Air Pollution Shortens Life Expectancy and Health Expectancy for Older Adults: The Case of China

Ming Wen, Ph.D.*
Department of Sociology
University of Utah
380 S 1530 E RM 301
Salt Lake City, UT 84112
Tel: 801-581-8041
Fax: 801-585-3784
Email: ming.wen@soc.utah.edu

Danan Gu, Ph.D.*
Population Division
United Nations
2 United Nations Plaza, DC2-1910
New York, NY10017
Tel: 917-367-9192
Email: gudanan@yahoo,com

* Both authors are corresponding authors. The views expressed in this paper are those of the authors and do not necessarily reflect those of University of Utah and the United Nations.

Text word count of text: 3,461

Abstract word count of text: 250

Running head: Air Pollution and Healthy Aging in China

Keywords: China, life expectancy, health expectancy, air pollution, aging

Funding: none

UU IR Author Manuscript

Air Pollution Shortens Life Expectancy and Health Expectancy for Older Adults:

The Case of China

ABSTRACT

Background: Outdoor air pollution is one of the most worrying environmental threats China faces today. Comprehensive and quantitative analysis of the health consequences of air pollution in China is lacking. This study reports age-sex-specific life expectancy (LE) and health expectancies (HEs) corresponding to different levels of air pollution based on associations between air pollution and individual risks for a host of health conditions and mortality net of individual- and community-level confounders.

Methods: This is a multilevel prospective cohort study based a nationally representative sample of Chinese elders. The main outcome measures in this study include life expectancy estimated from mortality and health expectancies based on five health conditions including activity of daily living (ADL), instrumental activity of daily living (IADL), cognitive status, self-rated health, and chronic conditions.

Results: Net of the controls, exposure to outdoor air pollution corresponded to subsequent reductions of LE and HEs for all five health conditions. These detrimental pollution effects were stronger for women. The gap in LE between areas with good air quality and moderately heavily polluted areas was 3.78 years for women of age 65 and 0.93 for men. The differences in HEs at age 65 were also large, ranging from 1.47 years for HE for good self-rated health in men to 5.20 years for ADL-disability-free HE in women.

Conclusions: Air pollution has devastating health impacts on Chinese elders reducing longevity and shortening health expectancies. Women are more vulnerable than men. More strict air policy should be implemented to pursue sustainable development in China.

UU IR Author Manuscript

Air Pollution Shortens Life Expectancy and Health Expectancies for Older Adults:

The Case of China

Recent three decades have witnessed China's magnificent economic development in the reform era. While rapid industrialization and urbanization improved many of the country's citizens' standards of living[1], the ensuing unwelcomed environmental effects have led to a legitimate public health and environmental justice concern[2]. Among a variety of environmental risks in China, outdoor air pollution is one of the most worrying and is among the worst in the world with seven of the ten most air-polluted cities found in China[3, 4]. Despite frequent media coverage and increasing scholarly writings on China's air pollution threats, comprehensive analysis of the air pollution and health link is not adequate. A handful of studies[5, 6, 7] relied on ecological time-series data to evaluate the effects of air pollution on aggregate health in China. There is a need for greater clarity on health effects at the individual level. Moreover, in order to detect chronic effects of air pollution on health, it is essential to conduct prospective studies using longitudinal surveys to characterize how exposure to air pollution is subsequently linked to health and mortality. This type of research has emerged in the West[8-11] although still inadequate in general and much lacking in China[12].

While adverse health effects of air pollutants appear to affect all age groups[13-16], there has been a recent call for a focus on air pollution research in the elderly as they are the principal group at risk for morbidity and mortality and are particularly vulnerable to air pollutants[17]. With the aging trends sweeping across developing and developed societies including China, healthy longevity is becoming a growingly important goal for older adults, their families, and the society as a whole. Hence, modifiable environmental factors of health, mortality or life expectancy (LE), and health expectancy (HE; the average lifetime that a person can expect to live without a health condition) should be rigorously investigated in different settings with results disseminated to the public, environmental activities, and policy makers.

