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Assessing Exposure Levels of Different Groups to Respirable Dust from Building Collapses During the 2023 Kahramanmaraş Earthquakes

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Abstract

In addition to the immediate destruction caused by earthquakes, significant long-term issues arise, including health problems resulting from dust produced during building demolitions. This study aimed to analyze the perceptual effects of this dust on individuals. A survey was conducted to assess the extent of dust exposure among three groups: a) Demolition officers (DO), b) Environmental safety officers (SO), and c. Individuals present during demolition (IP). Participants provided demographic data and responded to 28 questions about their dust exposure levels. The SO group reported the highest impact from dust, both physiologically and psychologically, while the DO and IP groups were less affected. Health issues, particularly respiratory problems, were notably prevalent. The SO group demonstrated higher sensitivity to dust exposure and the need for protective equipment, highlighting the inadequacy of current protective measures. Our findings also revealed that DO and IP groups had insufficient knowledge about the health risks associated with dust exposure and displayed limited interest in using protective measures. Conversely, although the SO group, with higher education levels, demonstrated greater awareness, they also failed to adequately prioritize protective measures. Overall, the results emphasize the need for improved awareness and more effective protective practices for all individuals involved in demolition activities.

1. Introduction

Earthquakes are among the most devastating natural disasters, causing significant damage to the environment and affecting millions of people worldwide. They occur because of sudden movements in the earth's crust. They seriously affect not only human life but also settlements and infrastructures. Due to its location on active fault lines such as the North Anatolian Fault, East Anatolian Fault, and West Anatolian Fault, Türkiye frequently experiences catastrophic earthquakes [1]. Recent major earthquakes provide notable examples both in terms of destruction, demolition, and their scientific aspects. The 1999 Gölcük Earthquake, with a magnitude of 7.4 MW, and the 7.2 MW Düzce Earthquake are among the most devastating natural disasters in modern Türkiye history [2]. These earthquakes deeply affected the Marmara Region, causing thousands of fatalities and significant damage to hundreds of thousands of buildings. The 7.2 MW Van Earthquake in 2011 resulted in hundreds of deaths and severe infrastructure losses in the Eastern Anatolia Region [3]. In one of the studies, it was stated that the Elazığ-Sivrice earthquake of 2020, with a magnitude of 6.8 MW, caused significant damage to or destruction of reinforced concrete buildings in the city center of Elazığ. It was particularly noted that buildings constructed before the year 2000 suffered more damage, raising concerns about the potential release of large amounts of toxic dust during debris removal activities [4]. In the same year, the 6.6 MW İzmir-Samos Earthquake [5] revealed that the collapsed and heavily damaged

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buildings were generally over 30 years old and had inadequate design and structural details. This brings up the issue of debris and its consequences [6]. In our case on February 6, 2023, two major earthquakes centered in the Kahramanmaraş province of Türkiye occurred, the first was recorded at 04:17 with a magnitude of 7.8 Mw, and the second was recorded at 13:27 with a magnitude of 7.6 Mw [7]. These earthquakes also caused severe destruction in the surrounding provinces, such as Hatay, Adıyaman, Gaziantep, Adana, Osmaniye, Kilis, Malatya, Şanlıurfa, Elazığ, and Diyarbakır which were affected to different levels depending on their distance from the earthquake epicenter [8]-[12]. The degree of building damage is shown in table 1.

Table 1. The extent of destruction caused by earthquakes is categorized, showing the levels of damage to buildings and the amount of debris removed as of January 2024 [13]

Province	Demolished	To be demolished urgently	heavily damaged	Moderately damaged	Slightly damaged and undamaged	Removed debris
Adana	38	41	3.330	4.087	358.645	517
Adıyaman	6.187	2.327	21.027	4.215	82.775	17.068
Diyarbakır	44	59	5.491	2.783	183.712	4.120
Elazığ	58	44	10.671	300	23.646	9.074
Gaziantep	4.126	1.988	14.304	5.513	265.262	11.109
Hatay	13.889	9.041	56.214	13.006	257.403	51.974
Kahramanmaraş	7.490	4.436	35.721	6.040	181.459	29.326
Kilis	457	151	1.926	488	32.335	1.769
Malatya	5.651	1.841	36.369	2.520	119.157	27.979
Osmaniye	702	531	9.167	1.074	122.840	8.009
Şanlıurfa	719	732	8.351	2.818	324.921	7.244
Total	39.361	21.191	202.571	43.344	1.952.155	168.189

