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# Effects Of Air Pollutants And Their Exposure On Frailty Risk: Meta-Analysis And Review

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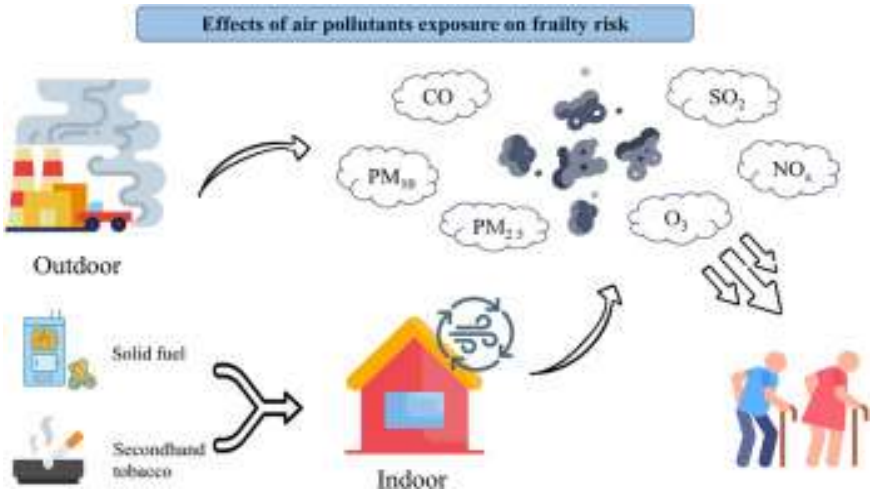
**Abstract**

Air pollutants have been investigated to be associated with many health issues. Recently, epidemiological studies have been suggested the association between air pollution exposure and risk of frailty with inconsistent findings. This meta-analysis and review was to summarize and evaluate the effects of exposure to various air pollutants on risk of frailty. PubMed, Embase, Scopus and Web of Science were systematically searched for relevant studies published before May 15, 2024. Studies that explored the potential relationship between exposure to air pollutants ($PM_{2.5}$, $PM_{10}$, $O_3$, $NO_x$, solid fuel, second hand tobacco) and risk of frailty were included. The quality of cross-sectional and cohort studies was evaluated using an eight-item assessment instrument for epidemiological studies and Newcastle-Ottawa Scale, respectively. A total of 9,717 papers were retrieved, of which 20 met the inclusion criteria. Meta-analysis indicated that $PM_{2.5}$ exposure was significantly associated with frailty assessed by the frailty index [OR (90% CI): 1.24 (1,11–1.38) per 10 $\mu g/m^3$ increment]. Moreover, solid fuel exposures were significantly associated with an increased risk of frailty assessed by the frailty phenotype [OR (90% CI): 1.91 (1.09–3.34)] or the frailty index [OR (90% CI): 1.25 (1.11–1.41)]. Exposure to $PM_{2.5}$ and solid fuel increases the risk of frailty. Environmental protection policies and public health measures should be developed to reduce $PM_{2.5}$ concentrations. Effective measures, such as improving stoves and using clean fuels, should be taken to reduce indoor air pollution levels.

**Graphical abstract**




## Introduction

Frailty, an age-related syndrome, has garnered significant attention from the global community due to the rapid rise in population aging. (Kojima et al., 2019). It is a multifactorial clinical syndrome characterized by multiple system disorders and decreased physiological reserves (Fried et al., 2001), which increase the vulnerability of the body and decrease the ability to resist environmental stress (Song et al., 2010). As a result, there is a higher likelihood of unfavorable outcomes such as falls, disability, comorbidities and death (Struijk et al., 2024). The prevalence of frailty among the elderly is rising due to faster population aging, according to epidemiological studies. A thorough systematic analysis of the epidemiology of frailty included 20 studies encompassing 61,500 community-based persons over 65 years old. The results showed that the prevalence of frailty ranged from 4.0% to 58.1%, with a combined prevalence of 10.5% (Collard et al., 2012).

There are numerous worldwide frailty evaluation instruments accessible, however as of yet there isn't a gold standard that is globally acknowledged for frailty detection (Buta et al., 2016). At present, Fried frailty phenotype (FFP), frailty index (FI) and FRAIL scale are commonly used measurements to assess frailty (Ng et al., 2024). Symptoms, signs, diseases, and disabilities are all considered as deficits and combined into the FI, which is made up of 25 or more items (Ng et al., 2024). It reflects the proportion of the person's potential defects and can provide a quantitative summary of vulnerability (Rockwood and Mitnitski, 2007). FFP is often used as a comparative measure of standard validity and comprises five criteria of frailty: unintentional weight loss, self-reported exhaustion, weakness (grip strength), slow walking speed, and low physical activity (Fried et al., 2001). The FRAIL scale is a commonly utilized patient-reported dichotomous scale that assesses five dimensions of frailty, including fatigue, resistance, ambulation, illnesses, and loss of weight (Morley et al., 2012). Both the FFP and FRAIL scale include three stages: robust (0 points), prefrail (1–2 points), and frail (3–5 points). Frailty is influenced by a wide range of factors, such as malnutrition (Boulos et al., 2016), sleep disorders (Pourmotabbed et al., 2020), depression (Chu et al., 2019), air pollution(Cohen and Gerber, 2017) and so on.

