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EVALUATION OF THE RELATIONSHIP BETWEEN SICK BUILDING SYNDROME PREVALENCE AND INDOOR AIR QUALITY IN SCHOOLS

Okullarda Hasta Bina Sendromu yaygınlığı ile iç ortam hava kalitesi arasındaki ilişkinin değerlendirilmesi

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Abstract

In this study, it was aimed to evaluate the relationship between Sick Building Syndrome (SBS) prevalence and indoor air quality in primary and middle schools in rural and urban areas in the west of Turkey. This cross-sectional study was carried out between September and November 2018 in three randomly selected schools in rural and urban areas. The questionnaire designed to reveal perceived indoor air quality and SBS was completed by the parents of the students. On determined days, particulate matter (PM) and carbon dioxide (CO_2) levels were measured in the classrooms. Multiple logistic regression model was developed to investigate the relationship between SBS and some variables. The study was conducted on 966 students. The prevalence of SBS was found to be 10.2%. The most common SBS symptoms were listed as fatigue, nasal congestion-discharge, cough, and headache, respectively. The measured $PM_{2.5}$, PM10, and CO_2 values were higher in the urban area than in the rural area. The risk of SBS was found to be higher in primary school students, in students who have poor perceived classroom air, lighting, and noise quality, and in students studying in classrooms with higher $PM_{2.5}$, PM_{10}, and CO_2 values. One in ten students had SBS. There was a relationship between SBS and poor perceived indoor air quality and increased CO_2 and PM values. Raising awareness about SBS and conducting studies aimed at improving related factors in schools are thought to be important.

Keywords: Sick building syndrome, indoor air quality, carbon dioxide, particulate matter, school.

Özet

Bu çalışmanın amacı, Türkiye'nin batısında yer alan kırsal ve kentsel bölgelerdeki ilköğretim okullarında Hasta Bina Sendromu (HBS) yaygınlığı ile iç ortam hava kalitesi arasındaki ilişkiyi değerlendirmektir. Bu kesitsel çalışma, kırsal ve kentsel alanlardan rastgele seçilen üç okulda Eylül-Kasım 2018 tarihleri arasında gerçekleştirildi. Öğrenci velileri tarafından, iç ortam hava kalitesi algısı ve HBS'yi tanımlamaya yönelik hazırlanan anket formu dolduruldu. Belirlenen günlerde sınıflarda partikül madde (PM) ve karbondioksit (CO_2) seviyeleri ölçüldü. HBS ile bazı değişkenler arasındaki ilişkiyi incelemek için çoklu lojistik regresyon modeli oluşturuldu. Araştırma 966 öğrencide gerçekleştirildi. HBS prevalansı %10,2 olarak bulundu. En sık görülen HBS semptomları yorgunluk, burun tıkanıklığı-akıntısı, öksürük ve baş ağrısı olarak sıralandı. Ölçülen ortalama $PM_{2.5}$, PM_{10} ve CO_2 değerleri kentsel bölgede kırsal bölgeye göre daha yüksekti. HBS olma riski; ilkokul öğrencilerinde, sınıf hava kalite algısı, sınıf aydınlatma algısı ve sınıf gürültü algısı kötü olanlarda, $PM_{2.5}$ ve PM_{10} değerlerinin daha yüksek ölçüldüğü sınıflardaki öğrencilerde daha yüksek bulundu. Her on öğrenciden birinde HBS vardı. HBS ile iç ortam hava kalitesinden rahatsız olma durumu ve artan CO_2 ve PM değerleri arasında bir ilişki vardı. Okullarda HBS konusunda farkındalığın artırılması ve ilgili unsurların iyileştirilmesine yönelik çalışmaların yapılmasının önemli olduğu düşünülmektedir.

Anahtar kelimeler: Hasta bina sendromu, iç ortam hava kalitesi, karbondioksit, partiküler madde, okul.