In addition to the immediate destructive effects of earthquakes, the safe demolition of damaged buildings is also of particular importance. After the completion of search and rescue operations after an earthquake, the removal of debris from collapsed buildings and the controlled demolition of severely damaged buildings require careful planning. During the demolition and debris removal operations, large amounts of dust and hazardous materials of different compositions, especially those originating from construction materials, carry the risk of being released into the atmosphere [14]. The possibility that respirable particles generated during building demolition and debris removal may contain toxic substances [15], heavy metals [16], and particulate matter (PM) can pose serious risks to both the environment and health [17]-[19]. This is a significant concern.

The World Health Organization (WHO) has established strict limits for PM exposure. According to WHO guidelines, the daily limit of 50 μg/m³ for PM10 should not be exceeded more than three times per year, with an annual average limit of 20 μg/m³. For PM2.5, WHO sets a more rigorous annual limit of 10 μg/m³ [20]. The presence of PM2.5 and PM10 in the atmosphere can be attributed to natural events like wildfires and dust storms [21], as well as anthropogenic sources such as the increasing number of vehicles, industrial activities, and other human activities [22]. Additionally, activities like building demolition and the disposal of demolition waste also contribute to PM emissions (Figure 1).

Figure 1. Demolition of a building generating significant PM emissions, illustrating the environmental impact of demolition activities on air quality (Şanlıurfa 2024)

It is well established that respirable dust particles (particulate matter with a diameter of <10 μm, PM10) also known as fine particles, have significant adverse effects on heart and lung health. Inhalation of these particles is strongly associated with an increased risk of cardiovascular and respiratory diseases. As the size of particles decreases, they are able to reach the smallest structures of the lungs, particularly the alveoli, where they can enter the bloodstream, thereby amplifying their harmful effects [23]-[26]. Inhalation of such dust has been linked to serious long-term health risks, including respiratory issues, cardiovascular diseases, and cancer [27]. It is stated that PM and other hazardous components emitted from damaged buildings, especially during earthquakes, can increase these health effects [28]. Elderly people, children, and people with chronic respiratory and cardiovascular diseases may be more sensitive to the adverse health effects of these toxic substances [29]. The demolition of buildings attracts the attention of people around, especially children (Figure 2). While the spectacle of collapsing structures can be fascinating, it's critical to acknowledge the potential hazards associated with this process. For vulnerable groups like children, exposure is even more concerning, as their respiratory systems are still developing. Therefore, implementing stringent dust control measures and ensuring proper safety protocols are essential to mitigate these risks and protect public health during demolition activities.

Figure 2. Children observing a building demolition, a source of PM pollution (Kahramanmaraş 2024)

Within the scope of this study, a survey was conducted to examine the opinions and suggestions of demolition workers (DO), environmental safety officers (SO), and individuals in the demolition area (IP) who were exposed to dust during the demolition of damaged buildings, regarding being affected by dust, taking protective measures and measures related to demolition, and the perceptual responses of all individuals in this category were evaluated.

The devastation caused by the earthquakes severely damaged infrastructure and affected local life, highlighting the urgent need to reconsider Türkiye strategies for coping with seismic risks. It also underscored the necessity of enhancing measures to protect air quality and public health during construction and demolition processes following earthquakes.

Exposure to respirable PM and other hazardous substances after natural disasters plays a critical role in determining potential public health and environmental risks in future disasters. The survey aimed to evaluate public awareness regarding the health risks posed by dust and particles from collapsed buildings and the precautions that should be taken to mitigate these risks. The data obtained will guide the planning of preventive measures for similar disaster situations in the future and contribute to raising public awareness on this issue. Studies of this nature are important for protecting public health and minimizing environmental risks after disasters. This research conducted in such cities as Şanlıurfa, Adıyaman, and Kahramanmaraş is also considered an important step in this direction.2. Material and Method

2.1. Study Area

The survey was conducted during the demolition of severely damaged buildings that the Ministry of Environment, Urbanization, and Climate Change decided to demolish in the provinces of Şanlıurfa, Adıyaman, and Kahramanmaraş which were affected by the February 6 earthquakes (Figure 3). In selecting the demolition area for the survey, priority was given to buildings located in residential areas and densely populated neighborhoods to better assess the potential impact of the demolition dust on a larger number of nearby residents.