At present, air pollution has become one of the primary environmental concerns affecting public health, with approximately 90% of the world's population being exposed to air pollution levels beyond the World Health Organization's recommendations (Dominguez et al., 2024). Air pollution raises mortality and morbidity and is a major contributor to the global burden of diseases (Cohen et al., 2017). Toxicological studies have investigated and suggested the negative health effects of pollutants in animal models, such as $PM_{10}$ (Guascito et al., 2023) and $PM_{2.5}$ (Liu et al., 2023). Epidemiological evidence demonstrates that exposure to air pollution, including outdoor and indoor air pollutants, is associated with respiratory diseases (Liu et al., 2022), cardiovascular diseases (Konduracka and Rostoff, 2022), cerebrovascular diseases (Avellaneda-Gomez et al., 2022), mental health (Duchesne et al., 2022) and many other health problems (Chin et al., 2022). Common outdoor air pollutants include sulfur dioxide ($SO_2$), carbon monoxide (CO), nitrogen dioxide ($NO_2$), particulate matter (including $PM_{2.5}$ and $PM_{10}$), and ozone ($O_3$) (Wan et al., 2023). According to a recent systematic meta-analysis and review, particulate matter exposure was associated with all-cause mortality, cardiovascular mortality, and respiratory mortality in older adults (Pouri et al., 2024). Furthermore, as they spend a large portion of their time indoors, elderly adults are at high risk of exposure to indoor air pollutants, such as including solid fuel and secondhand tobacco (García-Esquinas and Rodríguez-Artalejo, 2017), which may lead to a larger chance of health problems. For instance, a review discovered that indoor air pollution was significantly associated with cognitive impairment in older women (Bin Mahfoz et al., 2021). In the last decade, increasing epidemiological studies were conducted to explore the association between exposure to air pollution and risk of frailty, particularly with regard to $PM_{2.5}$, solid fuel and frailty, making meta-analysis possible. A cross-sectional study conducted in the United Kingdom with 2,20,079 participants aged 60 years and older revealed a correlation between exposure to $PM_{2.5}$, $PM_{2.5\text{-}10}$ or $NO_x$ and frailty (Veronese et al., 2023). After surveying 33,126 people in six middle-income countries who were 50 years of age or older, Guo et al. showed that $PM_{2.5}$ was linked to frailty in rural areas, but not in urban areas (Guo et al., 2022a). Myers et al. followed older adults hospitalized for myocardial infarction in Israel for 10–13 years and reported an association between $PM_{2.5}$ exposure and the incidence of frailty (Myers et al., 2013). By establishing a prediction model for indoor $PM_{2.5}$, Tong found no association between indoor $PM_{2.5}$ and frailty of the elderly in Hong Kong (Tong, 2020). Song et al. found that the use of biomass fuel increased the risk of vulnerability compared to clean fuel (Song et al., 2023). However, there is no meta-analysis and systematic review on the relationship between air pollution and physical frailty.

Therefore, to fill this gap, we conducted this systematic meta-analysis and review to comprehensively summarize and evaluate associations between exposure to various air pollutants (including $PM_{2.5}$, $PM_{10}$, $O_3$, $NO_x$, solid fuel, secondhand tobacco) and risk of frailty based on existing epidemiological studies.

**Methods**

This study was conducted according to the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) checklist (Stroup et al., 2000) and Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Table S1) (Page et al., 2021). The protocol has been registered in the platform - International Database of Systematic Reviews (INPLASY, https://inplasy.com/) with the number INPLASY202410101.

**Search results and study characteristics**

According to search strategy, a total of 9,717 relevant articles were retrieved from the four databases. After excluding duplicated studies, screening title, abstracts and full texts based on inclusion and exclusion criteria, 20 were included in this systematic review and meta-analysis These studies were published between 2010 and 2024 with a total of 378,651 participants. Participants in all studies were at least 45 years old and the sample size ranged from 540 to 220,079 frailty

**Discussion**

To the best of our knowledge, this is the first systematic meta-analysis and review to explore the relationship between exposure to air pollution and risk of frailty. Based on 20 eligible studies involving 378,651 participants, the results showed that exposure to $PM_{2.5}$ and solid fuel increased the risk of frailty. Due to the insufficient amount of literature related to $PM_{10}$, $O_3$, $NO_x$, $SO_2$, CO and secondhand tobacco, no meta-analysis was performed.

**Conclusion**

In conclusion, our findings suggest that exposure to $PM_{2.5}$ and solid fuel increases the risk of frailty. Therefore, environmental protection policies and public health measures should be developed to reduce $PM_{2.5}$ concentrations and effective measures, such as improving stoves and using clean fuels, should be taken to reduce indoor air pollution levels. It is encouraged to conduct more studies on the association between exposure to different air pollutants and risk of frailty

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