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Introduction

People living in developed and developing countries spend approximately 90% of their lives in indoor areas, such as offices, homes, schools, gyms, and public transport vehicles. Children who spend more time indoors than adults are more sensitive to exposure to environmental influences because of their rapid metabolism, undeveloped organ systems, and increased growth rates (1).

Indoor air quality deteriorates with high temperature, humidity, and presence of pollutants. Factors considered as pollutants such as cigarette smoke, radon, asbestos, lead, volatile organic compounds, carbon monoxide, sulfur dioxide, nitrogen oxides, formaldehyde, carbon dioxide (CO_2), and particulate matter (PM) are known to be associated with some symptoms (2, 3). One of the health problems caused by the deterioration of indoor air quality is Sick Building Syndrome (SBS).

SBS is defined as a condition occurring in those who spend time in modern buildings and who suffer from symptoms such as headache, fatigue, lack of concentration, and irritation of the skin and mucous membranes (4). In addition to environmental effects such as inadequate heating, ventilation, and air conditioning systems, poor indoor air quality, presence of mold and moisture, and noise, personal factors such as stress, psychosocial factors, and allergic conditions are considered the causes of SBS (5).

Although there is an increase in the number of studies on SBS, these studies mostly evaluate adults in the work environment. There are not enough studies in the literature about SBS in children. However, the World Health Organization (WHO) reported that 36% of respiratory diseases and 22% of chronic diseases in children are associated with poor indoor air quality in classrooms (6). In Turkey, no studies have been conducted so far to evaluate the association between SBS and indoor air quality. Exposure assessment is essential to determine the relationship between air pollution and its health effects. However, one of the biggest challenges of environmental epidemiology is to analyze the nature of this exposure (7). In particular, studies on vulnerable groups such as children, the elderly, and women are important.

In this study, it was aimed to evaluate the relationship between SBS prevalence and indoor air quality in primary and middle schools in rural and urban areas in the west of Turkey.

Material and Method

This cross-sectional study was carried out between September and November 2018 in three schools in rural and urban areas in the center of Kütahya, a city in western Turkey. Approval from the local ethics committee (Clinical Research Ethics Committee of Kütahya Health Sciences University (2018-13/11)) and administrative permits were obtained. In the Turkish educational system, primary and secondary education consists of four years of primary school, four years of middle school, and four years of high school. The population of the study consists of 14505 primary and middle school students studying in the central district of Kütahya, identified as the Education and Research Area of Kütahya Health Sciences University, under the protocol signed with the Provincial Health Directorate. As a result of the sample size calculation made with the Epi Info 7 program, the required sample size was calculated as 935. Two schools in the rural area and one school in the urban area were selected by simple random sampling method. The study was completed with 966 students out of 1089 (participation 88.71%) students. A total of 123 students were not included in the study due to the inability to reach the students, parents' disapproval of the study, asthma allergy with doctor diagnosis, and exclusion of incomplete questionnaires.

The schools in the rural area where the study was conducted were built 1986 and 2008 and have naturally ventilated classrooms with sizes ranging from 42-49 m^2. The rural school, which is 25 km from the city center, uses a coal-fired boiler while the rural school, which is 5 km from the city center, uses natural gas for heating. The school in the urban area consists of two reinforced concrete buildings built 1988 and 2001, with classrooms with sizes ranging from 45-50 m^2. It has no insulation, is naturally ventilated, and uses natural gas for heating. All three schools are cleaned on a regular basis.

The questionnaire form included questions aimed at finding the sociodemographic characteristics of the participants and the "MM 080 NA School" questionnaire. “MM Questionnaire” was developed by Andersson et al. in 1985 to assess the indoor air quality and its effects on the people living in these environments. Over the years, different versions of this questionnaire were used in environments such as offices, schools, hospitals, etc., each under a different name. The version used in our study was the "MM 080 NA School" form. This form includes evaluation sections on sociodemographic characteristics (sex, age, height, weight, parental education status, and parental occupation), allergy-asthma history, present symptoms, and general thoughts about home and classroom environment (8). This form was translated from English into Turkish and back from Turkish to English by two experts. The intelligibility, validity, and reliability of the questionnaire were tested with a group of 10 participants. The questionnaire comprised Likert-type items, which were confirmed to be clear and understandable, and Cronbach's alpha was calculated as 0.890.