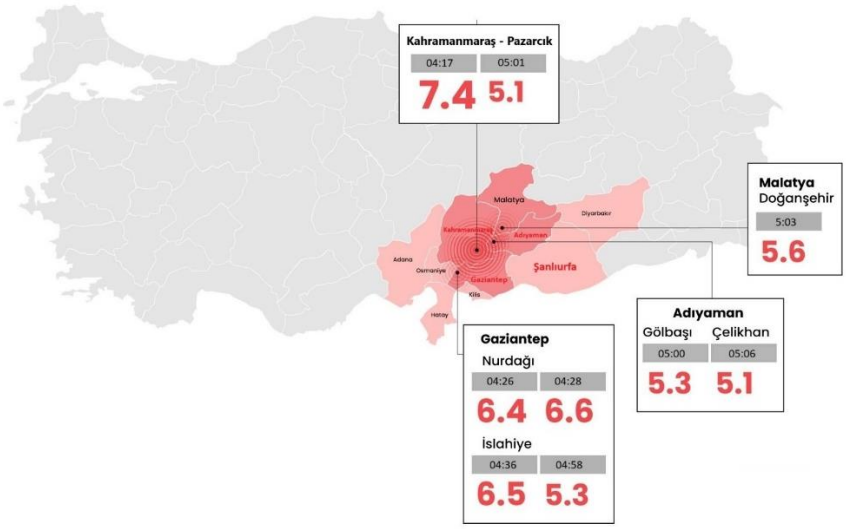

Figure 3. Showing the provinces affected by the Kahramanmaraş earthquakes on the map

2.2. Target Group

The survey targeted three groups: crane operators and other demolition workers at the demolition site (DO, 27 individuals), security personnel who ensured environmental security (SO, 28 individuals), and individuals who were not on duty at the time of the demolition but were in the vicinity (IP, 55 individuals).

2.3. Survey Application

Questions were designed to evaluate the perceptual effects of dust exposure during the demolition process on the target groups (DO, SO, and IP) in the region where the severely damaged buildings were demolished (Table 2). Participation in the survey was voluntary (Figure 4).

Figure 4. Conducting a survey in the severely damaged building demolition area.

2.4. Statistical Analysis

The ages of the participants were reported as mean ± SD (minimum-maximum) for each group. The average duration of stay in the demolition area was analyzed using ANOVA from the parametric tests, and group comparisons were conducted with the Bonferroni method in the post-hoc tests. The working hours in the sector and the duty hours in demolition activities of the DO and SO groups were compared with the t-test. The non-parametric Wilcoxon-Mann-Whitney U test was used to compare the responses given to the survey questions between the groups. The level of "$p<0.05$" was accepted as statistically significant.

3. Results and Discussion

The mean age of the participants in the survey was 40.0±9.9 (24-60 years old) in the DO group, 34.5±5.6 (25-43 years old) in the SO group, and 42.2±15.7 (18-73 years old) in the SO group. The genders of the participants were determined as 26 ♂ (man) and 1 ♀ (woman) in the DO group, 25 ♂ and 3 ♀ in the SO group, and 29 ♂ and 26 ♀ in the CG group. The education levels of the individuals in the groups participating in the survey were divided into primary, secondary school, high school, and university and the distribution of the education levels of each group is given in Figure 5.

