.^{12–14}

Smoking-related behavior may disturb hormonal changes of the menstrual cycle^{15,16}; in particular, smoking during adolescence and young adulthood increased the risk of developing premenstrual syndrome.¹⁷ In addition, the chemicals in cigarettes may disrupt the endocrine system and cause menstrual dysfunction, reduced ovarian reserve and fertility, or earlier menopause.¹⁸ Abnormally long menstrual cycles were associated with clinical insulin resistance and increased androgen levels in metabolic disorders such as type 2 diabetes and hyperglycemia.^{19,20}

The Korea National Health and Nutrition Examination Survey (KNHANES) was conducted to establish national statistics regarding health promotion, health-related consciousness and behavior, and food and diet status. It has been used for planning national health promotion and evaluation, developing health promotion programs, and establishing health policy. This study was performed to investigate the relationship between lifestyle factors and irregular menstrual cycles in nondiabetic Korean women. All lifestyle data were collected from KNHANES and analyzed to substantiate previous reports about female reproductive health. We found that risk of menstrual irregularity was closely associated with increasing BMI and smoking habits in nondiabetic Korean women.

Materials and Methods

Study population

This cross-sectional study was based on data from the fifth KNHANES (2010–2012).²¹ The contents of the fifth KNHANES consisted of a health interview survey, nutrition survey, and physical examination survey. These surveys were conducted every 3 years from 1988 to 2005; since 2007, it has been conducted annually.

The number of participants in the fifth KNHANES (2010–2012) was 8958 in 2010, 8518 in 2011, and 8057 in 2012. Inclusion criteria for the present study ($n = 3779$) were nondiabetic Korean women 19–49 years old who did not take any oral contraceptives or sex hormones. Nondiabetic participants were defined as having fasting plasma glucose <126 mg/dL, not on medication for diabetes, not receiving insulin injections, and not having received a physician's diagnosis of diabetes.

Data collection

The health interview included questions to determine the demographic, socioeconomic, and health characteristics of the subjects, including questions on age, weight, height, marital status, age at menarche, menstruation regularity, lifetime alcohol drinking experience, and lifetime smoking. BMI was calculated as weight (kg) divided by height squared (m^2). Regarding lifetime alcohol drinking experience, par-

ticipants who never drank alcohol in their lifetime were categorized as “No,” while those participants who ever drank more than one glass were categorized as “Yes.”

Among those who answered “Yes” in lifetime alcohol drinking experience, the age at which they started drinking alcohol was asked and those who had consumed alcohol in the past year were also asked, the frequency and amount of alcohol consumption per session.

Regarding lifetime smoking, participants who had never smoked cigarettes were categorized as “No,” while those participants who smoked even one cigarette in their lifetime were categorized as “Yes.” The smoking status was subdivided into nonsmoking, past smoking, and current smoking included daily and often. Among those who answered “Yes” in current smoking, further questions asked included age at onset of smoking, current smoking status, and current daily amount of smoking. Menstruation regularity is menstruating at regular intervals, and menstruation irregularity is one at irregular intervals, that is, menstruating every 3 months or more.

Statistical analyses

The KNHANES participants were not randomly sampled. The survey was designed using a complex, stratified, multistage probability-sampling design with a rolling survey sampling model; individual participants were not equally representative of the Korean population. To provide representative estimates of the Korean civilian population, survey weights were used in all of the analyses, which were calculated by taking sampling weight, nonresponse adjusting weight using estimated response probability, and calibration using poststratification. All lifestyle variables and differences in the prevalence of menstrual irregularities among each group were analyzed using the crosstabs chi-squared test.

To examine their potential effects on menstrual irregularity, age groups (19–29, 30–39, and 40–49 years), obesity groups, defined as per Asian BMI using modified WHO criteria^{22–24} (BMI <18.5 [underweight], 18.5–22.9 [normal weight], 23.0–24.9 [risk weight], 25.0–29.9 [obesity class I], and ≥ 30.0 [obesity class II]), lifetime alcohol drinking experience, lifetime smoking, and current smoking status were analyzed using logistic regression odds ratios (OR) with 95% confidence intervals (CIs) for each variable. It was constructed as two logistic regression models. In model 1, we adjusted for age, BMI, lifetime alcohol drinking experience, and lifetime smoking. In model 2, we added in marital status and age at menarche. A p value <0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 21.0 (IBM Co., Armonk, NY).

