Associations between environmental tobacco smoke exposure and oral health symptoms in adolescents

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Abstract
Background: Oral health condition in adolescence impacts the oral well-being throughout life. This study aimed to determine the association between environmental tobacco smoke (ETS) exposure and oral health in adolescents, using nationally representative data.

Methods: Using data from the 2020 Korea Youth Risk Behavior Web-based Survey, we assessed self-reported data on ETS exposure and oral health symptoms in 37,591 non-smoking adolescents. The dependent variables were self-reported oral health symptoms of adolescents (tooth fracture, dental pain, and gum bleeding). ETS exposure was the primary independent variable. Chi-square tests and multivariable logistic regression analyses were performed to examine these relationships.

Results: ETS exposure was positively associated with oral symptoms compared to no-ETS exposure in adolescents [boys, odds ratio (OR) 1.56, 95% confidence interval (CI) 1.46–1.66; girls, OR 1.50, 95% CI 1.41–1.60]; individuals with good oral health habits such as frequent tooth brushing [boys, three times or more a day, OR 1.38, 95% CI 1.24–1.53] and less soda consumption [girls, less than once a day, OR 1.73, 95% CI 1.29–2.33] had a weaker association. ETS exposure was positively associated with dental pain [boys, OR 1.55, 95% CI 1.45–1.66; girls, OR 1.50, 95% CI 1.41–1.60] and gum bleeding [boys, OR 1.43, 95% CI 1.29–1.58; girls, OR 1.32, 95% CI 1.21–1.44]; however, tooth fracture was significantly associated only in girls [OR 1.28, 95% CI 1.13–1.45].

Conclusions: ETS in various environments is negatively associated with oral health in adolescents. This association could vary depending on health habits. Sophisticated policies to protect South Korean adolescents from ETS can be developed from these findings.

Keywords: Tobacco, Oral health, Adolescent health

Background
Oral health refers to the health of teeth, gums, and the entire orofacial system that allows people to smile, chew, and speak [1]. Oral health has a significant impact on the overall health and quality of life of an individual. Poor oral health is also associated with a higher risk of mortality, including major causes of death such as cardiovascular and respiratory diseases, and infections [2, 3]. Therefore, the oral health condition in adolescence could impact oral well-being throughout life.

Environmental tobacco smoke (ETS) exposure, also known as passive smoking, includes a mixture of exhaled main and side-stream smoke that pollutes the air surrounding the area of tobacco consumption [4]. Tobacco smoke contains a deadly mix of more than...
Many studies have shown that ETS exposure is significantly associated with numerous diseases in adolescents. A study reported an association between ETS exposure measured by cotinine levels and metabolic syndrome in adolescents using the U.S. National Health and Nutrition Examination Survey [7]. According to a study conducted in Kuwait, asthma may be another negative health outcome in adolescents resulting from ETS exposure [8]. Another study showed an association between ETS exposure and depression among South Korean adolescents [9].

According to previous studies, tobacco smoke may affect the immune system and saliva flow, aggravating the oral health of an individual [10]. Most of the studies that examined the association between tobacco smoking and oral health focused on the direct effect of tobacco consumption on the smokers’ oral health [11, 12]. On the other hand, several recent studies have targeted the oral health of young children, which is mostly affected by parental ETS [13]. A previous study showed that parental smoking behavior is associated with caries in 5-year-old children [14]. Another study showed that children exposed to ETS had a high occurrence of enamel opacities, which increases the risk of dental caries [4].

However, previous studies that examined the association between ETS and health focused less on oral health in adolescents, which might be easily affected by the unhealthy behaviors among their peers, parents, community, as well as their own [15, 16]. Further, the ETS exposure location of adolescents might be more diverse than that of children as they spend a substantial amount of time outside home [17]. Furthermore, most studies to date that examine the association between ETS and oral health have been limited by small sample sizes and the difficulties of analyzing the effects of ETS exposure location of adolescents on various oral health symptoms.

Therefore, the present study aimed to determine the association between ETS exposure and the oral health symptoms in adolescents using a relatively large sample obtained from a national cross-sectional survey. After that, we further performed subgroup analysis according to the health behavior of adolescents as the association could vary depending on their oral health habits. The locations and frequencies of ETS exposure and the prevalence of three different oral health symptoms, i.e., tooth fracture, dental pain, and gum bleeding, were examined to specifically analyze the relationship.

