Analysis of obstruction of lung function in workers exposed to organic solvents at shoe factory

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Abstract. Shoe factory workers are exposed to many kinds of occupational hazards, including organic solvents. Exposure to organic solvent is reported to have adverse pulmonary effects and increases the risk of obstructive and restrictive pulmonary diseases. This study aimed at investigating the associations between organic solvent exposure, risk factors, and clinical symptoms of pulmonary function impairment among shoe factory workers. This cross-sectional study examined 134 shoe factory workers from two production areas, cementing and (n = 67) and stock fitting (n = 67). All the workers underwent pulmonary function testing, including the measurements of FVC and FEV₁/FVC values using a spirometer. The workers were also interviewed about their clinical symptoms and histories related to health and work. Of all the subjects, 17% (23 of 134) suffered from restrictive diseases. Risk factors such as age, work duration, and total cumulative exposure contribute to the symptoms. However, exposure to organic solvent did not significantly cause lung function disorders.

1. Introduction
Disturbances to the lung function occur in the form of obstructive disturbances, restrictive disturbances, or mixed disturbances. In obstructive disturbances, the constriction of the airway disturbs air flow [1,2]. In restrictive disturbance, disruption of lung expansion occurs [2]. Mixed disturbances are characterized by both forms of disturbance.

Exposure to pulmonary irritants in the workplace can give rise to breathing problems, lung parenchyma, and pleura. Fibrosis, lung destruction, and malignancy are the long-term effects of exposure [3,4]. Exposure to various irritants at low dosage can cause breathing symptoms and reduce the lung function [5,6]. Acute exposure to chemical substances in the workplace caused 5% of asthma and 2–3% alveolitis cases. For individuals with a history of asthma, even low concentrations of chemical exposure can trigger disease recurrence [7]. Recurring exposure to low dosage or acute high dosage exposure can reduce the lung function, which can be determined by spirometry test results [8].

In shoe manufacturing, organic solvents are used in several production processes [9-12]. Organic solvents have irritant characteristics and easily evaporate and, thus, can be inhaled easily. Organic solvent inhalation causes irritation of breathing airways and disturbances to obstructive as well as...
restrictive lung function [13-15]. However, research on the relationship between organic solvent exposure at shoe manufacturing plants and the risk factors and clinical symptoms of lung function disturbance has been limited.

2. Methods
This study used a cross-sectional method. The inclusion criteria were workers in a shoe factory for five or more years who were exposed to organic solvents (acetone and/or chlorine) with a normal thorax x-ray. The exclusion criteria were a history of tuberculosis or other systemic diseases that may affect the lung function.

The research began by simple random sampling of workers in the cementing and stock fitting sections of the factory. The workers in the cementing section were exposed to acetone and the workers in the stock fitting section were exposed to acetone and chlorine. Each group comprised 75 people. Physical and spirometry tests were performed for 150 respondents. The wrong maneuver during the spirometry test was performed by 16 respondents, and they were excluded from the analysis. Restrictive imaging in the spirometry test was performed for 23 respondents; the thorax x-ray was done. The thorax x-ray results were normal. Interviews were performed with 134 respondents using the Indonesian pneumobile project lung function questionnaire.

To assess the exposure to organic solvents (acetone and mixed acetone/chlorine), air monitoring of the cementing and stockfit sections was performed. In this method, the total cumulative exposure was calculated by multiplication of the work time and exposure rate.

3. Results
Spirometry test results showed that 23 people (17.1%) had restrictive lung function disturbances, specifically 9 people in the cementing section and 14 people in the stock fitting section. Air monitoring showed an acetone level in the cementing section of 57.90 ppm; in the stock fitting section, the acetone level was 64.80 ppm and the chlorine level was 0.001 ppm, giving a mixed solvent level of 0.13 ppm. All of the monitoring results were below NAB.

As Table 1 shows, most of the workers were female (59%), most of the workers were ≥23.5 years old (89.6%; average age 31 years, range 23–50 years old), and most had been working for less than 5 years (55%). The cumulative exposure was ≥7.7 ppm work years for most of the workers (52.2%) with an average cumulative exposure of 8.46 ppm work years (range 7.05–11.28). Chronic bronchitis symptoms were observed in 62.7% of the respondents in stock fitting and 40.3% of respondents in cementing.