The items about the classroom environment were 5-point Likert-type (very good, good, acceptable, bad, very bad) and aimed to reveal temperature conditions, air quality, lighting, noise conditions, space (row, chair, color), and cleanliness of the classrooms. These questions were answered by teachers and parents. Each of these questions was expressed as perception (ie, perceived temperature, air quality, etc.) and classified as good and poor perception. The participants' 'bad' and 'very bad' responses were accepted as poor perception while 'acceptable,' 'good,' and 'very good' responses were accepted as good perception.

The questions about current (last three months) general symptoms (fatigue, headache, sleeping problems, stomachache) and mucocutaneous symptoms (itching/burning/irritation of the eyes, irritated/stuffy/runny nose, cough, dry/flushed facial skin, scaling/itching scalp or ears, hands dry/itching/red skin) were answered as "yes / often (every week)," "yes / sometimes," or "no / never." Those who answered "yes / often" were asked whether these symptoms were caused by the school environment, which they answered as "yes," "no," or "I do not know." SBS was accepted to be present if there was at least one of the general symptoms and at least one of the mucocutaneous symptoms in the group indicating that the general symptoms and mucocutaneous symptoms experienced in the last three months were seen every week and that these symptoms originated from the school environment (Figure 1) (9).

The PM and CO_2 measurements were carried out twice in 42 classrooms in the first half and the second half of the lesson. While the measurements were made, the devices were calibrated while being transferred from one classroom to another. It was ensured that the doors and windows were closed during the lesson in the classrooms to be measured. Measurements were made at the farthest point from the door and windows. The measurements were performed by placing the devices at the average nose distance when the students sat on the desk. The "Particles Plus 8306 Handheld Particle Counter" device measures 0.3 to 25.0 µm with a flow rate of 0.1 CFM (2.83 LPM). "Testo 480 Multifunction Measuring Instrument" is a simple, manual, mobile, sensor-based device. The indoor air quality probe (IAQ) is used to measure the CO_2 level, temperature, and relative humidity of the environment.

