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Original Article

Association between high-caffeine beverage intake and oral diseases in adolescents

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ABSTRACT

Objectives: To comprehensively determine the association between oral diseases and high-caffeine beverage intake in adolescents. **Methods:** Data from 54,653 adolescents who were included in the 20th Korea Youth Risk Behavior Survey (2024) were analyzed. Logistic regression was performed to determine the association between caffeine intake frequency and oral diseases, adjusting for gender, grade, academic achievement, economic status, and toothbrushing frequency. **Results:** Compared with non-consumers, low-frequency consumers had an increased risk of dental caries (odds ratio [OR]=1.165; 95% confidence interval [CI]: 1.124–1.208), whereas high-frequency consumers had a significantly higher risk (OR=1.186; 95% CI: 1.064–1.320). Similarly, low-frequency consumers had an increased risk of periodontal disease (OR=1.077; 95% CI: 1.033–1.123), whereas high-frequency consumers had a significantly higher risk (OR=1.489; 95% CI: 1.328–1.670). **Conclusions:** The prevalence of dental caries and periodontal disease increased with higher consumption of high-caffeine beverages. Frequent intake of high-caffeine beverages was significantly associated with oral diseases in Korean adolescents.

Key Words: Adolescent, Caffeine, Dental caries, Periodontal diseases

Introduction

Caffeine reduces fatigue and enhances alertness, and its moderate consumption has been associated with improvements in metabolic syndrome–related parameters, such as hypertension and diabetes, as well as a decreased risk of heart failure, arrhythmia, stroke and other cardiovascular diseases [1]. In contrast, excessive caffeine intake may result in adverse effects, such as anxiety, insomnia, and gastrointestinal disturbances [2–4].

Caffeine is a naturally occurring alkaloid that functions as a central nervous system stimulant [5]. It is biosynthesized in various plants, with primary sources of extraction including coffee trees, tea plants, and cacao trees [5]. This compound is commonly found in a wide array of beverages frequently consumed by individuals. Specifically, caffeine is present in coffee-based drinks such as Americano and espresso, in teas including green and black varieties, in carbonated soft drinks, and in energy drinks such as Hot6, Monster Energy, and Red Bull [5]. Furthermore, caffeine is also found in chocolate and cocoa-containing beverages [5].

In recent years, there has been a significant increase in the consumption of high-caffeine beverages among adolescents in South Korea [6]. Products such as coffee and energy drinks are commonly consumed to alleviate fatigue, improve concentration, and reduce academic stress [7]. However, excessive intake of caffeinated beverages has been linked to sleep disturbances, including delayed sleep phase syndrome and reduced sleep quality [8,9]. Notably, individuals who consume caffeine five or more times per week tend to experience more severe adverse mental health outcomes, such as depression, which negatively affect the well-being

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of developing adolescents [9]. Additionally, high-caffeine beverages often contain considerable amounts of sugar and acidic additives. Sugar acts as a primary substrate for dental plaque formation, a critical factor in the development of dental caries and periodontal disease.

Adolescence constitutes a pivotal period for the development and consolidation of oral health behaviors. However, oral hygiene practices are often neglected during this stage, while the intake of high-sugar and acidic beverages is common, thereby creating an environment that promotes oral health problems [10]. According to data from the Korea Disease Control and Prevention Agency, in 2024, 60.3% of 12-year-olds have experienced permanent tooth decay, and the prevalence of gingival pain and bleeding is significantly high at 39.8% [11].

Energy drinks containing high levels of caffeine increase the risk of dental caries and periodontal disease not only because of excessive caffeine consumption but primarily due to the combined effects of acids and sugars present in these beverages [12,13]. The low pH and citric acid content in energy drinks contribute to the chemical erosion of tooth enamel and also cause erosion of the dentin surface [12,13]. Repeated exposure to these conditions significantly elevates the risk of developing dental caries [12,13].

Caffeine consumption from coffee is significantly associated with periodontal tissue damage, primarily due to its negative impact on calcium absorption, reduction in bone density, increased osteoclast activity, and inhibition of osteoblast function [14,15]. These factors collectively contribute to the degradation of alveolar bone [14,15]. Furthermore, prolonged intake of high doses of caffeine induces changes in metabolic and immune responses, which adversely affect the alveolar bone [14].