Tables 2 and 3 present the relationships between demographic, work, exposure, habit, and symptom risk factors and lung function disturbance in all workers and the workers in the cementing and stock fitting sections, respectively. For the overall study population, none of the relationships were statistically significant (p > 0.05).

Tables 4 present the relation between demographic, work, exposure, habit, and symptom risk factors on lung function disturbance in all workers and the two sections, respectively. As shown, total cumulative exposure (p = 0.016, ORc 2.328, CI 95% (1.164–4.655)), acetone level (p = 0.016, ORc 0.429, CI 95% (0.214–0.857)), and mixed solvent level (p = 0.016, ORc 0.429, CI 95% (0.214–0.857)) were significantly associated with the occurrence of chronic bronchitis symptoms.

For the stock fitting section (Table 5) work time (p = 0.00, ORc 0.405, 95% CI (0.280–0.584)) and total cumulative exposure (p = 0.00, ORc 14.795, 95% CI (4.149–2.758)) were significant. In the cementing section, age (p = 0.056, ORc 1.771, 95% CI (1.424–2.204)), work time (p = 0.00, ORc 7.538, 95% CI (2.263–25.111)), and total cumulative exposure (p = 0.015, ORc 3.563, 95% CI (1.259–10.084)) were significant. Based on the results above, variables with p-values < 0.25 were included in the multivariate analysis with logistic regression testing.

As Table 6 shows, the acetone level was significant in both sections (p = 0.013, Expβ 0.405, CI 95% (0.198–0.826)). In the stock fitting section, total cumulative exposure ≥7.7ppm and work years were significant (p = 0.039, Expβ 6.667, CI95% (1.099–40.434)). In the cementing section, only work time ≥5.5 years was significant (p = 0.008, Expβ 12.100, CI 95% (1.921–76.227)).
Table 1. Distribution of lung function disturbance frequency, demographic factors, habitual factors, and symptoms.

|                      | Stockfit (n=67) | Average | Cementing (n=67) | Average | Combined | Rerata |
|----------------------|----------------|---------|------------------|---------|----------|--------|
| **Lung function disturbance** |                |         |                  |         |          |        |
| Normal               | 53 (79.1%)     | -       | 58 (86.6%)       | -       | 111 (82.8%) |        |
| Restrictive          | 14 (20.9%)     | 9 (13.4%) | -               | -       | 23 (17.1%) |        |
| **Gender**           |                |         |                  |         |          |        |
| Female               | 45 (67.2%)     | -       | 34 (50.7%)       | -       | 79 (59.0%) |        |
| Male                 | 22 (32.8%)     | 33 (49.3%) | -               | -       | 55 (41.0%) |        |
| **Age**              |                |         |                  |         |          |        |
| ≥23. years old       | 58 (86.6%)     | 31 y.o (23-47) | 62 (92.5%) | 31 y.o (23–50) | 120 (89.6%) | 31th (23–50) |
| <23.5 years old      | 9 (13.4%)      | 5 (7.5%)  | 23 (17.1%)       | 14 (10.4%) | 61 (45%) | 6th (5–8) |
| **Work time**        |                |         |                  |         |          |        |
| ≥5.5 years           | 42 (62.7%)     | 6 years (5–8) | 19 (28.4%) | 6 years(5–8) | 61 (45%) | 6th (5–8) |
| <5.5 years           | 25 (37.3%)     | 48 (71.6%) | -               | -       | 73 (55%) |        |
| **Exposure cumulative total** |            |         |                  |         |          |        |
| ≥7.7ppm work years  | 35 (52.2%)     | 8.46 (7.05–11.28) | 35 (52.2%) | 8.46 (7.05–11.28) | 70 (52.2%) | 8.46 (7.05–11.28) |
| <7.7ppm work years  | 32 (47.8%)     | 32 (47.8%) | 32 (47.8%) | 64 (47.8%) |        |
| **Acetone level**    |                |         |                  |         |          |        |
| ≥61.3517             | -              | -       | -                | -       | 67 (50%) |        |
| <61.3517             | -              | -       | -                | -       | 67 (50%) |        |
| **The mix of organic solvent (Acetone dan Chlorin)** |            |         |                  |         |          |        |
| Available            | -              | -       | -                | -       | 67 (50%) |        |
| Unavailable          | -              | -       | -                | -       | 67 (50%) |        |
| **Smoking Habit**    |                |         |                  |         |          |        |
| Average smoker*      | 3 (4.5%)       | 1 (1.5%)  | 4 (3%)           |        |
| Mild smoker*         | 9 (13.4%)      | 16 (23.9%) | 25 (18.7%) |        |
| Not smoke            | 55 (82.1%)     | 50 (74.6%) | 105 (78.4%) |        |
| **The APD using habit** |            |         |                  |         |          |        |
| Never**              | 25 (37.3%)     | 32 (47.8%) | 57 (42.5%) |        |
| Sometimes**          | 41 (61.2%)     | 32 (47.8%) | 73 (54.5%) |        |
| Always               | 1 (1.5%)       | 3 (4.5%)  | 4 (3%)           |        |
| **The chronic brinchitis symptom** |            |         |                  |         |          |        |
| Yes                  | 42 (62.7%)     | 27 (40.3%) | 69 (51.5%) |        |
| No                   | 25 (37.3%)     | 40 (59.7%) | 65 (48.5%) |        |
| **Asphyxiate**       |                |         |                  |         |          |        |
| Yes                  | 10 (14.9%)     | 12 (17.9%) | 22 (16.4%) |        |
| No                   | 57 (85.1%)     | 55 (82.1%) | 112 (83.6%) |        |