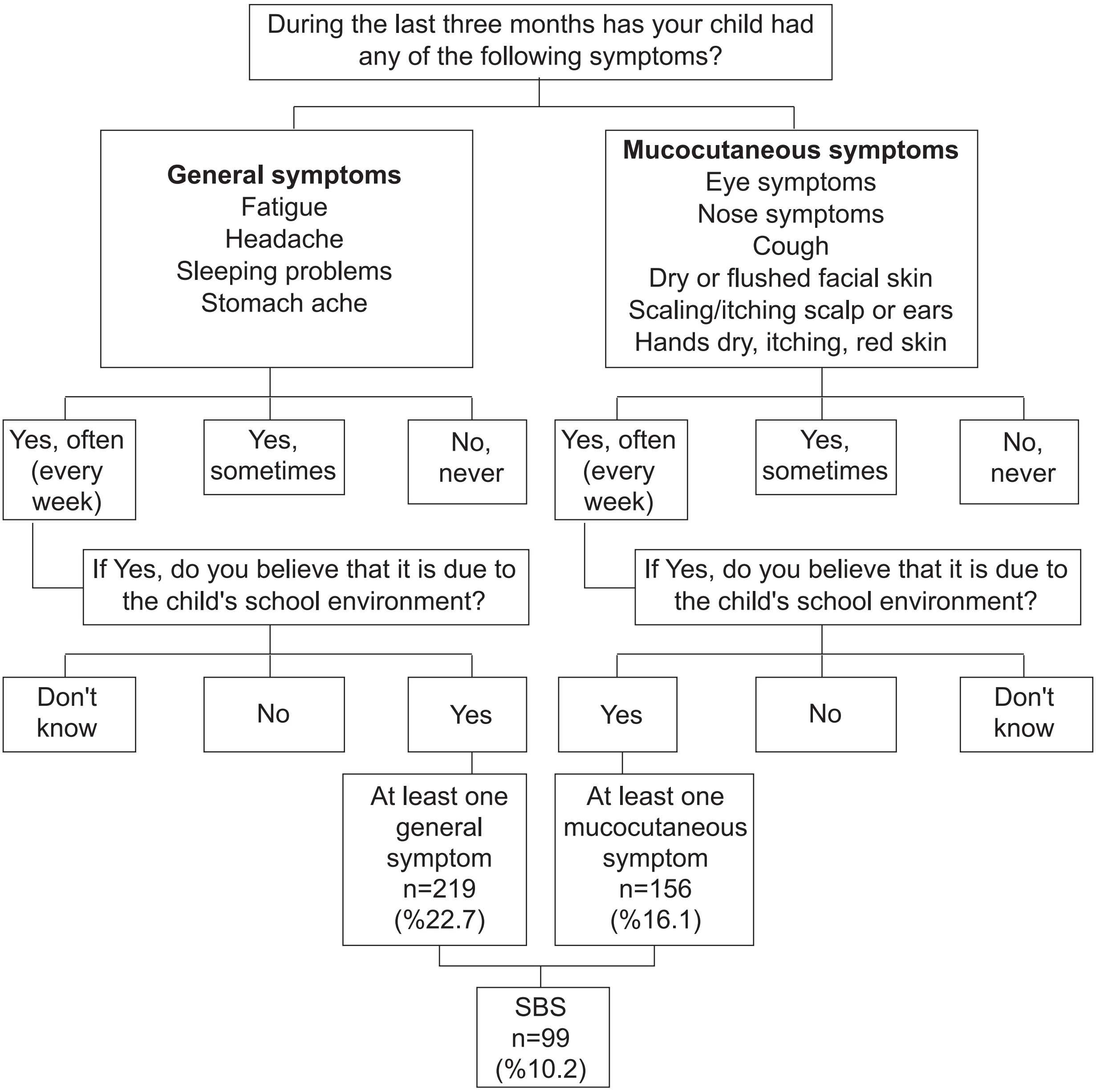

Figure 1: SBS diagnosis algorithm.

The data of the study was evaluated using the "SPSS 20" package program. In descriptive data, numbers and percentages were used for categorical variables, and mean, standard deviation, median, minimum, and maximum values were used for numerical variables. The suitability of numerical variables to normal distribution was examined by the Kolmogorov-Smirnov test. Pearson chi-square test was used for comparisons between categorical variables. Mann-Whitney U test was used to compare continuous variables that did not fit the normal distribution in two independent groups. In univariate analysis, the multivariate logistic regression model was established with independent variables giving p<0.10 value and corrected according to rural-urban. SBS was taken as the dependent variable, and perceived classroom indoor air quality questions and PM and CO_2 values (classified as categorical variables) were taken as the independent variables. Statistical significance was accepted as p≤0.05.

Results

Of the 966 students who participated in the study, 50.9% (n=92) were girls, 49.1% (n=474) were boys, and the mean age was 9.23 ± 1.90 (min:6 - max:13). 72.4% (n=699) of the students were studying in the urban area, and 47.9% (n=463) were primary school students.

Of the 966 students, 22.7% (n=219) had at least one general symptom, and 16.1% (n=156) had at least one mucocutaneous symptom. The prevalence of SBS was found to be 10.2% (n=99) in subjects with at least one general symptom and at least one mucocutaneous symptom. The examination of the frequency of SBS symptoms thought to be caused by the school environment yielded the following results: When the incidence of general symptoms was examined, 14.3% (n=138) had fatigue, 9.3% (n=90) had headache, 7.7% (n=74) had abdominal pain, and 4.7% (n=45) had sleeping problems. Also, when the incidence of mucocutaneous symptoms was examined, irritated, stuffy, or runny nose was seen in 11.9% (n=115), cough in 9.4% (n=91), and itching/burning/irritation of the eyes in 3.3% (n=32) (Figure 2).