Methods

Data

The data used in this study were obtained from the 2020 Korea Youth Risk Behavior Web-based Survey (Kyrbws) for adolescents aged 12–18 years. Kyrbws is a nationwide cross-sectional survey conducted by the Korea Disease Control and Prevention Agency (Kdca). The Kyrbws was a secondary dataset available in the public domain. And its data were de-identified to maintain respondents’ anonymity and confidentiality. This survey was approved by the Korean National Statistical Office (Approval No. 117058). The survey was conducted in accordance with the guidelines and regulations provided by the Institutional Review Board of the Kdca. Data is available for download from the Kdca website (https://www.kdca.go.kr/yhs/). Therefore, this present study did not require additional approval or prior consent from the Institutional Review Board.

The purpose of the Kyrbws survey is to examine the status of health behaviors of South Korean adolescents and identify health indicators for the formation and evaluation of health programs. The survey is conducted annually and anonymously, in approximately 400 high schools and middle schools. The data were collected from August to November 2020, and the total number of survey participants of 2020 Kyrbws was 54,948 (response rate of 94.9%) [18].

From the database, the following respondents were excluded: 6081 respondents (4234 boys and 1847 girls) who had smoked cigarettes such as conventional and electronic cigarettes, and heated tobacco products in their lifetime; 1447 adolescents (913 boys and 534 girls) whose teeth had been fractured due to exercise or accidents; and 9829 participants (6019 boys and 3810 girls) who did not agree to provide their household information. Finally, 37,591 samples (17,187 boys and 20,404 girls) were analyzed.

Variables

The dependent variable was self-reported oral health symptoms. To assess oral health symptoms, the Kyrbws inquired about the experience of “tooth fracture,” “dental pain,” and “gum bleeding” through four different indications: “chipped or broken tooth,” “toothache when eating or drinking,” “throbbing and sore tooth,” and “sore and bleeding gums” for last 12 months. We classified those who had more than one oral health symptom as “symptom group”, and those who did not as “symptomless group”. We further classified the “symptom group” based on each oral symptom.

The primary independent variable in this study was ETS exposure. The participants were asked about the frequency of inhalation of tobacco smoked by others during
Regardless of the sex, the ETS exposure group was significantly associated with oral health symptoms in adolescents after adjusting for control variables. The results are reported as OR and confidence intervals (CI). A subgroup analysis was performed and stratified by sex and location of ETS exposure. All statistical analyses were performed using SAS software (version 9.4, SAS Institute, Cary, NC, USA).

Statistical analysis
Chi-square test and multivariable logistic regression analysis were used to analyze the data. The general characteristics of the sample were analyzed using frequencies and means. Multivariable logistic regression analyses were performed to examine the association between ETS exposure and oral health symptoms in adolescents after adjusting for control variables. The results are reported as odds ratios (OR) and confidence intervals (CI). A subgroup analysis was performed and stratified by sex and location of ETS exposure. All statistical analyses were performed using SAS software (version 9.4, SAS Institute, Cary, NC, USA).

Results
We analyzed each variable according to sex. Table 1 presents the general characteristics of the participants. Among the 37,591 study participants, 17,187 (45.7%) were boys and 20,404 (54.3%) were girls. Based on the ETS exposure, the proportion of female students with oral health symptoms in the “ETS group” (57.3%) was higher than that of male students (48.5%). Table 2 shows the association between ETS exposure and oral health symptoms after adjusting for all confounding variables. Regardless of the sex, the ETS exposure group was significantly associated with oral health symptoms (boys, OR 1.56, 95% CI 1.46–1.66; girls, OR 1.50, 95% CI 1.41–1.60).

Table 3 shows the results of the subgroup analyses between ETS exposure and oral health symptoms by covariates related to the following oral health management behaviors: “Tooth brushing frequency in a day” and “Soda intake frequency”. In male adolescents, tooth brushing for three or more times a day (OR 1.38, 95% CI 1.24–1.53) had a smaller association between ETS exposure and oral health symptoms than less frequent tooth brushing. In female adolescents, there was a stronger association in those who brushed their teeth less than once a day (OR 1.73, 95% CI 1.29–2.33) than in those who brushed their teeth more often. Furthermore, male adolescents who drank soda more than once a day (OR 2.11, 95% CI 1.66–2.69) had a greater association than less frequent drinkers. Female adolescents who did not drink soda (OR 1.33, 95% CI 1.18–1.50) had a lesser association with oral symptoms than more frequent drinkers.

