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The Relationship Between Asthma/Allergy Symptoms in Children and Indoor Particulate Matter in Schools

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Abstract

BACKGROUND/AIMS: Air pollution is one of the major environmental problems and it is steadily increasing, especially in urban areas. When children start school, they are exposed to airborne pollutants in indoor areas more than outdoor areas. In this study, it was aimed to investigate the relationship between asthma symptoms and indoor particulate matter (PM) measurements and some risk factors in students attending a primary school in Western Türkiye.

MATERIALS AND METHODS: This cross-sectional study was conducted between October and December, 2018. The questionnaire form included questions about the asthma/allergy symptoms of the students, and certain environmental risk factors. Temperature, humidity and PM were measured in the indoor environment of the school.

RESULTS: This study was completed with 412 students and their mean age was 8.66±1.16 years. The two out of ten students had asthma symptoms, allergic rhinitis, or dry cough symptoms, and the prevalence of skin symptoms-eczema was around 4%.

CONCLUSION: The symptoms were related to a family history of asthma and carpets covering more than half of floor area of the home. The symptoms at school were found to be related to an increase in the number of students in the classroom and the PM values.

Keywords: Allergy symptoms, asthma, prevalence, school, indoor, particulate matter, children

INTRODUCTION

Asthma and other atopic diseases, such as allergic rhinitis and eczema, are common health problems affecting children's health. These diseases are seen at higher rates in developed countries compared to developing countries. To determine morbidity and mortality rates, studies determining the prevalence of symptoms related to diseases are valuable.[1,2] Early detection and treatment of allergic symptoms and the identification of risk factors are essential for the prevention of diseases.[2-4] Some of the risk factors may be listed as personal factors, such as age, sex, and immunological status, psychosocial factors, socioeconomic factors, characteristics of the home, and poor indoor air quality in schools, where children spend most of their time.[4-9] The World Health Organization (WHO) reported that 36% of respiratory diseases in children and 22% of chronic diseases are associated with poor indoor air quality in classrooms.[10] Indoor air quality deteriorates with higher temperatures, increased humidity, and the presence of pollutants. Pollutants such as particulate matters (PM), carbon dioxide, high levels of Volatile Organic Compounds, the presence of mold, and passive smoking are known to be associated with increased asthma and allergic symptoms in children.[3,7-9] Especially 0.5 µm diameter PMs enter into the lower airways easily, and close to 60% of $PM_{2.5}$ and PM_{10} are reported to be of external origin.[7-9] Due to building design, ventilation conditions, dynamic activities, and high numbers of students in a limited space, the school indoor environments increase exposure to air pollution.[7] At the same time, it has been stated in epidemiological studies that the exposure of children, who are more sensitive and vulnerable than

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adults, to polluted air in the school environment has negative effects on their neurological development.[3,5,6]

In cross-sectional studies conducted in our country, the prevalence of asthma diagnosed in children aged over six years ranged between 4.8% and 17.6%, while the prevalence of asthma symptoms was reported to be between 6.5% and 17.2%.[11,12] Among these studies evaluating the prevalence of the disease in conjunction with some environmental risk factors, there was no study examining the relationship between indoor PM and symptoms.

In this study, it was aimed to investigate the relationship between asthma symptoms and indoor PM measurements and some risk factors in students attending a primary school in the center of Kütahya in western Türkiye.

MATERIALS AND METHODS

Study Design

This was a cross-sectional study conducted between October and December, 2018. Local ethics committee [Clinical Research Ethics Committee of the Kütahya Health Sciences University (approval number: 2018-13/12)] and institution permissions were obtained for this study. The population of this study consisted of all students studying at a primary school randomly selected from the center of Kütahya.

Procedures

On the designated days, classroom teachers were informed about the study, and questionnaires were distributed to the parents of the students. Verbal and written information was given to the children and the parents about the purpose and scope of this study, and their written consent was obtained. PM measurements were performed in the classrooms on the days following the distribution of the forms. Since participation was voluntary, those children of parents who did not want to answer the questionnaire were excluded from the study. The total number of students studying at the school was 475, and the study was completed with 412 students who agreed to participate (with a participation rate of 86.7%).

