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Yuebin Lv

Jinhui Zhou

Virginia Byers Kraus

Tiantian Li

Jeremy A. Sarnat

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Authors

Yuebin Lv, Jinhui Zhou, Virginia Byers Kraus, Tiantian Li, Jeremy A. Sarnat, Jiaonan Wang, Yang Liu, Huashuai Chen, Melanie S. Brasher, Cheng Mao, Yi Zeng, and Xiaoming Shi

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Long-term exposure to $PM_{2.5}$ and incidence of disability in activities of daily living among oldest old

Yuebin Lv[a], **Jinhui Zhou**[a], **Virginia Byers Kraus**[b], **Tiantian Li**[a], **Jeremy A Sarnat**[c], **Jiaonan Wang**[d], **Yang Liu**[e], **Huashuai Chen**[f], **Melanie Sereny Brasher**[g], **Chen Mao**[h], **Yi Zeng**[f,i], **Tongzhang Zheng**[j], **Xiaoming Shi**[a,d,*]

[a]National Institute of Environmental Health, Chinese Center for Disease Control and Prevention, Beijing, 100021, China

[b]Duke Molecular Physiology Institute and Division of Rheumatology, Department of Medicine, Duke University School of Medicine, Durham, NC 27710, USA

[c]Rollins School of Public Health, Emory University, Atlanta, GA 30322, USA

[d]Center for Global Health, School of Public Health, Nanjing Medical University, Nanjing, Jiangsu, China

[e]Department of Environmental and Occupational Health, Emory University, Atlanta, GA 30322, USA

[f]Center for the study of Aging and Human Development and the Geriatric Division of School of Medicine, Duke University, Durham, NC 27708, USA

[g]Department of Sociology and Anthropology; Department of Human Development and Family Studies, University of Rhode Island, Kingston, RI 02881, USA

[*]**Correspondence to**: Xiaoming Shi, PhD, National Institute of Environmental Health, Chinese Center for Disease Control and Prevention, #7 Panjiayuan Nanli, Chaoyang, Beijing 100021, China; shixm@chinacdc.cn; Telephone: (+86) 1050930101; Fax: (+86) 1058900247.

Author statement
Conceptualization: Yuebin Lv, Xiaoming Shi
Data curation: Yuebin Lv, Xiaoming Shi, Jinhui Zhou
Formal analysis: Yuebin Lv, Xiaoming Shi
Funding acquisition: Xiaoming Shi, Yi Zeng
Investigation: Yuebin Lv, Jinhui Zhou, Virginia Byers Kraus, Huashuai Chen, Chen Mao, Yi Zeng, Xiaoming Shi
Methodology: Yuebin Lv, Xiaoming Shi
Project administration: Yuebin Lv, Jinhui Zhou, Yi Zeng, Xiaoming Shi
Resources: Xiaoming Shi
Software: Yuebin Lv, Xiaoming Shi
Supervision: Xiaoming Shi
Validation: Yuebin Lv, Xiaoming Shi, Tiantian Li, Jeremy A Sarnat, Jiaonan Wang, aYang Liu, Melanie Sereny Brashe
Visualization: Yuebin Lv, Jinhui Zhou, Jiaonan Wang
Roles/Writing - original draft: Yuebin Lv, Xiaoming Shi
Writing - review & editing: All authors

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Declarations of Interest
None.

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[h]Division of Epidemiology, School of Public Health, Southern Medical University, Guangzhou, 510515, China

[i]Center for Study of Healthy Aging and Development Studies, Peking University, Beijing, 100871, China

[j]Epidemiology Department, Brown University, Providence, RI 02912, USA

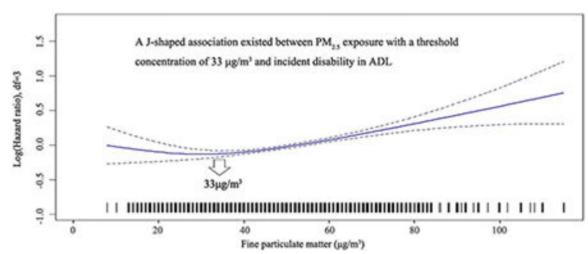
Abstract

Currently the Chinese government has adopted World Health Organization interim target-1 values as the national ambient air quality standards values. However, the population-based evidence was insufficient, especially for the oldest old (aged 80+). We evaluated the association of fine particulate matters ($PM_{2.5}$) exposure and incidence of disability in activities of daily living (ADL) in 15 453 oldest old in 886 counties/cities in China from 2002 to 2014 using Cox model with penalized splines and competing risk models to evaluate the linear or non-linear association. After adjusting for potential confounders, a J-shaped association existed between $PM_{2.5}$ exposure with a threshold concentration of 33 μg/m^3, and incident disability in ADL. Above this threshold, the risk magnitude significantly increased with increase of $PM_{2.5}$ concentrations; compared to 33 μg/m^3, the hazard ratio ranged from 1.03 (1.00-1.06) at 40 μg/m^3 to 2.25 (1.54-3.29) at 110 μg/m^3. The risk magnitude was not significantly changed below this threshold. Each 10 μg/m^3 increase in $PM_{2.5}$ exposure corresponded to a 7.7% increase in the risk of disability in ADL (hazard ratio 1.077, 95% CI 1.051-1.104). Men, smokers, and participants with cognitive impairment might be more vulnerable to $PM_{2.5}$ exposure. The study provided limited population-based evidence for the oldest old and detected a threshold of 33 μg/m^3, and supported that reduction to current World Health Organization interim target-1value (35 μg/m^3) and Chinese national ambient air quality standards (35 μg/m^3) or lower may be associated with lower risk of disability in ADL.