Notes:
* = on the combined analysis
** = on the combined analysis
Table 2. The relationship between demographic, work, exposure, habit, and symptom risk factors and lung function disturbance in all workers.

|                          | Restrictive Lung Function Disturbance | p     | ORc  | CI 95%         |
|--------------------------|---------------------------------------|-------|------|----------------|
|                          | Yes | No |     |     |                |
| Age                      |     |     |     |     |                |
| ≥ 23.5 years old         | 20  | 100 | 16.7| 83.3| 0.655 0.733 0.187–2.868 |
| < 23.5 years old         | 3   | 11  | 21.4| 78.6|                |
| Gender                   |     |     |     |     |                |
| Female                   | 14  | 65  | 17.7| 82.3| 0.838 1.101 0.439–2.759 |
| Male                     | 9   | 46  | 16.4| 83.6|                |
| Work Time                |     |     |     |     |                |
| > 5.5 years              | 8   | 36  | 18.2| 81.8| 0.827 1.111 0.432–2.860 |
| 5.5 years               | 15  | 75  | 16.7| 83.3|                |
| Work Section             |     |     |     |     |                |
| Stockfit                 | 14  | 53  | 20.9| 79.1| 0.252 1.702 0.681–4.257 |
| Cementing                | 9   | 58  | 13.4| 86.6|                |
| Exposure Cumulative Total|     |     |     |     |                |
| ≥ 7.7 ppm work years    | 11  | 59  | 15.7| 84.3| 0.642 0.808 0.329–1.985 |
| < 7.7 ppm work years    | 12  | 52  | 18.8| 81.3|                |
| Acetone organic solvent level|   |     |     |     |                |
| ≥ 61.3517                | 14  | 53  | 20.9| 79.1| 0.252 1.702 0.681–4.257 |
| < 61.3517                | 9   | 58  | 13.4| 86.6|                |
| Mix of solvent level     |     |     |     |     |                |
| Available                | 14  | 53  | 20.9| 79.1| 0.252 0.587 0.235–1.469 |
| Unavailable              | 9   | 58  | 13.4| 86.6|                |
| Smoking habit            |     |     |     |     |                |
| Average smoker *         | 4   | 0   | 100.0| 0.0| 0.569 1.350 0.478–3.812 |
| Mild smoker *            | 2   | 23  | 8.0 | 92.0|                |
| Non-smoker               | 17  | 88  | 16.2| 83.8|                |
| APD use habit            |     |     |     |     |                |
| Never **                 | 22  | 35  | 38.6| 61.4| 0.355 1.215 1.122–1.316 |
| Sometimes **             | 1   | 72  | 1.4 | 98.6|                |
| Always                   | 0   | 4   | 0.0 | 100.0|               |
| Chronic bronchitis symptom|   |     |     |     |                |
| Yes                      | 10  | 59  | 14.5| 85.5| 0.398 0.678 0.274–1.676 |
| No                       | 13  | 52  | 20.0| 80.0|                |
| Asphyxiate               |     |     |     |     |                |
| Yes                      | 4   | 18  | 18.2| 81.8| 0.890 1.088 0.331–3.577 |
| No                       | 19  | 93  | 17.0| 83.0|                |

The chi square test was used for categorical variables.