Measures

The questionnaire form included questions about the socio-demographic characteristics of the parents, the asthma/allergy symptoms of the students, their history of the physician-diagnosed diseases, and environmental risk factors. There were also questions about the students' gender, their number of siblings, allergic symptoms in school, the smoking status at home, and the conditions in the home. Data related to asthma/allergy symptoms were obtained through "*The International Study of Asthma and Allergies in Childhood-ISAAC*" questionnaire.

The *ISAAC questionnaire* is a form developed by the ISAAC Steering Committee to make comparisons between populations in different countries and to determine the prevalence and severity of asthma, allergic rhinitis, and eczema symptoms in children.[1,2] Many prevalence studies conducted in Türkiye have utilized this form.[11,12] This form investigates whether the children, their parents, or their siblings have had asthma during the last year or throughout their lives and whether they currently have asthma symptoms, allergic rhinitis, or eczema.

The "*Particles Plus 8306 Handheld Particle Counter*" was used at the beginning and end of the lessons for the measurement of the amount of PM away from windows and doors in the classrooms. It was ensured that the doors and windows were closed during the lesson in the classrooms to be measured. While the measurements were made, the devices were calibrated while being transferred from one classroom to another. It is a simple, manual, mobile, sensor-based device which measures temperature, humidity, and PM. This device counts PM values between 0.3 and 25 µm with an airflow rate of 0.1 CFM (2.83 LPM). In this study, we measured indoor air $PM_{2.5}$ (particles less than 2.5 µm in diameter) and PM_{10} (particles less than 10 µm in diameter) values. Measurements can be reported in accordance with ISO 14644-1, E GMP Annex 1, or FS 209. Measurements are given as $\mu g/m^3$.

Definitions

The presence of asthma, asthma symptoms, allergic rhinitis, or eczema in the previous one year was investigated according to the ISAAC form, and those students with any of these in the previous year were defined as the *symptomatic group*.

At the same time, the teachers were interviewed regarding each student in order to determine the severity and frequency of these symptoms while at school. As a result of these interviews, students with symptoms such as coughing, sneezing, runny nose, nasal congestion, itching, watering or reddening of eyes, and redness despite the absence of cold or flu, were defined as the *symptomatic in school group*.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences 27.0 statistical analysis program (IBM SPSS Corp.; Armonk, NY, USA). Qualitative data are given as numbers and percentages and evaluated by the chi-squared test. The means, standard deviations (SD), medians, minimums, and maximums values of the measured data are given. Since the data were not normally distributed, the Mann-Whitney U test was used for the comparison of the group medians, and logistic regression was used for further analysis. In the univariate analysis, two multivariate models were constructed with independent variables with $p<0.10$ values and corrected for age and sex. The *symptomatic group* in the previous year was included as the dependent variable for the first model and the *symptomatic in school group* for the second model. Categorical variables such as the presence of a family history of asthma, the smoking status at home, and carpets covering more than half of the floor area in the home were taken as independent variables for the first model. The presence of a family history of asthma, class size, and PM values measured in the environment (the linear logarithm of some were taken to provide a normal distribution) formed the variables for the second model. The statistical significance was set at $p<0.05$.

RESULTS

This study was carried out in a primary school with 412 students, of whom 47% (n=194) were girls and 52.9% boys (n=218). The mean age of the students in the 1st, 2nd, 3rd, and 4th grades was 8.66±1.16 years (minimum: 7, maximum: 11). Each grade had four classes, and the average size of the classes was 26.7±3.3 students (minimum: 22, maximum: 33).

According to the ISAAC form, the prevalence of asthma, asthma symptoms, allergic rhinitis, dry cough, and eczema, which had been present within the previous one year were 14.1%, 17%, 25.7%, 18.4%, and

4.6%, respectively. The prevalence of previous pneumonia was found to be 5.6%. When the symptoms seen in the school were evaluated, the prevalences were 22.3% for nasal discharge-congestion, 13.1% for dry cough-sneezing, 8.5% for redness-itching-watering of the eyes, and for skin dryness and redness, it was 3.6% (Table 1).

While there was no relationship between the gender and asthma symptoms of the students, the mean age of the symptom group was higher than that of the non-symptom group (Table 2).