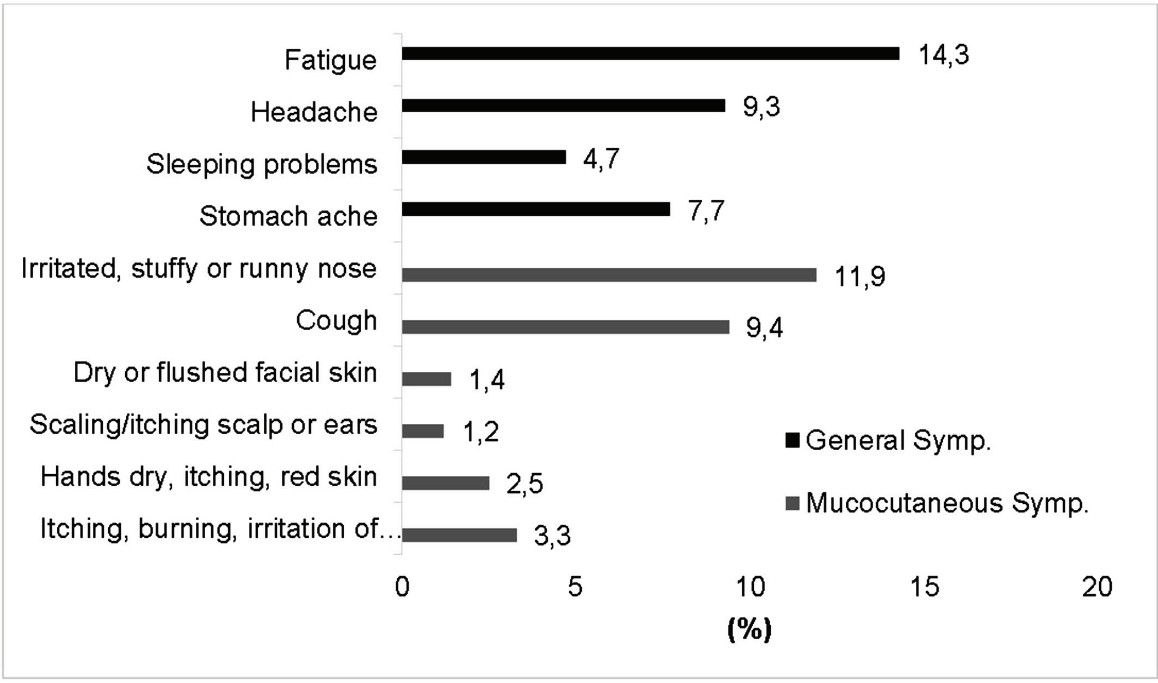

Figure 2: Percentage of the presence of SBS symptoms in children.

SBS level was found to be higher among students studying in urban areas than those studying in rural areas (p=0.010) and higher in primary school students than in middle school students (p=0.025). In the study, no relationship was found between sex, age, parental educational status, parental occupation, and SBS status (p>0.05) (Table 1).

The median values of temperature and PM and CO_2 measurements were higher in urban areas than in rural areas (Table 2).

Table 1: Comparison of SBS and sociodemographic characteristics.