Capsule:

A J-shaped association existed between long-term $PM_{2.5}$ exposure with a threshold concentration of 33 μg/m^3 and incident disability in ADL.

Graphical Abstract



Keywords

$PM_{2.5}$; disability; air pollution; oldest old; cohort study

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1. Introduction

Worldwide, aging-related physical disability has become a critical health concern with the rapidly growing number of older adults, who comprise the largest group of people with disabilities[1]. In China, the population aged 60 years and older with physical disability is predicted to reach 64.02 million by 2020, and 140 million by 2050[2, 3]. Regarded as a key indicator of overall health for older adults, disability represents a person's ability to perform usual tasks and activities, which are essential for self-care and independent living[4]. Elevated exposure to air pollution, especially over a long-term duration, is associated with various adverse health problems, such as increased risks for cardiovascular and respiratory diseases[5, 6]. Given that physical disability is a common functional consequence of these subclinical pathologic processes and co-morbid chronic diseases, it is likely that exposure to air pollution also influences physical disability in older age.

Evidence is growing for an association between ambient air pollution exposure and physical functioning of older adults[7–12]. Despite this, several knowledge gaps are identified in the prior literature: (1) prior studies mainly focused on older adults younger than age 80 years, although it is likely that adults within an older cohort may be extremely vulnerable to the negative effects of air pollution exposure given functional organ decline[13]. (2) previous studies have mainly focused on either a composite air pollution index (API) or nitrogen oxides (NOx) but have not assessed fine matter with a diameter <2.5 μm ($PM_{2.5}$) exposures, which are generally believed to be a primary driver of air pollution related adverse health. (3) Prior studies have been mostly conducted in developed countries where population exposures to $PM_{2.5}$ are low, such as Europe and North America. China, the largest developing country with a relatively high level of exposure to air pollution[14], is at a different stage of the epidemiologic transition, which means the conclusions drawn from developed countries may not reflect the situation in China. (4) In part, due to the lack of more accurate exposure data, prior studies have been conducted examining primarily community-level exposures partly. For the current analysis, we were able to access monitoring data throughout China, using satellite remote sensing combined with a nationwide networking of $PM_{2.5}$ monitoring[15]. (5) Prior studies were mainly cross-sectional study in design, or only accounting for acute effects of short-term exposures, while disability in activities of daily living (ADL) would be expected to relate to chronic, progressive effects of long-term exposure to air pollution[16]. (6) Prior studies used different measures of disability; and an internationally accepted measure was not used, such as Katz index of independence in ADL [17].

Currently, the Chinese government has adopted the World Health Organization (WHO) air quality interim target-1 values of 35 μg/m^3 as the National Ambient Air Quality Standards (NAAQS) values[15, 18, 19]; these are expected to be updated when sufficient evidence from epidemiologic research conducted in Chinese populations becomes available. The concurrent rapid population aging and environmental degradation in China[20] make it more urgent to study the role of air pollution in disability in ADL for oldest old (80+). With an attempt to contribute to the currently limited evidence, in this study, we analyzed data from a prospective cohort of the oldest old scattered across 866 community units (cities or counties) in 23 provinces of China, by exposure estimates derived from satellite observations; and

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determined disability in ADL by means of the Katz index and examined linear and non-linear dose-response relationships to explore the exposure limits most appropriate for the over 80 age group.

2. Materials and Methods

2.1 Study group

The study subjects were participants of the Chinese Longitudinal Healthy Longevity Survey (CLHLS). The study was chosen probabilistically to represent 85% of the total population of Chinese oldest old[12,20] and a national range of exposures to PM9.5 in ambient air (Figure 1). All participants underwent triennial assessments during which they completed questionnaires and underwent evaluation of AD[21]. In 2002-2014, we enrolled 15 453 participants aged 80 and older (mean age, 92.3±7.3 years), with available geographic topography information, and independent ADL at baseline, including 8141 octogenarians (aged 80-89), 4472 nonagenarians (aged 90-99), and 2840 centenarians (aged 100 and older). Among 15453 participants, 7387, 3177, 4393, 496 participants were enrolled in 2002, 2005, 2008 and 2011 survey respectively; and 2326, 2441, 2836, and 1142 participants died before the incidence of disability in ADL in 2002, 2005, 2008 and 2011 survey respectively. Cohort members were followed from the date of recruitment until the date of disability in ADL, death, emigration, or 1 September 2014 (whichever came first). All procedures performed in studies were approved by the biomedical ethics committee of Peking University (IRB00001052-13074). Written informed consents were obtained from all participants included in the study by themselves or their proxy respondents.

2.2 Exposure assessment

At baseline, we obtained geographic topography information from the community questionnaire of the CLHLS. Data on estimates of $PM_{2.5}$ came from the Atmospheric Composition Analysis Group from using satellite-, simulation- and monitor-based information[22]. Annual average residential $PM_{2.5}$ exposure with 0.01° spatial resolution (1.1×1.1 km) at the participants' home addresses was estimated according to the year of survey, from satellite observations by combining Aerosol Optical Depth (AOD) retrievals from multiple satellite products (MISR, MODIS Dark Target, MODIS and SeaWiFS Deep Blue, and MODIS MAIAC)[22]. The resultant $PM_{2.5}$ estimates were highly consistent (R^2=0.81) with out-of-sample cross-validated $PM_{2.5}$ concentrations from monitors[22]. Nearly all of the locations (99.3%) were sufficiently complete and correct to allow geocoding to an exact location; exposures were not updated given that only very few (2.1%) participants moved to another address. The correlation matrix of estimated $PM_{2.5}$ showed that the exposures from the year of 2002 to 2014 were highly correlated, the correlation coefficient ranged from 0.86 to 0.98 (Table 1), which suggested that the baseline $PM_{2.5}$ may be a good estimation of the exposure from recruitment to event incidence. $PM_{2.5}$ in the recruitment year of 2002, 2005, 2008 and 2011 was therefore used in the analysis. The improved ambient air pollution estimates from satellite monitoring may have lower exposure misclassification bias than the exposure estimates that relied only on fixed-location monitoring station.