Some of the socio-demographic characteristics of the parents and the characteristics of the homes they lived in are presented in Table 3. Table 4 presents the distributions of the means ± SD and minimum-maximum values for class sizes and the measured PM results in the classrooms.

The relationship between the symptomatic in the previous year group and the symptomatic group in terms of the students' risk factors at home and at school, their socio-demographic characteristics, and the measurements were evaluated by univariate analyses. As a result of this analysis, a regression model was created with independent variables giving $p<0.10$ value. These data are presented in Table 5.

According to Model 1, which was established to determine the relationship between asthma and the symptoms of the students seen within the previous year and some risk factors at home; the risk of having asthma was found to be 5.7 times higher ($p<0.001$) for those with a family history of asthma and 2.1 times higher ($p=0.024$) for those who lived in a home with carpets covering more than half of the floor area (Table 5).

According to Model 2, which was established to determine the relationship between asthma and symptoms seen in school and the PM measurements and some other risk factors; the risk of having asthma was found to be 3.5 times higher ($p<0.001$) in those children with a family history of asthma, 1.2 times higher ($p=0.007$) in those with an

Table 1. Distribution of symptoms in students within the previous year generally and at school

The symptomatic group within the previous year	**n**	**%**
Asthma	58	14.1
Asthma symptoms	70	17.0
Allergic rhinitis	106	25.7
Eczema	19	4.6
Pneumonia	23	5.6
Dry cough	76	18.4
The symptomatic in school group	**n**	**%**
No symptoms	216	52.4
Dry cough-sneezing	54	13.1
Runny nose-nasal congestion	92	22.3
Skin redness-itching	15	3.6
Redness-itching-watering of the eyes	35	8.5

Table 2. Comparison of age and gender with symptoms at school

The symptomatic group in the previous year				
	No symptoms (n=216) n (%)	**Symptoms (n=196) n (%)**	**Total (n=412) n (%)**	**Statistics**
Age				
Mean ± SD	8.50±1.09	8.84±1.07	8.66±1.16	t=-2.962 **p=0.003**
Gender				
Male	114 (52.3)	104 (47.7)	218 (52.9)	X^2=0.030
Female	102 (52.6)	92 (47.4)	194 (47.1)	p=0.954
The symptomatic in school group				
	No symptoms (n=347) n (%)	**symptoms (n=65) n (%)**	**Total (n=412) n (%)**	**Statistics**
Age				
Mean ± SD	8.57±1.14	9.14±1.17	8.66±1.16	t=-3.701 **p=0.001**
Gender				
Male	182 (83.5)	104 (16.5)	218 (52.9)	X^2=0.189
Female	165 (85.1)	92 (14.9)	194 (47.1)	p=0.664

SD: Standard deviation.

increased number of students in the classroom, and 1.1 times higher with each step increase of PM_{10} values (Table 5).

The changes in the frequency of the students' symptoms seen at school, according to the measured $PM_{2.5}$ and PM_{10} values are shown in Figure 1, 2. It was found that dry cough-sneezing increased in line with the measured $PM_{2.5}$ values, and redness-itching-irrigation symptoms increased in line with the measured PM_{10} values (Figure 1, 2).

DISCUSSION

Air pollution is one of the major environmental problems and it is steadily increasing, especially in urban areas. Pollution factors in outdoor and indoor air affect health negatively.[4] Children spend most of their lives at school and spend more than 70% of their school time in indoor areas. When children start school, they are exposed to airborne pollutants in indoor areas more than outdoor areas. Classrooms are the second most crucial indoor environment after homes for children.[9] There are PMs of different diameters and sizes in indoor air in classrooms. They are emitted from many sources, such as heating sources, building

Table 3. Socio-demographic characteristics of the students' parents and the homes they live

Socio-demographic characteristics of parents	**n**	**%**
Education of mother (primary school)	196	47.6
Education of father (primary school)	86	20.9
The presence of symptoms (asthma etc.) in the family	85	20.6
Characteristics of the home	n	%
Age of the building (older than 20)	210	51.0
Smoking status at home	143	34.7
House type (detached house)	62	15.0
Floor material (concrete)	82	19.9
Living in a home with carpets covering more than half of the floor area	257	62.4
House heating (stove)	27	6.5
Pets at home	74	17.9
Potted plants at home	193	46.8
Moisture/mold at home	27	6.7