Table 3 also reports the result of subgroup analyses between ETS exposure and oral health symptoms by demographic and socioeconomic factors of respondents. In female adolescents, when respondents’ family affluence was in low group, the association between ETS exposure and their oral health symptoms were stronger than in middle, and high group [low, OR 1.75, 95% CI 1.49–2.04; middle, OR 1.49, 95% CI 1.37–1.63; high, OR 1.40, 95% CI 1.24–1.59]. Likewise, in female adolescents, when their parents’ education level was lower, the association between ETS exposure and oral health symptoms was stronger [≤ middle, OR 1.72, 95% CI 0.74–3.97; high school, OR 1.66, 95% CI 1.44–1.91; ≥ college, OR 1.45, 95% CI 1.34–1.57]. On the other hand, those relationship according to family affluence and parents’ education level was not conspicuously shown in male adolescents.

In Table 3, we further analyzed the association according to age (middle school/high school) of respondents. The result showed that the association between ETS and their oral health symptoms were stronger when adolescents were older [boys, middle school, OR 1.49, 95% CI 1.36–1.63; high school, OR 1.66, 95% CI 1.51–1.83; girls, middle school, OR 1.47, 95% CI 1.35–1.61; high school, OR 1.54, 95% CI 1.41–1.68].

Table 4 shows the results of the subgroup analysis stratified by primary independent variables. Table 4 reports the OR for oral health symptoms according to ETS location and frequency. The groups that reported no ETS exposure at home, school, and other places were set as the reference groups. Notably, in male adolescents, ETS exposure at home of more than 4–6 days was stronger than in middle and high group [low, OR 1.75, 95% CI 1.11–1.33; 7 days, OR 1.34, 95% CI 1.15–1.56]. In female adolescents, ETS exposure at home of more than 4–6 days was more strongly associated with having oral symptoms than exposure for 1–3 days (1–3 days, OR 1.22, 95% CI 1.11–1.33; 7 days, OR 1.34, 95% CI 1.15–1.56). In female adolescents, ETS exposure at home of more than 4–6 days was more strongly associated with having oral symptoms than exposure for 1–3 days (1–3 days, OR 1.13, 95% CI 1.03–1.23; 4–6 days, OR 1.22, 95% CI 1.06–1.42; 7 days, OR 1.18, 95% CI 1.03–1.34). Furthermore, only girls had a significantly positive association with oral symptoms after 1–3 days of ETS exposure at school (OR 1.30, 95% CI 1.12–1.51). In male adolescents, ETS exposure of more than 4–6 days...
| Variables                                | Boys                                                                 | Girls                                                                 |
|------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|
|                                          | Oral health symptoms                                                | Oral health symptoms                                                |
|                                          | Total | Normality | Abnormality | N   | %      | N   | %      | N   | %      | N   | %      | N   | %      | N   | %      | N   | %      | N   | %      | N   | %      | P value | N   | %      | N   | %      | N   | %      | P value | N   | %      | N   | %      | P value |
| Total (N = 37,591)                       | 17,187 | 9,983     | 58.1       | 7,204 | 41.9     | 20,404 | 9,627     | 47.2 | 10,777 | 52.8     | <0.0001     | 12,598 | 6,175     | 49.0       | 6,423 | 51.0     | 7,224 | 57.3     | 7,753 | 42.7     | <0.0001     |
| Environmental tobacco smoke (ETS) exposure | 8246 | 48.0      | 4248 | 51.5 | 3,998 | 48.5 | 12,598 | 61.7 | 5,374 | 42.7 | <0.0001 |