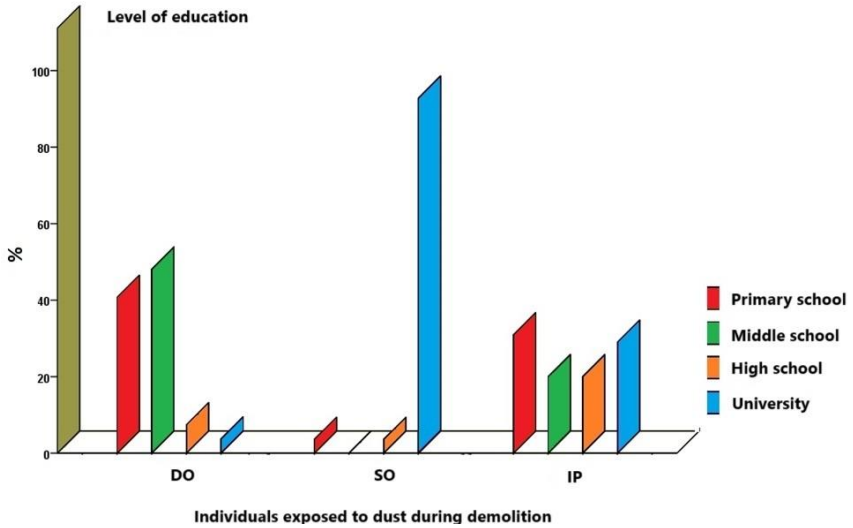

Figure 5. Distribution of education levels of individuals from the DO and SO groups and the IP group who were on duty during the demolition.

The average values obtained from the data regarding the working hours in the business line and the demolition activities of the DO and SO groups of the survey participants are shown in Figures 6 and 7.

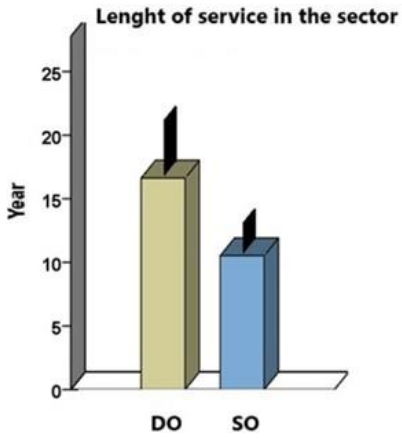

Figure 6. Working time of the DO and SO group individuals working in demolition in their job branches.

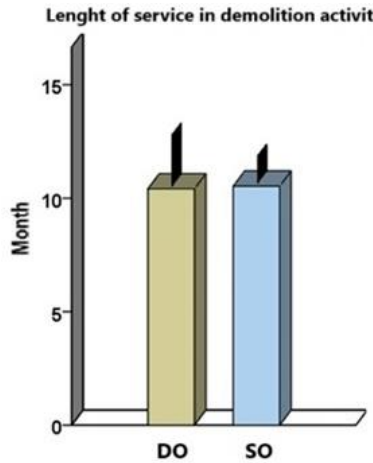

Figure 7. Working hours of the DO and SO group individuals working in the demolition activities.

The average values of the data indicating the average daily duration of stay in the demolition area of all survey participants are shown in Figure 8.

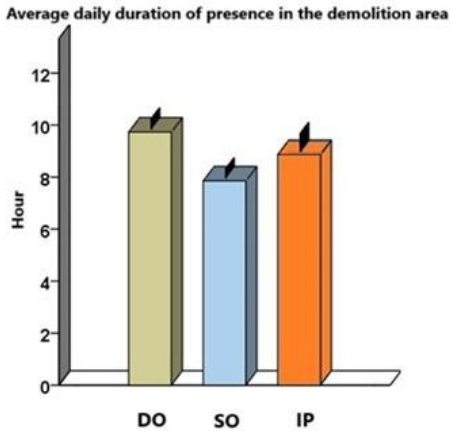

Figure 8. The average duration of stay in the destruction area of individuals in the DO, SO, and IP groups.

Participants' responses to the question regarding the perceptual determination of dust exposure levels during demolition were determined as low, medium, and high, and the obtained data are presented in Figure 9.

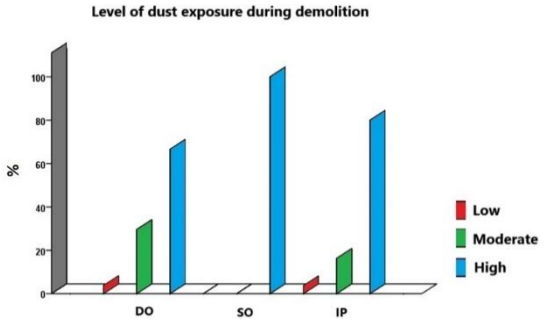

Figure 9. Proportional distribution of responses of survey participants showing the perceptual determination of dust exposure levels.