Table 4. Distribution of class size and measurement results

Characteristics of classes, results of the measurements	**Mean ± SD**	**Median**	**Min.-Max.**
$PM_{2.5}$ (μg/m^3)	99.71±18.41	97.49	76.32-143.68
PM_{10} (μg/m^3)	696.98±179.77	682.94	384.23-1187.02
Temperature (°C)	23.22±1.08	23.57	20.1-24.8
Humidity (%)	58.42±5.38	57.24	50.2-70.2
Class size	26.76±3.28	26	22-33

SD: Standard deviation, Min.: Minimum, Max.: Maximum, PM: Particulate matters.

Table 5. The relationship between some of the risk factors and the students' symptoms

	The relationship between some of the risk factors and the students who have seen symptoms within the previous year						
Model 1	**B**	**S.E.**	**Wald**	**p**	**OR**	**95% CI for OR**	
						Lower	**Upper**
The presence of symptoms (asthma etc.) in family	1.737	0.334	27.01	**<0.001**	5.68	2.95	10.33
Smoking status at home	0.632	0.360	3.08	0.079	0.53	0.26	1.07
Living in a home with carpets covering more than half of the floor area	0.746	0.332	5.07	**<0.001**	2.11	1.10	4.04
	The relationship between some risk factors and the group with symptoms at school						
Model 2	**B**	**S.E.**	**Wald**	**p**	**OR**	**95% CI for OR**	
						Lower	**Lower**
The presence of symptoms (asthma etc.) in family	1.264	0.312	16.37	**<0.001**	3.54	1.92	6.52
Class size	0.168	0.062	7.28	**0.007**	1.18	1.05	1.33
$PM_{2.5}$	0.007	0.001	37.06	**<0.001**	1.02	1.01	1.07
PM_{10}	0.010	0.002	39.28	**<0.001**	1.12	1.03	1.21

CI: Confidence interval, OR: Odds ratio, PM: Particulate matters, S.E.: Standard error.

construction materials, ventilation systems, the physical activities of children, and cleaning.[13] Exposure assessment is essential in order to determine the relationship between air pollution and its effects on health. However, one of the biggest challenges of environmental epidemiology is to analyze the nature of this exposure.[14]

We measured indoor air $PM_{2.5}$ and PM_{10} values in a city located in the west of Türkiye, especially on a street which had traffic congestion near schools. In this study, we aimed to evaluate the relationship between PM values and allergic symptoms in children at school and we tried to observe the effects of environmental exposure. At the same time, we also tried to determine risk factors in the home environment, and the prevalence of asthma, asthma-allergy symptoms in the previous year.

In our study, the prevalences of asthma, asthma symptoms, allergic rhinitis, dry cough, or eczema within the previous one year were 14.1%, 17%, 25.7%, 18.4%, and 4.6%, respectively. When the symptoms seen in school were evaluated, 22.3% were nasal discharge-congestion, 13.1% dry cough-sneezing, 8.5% redness-itching-watering in eyes, and 3.6% skin dryness and redness. In another study conducted in our country (Türkiye), similar prevalence values were reported.[11]

In a study of 39,782 children aged 3-6 years in day-care centers in China, the prevalence of doctor-diagnosed asthma was found to be 7.4%, rhinitis was 8.7%, and the prevalences of eczema, wheezing, and rhinitis within the previous one year were 24.1%, 19.7%, and 45%,[4] respectively. The prevalence of doctor-diagnosed asthma in children over six years of age in Nigeria was found to be 3.1%.[15] In another study, it was reported that 29.8% of children had daytime shortness of breath due to the school environment and 8.4% suffered from wheezing.[16] In another study, asthma-like symptoms, nasal allergy, and doctor-diagnosed asthma frequency were found to be higher in boys than in girls in any period of life.[17] In a multicenter study conducted in our country, it was reported that the frequency of symptoms in girls was higher.[11]

In our study, although no relationship was found between the prevalence of symptoms and gender, the mean age of the symptom group was found to be higher.

In addition to personal factors, genetic factors, environmental factors, and socio-economic factors, the poor physical properties of the home were reported to increase asthma and asthma symptoms.[4-9,15]

In support of these data, our study found that the risk of symptoms within the previous year was five times higher for those with a family history of asthma and two times higher for those who lived in homes with carpets covering a large amount of the floor area.