	SBS			Statistics*	
	Yes n (%)	No n (%)	Total n (%)	X^2	p
Sex					
Boys	429 (90.5)	45 (9.5)	474 (49.1)	0.576	0.448
Girls	438 (89.0)	54 (11.0)	492 (50.9)		
Age					
≤ 7	197 (86.8)	30 (13.2)	227 (23.5)	4.521	0.210
8-9	209 (88.6)	27 (11.4)	236 (24.4)		
10-11	392 (91.5)	36 (8.4)	428 (44.3)		
≥ 12	69 (92.0)	6 (8.0)	75 (7.8)		
Settlement					
Rural	251 (94.0)	16 (6.0)	267 (27.6)	6.641	**0.010**
Urban	616 (88.1)	83 (11.9)	699 (72.4)		
School					
Primary school	405 (87.5)	58 (12.5)	463 (47.9)	5.019	**0.025**
Middle school	462 (91.8)	41 (8.2)	503 (52.1)		
Mother Education					
Middle school and below	508 (91.2)	49 (8.8)	557 (59.4)	4.915	0.086
High school	213 (87.7)	30 (12.3)	243 (25.9)		
University	118 (85.5)	20 (14.5)	138 (14.7)		
Father Education					
Middle school and below	296 (90.5)	31 (9.5)	327 (35.9)	3.288	0.193
High school	317 (90.6)	33 (9.4)	350 (38.4)		
University	202 (86.3)	32 (13.7)	234 (25.7)		
Mother Occupation					
House-wife	633 (88.9)	79 (11.1)	712 (78.0)	4.274	0.233
Worker	79 (92.9)	6 (7.1)	85 (9.3)		
Civil servent	42 (84.0)	8 (16.0)	50 (5.5)		
Others	62 (93.9)	4 (6.1)	66 (7.2)		
Father Occupation					
Worker	355 (90.8)	36 (9.2)	391 (43.0)	4.228	0.238
Civil Servent	154 (89.0)	19 (11.0)	173 (19.0)		
Self-employment	188 (85.8)	31 (14.2)	219 (24.1)		
Others	116 (91.3)	11 (8.7)	127 (14.0)		

**Pearson chi-square test*

Table 2: Comparison of measured values in rural and urban areas.

	Total	Rural	Urban	Statistics*
	Median (min-max)	Median (min-max)	Median (min-max)	Z p
Temperature (°C)	24.45 (21.01-26.61)	23.52 (21.01-26.00)	24.63 (22.93-26.61)	Z=-3.330 **p<0.001**
Relative Humidity (%)	51.82 (47.32-60.92)	52.22 (47.32-58.38)	50.94 (49.32-60.92)	Z=-0.508 **p=0.611**
$PM_{2.5}$ (µg/m^3)	19.67 (11.42-67.82)	15.26 (12.49-35.26)	20.09 (11.42-67.82)	Z=-2.465 **p=0.014**
PM_{10} (µg/m^3)	260.64 (58.42-737.33)	227.71 (58.42-737.33)	272.62 (62.00-684.69)	Z=-2.221 **p=0.027**
CO_2 (ppm)	1578.90 (743.04-3046.18)	1239.78 (968.24-2625.84)	1583.66 (743.04-3046.18)	Z=-1.957 **p=0.050**

**Mann-Whitney U Test*

As a result of multivariate logistic regression model, the risk of SBS was found to be 2.3 times higher (p=0.002) for primary school students, 2.2 times higher (p=0.001) for the students whose parents and teachers have poor perceived classroom air quality, 3.7 times higher (p=0.002) for the students whose parents and teachers have poor perceived classroom lighting quality, 1.8 times higher (p=0.022) for the students whose parents and teachers have poor perceived classroom noise quality, 5.3 times higher (p=0.022) for the students in the classrooms with $PM_{2.5}$>45 µg/m³ values, 3.8 times higher (p=0.049) for the students in the classrooms with $PM_{2.5}$ values between 150 and 300 µg/m³ (Table 3).

Table 3: Multiple logistic regression results of class indoor perception and measurement values with SBS.

		95% CI for OR		
Risk Group	**Odds Ratio**	**Lower**	**Upper**	**p**
School				
Middle	1			
Primary	2.345	1.358	4.079	**0.002**
Classroom air perception				
Good	1			
Poor	2.238	1.376	3.641	**0.001**
Classroom lighting perception				
Good	1			
Poor	3.733	1.593	8.750	**0.002**
Classroom noise perception				
Good	1			
Poor	1.759	1.084	2.855	**0.022**
$PM_{2.5}$				
<25 µg/m³	1			
25-45 µg/m³	2.409	0.862	6.737	0.094
>45 µg/m³	5.321	1.269	22.304	**0.022**
PM_{10}				
<150 µg/m³	1			
150-300 µg/m³	3.846	1.006	14.707	**0.049**
>300 µg/m³	1.898	0.647	5.563	0.243
CO_2				
<1000 ppm	1			
1000-1500 ppm	1.544	0.576	4.141	0.388
1500-2000ppm	2.198	0.768	6.289	0.142
>2000ppm	1.935	0.647	5.787	0.238