Results

Table 1 presents the prevalence of menstrual irregularity according to each categorized variable. The prevalence of menstrual irregularity had a statistically significant association with age, BMI, marital status, age at menarche, starting age of alcohol drinking, lifetime smoking, current smoking status, and current daily amount of smoking ($p < 0.05$). The prevalence of menstrual irregularity was significantly higher in younger women: 18.4% at 19–29 years, 10.3% at 30–39 years, and 10.5% at 40–49 years. Based on Asian obesity criteria, the prevalence of menstrual irregularity was significantly higher in women with obesity class I (17.1%) and obesity class II

TABLE 1. GENERAL CHARACTERISTICS OF MENSTRUAL REGULARITY STATUS, KNHANES 2010–2012

Variables	Menstrual regularity		Menstrual irregularity		χ^2	p
	N	%	N	%		
Age (years)						
19–29	835	81.6	170	18.4	48.082	<0.001
30–39	1360	89.7	137	10.3		
40–49	1154	89.5	123	10.5		
Body mass index						
<18.5	333	88.2	39	11.8	20.409	0.015
18.5–22.9	1870	88.4	209	11.6		
23.0–24.9	553	87.1	75	12.9		
25.0–29.9	497	82.9	84	17.1		
≥30.0	94	78.8	21	21.2		
Marital status						
Married	2445	89.4	262	10.6	37.507	<0.001
Unmarried	904	82.3	168	17.7		
Age at menarche (years)						
<13	790	85.0	105	15.0	17.129	0.007
13–17	2491	88.0	309	12.0		
≥18	61	74.2	14	25.8		
Lifetime alcohol drinking						
No	214	88.3	23	11.7	0.399	0.639
Yes	3135	86.8	407	13.2		
Age at starting alcohol drinking (years)						
<19	772	82.9	141	17.1	19.327	<0.001
≥19	2360	88.4	266	11.6		
Frequency of alcohol drinking/year						
Nondrinking	647	88.3	71	11.7	10.572	0.241
Less than once a month	967	86.0	130	14.0		
1 time a month	509	84.3	70	15.7		
2–4 times a month	833	88.8	104	11.2		
2–3 times a week	319	87.7	42	12.3		
More than four times a week	56	81.9	10	18.1		
Drinking alcohol consumption at a time						
Nondrinking	647	88.3	71	11.7	3.629	0.344
<10 glasses	2538	86.9	324	13.1		
≥10 glasses	164	83.7	35	16.3		
Lifetime smoking						
No	2922	87.8	347	12.2	14.615	0.003
Yes	427	82.1	83	17.9		
Age at starting smoking (years)						
<19	133	78.9	32	21.1	1.963	0.244
≥19	293	83.8	51	16.2		
Smoking status						
Nonsmoking	2922	87.8	347	12.2	15.612	0.010
Past smoking	224	83.5	40	16.5		
Current smoking	203	80.7	43	19.3		
Current daily amount of smoking						
Nonsmoking	3146	87.5	387	12.5	11.354	0.042
<10 cigarettes	131	81.3	28	18.7		
≥10 cigarettes	72	79.8	15	20.2		

KNHANES, Korea National Health and Nutrition Examination Survey.

(21.2%) than in women with normal weight (11.6%; $p=0.015$). A significantly higher prevalence of menstrual irregularity was also found when age at menarche was <13 years ($p=0.007$) and when starting age of alcohol drinking was <19 years ($p<0.01$). However, the prevalence of menstrual irregularity was not affected by lifetime alcohol drinking experience compared with nondrinking (11.7% vs. 13.2%,

respectively, $p=0.639$). In contrast, lifetime smoking and current smoking were closely associated with menstrual irregularity ($p<0.05$).

Menstrual irregularity was significantly higher in women aged 19–29 years than in women aged 30–39 years (adjusted OR, 1.81; 95% CI, 1.16–2.83; Table 2). The probability of menstrual irregularity was significantly higher in women

TABLE 2. UNADJUSTED AND ADJUSTED ODDS RATIOS FOR AGE, BODY MASS INDEX, DRINKING, AND SMOKING ON MENSTRUAL CYCLE IRREGULARITY