The detrimental health effects of particles vary according to their shape, diameter, and chemical composition. Particularly fine particles, less than 2.5 µm in diameter ($PM_{2.5}$) and less than 1 µm in diameter (PM_1), can cause asthma, allergic rhinitis, and other allergic respiratory diseases. It has been reported that coarse particles (PM_{10}) smaller than 10 µm may cause allergic symptoms such as eye and skin irritations without entering the respiratory system.[13,18] However, a meta-analysis study found that PMs less than 2.5 µg/m^3 may cause skin symptoms such as atopic dermatitis or eczema.[19] In a panel study, it was reported that exposure to $PM_{2.5}$ and PM_{10} accelerates symptoms by changing the nasal microbiota.[20] In a study evaluating the relationship between indoor air quality and the respiratory symptoms of children, it was found that high $PM_{2.5}$ and PM_{10} values increased the risk of wheezing symptoms by 2.3 and 3 times, respectively.[17] In another study, the effect of PM1 and PM_{10} values on asthma symptoms could not be shown, but increased PM_1 values were found to increase the risk of eczema.[21] Moreover, it was shown that as the duration of exposure to these PMs and their concentrations increased, the number of findings also increased.[13,18]

The risk of asthma and asthma symptoms at school was found to be 1.1 times higher with each step increase in $PM_{2.5}$ and PM_{10} levels. However, high $PM_{2.5}$ values were associated with dry cough-sneezing, and high PM_{10} values were associated with redness-itching symptoms in the skin and eyes. Our results support the effects of exposure to fine and coarse particles seen in the literature.

In particular, increased $PM_{2.5}$ and PM_{10} concentrations have been shown to increase atopic diseases and allergic reactions in children in many

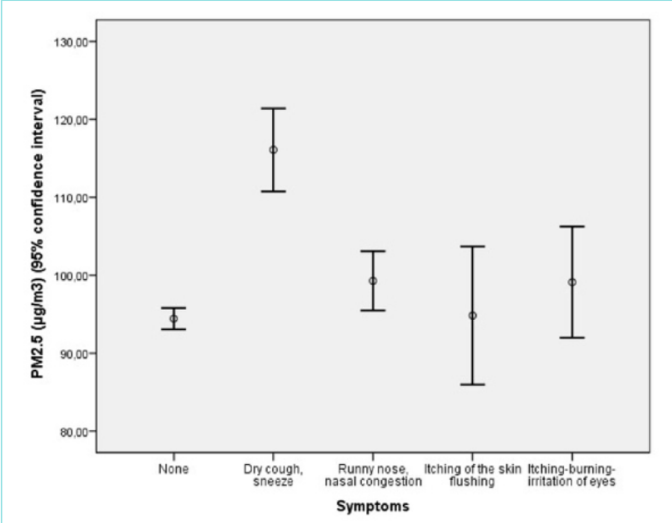

Figure 1. Distribution of students' symptoms in school according to measured $PM_{2.5}$ values.

PM: Particulate matters.

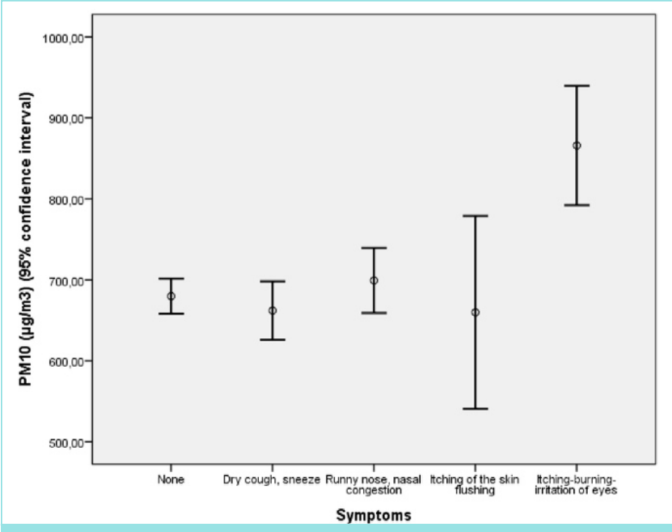

Figure 2. Distribution of students' symptoms in school according to measured PM_{10} values.