Caffeinated beverages have become widely consumed, and as previously noted, caffeine intake among Korean adolescents is on the rise [6]. A substantial body of literature has documented both the beneficial and adverse effects of caffeine on human health [1-3,16]. Research has primarily concentrated on the relationship between caffeine consumption and mental health issues in adolescents, including generalized anxiety disorder, sleep disturbances, stress, and suicidal behavior [8,9,17,18]. However, to date, there remains a paucity of studies investigating the impact of high-caffeine beverage consumption on dental caries and periodontal disease within this population.

This study investigated the effect of high-caffeine beverage consumption on the prevalence of dental caries and periodontal disease among Korean adolescents, employing data representative of this population.

Methods

1. Subjects

This study utilized raw data from the 20th Korea Youth Risk Behavior Survey (2024) (Government-Approved Statistical Survey approval number: 117058) [19]. The Korea Youth Risk Behavior Survey, conducted by the Korea Disease Control and Prevention Agency as a public statistical investigation, was anonymized by eliminating all personally identifiable information. Therefore, institutional review board approval was not required for this study.

The data were obtained from a self-administered online survey conducted annually to assess the health behaviors of adolescents in South Korea.

The study population consisted of students currently enrolled in middle and high schools nationwide. During the stratification phase, 17 cities and provinces were designated as strata. In the subsequent sample allocation phase, 400 middle schools and 400 high schools were proportionally distributed across these regions, with each city and province initially assigned five middle schools and five high schools. Schools and classes within these institutions were then randomly selected to participate in the survey. Ultimately, the final analysis included data from a total of 54,653 students.

2. Study instruments

1) General characteristics

To characterize the study participants, variables such as gender, grade level, academic achievement, and economic status were employed. Academic achievement and economic status were reclassified into three categories: 'high' (including high and upper-middle levels), 'middle' (middle level), and 'low' (comprising lower-middle and low levels).

2) Characteristics related to oral features

The study examined the variables of toothbrushing frequency, dental caries, and periodontal disease. In particular, toothbrushing frequency was categorized into three groups: once daily or less, twice daily, and three or more times daily.

Participants who reported experiencing dental pain when consuming cold or hot foods and beverages, or who described sensations such as throbbing, aching, or general tooth discomfort, were classified as having dental caries [20]. In contrast, individuals reporting gum pain or bleeding were identified as having periodontal disease [20].

3) Consumption of beverages with high caffeine content

High-caffeine beverage consumption was defined as the intake of such beverages two or more times per day, consistent with the Korea Food and Drug Administration's 2013 guidelines regarding the recommended maximum daily caffeine intake for adolescents [5]. In this study, participants were categorized into three groups: non-consumers, low-frequency consumers, and high-frequency consumers of high-caffeine beverages. Individuals who reported no consumption of these beverages in the preceding seven days were classified as the "non-consumer group." Those who consumed high-caffeine beverages from once weekly up to once daily were assigned to the "low-frequency consumption group," while participants reporting consumption of two or more times per day were designated as the "high-frequency consumption group."

3. Data analysis

The general characteristics and health-related attributes of the participants were summarized using unweighted frequencies and weighted percentages through frequency analysis. Associations between participant characteristics and oral diseases were evaluated using cross-tabulation analysis. To investigate variations in the prevalence of oral diseases based on the frequency of caffeine consumption, logistic regression analyses were conducted. Model 1 adjusted for gender, grade level, academic performance, and economic status, while Model 2 included further adjustments for oral health-related factors. Specifically, in the analysis of dental caries, Model 2 additionally controlled for toothbrushing frequency and the presence of periodontal disease; conversely, in the analysis of periodontal disease, Model 2 further adjusted for toothbrushing frequency and dental caries.

The results of the logistic regression analysis are presented as odds ratios with corresponding 95% confidence intervals. All statistical analyses were performed using a complex sampling design and weighted planning files to enhance the generalizability of the findings. Data analysis was conducted using IBM SPSS program (ver. 31.0; IBM Corp., Armonk, NY, USA), with statistical significance defined as 0.05.