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2.3 Outcome assessment

The internationally accepted Katz index of independence in ADL was used to assess disability[17]. Disability was identified if a participant needed help in any areas of the six daily tasks of dressing, eating, bathing, continence, toileting and cleaning themselves afterward, and indoor movement; a participant was considered independent if no help was required with any ADL. This resulted in scores ranging from 0 to 6; higher scores indicated better ADL. Participants who scored 5 or less were identified as disability in ADL; scored 6 were identified as normal ADL. The Katz index has been used in a variety of epidemiologic studies of aging, and has well-established reliability and validity[23], more details on Katz index were described in Supplementary 1.

2.4 Statistical analysis

To explore the linear or non-linear associations of $PM_{2.5}$ with disability in ADL, Cox models with penalized splines were conducted[24]. Based on the corrected Akaike Information Criterion (AIC), 3 degrees of freedom for $PM_{2.5}$ (coded as a continuous variable) were selected for the association analyses. Cox models with penalized splines showed a statistically significant J-shaped association for $PM_{2.5}$ with disability in ADL. Participants with 33 μg/m^3 had the minimum risk of disability in ADL based on the estimated parameters of penalized splines (J-shaped exposure-response function) after adjustment for the confounders. The hazard ratios (HRs) and 95% confidence intervals (CI) were evaluated for every 10μg/m^3 interval of $PM_{2.5}$ concentrations for 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 and 110 μg/m^3 in Cox models with penalized splines adjusting for the confounders, with reference to 33 μg/m^3. A number of potential confounding factors were measured, including age (continuous), sex, residence, current marital status, living pattern, educational level, occupation, source of income, parity, playing cards, smoking status, alcohol consumption, physical activity, hypertension, heart disease, cerebrovascular disease, diabetes mellitus, respiratory disease and cognitive impairment at baseline, based on the existing literature[25], and included in the final model specification. Living pattern has been defined as “living with family members” or “living alone or at nursing home”. Educational level was classified as illiterate and literate since most Chinese adults aged 80 and older didn’t receive any formal education. Occupation was categorized as farmer or non-farmer. Source of income was categorized as pension or other. Parity was the number of children and used as continuous variable. Smoking status was defined into three categories: current, former, and never. Alcohol drinking status was defined into three categories: current, former, and never. Data on the prevalence of chronic diseases such as heart disease, cerebrovascular disease, diabetes mellitus, and respiratory disease were collected. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) at baseline enrollment were measured to determine the presence of hypertension (SBP≥140 mmHg, DBP≥90 mmHg). Cognitive impairment was defined as the score of mini-mental status examination lower than 24. In the final analytic database, although less than 0.7% of individuals had missing data for any individual covariates, multiple imputation methods were used to impute missing values of covariates.

To correctly estimate the marginal probability of disability in ADL in the presence of mortality, competing risk models were constructed to estimate risk of disability in ADL for each 10 μg/m^3 increase in $PM_{2.5}$ adjusted for the above confounders. Using Cox models

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with penalized splines, we evaluated potential modifiers of an effect between $PM_{2.5}$ and disability in ADL such as sex, smoking status, residence, cognitive function, subgroup analyses in men and women, smokers and non-smokers, urban participants and rural participants, participants with cognitive impairment and normal cognition. Additionally, interactions between those modifiers and $PM_{2.5}$ for disability in ADL were tested.

To assess the robustness of the observed associations, a number of sensitivity analyses were conducted. (1) The predicted $PM_{2.5}$ concentrations were averaged at each of her/his residential locations from recruitment to event incidence, characterizing the historic long-term exposures. (2) Models were repeated for the participants who did not move to another address during the follow-up survey, even though address changes were only observed in very few of participants. (3) Crude models and models adjusted only for sex and age were also constructed, for adjusted variables may be plausible intermediates on the causal pathway. (4) Analyses were conducted excluding the participants lost to follow-up. (5) Models were conducted with a relatively “healthy” designation, by excluding individuals diagnosed with the comorbidities (heart disease, cerebrovascular disease, diabetes mellitus, and respiratory disease).

A P-value threshold of 0.05 was used to assess statistical significance. All analyses were carried out using SAS version 9.4 (SAS Inc., Cary, NC, USA) and R 3.4.2 (R foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1 Study participants

In total, the analysis included data from 15 453 individuals (Table 2). The mean age of the participants was 92.3±7.3 years; 43.9% were men and 18.0% lived in urban areas at baseline. Annual average residential $PM_{2.5}$ exposure at baseline ranged from 8.2 μg/m^3 to μg/m^3 (Figure 1). The mean annual $PM_{2.5}$ exposure was as follows: 50.2 μg/m^3 overall; 49.5 μg/m^3 for rural residents; 53.4μg/m^3 for urban residents; 49.9 μg/m^3 for participants with independent ADL; and 51.4 μg/m^3 for participants with disability in ADL. The mean (standard deviation, SD) of the follow-up time for included participants was 4.6 (3.1) years. Over a follow-up period of 71 396 person-years, 3373 (21.8%) incident cases of disability in ADL were ascertained.