Using data from a nationally representative longitudinal survey recently conducted in China, this study reports gender-specific life expectancy and health expectancies at different ages corresponding to different levels of air pollution based on the associations between community-level air pollution and individual risks for a host of health conditions and mortality. Many previous studies of environmental epidemiology have focused on acute pulmonary or respiratory diseases[18-23]. To the best of our knowledge, this study is one of the first few nationally representative studies using prospective multi-level design to quantify the mid- or long-term effects of outdoor air pollution on age-sex-specific LE and HEs in China.

METHODS

Study population

Data used in this study are from the third and fourth waves of the Chinese Longitudinal Health Longevity Survey (CLHLS) in 2002 and 2005. The CLHLS, which initiated in 1998, only included seniors aged 80 or above for the first two waves, covered 22 provinces in China where more than 85% of the national population resided. Starting from 2002, the third wave of the CLHLS added younger elders aged 65-79 in addition to those followed-up respondents. The CLHLS aimed to interview all centenarians in the sampled counties/cities with informed consents. Lists of centenarians were obtained from the local aging institutes. For each centenarian interviewed, one octogenarian, one nonagenarian, one septuagenarian, and one person aged 65 to 69 were randomly chosen to be interviewed based on a random code assigned to the sampled centenarian. If the random code assigned to a centenarian was an odd number, one female elder from each of four age groups was interviewed. Otherwise, four male elders were interviewed. The ages of the targeted persons aged 65 to 99 were pre-designated to match the last digit of the random code of the sampled centenarian. If there were no such appropriate targeted persons available in the village or street of the sampled centenarian, the CLHLS team recruited respondents from nearby villages, towns, streets or city districts. The CLHLS is representative of the elderly population in Mainland China because the respondents are randomly sampled and the distributions of key variables are comparable to those reported in other national surveys such as the National Health Service Survey and the Sampling Survey of the Aged Population in Urban-Rural China[24]. The CLHLS data include a weight variable reflecting the sampling design and ensuring the weighted sample distributions to match those in

the population in the twenty-two sampled provinces in terms of age, sex, and urban-rural residence. Therefore, weight is always applied when we estimate the distributable frequencies or means for the whole sample. Excluding those centenarians aged 106 or older whose self-reported age is less reliable [25], the 2002 wave interviewed 15,797 respondents aged 65 to 105, including 9,004 women and 6, 793 men. Excluding those who died or were lost to follow-up during the 2002-2005 period, 7,858 women and 5,944 men survived to the 2005 wave. All information was obtained through in-home interviews. Systematic assessments of the CLHLS indicate that the data quality is high[24, 26, 27].

Measurements

Air pollution was measured by the Air Pollution Index (API) at the prefecture or city level, shared by individuals and communities within the same prefecture or city. API is widely used in environmental research as a measure of the general air pollution [28-30]. The China National Environmental Monitoring Center (CNEMC) calculates API to assess the concentration of five pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter less than 10 microns in diameter (PM_{10}), carbon monoxide (CO), and ozone (O_3))[31]. These five pollutants are among the most common air pollutants found in China as well as in other developing countries[32-34]. Air quality of a community is then categorized into seven ordinal air pollution levels (APL) with lower scores indicating better air quality: excellent (API 0-50), good (API 50-100), slightly polluted (API 100-150), lightly polluted (API 150-200), moderately polluted (API 200-250), moderately heavily polluted (API 250-300), and heavily polluted (API≥300). We obtained these APL data in 1995 from the Chinese Natural Resources Database [35]. The detailed procedures of calculating the API and converting them to the APL are listed in the Appendix. We focus on 1995 to capture air pollution exposure because it was the only year during the 1990s that the APL data were publically accessible and also because health consequences of air pollution exposure likely take time to manifest. Research has shown that air pollution could yield significant mid- or long-term effects on health or mortality[11]; but the time lag or latency period has not been well taken into account in the current literature of air pollution epidemiology which is more focused on acute or short-term health impacts of air pollution.