Note:
* = On combined analysis
** = On combined analysis
Table 3. The relation between demographic, work, exposure, habit, and symptom risk factors and lung function disturbance in stock fitting and cementing sections.

|                      | Stockfit (n = 67) | Cementing (n = 67) |
|----------------------|------------------|-------------------|
|                      | Restrictive Lung Function Disturbance | Restrictive Lung Function Disturbance |
|                      | Yes  | No  | p   | Orc | 95% CI | Yes  | No  | p   | Orc | 95% CI |
| Age                  |      |     |     |     |        |      |     |     |     |        |
| ≥23.5 yo             | 11   | 47  | 81.0 | 0.324 | 0.468 | 0.101–2.169 | 9    | 53  | 85.5 | 0.360 | 1.170 | 1.056–1.296 |
| < 23.5 yo            | 3    | 6   | 66.7 |      |       |        | 0    | 0.0 | 5    | 100.0 |        |        |
| Gender               |      |     |     |     |        |      |     |     |     |        |
| Female               | 9    | 36  | 80.0 | 0.797 | 0.850 | 0.247–2.926 | 5    | 29  | 85.3 | 0.756 | 1.250 | 0.305–5.130 |
| Male                 | 5    | 17  | 77.3 |      |       |        | 4    | 29  | 87.9 |        |        |        |
| Work times           |      |     |     |     |        |      |     |     |     |        |
| ≥5.5 years           | 6    | 19  | 76.0 | 0.630 | 1.342 | 0.405–4.448 | 2    | 17  | 89.5 | 0.661 | 0.689 | 0.130–3.661 |
| < 5.5 years          | 8    | 34  | 81.0 |      |       |        | 7    | 41  | 85.4 |        |        |        |
| Exposure             |      |     |     |     |        |      |     |     |     |        |
| cumulative total     |      |     |     |     |        |      |     |     |     |        |
| ≥7.7ppm work years  | 7    | 20  | 80.0 | 0.850 | 0.893 | 0.275–2.901 | 4    | 31  | 88.6 | 0.615 | 0.697 | 0.170–2.861 |
| < 7.7ppm work years | 7    | 21  | 78.1 |      |       |        | 5    | 43  | 86.0 |        |        |        |
| Smoking habit        |      |     |     |     |        |      |     |     |     |        |
| Average smoker*      | 3    | 100.0 | 0 | 0.0 | 0.242 | 2.250 | 0.565–8.962 | 1    | 100.0 | 0 | 0.0 | 0.815 | 0.819 | 0.153–4.385 |
| Mild smoker*         | 1    | 11.1 | 8   | 88.9 |      |       |        | 1    | 6.3 | 15 | 93.8 |        |        |        |
| Non-smoker           | 10   | 18.2 | 45  | 81.8 |      |       |        | 7    | 14.0 | 43 | 86.0 |        |        |        |
| APD usage habit      |      |     |     |     |        |      |     |     |     |        |
| Never**              | 13   | 52.0 | 12  | 48.0 | 0.605 | 1.269 | 1.120–1.438 | 9    | 28.1 | 71.9 | 0.485 | 1.164 | 1.054–1.285 |
| Sometimes**          | 1    | 2.4 | 40  | 97.6 |      |       |        | 0    | 0.0 | 32 | 100.0 |        |        |        |
| Always               | 0    | 0.0 | 1   | 100.0 |      |       |        | 0    | 0.0 | 3 | 100.0 |        |        |        |
| Chronic bronchitis symptoms |      |     |     |     |        |      |     |     |     |        |
| Yes                  | 9    | 21.4 | 33  | 78.6 | 0.889 | 1.091 | 0.320–3.718 | 4    | 14.8 | 85.2 | 0.785 | 1.217 | 0.295–5.017 |
| No                   | 5    | 20.0 | 20  | 80.0 |      |       |        | 8    | 14.5 | 85.5 |        |        |        |
| Asphyxiate           |      |     |     |     |        |      |     |     |     |        |
| Yes                  | 3    | 30.0 | 7   | 70.0 | 0.443 | 1.792 | 0.398–8.064 | 1    | 8.3 | 91.7 | 0.567 | 0.534 | 0.060–4.72 |
| No                   | 11   | 19.3 | 46  | 80.7 |      |       |        | 8    | 14.5 | 85.5 |        |        |        |