<i>Variables</i>	<i>Unadjusted, OR (95% CI)</i>	<i>Adjusted model 1, OR (95% CI)</i>	<i>Adjusted model 2, OR (95% CI)</i>
Age, years			
30–39	1.00	1.00	1.00
19–29	1.98 (1.49–2.63)	2.08 (1.56–2.78)	1.81 (1.16–2.83)
40–49	1.03 (0.77–1.37)	1.02 (0.76–1.36)	1.00 (0.75–1.34)
Body mass index			
18.5–22.9	1.00	1.00	1.00
<18.5	1.02 (0.66–1.58)	0.87 (0.55–1.35)	0.83 (0.53–1.31)
23.0–24.9	1.12 (0.80–1.58)	1.29 (0.91–1.83)	1.33 (0.94–1.89)
25.0–29.9	1.56 (1.13–2.16)	1.84 (1.31–2.60)	1.94 (1.37–2.74)
≥30.0	2.04 (1.16–3.59)	2.00 (1.12–3.57)	2.18 (1.22–3.91)
Lifetime alcohol drinking			
No	1.00	1.00	1.00
Yes	1.14 (0.66–1.97)	1.07 (0.61–1.87)	0.91 (0.52–1.58)
Lifetime smoking			
No	1.00	1.00	1.00
Yes	1.58 (1.16–2.14)	1.41 (1.03–1.91)	1.42 (1.04–1.93)
Current smoking status			
Nonsmoking	1.00	1.00	1.00
Past smoking	1.43 (0.93–2.20)	1.32 (0.86–2.02)	1.33 (0.87–2.04)
Current smoking	1.73 (1.17–2.55)	1.49 (1.01–2.20)	1.43 (0.97–2.13)

Adjusted model 1: Adjusted for age, body mass index, alcohol drinking experience, and smoking.

Adjusted model 2: Adjusted for age, body mass index, alcohol drinking experience, smoking, marital status, and age at menarche.
CI, confidence interval; OR, odds ratio.

with obesity class I (adjusted OR, 1.94; 95% CI, 1.37–2.74) and obesity class II (adjusted OR, 2.18; 95% CI, 1.22–3.91) compared to women with normal weight. There was a statistically significant association of lifetime smoking experience on menstrual irregularity compared to nonsmoking, but not of lifetime drinking compared to nondrinking. The possibility of menstrual irregularity was higher in the smoking group than the nonsmoking group (adjusted OR, 1.42; 95% CI, 1.04–1.93) and marginally higher although not statistically significant, with current smoking compared to nonsmoking (adjusted OR, 1.43; 95% CI, 0.97–2.13).

Further logistic regression analyses by age groups were performed to evaluate the possible effects of BMI, lifetime alcohol drinking experience, and lifetime smoking on menstrual irregularity (Table 3). In 19- to 29-year-old women, obesity was the most significant factor predicting menstrual irregularity ($p < 0.001$), but lifetime drinking and lifetime smoking were not predictive of menstrual irregularity. The prevalence of menstrual irregularity was significantly higher with obesity class I (adjusted OR, 2.33; 95% CI, 1.24–4.37) and obesity class II (adjusted OR, 2.89; 95% CI, 1.21–6.90). Moreover, lifetime smoking experience showed a statistically significant association with menstrual irregularity in 30- to 39-year-old women ($p = 0.004$). The prevalence of menstrual irregularity in the smoking group was marginally higher although not significant than the nonsmoking group (adjusted OR, 1.58; 95% CI, 0.98–2.54). In women aged 40–49 years, there was no statistically significant association with obesity, lifetime alcohol drinking experience, or lifetime smoking.

Discussion

The KNHANES data have been analyzed by many cross-sectional and epidemiological public health studies in Korea,

including studies reporting improvements in glycemic control in diabetes, relationships between body fat percent and bone mineral density, the prevalence of osteoporosis and microalbuminuria, antioxidant capacity of the diet, and risk factors and comorbidities of obstructive pulmonary disease.^{25–30} A regular and normal menstrual cycle might be closely related to fecundity and successful pregnancy and influenced by various metabolic disorders and chronic diseases.^{31–33}

The objective of this study was to explore the relationship between lifestyle factors and irregular menstrual cycles of nondiabetic Korean women using KNHANES data. We found that menstrual irregularity had a statistically significant relationship to age, BMI, marital status, age at menarche, and smoking. Higher BMI at a younger age (19–29 years old; $p < 0.001$) and smoking habits in middle-aged women (30–39 years old; $p < 0.005$) were major significant factors associated with menstrual irregularity in nondiabetic Korean women. Interestingly, the prevalence of menstrual irregularity was significantly higher at age 19–29 years, with a prevalence of 18.4%, compared to 10.3% at age 30–39 years and 10.5% at age 40–49 years. This may be related to increasing social stresses and pollutants in the environment in the recently developing Korean society.