| Yes                                      | 8941 | 52.0      | 5735 | 64.1 | 3,206 | 35.9 | 7,806 | 38.3 | 4,253 | 54.5 | <0.0001 |
| No                                       | 0.004 | 0.829     | 3,149 | 41.0 | 8,546 | 41.9 | 4,039 | 47.3 | 4,507 | 52.7 | <0.0001 |
| Region                                   | Metropolitan        | 7,686 | 44.7      | 4,537 | 59.0 | 3,149 | 41.0 | 8,546 | 41.9 | 4,039 | 47.3 | <0.0001 |
| Urban                                    | 8,177 | 47.6      | 4,647 | 56.8 | 3,530 | 43.2 | 10,188 | 49.9 | 4,812 | 47.2 | <0.0001 |
| Rural                                    | 1,324 | 7.7       | 799 | 60.3 | 525 | 39.7 | 1,670 | 8.2 | 776 | 46.5 | <0.0001 |
| Middle and high school                   | 6,667 | 38.8      | 3,705 | 55.6 | 2,962 | 44.4 | 8,769 | 43.0 | 3,774 | 43.0 | <0.0001 |
| High school                              | 10,520 | 61.2      | 6,278 | 59.7 | 4,242 | 40.3 | 11,635 | 57.0 | 5,853 | 50.3 | <0.0001 |
| Middle school                            | 6,692 | 40.7      | 3,953 | 56.5 | 3,039 | 43.5 | 7,707 | 37.8 | 3,561 | 46.2 | <0.0001 |
| High                                     | 5,149 | 30.0      | 3,131 | 50.8 | 2,018 | 39.2 | 6,493 | 31.8 | 3,222 | 49.6 | <0.0001 |
| Middle                                   | 5,046 | 29.4      | 2,899 | 57.5 | 2,147 | 42.5 | 6,204 | 30.4 | 2,844 | 45.8 | <0.0001 |
| Low                                      | 4,377 | 25.5      | 2,156 | 49.3 | 2,221 | 50.7 | 7,915 | 38.8 | 3,157 | 39.9 | <0.0001 |
| Stress level                             | 7,778 | 45.3      | 4,445 | 57.1 | 3,333 | 42.9 | 9,181 | 45.0 | 4,511 | 49.1 | <0.0001 |
| High                                     | 5,032 | 29.3      | 3,382 | 67.2 | 1,650 | 32.8 | 3,308 | 16.2 | 1,959 | 59.2 | <0.0001 |
| Middle                                   | 4,377 | 25.5      | 2,156 | 49.3 | 2,221 | 50.7 | 7,915 | 38.8 | 3,157 | 39.9 | <0.0001 |
| Low                                      | 7,208 | 41.9      | 4,528 | 62.8 | 2,680 | 37.2 | 10,955 | 53.7 | 5,437 | 49.6 | <0.0001 |
| Toothbrushing frequency in a day          | 8,173 | 47.6      | 4,579 | 56.0 | 3,594 | 44.0 | 8,350 | 40.9 | 3,784 | 45.3 | <0.0001 |
| 3 times or more a day                    | 1,806 | 10.5      | 876 | 48.5 | 930 | 51.5 | 1,099 | 5.4 | 406 | 36.9 | <0.0001 |
| Twice a day                              | 13,199 | 7.7       | 752 | 57.0 | 567 | 43.0 | 9,01 | 4.4 | 396 | 44.0 | <0.0001 |
| None or once a day                       | 3,239 | 18.8      | 1,954 | 60.3 | 1,285 | 39.7 | 5,701 | 27.9 | 2,865 | 50.3 | <0.0001 |
| Soda intake frequency                    | 6,626 | 38.6      | 4,364 | 65.9 | 2,262 | 34.1 | 5,521 | 27.1 | 3,032 | 54.9 | <0.0001 |
| More than once a day                     | 5852 | 34.0      | 3,341 | 57.1 | 2,511 | 42.9 | 6,844 | 33.5 | 3,362 | 49.1 | <0.0001 |
| 1–6 times a week                         | 4709 | 27.4      | 2,278 | 48.4 | 2,431 | 51.6 | 8,039 | 39.4 | 3,233 | 40.2 | <0.0001 |
| None                                     | 0.015 | 0.001     | 5701 | 27.9 | 2,865 | 50.3 | 2,836 | 49.7 | 4,806 | 59.8 | <0.0001 |
| Sleep time for fatigue recovery          | 6626 | 38.6      | 4,364 | 65.9 | 2,262 | 34.1 | 5,521 | 27.1 | 3,032 | 54.9 | <0.0001 |
| Sufficient                               | 5852 | 34.0      | 3,341 | 57.1 | 2,511 | 42.9 | 6,844 | 33.5 | 3,362 | 49.1 | <0.0001 |
| Normal                                   | 4709 | 27.4      | 2,278 | 48.4 | 2,431 | 51.6 | 8,039 | 39.4 | 3,233 | 40.2 | <0.0001 |