3.2 Association between $PM_{2.5}$ and disability in ADL

Using a Cox model with penalized splines adjusted for potential confounders, a J-shaped association was observed between $PM_{2.5}$ exposure and disability in ADL with a threshold concentration of 33 μg/m^3. Above this threshold, the risk magnitude significantly increased with increase of $PM_{2.5}$ concentrations; not significantly changed blow this threshold. Compared to 33 μg/m^3, the hazard ratios for different $PM_{2.5}$ thresholds of exposure of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 and 110 μg/m^3 were 1.09(0.86-1.39), 1.02(0.89-1.17), 0.99 (0.93-1.06), 1.03 (1.00-1.06), 1.11 (1.09-1.14), 1.23 (1.20-1.27), 1.38 (1.31-1.45), 1.54 (1.41-1.71), 1.75 (1.48-2.07), 1.98 (1.53-2.58) and 2.25 (1.54-3.29) respectively (Figure 2). The value at which the curve becomes significantly non-zero was 40 μg/m^3. The competing

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risk models showed that each 10 μg/m^3 increase in $PM_{2.5}$ exposure corresponded to a 7.7% increase in the risk of disability in ADL (HR 1.077 [1.051-1.104]).

3.3 Sub-group and sensitivity analyses

Significant interactions of sex (*P*=0.012), smoking status (*P*=0.008), and cognitive function (*P*<0.001) with $PM_{2.5}$ for disability in ADL were observed; there were no significant interactions of residence location with $PM_{2.5}$. Men, smokers, and participants with cognitive impairment might be more vulnerable to the effects of long-term $PM_{2.5}$ exposure (Figure 3). The associations of $PM_{2.5}$ and disability in ADL were unchanged or slightly strengthened in the various sensitivity analyses that included the following: lagging 1-, 2-, 3-, 4-years exposure period exposure (Supplementary Table S1).; averaging exposures from baseline to the event, excluding participants with address changes, only adjusting for sex and age, excluding participants lost to follow-up, and excluding participants with comorbidities (Supplementary Table S2).

4. Discussion

In this prospective cohort study of community-based oldest old, higher risk of disability in ADL incidence occurred among those with individual, higher long-term exposure to $PM_{2.5}$. In addition, men, smokers, and participants with cognitive impairment might be more vulnerable to this effect. Our study adds to the current limited evidence of an adverse effect of $PM_{2.5}$ on physical functioning in oldest old; to our knowledge, this is the first cohort study to demonstrate the association for this specific age group. The major contribution of our study is the identification of the threshold value (33 μg/m^3) of $PM_{2.5}$ for disability in ADL incidence in a large subsample of oldest-old living in 866 highly diverse counties and cities in a nationwide representative study. The strengths of this study also included standard measurements of disability, exposure estimation at an individual level, extensive information regarding important confounding factors, accounting for possible bias from selective attrition and use of Cox models with penalized splines to estimate the shape of the dose-response relationship.

4.1 Previous studies

Our findings are generally consistent with the limited prior epidemiological evidence focusing on older adults. In the cross-sectional study of the 2002 wave of the CLHLS, a higher API at the county or city level was associated with a 25% higher risk of disability in ADL among Chinese older adults aged 65+[7]. The study of the CLHLS 2002-2005 wave also revealed a decrease in 3-yr self-reported health expectancies with increasing API at the county or city level[8]. In a cohort of 1762 Dutch older adults aged 55 to 85, long-term exposure to air pollution, such as NO_2, PM_{10}, and PMcoarse, adversely affected performance-based and self-reported physical functioning[9]. A recent study from Chicago using NO_x as an indicator of traffic-related air pollution identified a significant association between long-term air pollution exposure and progression in physical disability among older adults[10]. An early study reported an association of short-term exposure to $PM_{2.5}$ with increased disability days[11]. A cross-sectional study among more than 45 000 adults (mean age: 56 years) from China, Ghana, India, Mexico, Russia, and South Africa showed that

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exposure to ambient $PM_{2.5}$ might be one risk factor for disability with women and older adults as the vulnerable population[12].

Unlike the majority of the prior cross-sectional studies, as a prospective cohort study, the present study makes it possible to identify a more confident relationship between $PM_{2.5}$ exposure and disability in ADL. Our ability to estimate exposures at an individual level provides unique and valuable data to complement those prior studies at a community-based level. Notably, the hazard ratio for oldest old in our study was significantly higher than in other studies conducted in adults or younger elderly in the general population[7–12]. The oldest old generally have worse health conditions, which may diminish their ability to adapt to air pollution exposure. In consideration of the unique characteristics for those aged 80+, the extent to which our results might generalize to other age groups are unclear.

4.2 Explanations

There are known or postulated biological mechanisms that support the plausibility of an association between ambient $PM_{2.5}$ exposure and disability. Inhaled fine particles may enter by direct translocation through the olfactory bulb, then could elicit inflammatory responses and oxidative stress[26], which have also been one pathological pathway of the occurrence of disability[10]. Higher air quality promotes outdoor physical activities, which may protect against risk for subsequent disability in ADL and enhance recovery after the onset of disability in ADL[23]. It is also possible that chronic exposure to $PM_{2.5}$ could result in damage in methylation of DNA repair genes[27], which may be linked to disability. Because disability and health status were likely to be results of $PM_{2.5}$ exposure rather than causes of it, and because of our use of a prospective cohort study design, reverse causality is not likely to be a big concern in the present study. Additionally, selection bias was partly examined by a number of sensitivity and subgroup analyses.