Results

1. General characteristics and oral-related characteristics

The results of the analysis concerning the participants' general and oral health-related characteristics are summarized in <Table 1>. The study sample consisted of 54,653 individuals, comprising 28,090 male students (51.5%) and 26,563 female students (48.5%). Regarding tooth brushing frequency, 9.2% of participants reported brushing once or less per day, 48.8% brushed twice daily, and

42.0% brushed three or more times per day. In terms of high-caffeine beverage consumption, 27,513 participants (49.5%) reported no consumption, 25,589 (47.5%) reported low-frequency consumption, and 1,551 (3.0%) reported high-frequency consumption. Furthermore, 23,080 participants (42.5%) indicated a history of dental caries, while 11,095 participants (20.3%) reported having experienced periodontal disease.

Table 1. Characteristic of study population (N=54,653)

Characteristics	Division	N	%
Gender	Boy	28,090	51.5
	Girl	26,563	48.5
Grade	Middle school 1st	9,887	17.2
	Middle school 2nd	9,725	17.1
	Middle school 3rd	9,475	16.2
	High school 1st	8,972	16.9
	High school 2nd	8,719	17.2
	High school 3rd	7,875	15.4
Academic achievement	High	20,838	38.2
	Middle	15,844	29.0
	Low	17,968	32.8
Economic status	High	23,143	43.2
	Middle	25,431	46.1
	Low	6,074	10.7
Frequency of toothbrushing	≤1 time daily	5,178	9.2
	2 times daily	26,671	48.8
	≥3 times daily	22,804	42.0
Caffeinated beverage intake	No	27,513	49.5
	Light	25,589	47.5
	Heavy	1,551	3.0
Dental caries	No	31,573	57.5
	Yes	23,080	42.5
Periodontal disease	No	43,558	79.7
	Yes	11,095	20.3

Values are presented as unweighted N and weighted %.

2. Chi-square tests of dental caries and periodontal disease in adolescents according to general and health-related characteristics

The findings of the analysis examining variations in dental caries and periodontal disease according to participants' general characteristics and the frequency of high-caffeine beverage consumption are presented in <Table 2>.

In the context of dental caries, 39.4% of male students and 45.7% of female students reported having experienced the condition, indicating a statistically significant difference between genders (p<0.001). Analysis by grade level revealed that first-year middle school students exhibited the lowest prevalence of dental caries, with incidence rates progressively increasing in higher grades; third-year high school students demonstrated the highest prevalence (p<0.001). Moreover, an inverse relationship was identified between economic status and the experience of dental caries, such that lower economic status was associated with a higher prevalence. Additionally, a lower frequency of tooth brushing was significantly correlated with an increased occurrence of dental caries (p<0.001). Regarding the consumption of high-caffeine beverages, 40.3% of students who reported no consumption, 44.5% of those who consumed infrequently, and 46.3% of frequent consumers experienced dental caries, demonstrating a positive correlation

between the frequency of high-caffeine beverage intake and the prevalence of dental caries (p<0.001).

In the context of periodontal disease, 18.3% of male students and 22.5% of female students reported experiencing the condition, with this difference reaching statistical significance (p<0.001). Analysis by grade level revealed that first-year middle school students exhibited the lowest prevalence of periodontal disease, with rates progressively increasing in higher grades and peaking among third-year high school students (p<0.001). Regarding toothbrushing frequency, 24.8% of students who brushed once or less per day, 20.1% of those who brushed twice daily, and 19.6% of those brushing three or more times daily reported periodontal disease, indicating a significant inverse relationship between brushing frequency and disease prevalence (p<0.001). Furthermore, consumption of high-caffeine beverages was positively associated with periodontal disease prevalence: 19.1% of non-consumers, 21.1% of low-frequency consumers, and 26.9% of high-frequency consumers reported the condition (p<0.001).