| Not sufficient                            | 0.015 | 0.001     | 5701 | 27.9 | 2,865 | 50.3 | 2,836 | 49.7 | 4,806 | 59.8 | <0.0001 |
| Variables                        | Boys   |          |          |          |           |          |          |          |          |          |          |          |          |          |
|---------------------------------|--------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|                                 | Total  | Normality| Abnormality| P value | Total     | Normality| Abnormality| P value | Total     | Normality| Abnormality| P value |          |          |          |
|                                 | N %    | N %      | N %      |          | N %      | N %      |          |          | N %      | N %      |          |          |          |          |
| Family affluence                |        |          |          |          |          |          |          |          |          |          |          |          |          |          |
| High                            | 4186   | 24.4     | 2355     | 56.3     | 1831      | 43.7     |          |          | 5687     | 27.9     | 2620      | 46.1     | 3067     | 53.9     |
| Middle                          | 9402   | 54.7     | 5436     | 578      | 3966      | 42.2     |          |          | 11,084   | 54.3     | 5232      | 47.2     | 5852     | 52.8     |
| Low                             | 3599   | 20.9     | 2192     | 609      | 1407      | 39.1     |          |          | 3633     | 17.8     | 1775      | 48.9     | 1858     | 51.1     |
| Having parents                  |        |          |          |          |          |          |          |          |          |          |          |          |          |          |
| Both parents                    | 16,191 | 94.2     | 9395     | 580      | 6796      | 42.0     |          |          | 19,290   | 94.5     | 9103      | 47.2     | 10,187   | 52.8     |
| Single parent or none           | 996    | 5.8      | 588      | 590      | 408       | 41.0     |          |          | 1114     | 5.5      | 524       | 47.0     | 590      | 53.0     |
| Parent's education level        |        |          |          |          |          |          |          |          |          |          |          |          |          |          |
| ≤ Middle                        | 132    | 0.8      | 83       | 629      | 49        | 37.1     |          |          | 164      | 0.8      | 71        | 43.3     | 93       | 56.7     |
| High school                     | 3056   | 17.8     | 1747     | 57.2     | 1309      | 42.8     |          |          | 4297     | 21.1     | 1969      | 45.8     | 2328     | 54.2     |
| ≥ College                       | 10,716 | 62.3     | 6021     | 562      | 4695      | 43.8     |          |          | 13,119   | 64.3     | 6065      | 46.2     | 7054     | 53.8     |
| Unknown                         | 3283   | 19.1     | 2132     | 64.9     | 1151      | 35.1     |          |          | 2824     | 13.8     | 1522      | 53.9     | 1302     | 46.1     |
at other indoor places during the last 7 days, was more strongly associated with oral symptoms, as compared to ETS exposure of 1–3 days of ETS (1–3 days, OR 1.42, 95% CI 1.32–1.54; 4–6 days, OR 1.84, 95% CI 1.56–2.17; 7 days, OR 1.72, 95% CI 1.32–2.23). Female adolescents were more strongly associated with oral symptoms in case of 7 days of ETS exposure than its lesser frequency at other indoor places (1–3 days, OR 1.39, 95% CI 1.30–1.49; 4–6 days, OR 1.70, 95% CI 1.50–1.93; 7 days, OR 1.88, 95% CI 1.60–2.20).