The association between $PM_{2.5}$ and disability in ADL has appeared to be stronger in men, has also been reported previously[28]. Specifically, we hypothesize that this may be attributable more time spent outdoors, higher level of physical activity in daily life required more air inhalation for men, leaded to higher accumulation of toxic chemicals from the air than women. Notably, participants with cognitive impairment were not as adept at handling these added stressors and, therefore, have a higher risk of disability in ADL as a result of the exposure[21]. Not surprisingly, it was found that the adverse effects of $PM_{2.5}$ exposure were greater in smokers, considering the combined effects of air pollution and smoking on health[29].

In a large epidemiologic study, personal air monitoring devices is impractical, especially for measuring long-term exposures. By contrast, GIS-based spatiotemporal models offered the ability to estimate individual annual average exposures at baseline and averaged exposures from baseline to the event for the 15 453 participants, which has been validated and applied in previous studies[22]. The exposure measurements were based on participants’ residential locations, and thus limited by the assumption that participants spent most of their time at home; an assumption we believe to be reasonable for the oldest old in this study.

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Policy implications—The study found that the oldest old may be more vulnerable to the negative effects of long-term air pollution exposure. It suggested detailed measurements targeting on different populations including the general adults, younger elderly and the oldest old may be needed to identify the high-risk population and give their priority to health protection in the rural and urban regions. Additionally, in the published integrated exposure-response model for long-term exposure of $PM_{2.5}$ from global burden of diseases, the concentration range of 50-100 μg/m^3 were estimated by second-hand smoke due to the gap of epidemiological evidence on high ambient $PM_{2.5}$ exposure and health outcome from developing countries[30]. The developing countries, was similar to the $PM_{2.5}$ exposure and at a similar different stage of the epidemiologic transition to China. Future studies are needed to investigate whether the conclusions drawn from in China can be transferred to other developing countries with similar characteristics. The results will provide important policy implications to policy-makers and service providers in the disciplines of health and environmental protection, especially in the developing countries such as China and India[31].

Increasing awareness of the harmful effects of air pollution has led to the development of guidelines to prevent excess exposure to these toxicants. For better air quality management to protect public health, the Chinese NAAQS were revised by adopting the interim target values in air quality guidelines in 2012, in which concentration limits for annual averages of $PM_{2.5}$ were 35 μg/m^3[18,19]. However, the formulation of air quality standards requires integrated assessments of risks of air pollution attributable to disease burden and feasibility of environmental management[32]. Our results support that reduction to current WHO air quality interim target-1 and Chinese national ambient air quality standards (35 μg/m^3) may be associated with lower risk of disability in ADL. It highlight more air pollution health researcher were needed to explore the benefits of continued reductions for cleaner air (i.e., 10ug/m^3 for $PM_{2.5}$ annual average) in setting up health risk management-based air quality standards in China..

4.3 Limitations

Several limitations merit attention. First, our study provides only indirect evidence for an effect of $PM_{2.5}$ exposure since air pollution is a complex mixture in which $PM_{2.5}$ is one component among many. Second, only outdoor exposures to $PM_{2.5}$ were estimated based on residential location, insufficient adjustment of indoor air pollution (such as household solid fuel use), second-hand smoking and other air pollutants, which may lead to potential confounding[32], may comprise a limitation in this study. Third, in this study, more accurate estimation of $PM_{2.5}$, such as the $PM_{2.5}$ exposure at actually date of survey, were not available, even though lagging 1-, 2-, 3-, 4-years exposure period exposure were matched. Fourth, it is possible that there is information bias in the design of the present study, as a result that disability in ADL could be occurred at any time during a 2- to 3-year interval of follow-up, the exact date of the event was not collected. Fifth, potential reversibility of the incident disability in ADL when performing Cox models may weaken the robustness of the present finding, although the probability of reversible physical disability was relatively low for this population of oldest old with an average age of 92.3±7.3 years.

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5. Conclusions

We observed a clear J-shaped dose-response relationship of long-term exposure to $PM_{2.5}$ with corresponding disability in ADL incidence among Chinese oldest old; the risk magnitude increased with increments of $PM_{2.5}$ concentrations. This association was detected at a threshold of 33 μg/m^3, which was basically consistent with current Chinese NAAQS, demonstrating that current annual averages for $PM_{2.5}$ in NAAQS can be sufficient for mitigating excess risk of disability in ADL from long-term $PM_{2.5}$ exposures for those aged 80+. Therefore, air pollution reduction may be a means for reducing the public health burden of disability and increasing the quality of life of the older adults-particularly aged 80+, men, smokers and people with cognitive impairment. However, the generality of our findings should be further confirmed in other studies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- The dose-response relationship between long-term $PM_{2.5}$ exposure and ADL was J-shaped
- The identification of a threshold of 33 μg/m^3 for $PM_{2.5}$ and ADL disability incidence
- The first cohort study to demonstrate effect of $PM_{2.5}$ on ADL for the oldest old
- Air pollution reduction may reduce the public health burden of disability in the elderly.

