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Original Article

Respiratory health of municipal solid waste workers in Greece: A Cross-Sectional Study

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ABSTRACT

Introduction: Municipal solid waste workers (MSWWs) are routinely exposed to airborne pollutants, including bioaerosols and combustion by-products, which may contribute to respiratory symptoms and reduced lung function. This study aimed to evaluate the respiratory health of MSWWs employed in local government cleaning services across six municipalities in Greece.

Methods: A cross-sectional study was conducted among 621 municipal employees, including 407 MSWWs and 214 office-based employees as controls. Participants underwent spirometry according to ERS/ATS 2019 guidelines and completed a structured questionnaire assessing respiratory symptoms, occupational history, and smoking status. Descriptive statistics were calculated. Between group comparisons were performed using unadjusted independent sample t-tests for continuous variables and chi-square tests for categorical variables. Pearson's correlation coefficient was used for correlation analyses.

Results: MSWWs demonstrated significantly lower mean FEV1 and FVC values compared to office employees ($p < 0.001$ and $p = 0.004$, respectively). Respiratory symptoms (cough, sputum production, wheezing, dyspnea) were more frequently reported among MSWWs. Descriptive stratified analyses indicated lower spirometric values among current smokers in both occupational groups; however, interaction effects were not formally tested. Spirometric indices showed modest inverse associations with years of employment; these associations were descriptive and may reflect confounding (e.g., age) rather than cumulative exposure effects.

Conclusion: These unadjusted findings are consistent with a potential occupational contribution to respiratory health differences. However, causal inference is limited. Further studies incorporating quantitative exposure assessment and multivariable modeling are recommended.

Keywords: Cross-Sectional Study; Greece; Municipal Solid Waste Workers; Occupational Exposure; Respiratory Symptoms; Smoking; Spirometry;

Introduction

Municipal solid waste management (MSWM) is a vital component of urban infrastructure and public health. Workers engaged in street cleaning and waste collection are routinely exposed to airborne pollutants, including particulate matter, bioaerosols, and combustion by-products, particularly in high-traffic urban environments. These occupational exposures, compounded by physically demanding outdoor work, have been associated with increased prevalence of respiratory symptoms and reductions in pulmonary function in several

occupational studies.[1,2]

While international data have reported respiratory effects among municipal solid waste workers (MSWWs), the magnitude and consistency of these associations vary considerably, influenced by factors such as waste composition, job tasks, environmental conditions, and the use of personal protective equipment (PPE).[3,4] In many settings, MSWWs have reported elevated rates of cough, sputum production, wheezing, and dyspnea, alongside modest but measurable decreases in spirometric indices such as FVC and FEV_1.[5]

In Greece, where waste recycling infrastructure remains limited and municipal waste generation is high, MSWWs often operate under occupational conditions that may lack consistent health and safety safeguards. However, context-specific data assessing respiratory outcomes in this workforce are limited. A cross-sectional study among municipal workers in the Attica region identified a higher prevalence of respiratory symptoms and decreased spirometric values among MSWWs compared with controls.[6]

Therefore, the present study aimed to compare respiratory symptoms and lung function indices between MSWWs and a control group of office-based municipal employees across six municipalities in Attica, Greece. The study also explored descriptive associations with smoking status and duration of employment.

Methods

This cross-sectional study was conducted from October 2023 to February 2024 in six municipalities in the Attica region, Greece. A total of 627 municipal employees initially responded to the study invitation (413 MSWWs and 214 office employees who served as the internal control group). Six MSWWs were excluded due to recent respiratory infection or spirometry contraindications; therefore, 621 participants (407 MSWWs and 214 office employees) were included in the final analysis

Participants were recruited following internal announcements within municipal services and informed invitations to staff. All employees who were present during the study period and consented to participate were included. The study therefore used a voluntary convenience sampling approach rather than probability-based sampling.

Inclusion criteria were active municipal employment in either sanitation services (MSWWs) or office-based positions during the study period and the ability to perform spirometry according to ATS/ERS guidelines. Exclusion criteria included recent respiratory infection within the preceding four weeks, contraindications to spirometry based on ATS/ERS safety screening, or unacceptable spirometric maneuvers. Among the MSWWs, 59.8% (n = 243) were garbage truck workers and 40.2% (n = 164) were street sweepers. All exposed participants were actively engaged in outdoor sanitation tasks. The overall response rate was 26.8% for MSWWs and 10.8% for office employees. Response rates varied across municipalities, ranging from 7.7% to 53.3% among MSWWs and from 5.9% to 22.9% among office employees, with the highest participation observed in Nikaia–Renti and Elefsina. Detailed participation rates by municipality are presented in Supplementary Table S1. Data collection was conducted through face-to-face interviews using a structured questionnaire and spirometry testing performed by trained personnel. The questionnaire collected information on demographic characteristics (age, sex, body mass index), occupational history (job title and years of employment), smoking status (categorized as current, former, or never smoker), respiratory symptoms (cough, sputum production, wheezing, dyspnea), and reported use of personal protective equipment (PPE). Participants were asked to report symptoms experienced during the preceding 12 months. The questionnaire was based on previously published occupational health surveys and adapted to the local municipal context. The full questionnaire is provided as Supplementary Table S2.