The chi square test was used for categorical variables.
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Table 4. The relation between demographic, work, exposure, habit, and symptom risk factors and lung function disturbance in all workers.

| Chronic Bronchitis Symptoms | Yes | No | p   | ORc       | CI 95%           |
|-----------------------------|-----|----|-----|-----------|------------------|
| Age                         |     |    |     |           |                  |
| ≥ 23.5 years old            | 63  | 57 | 47.5| 0.494     | 1.474            |
| < 23.5 years old            | 6   | 8  | 57.1| 0.482–4.505|                  |
| Gender                      |     |    |     |           |                  |
| Female                      | 37  | 42 | 53.2| 0.196     | 0.633            |
| Male                        | 32  | 23 | 41.8| 0.316–1.268|                  |
| Work times                  |     |    |     |           |                  |
| ≥ 5.5 years                 | 25  | 19 | 43.2| 0.388     | 1.376            |
| < 5.5 years                 | 44  | 46 | 51.1| 0.666–2.842|                  |
| Exposure cumulative total   |     |    |     |           |                  |
| ≥ 7.7 ppm work years        | 43  | 27 | 38.6| 0.016     | 2.328            |
| < 7.7 ppm work years        | 26  | 38 | 59.4| 1.164–4.655|                  |
| Smoking habit               |     |    |     |           |                  |
| Average smoker*             | 3   | 1  | 25.0| 0.198     | 1.733            |
| Mild smoker*                | 15  | 10 | 40.0| 0.746–4.022|                  |
| Non-smoker                  | 51  | 54 | 51.4|          |                  |
| APD usage habit             |     |    |     |           |                  |
| Never *                     | 26  | 31 | 54.4| 0.340     | 0.344            |
| Sometimes*                  | 40  | 33 | 45.2| 0.035–3.392|                  |
| Always                      | 3   | 1  | 25.0|          |                  |
| Acetone level               |     |    |     |           |                  |
| ≥ 61.3517                   | 27  | 39 | 59.1| 0.016     | 0.429            |
| < 61.3517                   | 42  | 26 | 38.2| 0.214–0.857|                  |
| The mixed solvent level     |     |    |     |           |                  |
| Available                   | 27  | 39 | 59.1| 0.016     | 0.429            |
| Unavailable                 | 42  | 26 | 38.2| 0.214–0.857|                  |

The chi square test was used for categorical variables.

Table 5. The relation between demographic, work, exposure, habit, and symptom risk factors and lung function disturbance in the cementing and stock fitting sections.