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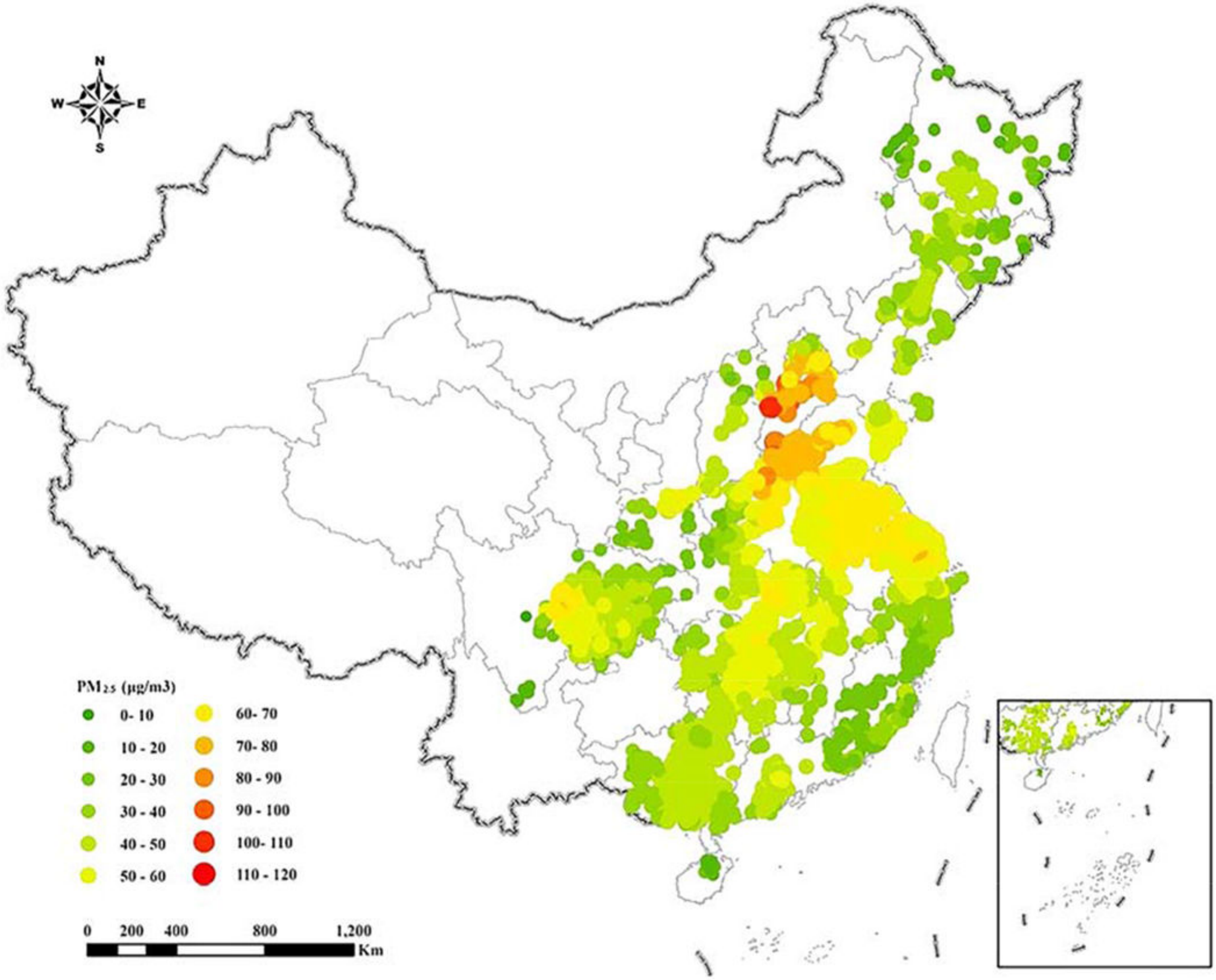

Figure 1.

Annual average residential $PM_{2.5}$ exposure with 0.01° spatial resolution (1.1x1.1 km) in 23 provinces of China at baseline for 15,453 participants

Annual average residential $PM_{2.5}$ exposure at baseline ranged from 8.2 $\mu g/m^3$ to 115.1 $\mu g/m^3$, the mean annual $PM_{2.5}$ exposure was 50.2 $\mu g/m^3$ overall.