Use of PPE was assessed via the questionnaire item with three options “Always,” “Sometimes,”

and "Never."

Spirometry was performed in accordance with ERS/ATS 2019 guidelines using a portable, calibrated digital spirometer (MIR Spirobank II®, Medical International Research, Italy).[7] The measured parameters included forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), the FEV_1/FVC ratio, and forced expiratory flow at 25–75% of pulmonary volume (FEF25–75). Results were expressed as absolute values and as percentages of predicted values adjusted for age, sex, and height. Predicted values were calculated using the NHANES III reference equations as implemented in the spirometer software. Only spirometry tests meeting ERS/ATS acceptability and reproducibility criteria were included in the analysis.

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., USA). Continuous variables were summarized as means and standard deviations (SD), and categorical variables as frequencies and percentages. Between-group differences were assessed using independent-sample t-tests for continuous variables and chi-square tests for categorical variables. Correlation analyses between years of employment and spirometric indices were conducted using Pearson's correlation coefficient. A p-value <0.05 was considered statistically significant. There were no missing data for primary study variables.

The study was observational and non-interventional and was conducted in accordance with the principles of the Declaration of Helsinki (2013). According to applicable national regulations for non-interventional observational research involving no biological sampling or identifiable personal data, formal ethics committee approval was not required. All participants were informed about the procedures of the study, and verbal informed consent was obtained prior to participation. Participation was voluntary, and confidentiality and anonymity were maintained throughout data collection and analysis.

Results

A total of 621 employees participated: 407 MSWWs and 214 office employees. Among MSWWs, 243 (59.8%) were garbage truck workers and 164 (40.2%) were street sweepers. Response rates were 26.8% for MSWWs and 10.8% for office employees, varying by municipality (Supplementary Table S1). Demographic and baseline characteristics are summarized in Table 1.

Table 1. Demographic characteristics and baseline characteristics of MSWWs and office employees

Variable	MSWWs (n = 407)	Office employees (n = 214)	p-value
Age (years, mean ± SD)	46.3 ± 6.4	44.8 ± 7.1	0.11
Gender (male, %)	81.3%	68.7%	<0.01
BMI (kg/m²)	27.6 ± 3.4	26.8 ± 3.2	0.08
Current smoking (%)	39.5%	37.8%	0.64
Employment duration (years)	15.2 ± 7.5	10.6 ± 6.8	<0.01

Values are presented as mean ± standard deviation (SD) or percentage (%), for continuous variables and as percentages for categorical variables. p-values refer to between-group comparisons (t-test for continuous variables, chi-square test for categorical variables). Employment duration was used as a proxy for cumulative occupational exposure. Smoking refers to current smokers unless otherwise specified.

The mean age of the total population was 45.7 ± 6.8 years, and 77.2% were male. Given differences in sex distribution and employment duration between groups, spirometric comparisons are presented descriptively. Spirometric parameters among exposed and control groups, overall and stratified by smoking status, are presented in Table 2.

Table 2. Spirometric parameters among MSWWs and office employees, overall and stratified by smoking status.

Parameter	MSWWs (mean ± SD)	Office Employees (mean ± SD)	Mean Difference	95% CI	p-value
FEV_1 (% predicted)	91.5 ± 11.7	98.7 ± 10.9	–7.2	–9.05 to –5.35	< 0.001
FVC (% predicted)	94.1 ± 10.3	98.4 ± 9.8	–4.3	–5.95 to –2.65	0.004
FEV_1/FVC ratio	0.74 ± 0.06	0.76 ± 0.05	—	—	0.051
FEF25–75 (% predicted)	68.2 ± 22.1	74.5 ± 21.7	—	—	0.038
Stratified by smoking status					
FEV_1 – Current Smokers	89.4 ± 11.2	95.5 ± 10.1	—	—	0.015
FEV_1 – Former/Never Smokers	93.6 ± 10.9	100.2 ± 11.0	—	—	< 0.001
FVC – Current Smokers	91.5 ± 9.9	96.1 ± 8.5	—	—	0.033
FVC – Former/Never Smokers	96.7 ± 10.1	100.4 ± 10.3	—	—	0.007

Values are presented as mean ± standard deviation (SD). % predicted values are based on ERS/ATS reference equations adjusted for age, sex, and height. Mean differences and 95% confidence intervals (CI) were calculated for comparisons between groups using independent-sample t-tests.