The responses given by the participants in the survey and the statistical analysis results of the differences between the groups are given in (Table 2). While preparing the table, only the "yes" responses of the participants were reflected, and all responses were used together in the statistical analyses.

Table 2. Proportional evaluation of the responses to the questions asked to the participants in the survey between the groups

Survey questions	Percentage of those who answered "Yes" (%)		
	DO	SO	IP
Does the dust generated during the demolition of the building cause difficulties in doing your job?	74,1	100,0 [a]*	89,1
Do you have any health problems related to your respiratory system?	33,3	35,7	38,2
Do you have any health problems due to the dust generated during the demolition of the building?	48,1	78,6 [a]*	70,9
Were the respiratory tract (nose, throat, etc.) affected by the dust generated during the demolition?	77,8	100,0 [a]*	90,9
Did you have a cough due to the dust generated during the demolition?	63,0	89,3 [a]*	80,0
Did the dust generated during the demolition affect your eyes?	85,2	100,0[a]*	85,5[c]*
Did you feel any difference in your skin due to the dust generated during the demolition?	70,4	92,9 [a]*	58,2[c]*
Did the building demolition affect your psychological state?	70,4	89,3	74,5
Do you smoke?	74,1	39,3 [a]*	47,3[b]*
Do you feel any difference in the level of dust affecting you if you smoke?	75,0	75,0	76,9
Did you feel the need to reduce the amount of cigarettes you smoked during the demolition?	70,5	83,0	80,8
Do you have information about the content of the dust generated during the demolition of the building?	3,7	57,1[a]**	23,6[b]* [c]*
Have you been informed about the risks and safety measures related to exposure to dust during the demolition of damaged buildings?	22,2	10,7	5,5[b]*
Do you know what precautions should be taken during the demolition of a building?	22,2	28,6	30,9
Have you been provided with adequate equipment such as goggles or a filtered respiratory mask?	14,8	10,7	3,6
Do you take care to use the protective equipment provided to you during the demolition of a building?	14,8	92,9[a]**	56,4[b]** [c]*
Do you believe that the dust-related equipment provided to you is sufficiently protective?	14,8	71,4[a]**	49,1[b]*
Do you think the precautions taken during the demolition of damaged buildings are sufficient?	22,2	0,0[a]*	12,7[c]*
Have you provided any feedback to any official institutions regarding the precautions taken during the demolition of damaged buildings?	18,5	17,9	27,3
Have you made any observations that you think should be taken into consideration regarding the disposal of dust generated during the demolition of buildings?	81,5	96,4	80,0
Have you informed the official institutions about this observation?	7,4	21,4	30,9[b]*

"a" shows the comparison between DO and SO, "b" shows the comparison between DO and ÇH, and "c" shows the comparison between SO and IP. "*" indicates $p<0.05$, "**" indicates $p<0.001$.

The demolition of buildings that have been severely damaged in earthquakes involves work that requires the utmost attention in terms of environmental safety. During these works, every individual, from the individuals in the vicinity to the demolition workers and the security personnel who ensure environmental safety, is affected to varying degrees by the dust generated during the demolition process. There is always a risk that these effects will cause health problems for all those involved. This

research, conducted in such cities as Şanlıurfa, Adıyaman, and Kahramanmaraş is also considered an important step in this direction. Therefore, understanding the effects of dust exposure on individuals and developing appropriate solutions will help mitigate the potential problems that may arise in the future. It will also contribute significantly to the implementation of predictive and more conscious approaches when similar situations occur. In our study conducted for this purpose, questions were asked to group individuals who are likely to be exposed to dust during building demolitions and to obtain information about their status of being affected by this exposure and the level of precautions taken. It is reported that the dust generated during demolition can cause significant harm to human health for those living and working in places close to demolition activities, along with the relatively harmful properties of the dust content [30]-[31]. Our study found that the negative impact of the dust generated during the demolition of damaged buildings on work performance was significantly higher in the SO group compared to the DO group and higher than in the IP group. It was found to be particularly striking that the DO group was found to be least affected by the dust. We can assume that since these individuals perform their duties in the demolition vehicles, it is estimated that this may be a result of these individuals being accustomed to such working conditions (Figure 6). Although the work branches were different between the DO and SO groups, there was no significant difference in the duration of their involvement in demolition activities (Figure 7). This suggests that both groups experienced similar levels of exposure to the dust generated during demolition activities. However, the stronger reactions observed among the SO group, despite their comparable experience in demolition work, may be attributed to other factors, such as their higher level of education, which might have increased their awareness and sensitivity to dust exposure (Figure 5).