Figure 1 presents the OR for the three oral health symptoms. In male adolescents, there was a positive association between ETS experience and dental pain (OR 1.55, 95% CI 1.45–1.66) and gum bleeding (OR 1.43, 95% CI 1.29–1.58). In female adolescents, there was a positive association between ETS experience and all three oral symptoms: tooth fracture (OR 1.28, 95% CI 1.13–1.45), dental pain (OR 1.50, 95% CI 1.41–1.60), and gum bleeding (OR 1.32, 95% CI 1.21–1.44).

**Table 2** Association between ETS and oral health symptoms

| Variables                        | Boys | Girls |
|----------------------------------|------|-------|
|                                  | OR   | 95% CI| OR   | 95% CI|
| **Environmental tobacco smoke (ETS) exposure** |       |       |       |       |
| Yes                              | 1.56 | (1.46–1.66) | 1.50 | (1.41–1.60) |
| No                               | 1.00 |       | 1.00 |       |
| **Region**                       |      |       |      |       |
| Metropolitan                     | 1.05 | (0.93–1.20) | 0.98 | (0.84–1.13) |
| Urban                            | 1.14 | (1.00–1.30) | 0.96 | (0.83–1.11) |
| Rural                            | 1.00 |       | 1.00 |       |
| **Middle and high school**       |      |       |      |       |
| High school                      | 1.09 | (1.01–1.17) | 1.35 | (1.26–1.44) |
| Middle school                    | 1.00 |       | 1.00 |       |
| **Academic achievement**         |      |       |      |       |
| High                             | 1.00 |       | 1.00 |       |
| Middle                           | 0.85 | (0.79–0.92) | 0.84 | (0.78–0.91) |
| Low                              | 0.93 | (0.85–1.02) | 0.92 | (0.84–0.99) |
| **Stress level**                 |      |       |      |       |
| High                             | 1.62 | (1.47–1.79) | 1.81 | (1.64–2.00) |
| Middle                           | 1.35 | (1.25–1.47) | 1.39 | (1.27–1.52) |
| Low                              | 1.00 |       | 1.00 |       |
| **Toothbrushing frequency in a day** |      |       |      |       |
| 3 times or more a day            | 1.00 | (1.22–1.41) | 1.00 |       |
| Twice a day                      | 1.31 |       | 1.21 | (1.12–1.30) |
| None or once a day               | 1.78 | (1.58–2.02) | 1.68 | (1.45–1.95) |
| **Soda intake frequency**        |      |       |      |       |
| More than once a day             | 1.09 | (0.94–1.26) | 1.21 | (1.03–1.42) |
| 1–6 times a week                 | 1.05 | (0.96–1.15) | 1.16 | (1.09–1.25) |
| None                             | 1.00 |       | 1.00 |       |
| **Sleep time for fatigue recovery** |      |       |      |       |
| Sufficient                       | 1.00 |       | 1.00 |       |
| Normal                           | 1.26 | (1.16–1.37) | 1.11 | (1.02–1.20) |
| Not sufficient                   | 1.70 | (1.55–1.86) | 1.45 | (1.34–1.57) |
| **Family affluence**             |      |       |      |       |
| High                             | 1.16 | (1.04–1.30) | 1.08 | (0.98–1.20) |
| Middle                           | 1.13 | (1.02–1.24) | 1.05 | (0.96–1.15) |
| Low                              | 1.00 |       | 1.00 |       |
| **Having parents**               |      |       |      |       |
| Both parents                     | 1.00 |       | 1.00 |       |
| Single parent or none            | 1.06 | (0.90–1.24) | 1.10 | (0.95–1.27) |
| **Parents’ education level**     |      |       |      |       |
| ≤ Middle                         | 1.00 |       | 1.00 |       |
| High school                      | 1.36 | (0.92–2.01) | 0.80 | (0.56–1.15) |
| ≥ College                        | 1.44 | (0.98–2.13) | 0.85 | (0.59–1.21) |
| Unknown                          | 1.07 | (0.72–1.60) | 0.66 | (0.45–0.95) |

**Discussion**

Most studies on ETS exposure of non-smoking adolescents have focused on the prevalence of respiratory or mental diseases. However, we aimed to determine the association between ETS and oral health status in adolescents. The results of this study found that non-smoking adolescents who experienced ETS exposure more than once had various oral symptoms regardless of the sex.

The mechanism behind the association between ETS and tooth fracture can be explained by the results of previous studies. The messenger RNA expression of dentin matrix acidic phosphoprotein-1, bone sialoprotein, and alkaline phosphatase activity were significantly decreased in nicotine-treated human dental pulp cells, and mineralized nodule formation was also inhibited by nicotine in human dental pulp cell [19, 20]. Even non-smokers show similar level of nicotine in their bodies when exposed to ETS for a long time [21], therefore, the functions of dentin matrix synthesis and mineralization may be decreased in the dental pulp cells of adolescents who exposed by ETS, which could lead to their tooth fracture.

Also, it is reported that ETS exposure may lead to a decrease in saliva flow rate and salivary α-amylase activity along with an increase in peroxidase activity, indicating the incidence of oxidative stress [22]. One study explained that ETS exposure could lead to elevation of interleukin-1beta, albumin, and aspartate aminotransferase levels in saliva [23]. Considering these mechanisms, abnormal oral health symptoms of dental pain, and gum bleeding in non-smoking adolescents could result from ETS exposure.