MSWWs had lower mean FEV1 and FVC values compared with office employees (mean difference in FEV1: -7.2%, 95% CI: -9.05 to -5.35; mean difference in FVC: -4.3%, 95% CI: -5.95 to -2.65; p<0.001 and p = 0.004, respectively). Large standard deviations were observed in some strata (notably among smokers), indicating heterogeneity in spirometric values within groups. Self-reported respiratory symptoms (cough, sputum production, dyspnea, and wheezing) were more common among MSWWs than office employees (Table 3).

Table 3. Prevalence of respiratory symptoms among MSWWs and office employees

Symptom	MSWWs	Office employees	p-value
Cough	28.9%	15.4%	<0.001
Sputum production	24.1%	10.3%	<0.001
Dyspnea	19.2%	7.5%	<0.001
Wheezing	8.8%	4.2%	0.03

Values represent self-reported symptoms experienced within the past 12 months. p-values derived from Chi-square tests. Statistical significance set at p < 0.05.

These comparisons are unadjusted and should be interpreted considering baseline differences and potential reporting biases. Regarding respiratory PPE use, none of the MSWW participants reported consistent or occasional use; all selected the "Never" option. Spirometric results by years of employment are shown in Table 4.

Table 4. Spirometric parameters among MSWWs by years of employment

Years of employment	n	FVC (% predicted)	FEV_1 (% predicted)	FEV_1/FVC ratio	p-value
≤10 years	132	96.8 ± 9.7	94.3 ± 10.6	0.78 ± 0.05	Reference
11–20 years	178	93.5 ± 10.2	90.4 ± 11.8	0.76 ± 0.04	0.03
>20 years	97	90.2 ± 11.3	87.6 ± 12.5	0.75 ± 0.06	0.01

Values are presented as mean ± standard deviation (SD). Comparisons were conducted using independent sample t-tests relative to the reference group (≤10 years). $p < 0.05$ was considered statistically significant.

Years of employment showed modest inverse correlations with spirometric indices. Because years of employment is correlated with age and does not capture task variability or exposure intensity, these associations should not be interpreted as evidence of temporal decline or cumulative exposure effects. Correlation coefficients are presented in Supplementary Table S3.

Discussion

This study examined respiratory health among MSWWs in Greece and found that cough, sputum production, dyspnea, and wheezing were more frequently reported by MSWWs than office employees. In addition, MSWWs exhibited significantly lower FEV_1 and FVC values, though mean spirometric indices remained within normal limits. Despite these findings, spirometric reductions were not severe and may reflect the influence of the "healthy worker effect," whereby individuals with pre-existing respiratory disease may self-select out of physically demanding jobs.[8] These findings are consistent with prior studies suggesting occupational exposure in waste collection can negatively impact respiratory health.[9-12]

Similar trends have been documented in national studies. Athanasiou et al. reported decreased FVC and a higher prevalence of respiratory symptoms among MSWWs,[6] while Papageorgiou et al. observed reduced small airway flow (MMEF%pred) in this population.[13] Internationally, Vimercati et al. in Italy and Abou-ElWafa et al. in Egypt reinforce concerns regarding the respiratory risks associated with waste handling work, particularly in the absence of adequate protective measures.[10,11]

To the best of our knowledge, this is the largest study conducted in Greece to evaluate the respiratory health of municipal solid waste collection workers. The relatively large and diverse sample and inclusion of six municipalities across Attica broaden the geographic coverage of the study; however, voluntary participation and response rates may limit generalizability.

Smoking was strongly associated with reduced FEV1 values, as expected. Although stratified analyses showed lower spirometric indices among current smokers, no formal interaction testing was conducted; therefore, any synergistic effect between occupational exposure and smoking must be interpreted cautiously.

Importantly, none of the waste workers reported consistent use of PPE, despite reported availability. This reported lack of respiratory PPE use may indicate a potential occupational health gap. Previous studies suggest that consistent PPE use may mitigate exposure to airborne contaminants such as bioaerosols and particulate matter.[12,14,15] Furthermore, the importance of longitudinal studies in understanding the chronic respiratory effects of occupational bioaerosol exposure has been underscored by a

13-year follow-up among compost workers, which demonstrated persistent pulmonary function decline associated with prolonged exposure durations.[5]

This study has several limitations. The cross-sectional design precludes causal inference. Exposure was classified based on job title, which may introduce misclassification bias. Data on PPE use were self-reported, and no quantitative exposure measurements (e.g., dust or bioaerosol levels) were collected. No multivariable regression analysis was performed; therefore, potential confounding by age, sex, BMI, smoking status, or employment duration cannot be excluded. While years of employment were inversely correlated with lung function, this relationship may be confounded by age and unmeasured task-specific exposure. Additionally, the custom questionnaire used was not formally validated, although it was based on prior occupational health instruments.