While no significant difference was found between the groups when the individuals participating in our study were evaluated in terms of ongoing health problems related to the respiratory system in general, it was revealed that the effects of the respiratory system organs (nose and throat) due to the dust formed during the demolition occurred mostly in the SO group and were significantly lower in the DO group than in the SO group. In the IP group, it was determined that the level of this impact was close to that of the SO group. While a significantly higher rate of cough, eye, and skin problems was observed in all individuals in the SO group, these issues were found to be at a lower level in the DO group. In individuals in the IP group, these symptoms were observed at a higher level than in the DO group (Table 2). All these findings indicate that personnel involved in tasks related to environmental safety are in a more sensitive position in terms of dust exposure. It draws our attention that merely wearing a protective mask during SO's demolition duties may not be sufficient and that protective goggles or medications may be needed to protect the eyes from dust. We believe that this situation requires consultation with an ophthalmologist and that preventive measures should be arranged according to their recommendations. The same should be considered for skin sensitivity, and we believe that consulting a dermatologist and implementing additional protective measures for SO (such as protective creams, dust-impermeable clothing, etc.) would bring positive results. Another important aspect in terms of human health is human psychology. Disasters disrupt the flow of life and sometimes result in significant loss of life within the community. Among natural disasters, earthquakes, which have the most devastating impact, are considered the most traumatic events causing the greatest harm to society [32]-[33]. After the occurrence of two severe and destructive earthquakes, the beginning of the demolition process of damaged buildings causes new traumatic effects with new associations on individuals whose psychological state is already devastated. In our study, we observed that the psychological effects of building demolitions were at the highest level among individuals in the SO group in the demolition area. Although the psychological responses of individuals in the DO and IP groups were found to be at a lower level compared to the SO group, no significant difference was detected among the three groups (Table 2). This situation suggests that compared to the DO group, who had previously participated in similar activities due to their duties, the lesser familiarity of individuals in the SO group with the event may have been an important factor in them being more psychologically affected by the dramatically disturbing sight of building demolitions. Examination of the psychological effects of the post-earthquake destruction processes on these three separate groups will be of critical importance to increase the effectiveness of post-earthquake support programs. The more intense effects observed in the SO group indicate the need to provide psychosocial support to these individuals as a priority. At the same time, understanding the less obvious but potentially long-term psychological effects in the DO and IP groups will contribute to the comprehensive planning of support strategies. Additionally, providing moral

support to individuals who are psychologically affected will play a significant role [34].

While both smoking and dust exposure can lead to clinically significant respiratory dysfunction [35], it is also known that smoking itself is a major problem in our society. The numerous harmful effects of smoking, along with the differences in levels of habit due to people's socioeconomic status, present a separate social problem. It is not surprising that the smoking rate is higher in the DO group due to their lower education levels and living standards compared to the SO group. However, it was observed that the responses of smokers regarding both the difference in the level of impact from dust and the need to reduce the amount of smoking during demolition were surprisingly similar across all three groups. It can be said that there are similarities in the behavior and characteristics of smokers.

Individuals in the DO group stand out as having the least awareness regarding the content of the dust released during building demolition. It has been observed that the SO group has a significantly higher level of awareness on this subject compared to other groups. The knowledge of individuals in the IP group about the content of the dust released during demolition is also observed to be behind that of the SO group, similar to the DO group. This situation parallels individuals' education levels and suggests that individuals in the SO group might have consulted various sources due to curiosity sparked by their involvement in demolition activities. Although all three groups share the belief that dust exposure during demolition can lead to serious health problems in the future, this approach was found to be significantly higher in the SO group. All SO personnel were concerned that this exposure could lead to serious and permanent health problems for them in the future.