The present study also reports that the association between ETS exposure and oral health is statistically significant even when adolescents have different oral health management behaviors. However, the adverse effects of ETS exposure on oral health symptoms of adolescents
can be reduced by good health habits, such as brushing teeth more often and consuming soda less frequently. Previous studies have shown that adolescents who brush their teeth twice or more a day have significantly lower incidence of caries and counts of decayed, missing, or filled teeth [24]. These preventive oral health behaviors may lower the effects of ETS exposure. Lifestyle factors such as drinking soda also lead to negative oral health symptoms. Increased soda consumption is significantly associated with the prevalence of dental erosion, according to a previous study [25, 26]. Additionally, those results about the association between ETS exposure and oral health symptoms in older adolescents might be result of the cumulative effect, in that, bad oral health is progressive in nature [29, 30], and negative effects of ETS also becomes cumulative [31, 32]. As adolescents age, they might become more vulnerable to ETS.

| Variables                              | Boys                        | Girls                        |
|----------------------------------------|-----------------------------|------------------------------|
|                                        | Oral health symptoms        | Oral health symptoms         |
|                                        | None                        | None                        |
|                                        | ETS exposure                | ETS exposure                |
|                                        | OR  | 95% CI | OR  | 95% CI |
| Toothbrushing frequency in a day        |     |        |     |        |
| 3 times or more a day                  | 1.00 | (1.24–1.53) | 1.00 | (1.39–1.65) |
| Twice a day                            | 1.00 | (1.58–1.90) | 1.00 | (1.34–1.61) |
| None or once a day                     | 1.00 | (1.28–1.97) | 1.00 | (1.29–2.33) |
| Soda intake frequency                  |     |        |     |        |
| More than once a day                   | 1.00 | (1.66–2.69) | 1.00 | (1.10–2.09) |
| 1–6 times a week                       | 1.00 | (1.40–1.64) | 1.00 | (1.47–1.72) |
| None                                   | 1.00 | (1.31–1.84) | 1.00 | (1.18–1.50) |
| Middle and high school                 |     |        |     |        |
| High school                            | 1.00 | (1.51–1.83) | 1.00 | (1.41–1.68) |
| Middle school                          | 1.00 | (1.36–1.63) | 1.00 | (1.35–1.61) |
| Family affluence                       |     |        |     |        |
| High                                   | 1.00 | (1.36–1.80) | 1.00 | (1.24–1.59) |
| Middle                                 | 1.00 | (1.42–1.68) | 1.00 | (1.37–1.63) |
| Low                                    | 1.00 | (1.35–1.84) | 1.00 | (1.49–2.04) |
| Parents’ education level               |     |        |     |        |
| ≤ Middle                               | 1.00 | (0.68–3.42) | 1.00 | (0.74–3.97) |
| High school                            | 1.00 | (1.52–2.11) | 1.00 | (1.44–1.91) |
| > College                              | 1.00 | (1.42–1.67) | 1.00 | (1.34–1.57) |
| Unknown                                | 1.00 | (1.21–1.70) | 1.00 | (1.34–1.88) |

| Table 4 Results of subgroup analysis stratified by interesting variable |
|-------------------------------------------------------|---------------------|---------------------|
| Variables                                              | Boys                | Girls               |
|                                                        | Oral health symptoms | Oral health symptoms |
|                                                        | OR      | 95% CI  | OR      | 95% CI  |
| Home ETS                                               |         |         |         |         |
| None                                                   | 1.00    |         | 1.00    |         |
| 1–3 days                                               | 1.22    | (1.11–1.33) | 1.13 | (1.03–1.23) |
| 4–6 days                                               | 1.17    | (0.99–1.39) | 1.22 | (1.06–1.42) |
| 7 days                                                 | 1.34    | (1.15–1.56) | 1.18 | (1.03–1.34) |
| School ETS                                             |         |         |         |         |
| None                                                   | 1.00    |         | 1.00    |         |
| 1–3 days                                               | 1.14    | (0.98–1.34) | 1.30 | (1.12–1.51) |
| 4–6 days                                               | 0.95    | (0.64–1.42) | 0.94 | (0.64–1.38) |
| 7 days                                                 | 1.03    | (0.66–1.61) | 1.48 | (0.88–2.48) |
| Else ETS                                               |         |         |         |         |
| None                                                   | 1.00    |         | 1.00    |         |
| 1–3 days                                               | 1.42    | (1.32–1.54) | 1.39 | (1.30–1.49) |
| 4–6 days                                               | 1.84    | (1.56–2.17) | 1.70 | (1.50–1.93) |
| 7 days                                                 | 1.72    | (1.32–2.23) | 1.88 | (1.60–2.20) |
Additional subgroup analyses of the locations and frequencies of ETS exposure confirmed that there was a statistically significant occurrence of oral health symptoms in both sex groups when they experienced ETS exposure at home. Furthermore, frequent ETS exposure at other indoor locations was associated with oral health symptoms. However, a significant association between frequent ETS exposure at school and oral health symptoms when compared with non-school ETS exposure, was observed only in female adolescents.