CI: Confidence Interval

Discussion

Indoor air quality is becoming increasingly important for children who have to spend more time indoors than adults (1). The deterioration of indoor air quality leads to some health problems, one of which is SBS. In this study, we aimed to determine the prevalence of SBS in students in three schools, which were located in a western province in Turkey, and evaluate the relationship between PM and CO_2 values and SBS and perceived air quality.

Although there is no generally accepted diagnostic criterion for SBS, in some studies, as in our study, the diagnosis can be made based on the symptoms seen in individuals (9). Also, some researchers have conducted studies on the frequency of symptoms rather than diagnosis (10,11). In our study, the prevalence of SBS was 10.2%. While the prevalence of SBS in adults varies between 20.9 and 27.8% in the literature, there are no studies indicating the prevalence in the pediatric population (9,12). In this respect, our study is the first study to investigate the prevalence of SBS in children. At the same time, it is the only study in Turkey that evaluates the relationship between indoor air quality and SBS.

In our study, the prevalence of SBS was found to be higher in students studying in urban areas than those studying in rural areas. In addition, measured PM and CO_2 values in urban areas were higher than in rural areas. Branco et al. reported that children are exposed to indoor air pollution more severely in urban areas than in rural areas and that this indoor pollution is mostly caused by $PM_{2.5}$ and CO_2 (13). It has been shown that rhinoconjunctivitis and allergic symptoms appear less in students in rural areas than in urban areas and that the indoor air quality of classrooms in rural areas is better (14). In a study conducted in Korea, the number of indoor pollutants was found to be more in urban areas (15). In accordance with the literature, it can be considered that higher levels of air pollution in urban areas increase indoor air pollution, which is the main reason for higher SBS levels among students studying in urban areas. In addition, some studies reported higher numbers of students and a higher prevalence of SBS in urban areas (13), which is consistent with our findings.

In our study, while the percentage of participants having at least one general symptom was 22.7%, the percentage of those having at least one mucocutaneous symptom was 16.1%. Zhang et al. reported that the percentage of general symptoms ranged from 20.4% to 28.6%, mucosal symptoms ranged from 22.7% to 33.4%, and the incidence of cutaneous symptoms ranged from 4.6% to 8.0% (16–18). In other studies, the frequency of general symptoms ranged from 18.3% to 42.0%, mucosal symptoms ranged from 13.9% to 45.18%, and the frequency of skin symptoms ranged from 2.2% to 9.4% (12, 19, 20).

When all the symptoms were examined, the most common symptoms were fatigue, irritation, stuffy or runny nose, cough, and headache, respectively. In a study conducted on primary school students in Japan, the most common symptoms were nasal symptoms, skin symptoms, cough, and eye symptoms (11). In Malaysia, the symptoms in the students were fatigue, headache, rhinitis, sore throat, eye, and skin symptoms (10). In their study conducted in 2019, Amouei et al. reported the most common SBS symptom as dizziness in winter and fatigue in spring (21). In another study, similar to our study, the most common symptoms were fatigue, nasal congestion/discharge, cough, and headache (16).

In our study, the risk of SBS was found to be two times higher in participants with poor perceived air quality caused by some variables such as dry air and stuffy classrooms than in participants with good perceived air quality. In studies conducted with adults, SBS has been reported to be more common in patients, especially with eye symptoms, fatigue, and skin symptoms (5, 9). It can be thought that variables such as increased mold, humidity, CO_2 concentration, and human activities in the indoor environment may cause dry air, stuffiness, and odor.