Although the SO group appears more sensitive to the risks of exposure to dust during demolition, the level of awareness regarding the risks of dust exposure during the demolition of damaged buildings and related safety measures was quite low in all groups. A very small amount of individuals in the DO and SO groups received information on this matter, and this important issue has been seriously overlooked. Similarly, it was observed that individuals from all groups had low awareness of the precautions that should be taken during building demolition. Despite the low level of information among the public in the demolition area, they were more knowledgeable about the precautions to be taken during demolition compared to the DO and SO groups. We think this may be related to the public paying more attention to warnings given in visual and written media. Additionally, the lack of adequate information from institutions about the risks of dust exposure and safety measures significantly increases the risk of future health problems, especially in the DO and SO groups.

The fact that a very small proportion of individuals, especially in the DO and SO groups, as well as in the IP group, were provided with equipment such as goggles or respiratory masks with filters shows that institutional support for protecting the health of individuals has been quite weak. It is noteworthy that only the individuals in the DO group were provided with goggles and masks with filters by their institutions, while a large proportion of the individuals in the SO group had to obtain this equipment on their own. Although the IP group individuals were not as active as the SO group, they showed more effort in acquiring and using this equipment on their own. The fact that demolition workers receive little support in terms of equipment and show weakness in acquiring and using protective equipment due to their own negligence lays the groundwork for the risk of many serious diseases, especially respiratory system diseases, due to dust exposure in the future.

The DO personnel approached the protective equipment provided against dust, even if limited, with skepticism and did not have much faith in their protective effect. This situation might be related to the lower education level of the DO group because the belief in the adequacy of the protective effect of the equipment was quite high among the SO group, which had a higher level of education. In the IP group, positive and negative opinions on this matter were expressed equally. This could also be related to the education level in the IP group, similar to the DO group, since nearly half of the DO group had high school and university education, while the other half had only primary or secondary school education. It is not surprising that individuals with lower levels of education have a weaker approach to protective equipment against dust, as believing in the reliability of protective equipment requires a sufficient informational background.

When the opinions of individuals consulted about the measures taken during demolition were considered, it was observed that there was significant distrust, especially within the SO group regarding these precautions. None of the participants in the SO group reported feedback indicating that the measures taken during demolition were sufficient, whereas there was a slight indication in the DO group that the measures could be sufficient. Individuals in the IP group provided low levels of feedback on the sufficiency of the measures taken during demolition.

In this situation, it is paradoxical that the feedback from individuals in all three groups to official authorities regarding the measures taken during demolition remained quite limited. Although the IP group showed slightly more sensitivity in this regard, the level of attempting to provide feedback to official authorities remained low. However, it was observed that individuals in all three groups had quite a few of their own unique ideas regarding the disposal of the dust. Despite having many observations in their minds about dust disposal, the rate of conveying these ideas to official authorities remained low in all groups, with the lowest being in the DO group. Notably, the performance of the SO personnel, particularly those with higher education levels, was also disappointingly low. This lack of feedback from the DO group is likely related to lower education levels, which may contribute to a lack of confidence in conveying their ideas to official authorities.

4. Conclusion and Suggestions

In conclusion, the education levels of individuals across the three categories had a significant impact on their physical and psychological responses to dust exposure from the demolition of damaged buildings, as well as their approaches and suggestions regarding protective measures. However, a general lack of confidence hindered their ability to effectively communicate their concerns and demands to official authorities.

As a result of our study, even when filtered masks were provided to the DO group, their proper usage and adherence to guidelines regarding when to use the masks were insufficient. Therefore, protective equipment (filtered masks, protective goggles, dust-proof clothing, gloves) should be provided and accompanied by training programs aimed at ensuring their effective use. These programs should cover the correct use, maintenance, and importance of the equipment. In addition, continuous monitoring of protective equipment usage in work areas is essential to enforce compliance and address any gaps in implementation. The protective equipment provided should not be generic but tailored to the specific needs of each worker through a personalized Personal Protective Equipment (PPE) plan. This plan should account for the worker's role, responsibilities, and working conditions, ensuring that the equipment is fit for purpose. Furthermore, the equipment should be designed to protect not only the workers but also the surrounding public, and a system should be established that enforces the mandatory use of this equipment.

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Contributions of the authors

Tuba Rastgeldi Dogan: Supervision, Review, Writing original draft preparation, Data Collection Final Approval. Ali Süzergöz: Literature Review, Data Collection, Data Analysis.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study complies with research and publication ethics.

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