A previous study with a purpose similar to that of our study showed that children of parents who smoked a higher number of cigarettes reported higher cotinine concentrations than children of non-smoking parents [13]. Furthermore, another study showed that adults who experienced ETS exposure for more than two hours per day had a higher risk of cardiovascular disease than adults who experienced it for less than two hours per day [33]. As shown in these studies, the frequency of ETS could become an important factor that determines the wellness of individuals who are exposed to ETS.

Finally, the present study examined the association between ETS exposure and the prevalence of these three oral symptoms. There was a significant association between ETS and dental pain and gum bleeding in the male adolescent group and tooth fracture, dental pain, and gum bleeding in the female adolescent group. These results based on sex differences are similar to those of several previous studies, which show a stronger association of ETS with numerous diseases in the female group than in the male group; however, this should be interpreted cautiously and investigated further [34, 35].

This study has several limitations that should be considered. First, cross-sectional data were used. Therefore, the association between variables could be confirmed; causality could not be determined. Second, the results were derived from self-reported data. We specifically assessed the oral health symptoms of an individual, ETS frequencies, socioeconomic status, and health behavior covariates based on self-reported data. This finding may have been subject to recall bias [36]. Hence, the data may not have been accurately measured and may not be reliable. To provide more reliable results, future research should be conducted using the results of clinical examinations to assess the oral health status, and assessment of biological biomarkers such as salivary/blood cotinine levels to substantiate the results from self-reported data. Third, there might be factors such as individual lifestyle and personal traits, which co-vary with the oral symptoms of an adolescent and are not considered in this research model.

Despite these limitations, our study has several strengths. First, we used nationally representative data that were suitable for generalizing the results of the study to the overall South Korean adolescent population in middle and high schools. Furthermore, KYRBWS is an anonymous web-based survey that is likely to obtain relatively honest responses [37]. Third, in South Korea, few studies have been performed on the associations between ETS and oral health of adolescents, which analyzes these relationships in multi-dimensional aspects.

**Conclusion**

Our study is meaningful because it reflects the current ETS patterns of non-smoking South Korean adolescents and their association with oral symptoms. The findings of our study emphasize the importance of protecting adolescents from ETS in various environments. Multi-dimensional aspects of ETS exposure of adolescents and health habits should be considered when developing...
sophisticated health policies. The results of this study can be used as a baseline for developing effective policies to protect South Korean adolescents from ETS exposure.

Abbreviations
ETS: Environmental tobacco smoke; KYRBWS: Korea Youth Risk Behavior Web-based Survey; KDCA: Korea Disease Control and Prevention Agency; OR: Odds ratio; CI: Confidence interval.

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Author contributions
Ms. N-YY had full access to all of the data in the study and takes responsibility for the accuracy of the data analysis. Concept and design: N-YY, E-CP. Acquisition, analysis, or interpretation of data: N-YY, E-CP, IY. Drafting of manuscript: N-YY. Critical revision of the manuscript of important intellectual content: N-YY, IY, YSP, E-CP. Statistical analysis: N-YY. Supervision: E-CP. All authors read and approved the final manuscript.

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Availability of data and materials
Publicly available datasets were analyzed in this study. These data can be found here: [https://www.kdca.go.kr/yhs](https://www.kdca.go.kr/yhs) (accessed on 13 July 2022).

Declarations
Ethics approval and consent to participate
The Korea Youth Risk Behavior Web-based Survey was a secondary dataset available in the public domain. And its data were de-identified to maintain respondents’ anonymity and confidentiality. This survey was approved by the Korean National Statistical Office (Approval No. 117058). This study did not require additional approval or prior consent from the Institutional Review Board.

Consent for publication
Not applicable.

Competing interests
The authors have no conflicts of interest to disclose.

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