BMI is a calculated value derived from body weight and height and represents the obesity of an individual. Our study showed that BMI based on Asian obesity criteria was strongly associated with menstrual irregularity. Women with obesity class I or II had a significantly higher risk of menstrual irregularity compared to women with normal weight. Other studies have also reported that BMI was closely associated with various metabolic disorders and chronic diseases, such as hyperinsulinemia, hypertension, inflammation, and ovarian cancer.^{34–39} In addition, BMI has been shown to be a critical risk factor for women's reproductive health, such as

TABLE 3. ODDS RATIOS FOR BODY MASS INDEX, DRINKING, AND SMOKING ON MENSTRUAL CYCLE IRREGULARITY AMONG AGE GROUPS

Age (years)	Variables	Unadjusted, OR (95% CI)	Adjusted model 1, OR (95% CI)	Adjusted model 2, OR (95% CI)
19–29	Body mass index			
	18.5–22.9	1.00	1.00	1.00
	<18.5	0.68 (0.37–1.23)	0.69 (0.38–1.25)	0.68 (0.37–1.24)
	23.0–24.9	1.16 (0.60–2.25)	1.23 (0.63–2.39)	1.29 (0.66–2.51)
	25.0–29.9	2.06 (1.10–3.84)	2.28 (1.20–4.31)	2.33 (1.24–4.37)
	≥30.0	2.98 (1.38–6.44)	2.66 (1.14–6.24)	2.89 (1.21–6.90)
	Lifetime alcohol drinking			
	No	1.00	1.00	1.00
	Yes	0.74 (0.26–2.11)	0.71 (0.23–2.16)	0.75 (0.24–2.39)
	Lifetime smoking			
	No	1.00	1.00	1.00
	Yes	1.53 (0.99–2.38)	1.63 (1.02–2.62)	1.57 (0.96–2.56)
30–39	Body mass index			
	18.5–22.9	1.00	1.00	1.00
	<18.5	1.12 (0.49–2.54)	1.09 (0.48–2.48)	1.03 (0.45–2.35)
	23.0–24.9	1.68 (0.99–2.86)	1.71 (1.01–2.91)	1.71 (0.99–2.94)
	25.0–29.9	1.94 (1.12–3.36)	1.92 (1.10–3.34)	1.95 (1.12–3.41)
	≥30.0	2.11 (0.76–5.86)	2.16 (0.77–6.03)	2.32 (0.82–6.61)
	Lifetime alcohol drinking			
	No	1.00	1.00	1.00
	Yes	1.45 (0.54–3.87)	1.10 (0.40–2.98)	1.07 (0.39–2.88)
	Lifetime smoking			
	No	1.00	1.00	1.00
	Yes	1.94 (1.23–3.06)	1.69 (1.07–2.68)	1.58 (0.98–2.54)
40–49	Body mass index			
	18.5–22.9	1.00	1.00	1.00
	<18.5	1.91 (0.91–5.14)	2.04 (0.73–5.65)	2.13 (0.80–5.68)
	23.0–24.9	1.05 (0.59–1.89)	0.99 (0.54–1.81)	0.98 (0.53–1.81)
	25.0–29.9	1.53 (0.90–2.58)	1.50 (0.88–2.56)	1.54 (0.91–2.61)
	≥30.0	0.83 (0.20–3.44)	0.78 (0.20–3.05)	0.76 (0.20–2.83)
	Lifetime alcohol drinking			
	No	1.00	1.00	1.00
	Yes	1.09 (0.50–2.35)	1.09 (0.49–2.44)	1.05 (0.47–2.33)
	Lifetime smoking			
	No	1.00	1.00	1.00
	Yes	0.74 (0.36–1.50)	0.76 (0.37–1.57)	0.77 (0.36–1.64)

Adjusted model 1: Adjusted for age, body mass index, alcohol drinking experience, and smoking.