Table 2. Chi-square tests of dental caries and periodontal disease in adolescents according to general and health-related characteristics

Unit: N(%)

Characteristics	Dental caries		p^*	Periodontal disease		p^*
	No	Yes		No	Yes	
Gender						
Boy	17,129(60.6)	10,961(39.4)	<0.001	23,003(81.7)	5,087(18.3)	<0.001
Girl	14,444(54.3)	12,119(45.7)		20,555(77.5)	6,008(22.5)	
Grade						
Middle school 1st	6,266(62.8)	3,621(37.2)	<0.001	8,126(81.9)	1,761(18.1)	<0.001
Middle school 2nd	5,485(55.9)	4,240(44.1)		7,672(78.9)	2,053(21.1)	
Middle school 3rd	5,287(55.8)	4,188(44.2)		7,465(79.0)	2,010(21.0)	
High school 1st	5,181(57.6)	3,791(42.4)		7,227(80.6)	1,745(19.4)	
High school 2nd	4,998(57.5)	3,721(42.5)		6,962(79.8)	1,757(20.2)	
High school 3rd	4,356(55.3)	3,519(44.7)		9,692(77.7)	1,769(22.3)	
Academic achievement						
High	11,781(56.5)	9,057(43.5)	<0.001	16,376(78.8)	4,462(21.2)	<0.001
Middle	9,525(59.5)	6,319(40.5)		12,868(81.0)	2,976(19.0)	
Low	10,265(57.0)	7,703(43.0)		14,312(79.5)	3,656(20.5)	
Economic status						
High	13,912(59.8)	9,231(40.2)	<0.001	18,544(80.0)	4,599(20.0)	<0.001
Middle	14,646(57.4)	10,785(42.6)		20,413(80.3)	5,018(19.7)	
Low	3,011(49.3)	3,063(50.7)		4,597(75.8)	1,477(24.2)	
Frequency of tooth brushing						
≤1 time daily	2,656(51.0)	2,522(49.0)	<0.001	3,893(75.2)	1,285(24.8)	<0.001
2 times daily	15,091(56.4)	11,580(43.6)		21,317(79.9)	5,354(20.1)	
≥3 times daily	13,826(60.4)	8,978(39.6)		18,348(80.4)	4,456(19.6)	
Caffeinated beverage intake						
No	16,475(59.7)	11,038(40.3)	<0.001	22,231(80.9)	5,282(19.1)	<0.001
Light	14,269(55.5)	11,320(44.5)		20,181(78.9)	5,408(21.1)	
Heavy	829(53.7)	722(46.3)		1,146(73.1)	405(26.9)	

*by chi-square test

Values are presented as unweighted N (weighted %).

3. The association between the intake of high-caffeine beverages and the prevalence of dental caries

The results concerning the relationship between the frequency of high-caffeine beverage consumption and the prevalence of

dental caries are summarized in <Table 3>. Relative to the non-consumption group, low-frequency consumers demonstrated a 1.188-fold higher prevalence of dental caries, and high-frequency consumers exhibited a 1.277-fold higher prevalence (p<0.001).

In Model 1, relative to the non-consumption group, low-frequency consumers demonstrated a 1.179-fold higher prevalence of dental caries, and high-frequency consumers exhibited a 1.265-fold higher prevalence (p<0.001). Similarly, in Model 2, the low-frequency consumption group had a 1.165-fold higher prevalence (p=0.002), and the high-frequency consumption group had a 1.186-fold higher prevalence (p<0.001) compared to the non-consumption group.

Table 3. Logistic regression analysis for dental caries

Variables	Dental caries					
	Crude	p^*	Model 1	p^*	Model 2	p^*
Caffeinated beverage intake						
No	1.000		1.000		1.000	
Light	1.188 (1.148-1.229)	<0.001	1.179 (1.139-1.221)	<0.001	1.165 (1.124-1.208)	0.002
Heavy	1.277 (1.151-1.416)	<0.001	1.265 (1.139-1.405)	<0.001	1.186 (1.064-1.320)	<0.001

*Values are estimated odds ratio (95% confidence interval).
Model 1: adjusted for gender, grade, academic achievement, economic status; Model 2: adjusted for gender, grade, academic achievement, economic status, frequency of tooth brushing, periodontal disease

4. The relationship between high-caffeine beverage consumption and the prevalence of periodontal disease

The findings from the analysis examining the relationship between the frequency of high-caffeine beverage intake and periodontal disease are presented in <Table 4>. Compared to individuals who abstained from high-caffeine beverages, those with low-frequency caffeine intake exhibited a 1.129-fold increase in the prevalence of periodontal disease, whereas individuals with high-frequency consumption showed a 1.556-fold increase (p<0.001). In Model 1, relative to the non-consumption group, low-frequency caffeine consumers demonstrated a 1.124-fold higher prevalence, and high-frequency consumers exhibited a 1.542-fold higher prevalence of periodontal disease (p<0.001). Similarly, in Model 2, the prevalence of periodontal disease was 1.077 times greater among low-frequency consumers and 1.489 times greater among high-frequency consumers compared to non-consumers (p<0.001).