Despite these limitations, this is the largest study to date in Greece examining the respiratory health of MSWWs, with over 600 participants across six municipalities. The limited number of Greek studies on this topic underscores the importance of the current findings. This study contributes context-specific data and highlights occupational health challenges in an under-monitored workforce.

Conclusion

This cross-sectional study found a higher prevalence of respiratory symptoms and modest reductions in lung function among MSWWs compared with office employees. Although causal relationships cannot be inferred, the findings are consistent with possible occupational influences on respiratory health. The findings emphasize the need for regular health surveillance and consistent use of respiratory protective equipment among sanitation workers. Future prospective studies with quantitative exposure assessment and adjusted analytical approaches are recommended to more accurately assess long-term respiratory risks in this population.

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Supplementary Table S1. Participant Distribution and Response Rates by Municipality

Municipality	MSWWs Invited	MSWWs Responded	ResponseRate (%)	Office Workers Invited	Office Workers Responded	Response Rate (%)
Agia Varvara	161	48	29.8	196	18	9.2
Elefsina	165	88	53.3	397	21	5.3
Nea Smyrni	271	35	12.9	331	15	4.5
Nea Ionia	299	23	7.7	238	14	5.9
Nikaia–Renti	463	190	41.0	528	121	22.9
Spata–Artemida	181	29	16.0	296	25	8.4
Total	1540	413	26.8	1986	214	10.8

MSWWs = Municipal Solid Waste Workers; R/R % = Response Rate Percentage

Supplementary Table S2. Structured Questionnaire Administered to Study Participants

UNIFIED FORM
PRE-EXAMINATION SCREENING & SPIROMETRY
(According to ATS/ERS Guidelines)

A. EMPLOYEE INFORMATION

Employee ID: ……
Gender: ☐ Male ☐ Female
Age: …… years
Height: …… cm
Weight: …… kg
Job Position:
☐ Street cleaner
☐ Waste collection worker
☐ Garbage truck driver
☐ Other: ……
Years of employment in sanitation services: ……

B. RESPIRATORY & MEDICAL HISTORY

Have you ever been diagnosed with:

Condition	YES	NO
Asthma	☐	☐
Chronic bronchitis	☐	☐
COPD	☐	☐
Other lung disease	☐	☐

Do you frequently experience:

Symptom	YES	NO
Cough	☐	☐
Sputum production	☐	☐
Wheezing	☐	☐
Exertional dyspnea	☐	☐

Respiratory infection within the last 4 weeks: ☐ YES ☐ NO

C. CONTRAINDICATION SCREENING (ATS/ERS SAFETY CHECK)

Do you currently have or have you recently had (within the last 12 months):

Condition	YES	NO
Hemoptysis	☐	☐
Syncope during forced expiration	☐	☐
Myocardial infarction / severe cardiac event (last 3 months)	☐	☐
Thoracic or abdominal surgery (last 3 months)	☐	☐

➞ Any "YES" answer requires medical judgment or test postponement.

D. SMOKING HISTORY

☐ Never smoker
☐ Former smoker
☐ Current smoker
If current/former smoker:
Years of smoking: ……
Cigarettes per day: ……

E. OCCUPATIONAL EXPOSURE

During your work, are you exposed to:

Factor	YES	NO
Dust / airborne particles	☐	☐
Exhaust fumes	☐	☐

Use of respiratory personal protective equipment (PPE):
☐ Always
☐ Sometimes
☐ Never

F. MEDICATIONS (ATS/ERS PRE-TEST)

Do you take respiratory medications? ☐ YES ☐ NO
If yes: ……
Have you used inhaled medications today? ☐ YES ☐ NO

G. FINAL MEDICAL ASSESSMENT

☐ Fit for spirometry
☐ Postponement – reason: ……
Comments / Interpretation:
……

H. COMPLIANCE STATEMENT

Spirometry was performed in accordance with ATS/ERS guidelines, following structured pre-test screening, with acceptable and reproducible maneuvers.
Occupational Physician: ……

This questionnaire was developed based on relevant occupational health and spirometry guidelines (ATS/ERS 2019).

Supplementary Table S3. Correlation of spirometric parameters with years of employment

Parameter	Pearson's r	p-value
FVC (% predicted)	–0.27	0.01
FEV_1 (% predicted)	–0.33	0.001
FEV_1/FVC ratio	–0.21	0.02

Values represent Pearson's correlation coefficients (r). $p < 0.05$ was considered statistically significant.