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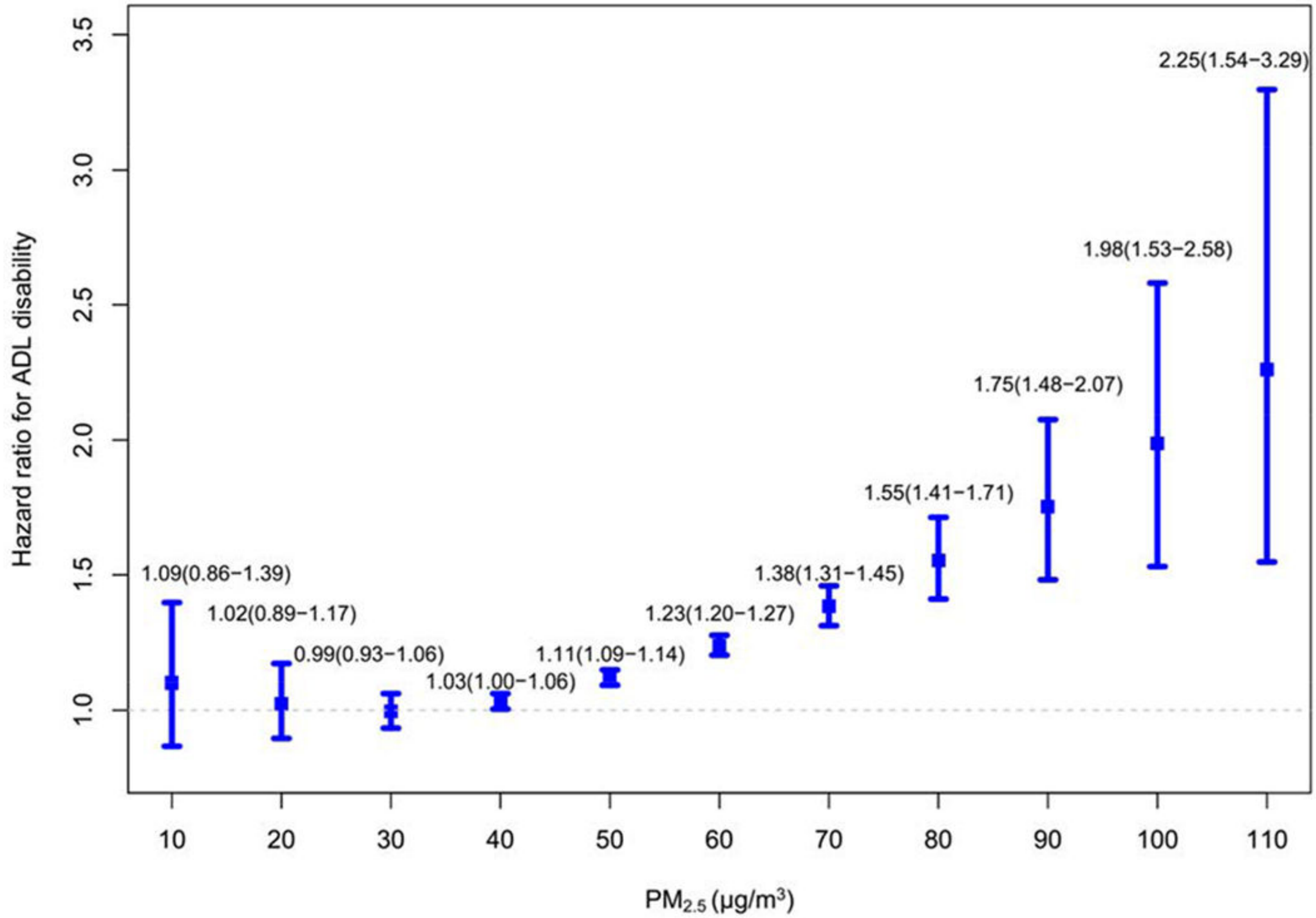

Figure 2.

Association of $PM_{2.5}$ and disability in ADL in Cox models with penalized splines among Chinese oldest old (33 μg/m^3 as reference).[a]

[a] Adjusting for age, sex, residence, current marital status, living pattern, educational level, occupation, source of income, parity, playing cards, smoking status, alcohol consumption, physical activity, hypertension, heart disease, cerebrovascular disease, diabetes mellitus, respiratory disease and cognitive impairment at baseline.

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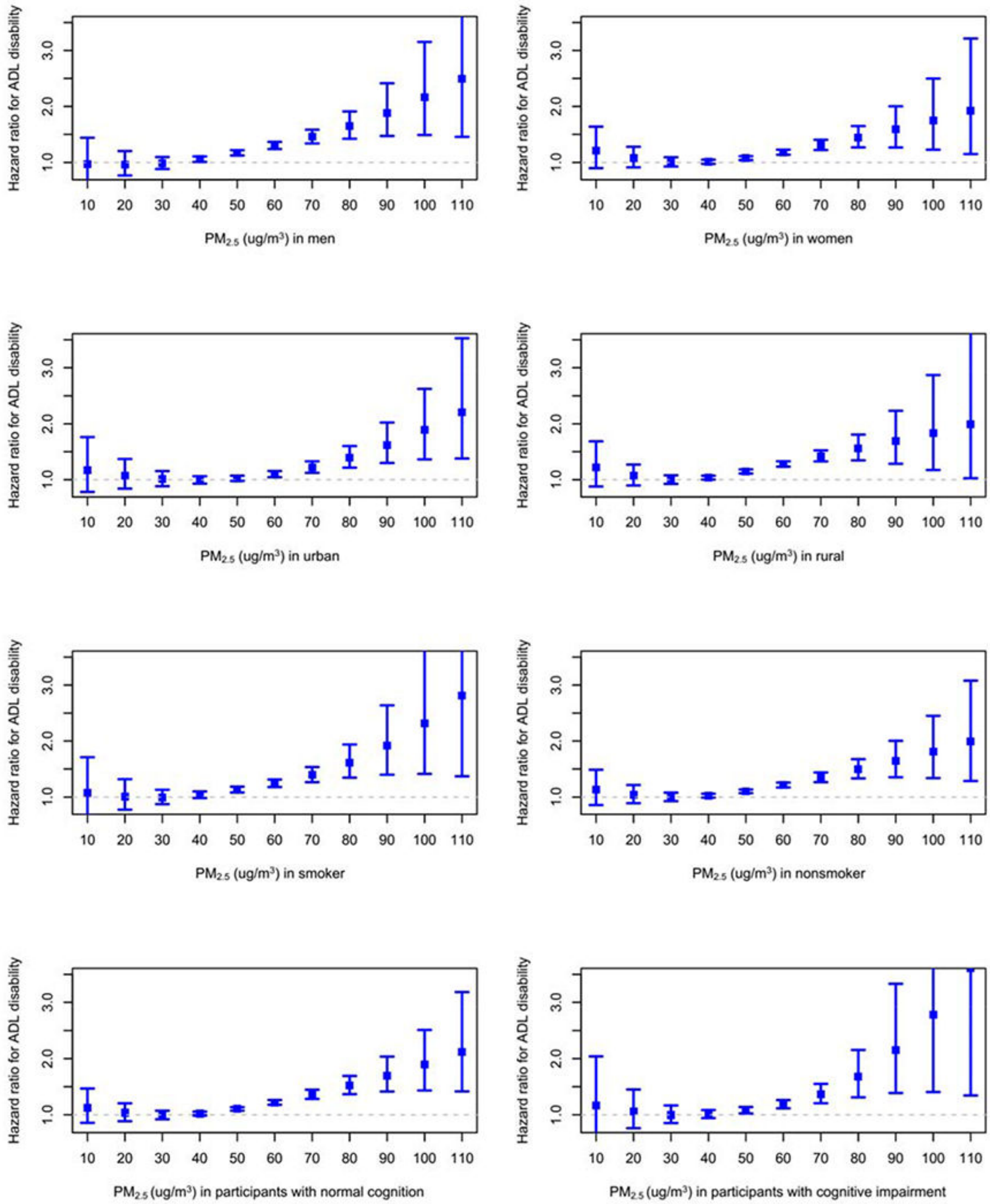

Figure 3.