Table 4. Logistic regression analysis for periodontal disease

Variables	Periodontal disease					
	Crude	p^*	Model 1	p^*	Model 2	p^*
Caffeinated beverage intake						
No	1.000		1.000		1.000	
Light	1.129 (1.086-1.175)	<0.001	1.124 (1.080-1.170)	<0.001	1.077 (1.033-1.123)	<0.001
Heavy	1.556 (1.397-1.734)	<0.001	1.542 (1.380-1.723)	<0.001	1.489 (1.328-1.670)	<0.001

*Values are estimated odds ratio (95% confidence interval).
Model 1: adjusted for gender, grade, academic achievement, economic status; Model 2: adjusted for gender, grade, academic achievement, economic status, frequency of tooth brushing, dental caries

Discussion

Adolescence constitutes a critical period for the development of dietary and oral hygiene behaviors, during which frequent consumption of high-caffeine beverages presents a considerable risk for the progressive decline of oral health. Previous studies

have demonstrated that adolescents commonly consume high-caffeine drinks habitually to cope with academic stress, reduce fatigue, and maintain alertness, behaviors that may negatively impact overall health outcomes [7]. The results of the current study support this association, indicating a relationship between high-caffeine beverage intake and deteriorating oral health among adolescent populations.

This study identified a correlation between the increased frequency of high-caffeine beverage consumption among adolescents and a higher prevalence of dental caries. The findings suggest that the adverse effects on oral health may result not only from excessive caffeine intake but also from the combined impact of acidic and sugary constituents present in these beverages. Previous research has demonstrated that energy and sports drinks, characterized by low pH levels and elevated citric acid concentrations, contribute to the erosion of tooth enamel and dentin, as well as compromise the structural integrity of dental restorations [21]. Additionally, an analysis of carbonated and energy drinks marketed in the Middle East indicated that their acidic properties and high sugar content promote dental plaque formation and accelerate the progression of tooth erosion [22].

The findings of this study are significant as they offer empirical support for the basis of experimental research through the analysis of actual consumption behavior data from South Korean adolescents. Given the evidence indicating that excessive intake of high-caffeine beverages increases the risk of dental caries within this population, it is essential to formulate policies aimed at improving beverage consumption patterns and promoting oral health among young individuals.

This study identified a positive correlation between frequent consumption of high-caffeine beverages and an increased prevalence of periodontal disease among adolescents. Caffeine is recognized for its diuretic properties and its capacity to reduce saliva production, which may exacerbate xerostomia and, over time, act as a contributory risk factor for periodontal disease [23]. Consistent with these findings, a cross-sectional study conducted in Germany involving 6,209 adults aged 45 to 74 revealed a significant association between coffee consumption frequency and periodontal disease; individuals with higher coffee intake exhibited a greater prevalence of periodontal disease compared to those with lower consumption levels [24]. Additionally, analysis of data from the 2008–2010 Korea National Health and Nutrition Examination Survey, which included 16,730 Korean adults, demonstrated that increased coffee consumption frequency was significantly associated with an elevated risk of periodontal disease in men [25]. The present study not only corroborates previous findings from adult populations but also extends the evidence by indicating that consumption of caffeine-containing beverages may influence the development of periodontal disease during adolescence.

This study utilizes cross-sectional survey data, which limits the ability to establish definitive causal relationships. Additionally, the analysis is constrained by difficulties in fully accounting for certain confounding variables, such as specific types of high-caffeine beverages and dietary factors.

In this study, the identification of dental caries and periodontal disease relied on self-reported survey data. Since these self-reports may not precisely correspond to clinical diagnoses, the reported prevalence of oral diseases should be interpreted cautiously, as it may either overestimate or underestimate the actual prevalence.