PM: Particulate matters.

studies.[13,14,22,23] The WHO has determined the limit values of PM_{10} and $PM_{2.5}$ for indoor air as 50 μg/m^3 and 25 μg/m^3, respectively.[24] When studies measuring the values of $PM_{2.5}$ and PM_{10} indoors in schools were examined, $PM_{2.5}$ and PM_{10} values were found to be higher than the criteria determined by the WHO, as can be seen in a study conducted in Qatar in 16 schools,[25] and by measurements made by Ruggieri et al.[26] in a study in 73 classrooms in 20 schools in Portugal.[27] In China, the $PM_{2.5}$ and PM_{10} values measured in four schools were close to our results.[28]

The mean values of $PM_{2.5}$ and PM_{10} measured in our study were higher than those reported in most other studies. When other studies are examined, it is not correct to make a comparison by considering the measurement values alone. Other factors which may affect the measurement results, such as differences in the season when the measurements were made, the location of the school (distance to the street), the class size, the capacity of the measuring device, the frequency and duration of the measurements, etc. should also be considered.[13,14,16] Furthermore, it should be remembered that close to 60% of $PM_{2.5}$ and PM_{10} in indoor environments originate from the outdoor environment.[7-9]

The fact that we did not carry out our measurements for 24 hours, the high outdoor PM values due to the winter season, and the fact that the classes were more crowded than those reported in other studies, can be put forward as the reasons for the higher measurement results obtained in this study. The risk of asthma and asthma symptoms seen in the school increased by 1.2 times as the number of students in the classroom increased.

Study Limitations

The limitations of this study include the fact that only one questionnaire was applied in one school in an urban area, and that the measurement durations were relatively short. Another limitation is that symptom diagnosis was based on the participants' responses, which might have been affected by memory-related factors. In addition, conducting this study during the autumn/winter season might have affected the results. In our region (Western Türkiye) which has continental climate characteristics, the average daytime temperatures vary between -1 °C and 10 °C during this season. Some of the symptoms may have been due to seasonal viral illnesses. However, since there had been no previous epidemiological studies conducted for this period of the year, the expected rate of viral illnesses is unknown.

CONCLUSION

As a result, approximately two out of ten students had asthma symptoms, allergic rhinitis, or dry cough symptoms, and the prevalence of skin symptoms-eczema was around 4%. The symptoms seen in the previous year were related to a family history of asthma and carpets covering more than half of floor area in the home. On the other hand, the symptoms at school were found to be related to an increased number of students in the classroom and the $PM_{2.5}$ and PM_{10} values.

In this respect, we think that school administrations should be informed in order to make arrangements and take measures to improve the indoor air quality of the school. Adequate ventilation and regular cleaning practices in indoor environments are important at this stage. At the same time, it is essential to eliminate allergen risk factors in the home environment and raise awareness in parents about the continuity of health education. As a next step, studies can be planned in order to determine advanced tests and treatment plans for at risk students.

MAIN POINTS

- When children start school, they are exposed to airborne pollutants in indoor areas more than outdoor areas. There are PMs of different sizes and emitted from many sources in the indoor air in the classroom.
- We measured indoor air $PM_{2.5}$ and PM_{10} values in a city location, especially on a street which had traffic congestion near schools.
- The asthma-allergy symptoms at school were found to be related to an increase in the number of students in the classroom and the PM values measured.
- School administrations should be informed in order to make arrangements and take measures to improve the indoor air quality of the school.

ETHICS

Ethics Committee Approval: Local ethics committee [Clinical Research Ethics Committee of the Kütahya Health Sciences University (approval number: 2018-13/12)] and institution permissions were obtained for this study.

Informed Consent: Verbal and written information was given to the children and the parents about the purpose and scope of this study, and their written consent was obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: İ.A., Design: İ.A., Supervision: İ.A., Fundings: İ.A., Ö.F.T., Materials: İ.A., Ö.F.T., Data Collection and/or Processing: İ.A., Ö.F.T., Analysis and/or Interpretation: İ.A., Literature Search: İ.A., Ö.F.T., Writing: İ.A., Critical Review: Ö.F.T.

DISCLOSURES

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