Air pollution is one of the major environmental problems, and it is increasing, especially in urban areas (22). WHO determined that the limit values at 24-hour concentrations were 25 µg/m^3 for $PM_{2.5}$ and 50 µg/m^3 for PM_{10} (23). In most studies where $PM_{2.5}$ and PM_{10} measurements were performed in the school environment, measurement results were found to be higher than the WHO criteria (24, 25). When compared with the literature data, the $PM_{2.5}$ values we measured were lower than those found in other studies but were still above the limit values. However, the PM_{10} values we measured were higher than those reported in the literature. $PM_{2.5}$ and PM_{10} sources are different and vary between regions and countries (26). High PM_{10} values obtained in this study can be attributed to the agricultural and soil activities in rural areas, and mainly to the particles from the traffic activities in urban areas.

One of the important indoor pollutants is CO_2. The most important source of CO_2 is CO_2 produced by respiration, and it varies according to the number of people in the environment and volume and ventilation characteristics of the environment (27). Although WHO has established a limit of 1000 ppm for indoor CO_2 concentration (28), it has been reported that symptoms such as lack of concentration and headache are seen above 800 ppm (29). In our study, the median CO_2 value was found to be 1578 ppm. Mendell et al. measured the CO_2 value in a wide range as 600-7000 ppm in three schools and 150 classrooms (29). Muscatiello et al. determined the CO_2 level in the range of 352-1591 ppm (30). In a study conducted in Greece, it was found that CO_2 values were in the range of 893-2082 ppm and CO_2 levels increased as the number of students in the classrooms increased (31). Although our results were higher than 1000 ppm, which was the WHO limit value, it was found to be compatible with other studies in the literature. As classrooms are crowded and adequate ventilation is not possible, especially in winter due to the cold weather, it can be predicted that CO_2 levels will be high.

A study conducted with students in Malaysia demonstrated the relationship between PM_{10} and CO_2 and SBS symptoms (10). Many studies have shown that headache, fatigue, and lack of concentration increase and school performance decreases with increasing CO_2 concentration (29, 30). In a study conducted with students, it was found that high CO_2 concentration increased SBS and decreased short-term performance (32). Because the main source of CO_2 is human respiration, the risk of SBS increases when classrooms are not adequately ventilated (3). In addition, it was shown that not only the measurement values but also psychosocial factors are related to perceived indoor air quality (33). In a study conducted in schools in 2016, it was found that poor perceived indoor air quality was 1.6 times higher when $PM_{2.5}$ was above 25 µg/m^3 and 1.2 times higher when CO_2 was above 1000 ppm (34). The literature data are similar to the findings of our study. It is clear that $PM_{2.5}$, PM_{10}, and CO_2 values have an effect on both indoor air quality and SBS.

Limitations of the study can be listed as the diagnosis of SBS through self-report measures, short measurement times, inability to observe seasonal differences, and measurement of only PM and CO_2 values, although there are many determinants of indoor air quality (biological pollutants, carbon monoxide, radon, polycyclic aromatic hydrocarbons, nitrogen oxides, sulfur dioxide, formaldehyde, pesticides, asbestos, lead, volatile organic compounds, etc.).

Conclusions

The prevalence of SBS was 10.2%. The risk of SBS was found to be higher in urban areas, in primary school students, in students whose parents and teachers have poor perceived classroom air, lighting, and noise quality, and in students in classrooms with higher values of $PM_{2.5}$, PM_{10}, and CO_2.

School administrators should be informed about indoor air quality and SBS and take measures to improve air quality. Schools should be cleaned on a regular basis, and air-cleaning devices, if affordable, should be used. Classrooms should be ventilated frequently to keep the carbon dioxide levels under control.

In urban areas where PM values are high, PM contents should be investigated, and sources of pollutants should be prevented. For this purpose, cooperation should be ensured among institutions (municipalities, universities, school administrations). In addition, periodic training should be organized to raise awareness among parents and school management about air pollutants and their effects. Students who are considered to be at risk for environmental exposure should be referred to health institutions for detailed consultations and examinations.

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