Subgroup analyses: association of $PM_{2.5}$ and disability in ADL in Cox models with penalized splines among Chinese oldest old (33 μg/m^3 as reference).

[a] Adjusting for age, sex, residence, current marital status, living pattern, educational level, occupation, source of income, parity, playing cards, smoking status, alcohol consumption, physical activity, hypertension, heart disease, cerebrovascular disease, diabetes mellitus, respiratory disease and cognitive impairment at baseline

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Table 1.

The correlation matrix of $PM_{2.5}$ exposure from the year of 2002 to 2014 (N = 453) [†]

$PM_{2.5}$	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2002	1.00	-	-	-	-	-	-	-	-	-	-	-	-
2003	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-
2004	0.94	0.89	1.00	-	-	-	-	-	-	-	-	-	-
2005	0.96	0.92	0.96	1.00	-	-	-	-	-		-	-	-
2006	0.92	0.93	0.89	0.94	1.00	-	-	-	-	-	-	-	-
2007	0.94	0.96	0.89	0.93	0.94	1.00	-	-	-	-	-	-	-
2008	0.95	0.96	0.9	0.92	0.92	0.97	1.00	-	-	-	-	-	-
2009	0.94	0.94	0.88	0.9	0.9	0.95	0.98	1.00	-	-	-	-	-
2010	0.92	0.96	0.86	0.93	0.93	0.95	0.94	0.92	1.00	-	-	-	-
2011	0.95	0.94	0.88	0.93	0.93	0.96	0.96	0.96	0.96	1.00	-	-	-
2012	0.93	0.93	0.9	0.95	0.96	0.96	0.96	0.93	0.94	0.96	1.00	-	-
2013	0.93	0.96	0.84	0.91	0.93	0.95	0.95	0.95	0.96	0.98	0.95	1.00	-
2014	0.93	0.96	0.88	0.91	0.91	0.96	0.97	0.96	0.95	0.96	0.95	0.96	1.00

[†] All the *P* value of the correlation coefficients were <0.001.

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Table 2.

Baseline characteristics of the study participants by disability in ADL status (N = 15,453).

Characteristics	All	Independent ADL	Disability in ADL	*P* value
Number of participants *	15453 (100)	12080 (78.2)	3373 (21.8)	
Age (year) #	92.3±7.3	91.9±7.2	93.8±7.4	<0.001
Sex				<0.001
Men *	6790 (43.9)	5507 (45.6)	1283 (38.0)	
Women *	8663 (56.1)	6573 (54.4)	2090 (62.0)	
Residence				<0.001
Urban *	2781 (18.0)	2016 (16.7)	765 (22.7)	
Rural *	12672 (82.0)	10064 (83.3)	2608 (77.3)	
Marital status				0.022
In marriage *	4083 (26.4)	3140 (26.0)	943 (28.0)	
Not in marriage *	11370 (73.6)	8940 (74.0)	2430 (72.0)	
Education				0.009
Illiteracy *	10420 (67.4)	8083 (66.9)	2337 (69.3)	
Literacy *	5033 (32.6)	3997 (33.1)	1036 (30.7)	
Living pattern				<0.001
Live with family members *	12325 (79.8)	9544 (79.0)	2781 (82.4)	
Live alone or at nursing home *	3128 (20.2)	2536 (21.0)	592 (17.6)	
Tobacco smoking				<0.001
Current *	10454 (67.7)	8077 (66.9)	2377 (70.5)	
Former *	2929 (19.0)	2372 (19.6)	557 (16.5)	
Never *	2070 (13.4)	1631 (13.5)	439 (13.0)	
Alcohol drinking				<0.001
Current *	10630 (68.8)	8193 (67.8)	2437 (72.3)	
Former *	3364 (21.8)	2718 (22.5)	646 (19.2)	
Never *	1459 (9.4)	1169 (9.7)	290 (8.6)	
Regular exercise	5329 (34.5)	4090 (33.9)	1239 (36.7)	0.002
Hypertension *	7827 (51.3)	5992 (49.6)	1835 (54.4)	
Heart disease *	937 (6.1)	670 (5.5)	267 (7.9)	<0.001
Diabetes *	178 (1.2)	130 (1.1)	48 (1.4)	0.095
Cerebrovascular disease *	415 (2.7)	292 (2.4)	123 (3.6)	<0.001
Respiratory disease *	1615 (10.5)	1321 (10.9)	294 (8.7)	<0.001
Cognitive impairment *	3488 (22.6)	2751 (22.8)	737 (21.8)	0.257
$PM_{2.5}$ (ug/m^3) #	50.2±13.4	49.9±13.2	51.4±14.3	<0.001

ADL: activities of daily living; $PM_{2.5}$: fine particulate matter with diameter <2.5 μm

*: Indicating categories variables displayed as sample size (%)

#: Indicating continuous variables displayed as mean±SD.

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