Adjusted model 2: Adjusted for age, body mass index, alcohol drinking experience, smoking, marital status, and age at menarche.

ovulation, menstruation, pregnancy, and delivery.^{40–44} Obesity, metabolic syndrome, heart disease, and breast cancer are also factors related to early menarche and menstrual irregularity.^{45–47} In Korea, height was positively related and waist circumference was inversely related to a menarche age of 16 to 18 years. Compared with early menarche, late menarche in girls was associated with later menstrual irregularity⁴⁸; furthermore, girls with early menarche had a higher tendency to be obese in adulthood.⁴⁹ In addition, early menstruation was associated with increasing BMI in adolescent girls in Korea.⁵⁰ This is in contrast to an American report that BMI was not associated with age at menarche.⁵¹

However, the age at menarche, especially ≥14 years, is related with longer menstrual cycles and cycle variability,⁵² and a short menstrual cycle was associated with both an early age at menarche and smoking.⁵³ It has also been reported that long menstrual cycles were associated with an earlier age at menarche and increasing weight.⁵⁴ Likewise, our current study shows that when the age at menarche is <13 years or >18 years, there was a significantly higher prevalence of menstrual

irregularities compared to an age at menarche of 13–17 years; this was especially true when the age at menarche was >18 years old, with a higher prevalence of menstrual irregularity than the other groups. These data confirm that the age at menarche is related to a woman's menstrual cycle and, consequently, influences a woman's reproductive health.

The present study demonstrated that women who start smoking earlier than 19 years of age or who currently smoke >10 cigarettes per day had a significantly increased risk of menstrual irregularity. Other studies have reported that women who smoke showed a higher prevalence of both irregular and shorter menstrual cycles,^{53,55} lower estrogen levels,^{31,56} and higher levels of follicle-stimulating hormone.⁵⁷ In addition, current smoking and heavy smoking were detrimental factors for early menopause, whereas previous smoking had less influence.^{58–61} As demonstrated in our study, current smoking has a stronger relationship to irregular menstrual cycles than past smoking, with statistically high significance in middle-aged women 30–39 years old. The detrimental effect of smoking in middle-aged women may be explained

by chemicals in cigarette smoking, which accelerate the loss of reproductive and follicular depletion.⁶² According to 2013 statistics regarding Korean health behaviors and chronic diseases, the smoking rate for all women was 6.2%, with the highest rate at 9.1% in the 19–29 year age range.⁶³

Interestingly, we found that menstrual irregularity had a statistically significant association with smoking, but not with drinking, indicating that smoking might be a stronger risk factor than drinking for women's reproductive health. In addition, women's smoking was strongly associated with a wide range of diseases and disorders, such as lung cancer, respiratory disease, and heart disease, and it has a close relationship with female health issues, such as miscarriage, ectopic pregnancy, infertility, lower birth weight, and early menopause.^{64–70} Thus, many governments, including Korea, are trying to deter people from smoking with antismoking campaigns in the mass media that stress the harmful long-term effects of smoking. Passive smoking or secondhand smoking may also be harmful for women's reproductive health. However, we were unable to determine the effect of passive smoking.

Limitations of the present study included the fact that the individual lifestyle factors were self-reported on a survey and that there was no detailed segmentation of the menstrual cycle. There was no clinical test to measure female hormone levels; thus, we were unable to physiologically confirm the degree of menstrual irregularity. In addition, stress and parity associated with menstrual irregularity were statistically significant (data not shown), but we did not perform further analysis in this study focusing on BMI, smoking, and drinking.

Other potential covariates, such as polycystic ovary syndrome, pelvic inflammatory disease, eating disorders, sexual activity, etc., were not included in the KNHANES data. Another weak point is that the participants were not derived from a large population. However, the data confirmed and substantiated previous reports regarding the detrimental effects of higher BMI and smoking habits on the reproductive health of Korean women. In addition, the present study expands upon the use of KNHANES data to determine major risk factors of lifestyle and behavior associated with other disorders and diseases. We suggest the promotion of lifestyle factors to facilitate and maintain women's reproductive health.

Conclusions

Taken together, the findings of this study demonstrated that menstrual irregularity in nondiabetic Korean women was closely associated with age, BMI, and smoking. The prevalence of menstrual irregularity was significantly higher in women <30 years old. In younger women, menstrual irregularity was highly impacted by BMI, whereas in middle-aged women, it was impacted by smoking. These lifestyle factors may influence the homeostasis of endogenous and ovarian hormones that contribute to a regular menstrual cycle. Weight loss and smoking cessation should be recommended to promote Korean women's reproductive health.

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Authors' Contributions

A.N.J., J.H.P., J.H.K., S.H.K., B.C.J., B.H.C., J.W.S., and J.H.J. participated in the design of the study and in writing the article. A.N.J. conducted the data analysis and wrote the first draft of the article. A.N.J., J.H.P., J.W.S., and J.H.J. participated in data analysis and interpretation. The article was amended after review by J.H.K., S.H.K., B.C.J., and B.H.C. All authors read and approved the final article.

Author Disclosure Statement

No competing financial interests exist.

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