| Chronic bronchitis | Stockfit (n = 67) | Cementing (n = 67) |
|--------------------|-------------------|--------------------|
| Yes | No | p | ORc | 95% CI | Yes | No | p | ORc | 95% CI |
| Age ≥23.5 yo       | 38  | 20 | 34.5| 0.224 | 2.375 | 0.573–9.844 | 27  | 35 | 56.5 | 0.056 | 1.771 | 1.424–2.204 |
| <23.5 yo           | 4   | 5  | 55.6| 0.000 | 0.000 | 0.000–5.603 | 0   | 0  |      | 1.000 | 1.000 |                  |
| Gender Female      | 27  | 18 | 40.0| 0.516 | 0.700 | 0.238–2.056 | 11  | 23 | 67.6 | 0.178 | 0.508 | 0.189–1.369 |
| Male               | 15  | 7  | 31.8| 0.000 | 0.000 | 0.000–1.000 | 0   | 0  |      | 1.000 | 1.000 |                  |
| Work times ≥5.5 years | 25  | 0  | 0.000| 0.000 | 0.000 | 0.000–5.603 | 14  | 5  | 26.3 | 0.000 | 7.538 | 2.263–25.111 |
| <5.5 years         | 17  | 25 | 59.5| 0.000 | 0.000 | 0.000–5.603 | 17  | 25 | 59.5 | 0.000 | 7.538 | 2.263–25.111 |
| Exposure cumulative total | ≥7.7 ppm work year | 31  | 14.4 | 11.4| 0.000 | 14.795 | 4.149–2.5758 | 19  | 16 | 45.7 | 0.015 | 3.563 | 1.259–10.084 |
| <7.7 ppm work year | 11  | 21 | 65.6| 0.000 | 0.000 | 0.000–5.603 | 8   | 25 | 75.0 | 0.000 | 1.000 |                  |
| Smoking habit      | Average smoker*  | 3   | 0  | 0.000| 0.330 | 2.000 | 0.487–8.222 | 0   | 0  | 1.000| 0.511 | 1.450 | 0.478–4.403 |
| Mild smoker*       | 6   | 3  | 33.3| 0.000 | 0.000 | 0.000–5.603 | 8   | 50 | 50  | 0.000 | 1.000 | 1.000–1.000 |
| Non-smoker         | 33  | 22 | 40.0| 0.000 | 0.000 | 0.000–5.603 | 19  | 38 | 62.0| 0.000 | 1.000 | 1.000–1.000 |
| APD usage habit    | Never**          | 15  | 10 | 40.0| 0.000 | 0.437 | 1.610 | 1.333–1.943 | 13  | 19 | 59.4 | 0.801 | 1.368 | 0.118–15.885 |
| Sometimes**        | 26  | 15 | 36.6| 0.000 | 0.000 | 0.000–5.603 | 13  | 19 | 59.4 | 0.801 | 1.368 | 0.118–15.885 |
| Always             | 1   | 0  | 0.000| 0.000 | 0.000 | 0.000–5.603 | 1   | 33 | 66.7| 0.000 | 1.000 | 1.000–1.000 |

The chi square test was used for categorical variables.
Table 6. Multivariate analysis of the relation between total cumulative exposure, acetone level, work times, and age on chronic bronchitis symptoms.

| Stockfit | Cementing | Combined |
|----------|-----------|----------|
| Acetone level | - | - | - |
| Exposure cumulative total | 1.897 | 0.920 | 0.039 | 6.667 | 1.099 | 0.434 | 0.547 | 1.069 | 0.609 | 1.727 | 0.212 | 14.048 | 0.903 | 0.365 | 0.013 | 2.466 | 1.207 | 5.039 |
| Work times | 20.744 | 7617.8 | 0.998 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Age | 0.758 | 1.047 | 0.469 | 0.469 | 0.060 | 3.648 | 18.952 | 17974.8 | 0.999 | - | - | - | - | - | - | - | - | - | - |
| Constant | -5.907 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

4. Discussion
Restrictive lung function was observed in 17.1% of the workers. However, in the bivariate analysis, there was no relation between demographic, work, exposure, habit, and symptom risk factors and restrictive lung function disturbance in all the workers or the stock fitting and cementing sections individually. This lack of finding may be because most of the workers had less than 10 years of exposure, and so the irritant effect of organic solvent had not yet triggered lung function disturbance [16,17].

However, the irritant effects of organic solvents resulted in significant chronic bronchitis symptoms. This parallels previous results of workers in factories that use organic solvents in the production process [11,16,18]. In the cementing section, age, work time, and total cumulative exposure had significant relations with the occurrence of chronic bronchitis symptoms.

Logistic regression tests were performed for both sections, and the dominant variable of occurrence of chronic bronchitis symptoms was the acetone level. Meanwhile, the dominant variable in the stock fitting section that caused chronic bronchitis symptoms was total cumulative exposure ≥7.7 ppm work years; total cumulative exposure variable ≥7.7 ppm work years was 6.677 times greater than total cumulative exposure < 7.7 ppm work years on the occurrence of chronic bronchitis symptoms. The dominant variable in the cementing section on the occurrence of chronic bronchitis symptoms was work time; the effect of work time ≥5.5 years was 12.100 times greater than work time < 5.5 years on the occurrence of chronic bronchitis symptoms.

5. Conclusions
This study found no relation between organic solvents in the ketone group (acetone) or the mix of a ketone and halogen (acetone and chlorine) on lung function disturbance. Demographic risk factors, work risk factors, habitual risk factors, and symptom risk factors did not show a significant relationship with lung function disturbance.

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