This study leverages data from the Youth Health Behavior Survey to represent Korean adolescents effectively. Furthermore, although prior domestic research has explored the relationship between caffeine intake and both mental and physical health among adolescents, this study is novel in its focus on the effects of caffeine-containing beverage consumption on oral health.

This study indicates that the consumption of high-caffeine beverages may negatively impact the oral health of adolescents, underscoring the need for improvements in oral health education and policy frameworks. Integrating information about caffeine-containing beverage intake into oral health education programs aimed at adolescents should be considered. It is essential to raise adolescents' awareness of the potential increased risk of oral diseases associated with high-caffeine beverage consumption, and the development of effective strategies for communicating this information is imperative. Future research should employ longitudinal study designs to more precisely clarify the causal relationship between caffeine beverage consumption and oral health outcomes. Furthermore, quantitative analyses utilizing physiological indicators, such as salivary flow rate and pH changes, are recommended to further validate these findings.

Conclusions

This study utilized data from the 20th Korea Youth Risk Behavior Survey (2024) to examine the impact of high-caffeine beverage consumption on the prevalence of oral diseases among Korean adolescents.

1. In the analysis of the relationship between the frequency of high-caffeine beverage consumption and the prevalence of dental caries, Model 2—adjusted for sociodemographic factors, toothbrushing frequency, and periodontal disease—indicated that individuals with low-frequency caffeine intake had a 1.165-fold increase in the incidence of dental caries (p=0.002). Similarly, those with high-frequency caffeine consumption exhibited a 1.186-fold higher prevalence of dental caries (p<0.001) compared to individuals who abstained from high-caffeine beverages.

2. In the analysis of the relationship between the frequency of high-caffeine beverage consumption and periodontal disease, Model 2—adjusted for sociodemographic factors, toothbrushing frequency, and dental caries—indicated that individuals with low-frequency caffeine intake had a 1.077-fold higher prevalence of periodontal disease, whereas those with high-frequency caffeine intake exhibited a 1.489-fold higher prevalence compared to non-consumers of high-caffeine beverages (p<0.001).

This study established a significant correlation between the frequency of high-caffeine beverage consumption and the prevalence of oral diseases among South Korean adolescents.

Notes

Author Contributions

Conceptualization: ES Lee, SH Son; Data collection: ES Lee, SH Son; Formal analysis: SH Son; Writing-original draft: ES Lee, SH Son; Writing-review&editing: ES Lee, SH Son

Conflicts of Interest

The authors declared no conflicts of interest.

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Ethical Statement

None.

Data Availability

The 20th Korea Youth Risk Behavior Survey (2024) data can be obtained from Korea Disease Control and Prevention Agency repository source.

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청소년의 고카페인 음료 섭취와 구강질환 증상의 관련성

초록

연구목적: 본 연구는 한국 청소년의 고카페인 음료 섭취와 구강질환과의 관련성을 알아보고자 수행되었다. **연구방법:** 제20차 청소년건강행태조사(2024) 자료를 활용하여 총 54,653명의 청소년을 대상으로 하였다. 카페인 섭취 빈도와 구강질환 간 연관성을 알아보기 위해 로지스틱 회귀분석을 시행하였으며, 성별, 학년, 학업성적, 경제수준, 칫솔질 빈도를 보정하였다. **연구결과:** 비섭취군과 비교하여 저빈도 섭취군은 치아우식증 유병률이 높게 나타났으며(OR=1.165; 95% CI: 1.124–1.208), 고빈도 섭취군에서는 유병률이 더욱 높게 나타났다(OR=1.186; 95% CI: 1.064–1.320). 치주질환에서 저빈도 섭취군의 유병률이 높게 나타났으며(OR=1.077; 95% CI: 1.033–1.123), 고빈도 섭취군은 더욱 높게 나타났다(OR=1.489; 95% CI: 1.328–1.670). **결론:** 고카페인 음료의 섭취 빈도가 증가할수록 청소년의 치아우식증과 치주질환 유병률이 높아지는 경향을 보였으며, 고카페인 음료 섭취가 청소년의 구강건강에 영향을 미칠 수 있음을 시사한다.

색인: 청소년, 카페인, 치아우식, 치주질환