Based on the CLHLS sample of survivors in 2005, age-sex-specific death rates by the level of air-pollution were estimated from sex-stratified proportional Cox hazard models. The CLHLS collected the interview date of the follow-up wave in 2005 for those survivors and the date at death for those who died during the follow-up. With these death rates, we used conventional method to construct life tables[36] and obtain the age-sex-specific LEs. As shown in Figure 1, the overall age-sex-specific death rates and LEs in the CLHLS datasets from 2002 to 2005 are considerably similar to those in the 2000 census. The drop-off of congruence with Census 2000 after age 94 in both genders was likely due to age exaggeration in the 2000 Census in this age group[27].

(Figure 1 about here)

Health conditions were measured by five self-reported variables capturing several key dimensions of health in later life: Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL), cognitive impairment, self-rated health, and chronic disease conditions. ADL refers to the following basic personal-care activities: (a) bathing, (b) dressing, (c) eating, (d) indoor transferring, (e) toileting, and (f) continence. Since the ADL distribution was highly skewed in this sample, with 66% reporting no difficulty performing any of these activities, we dichotomized it into "disabled" (having at least one ADL limitation) and "no limitation," with the latter as the reference category).

IADL refers to the following activities: (a) visiting neighbors, (b) shopping, (c) cooking, (d) washing clothes, (e) walking one kilometer, (f) lifting five-kilograms, (g) crouching and standing up three times, and (h) taking public transportation. Choices for each item were: "able to do without help," "need some help," and "need full help." In a similar vein, we dichotomized IADL into disabled (having at least one IADL limitation) and non-disabled.

Cognitive impairment was measured by the Mini-Mental Status Examination (MMSE)[37], covering the following aspects of cognitive functioning: orientation, registration, duplication and design, calculation, recall, naming, and language, with a total score ranging from 0 to 30. It was adapted to the cultural and socioeconomic circumstances in China[38]. Following previous work[37, 39], we classified the respondents into cognitive

impaired (score less than 18) and cognitive unimpaired (score equal to or greater than 18). Different from the traditional one used in the Western nations[37], this cut-off point arguably better captures the cognitive function of the Chinese elderly population considering more than 85% of Chinese old adults aged 65 or older did not receive more than six years of education[39].

Self-rated health (SRH) has been shown to be an effective measure of individual health status and has a strong predictive power of comorbidity and mortality[40]. It is assessed by a general question: "In general, would you say your health is: (1) very good, (2) good, (3) so so, (4) bad, or (5) very bad?" To account for distributional skew, we combined the SRH responses into the following two categories: "poor" (combining (3) to (5)) and "good" (combining (1) and (2)), with the latter as the reference category.

The CLHLS collected information on more than 20 chronic conditions (e.g., cardiovascular diseases, pneumonia, and arthritis). For this analysis, chronic disease was operationalized as having at least one disease (coded 1) compared to no disease (coded 0). The validity of this measure has been confirmed elsewhere[27].

Sullivan's method was employed to estimate the five HEs, namely LEs free of a specific health condition (e.g., functional disability or cognitive impairment), which have drawn increasing attention in aging studies[41]. The formula[42] for calculating HEs is as below:

$$HE_x = \frac{x\sum^{\omega} L_x^h}{l_x} = \frac{x\sum^{\omega} L_x h_x}{l_x}$$

where HE_x represents health expectancy; l_x the number of living persons in the life table at age *x*; *Lx* is person-years lived at age *x*; h_x is the prevalence of a healthy state (e.g., ADL active) at age *x*; Lh_x is person-years lived in a healthy state at age *x*. Using the Sullivan method, expected LE in IADL or ADL disability-free, cognitive impairment-free, good or very good SRH, and disease-free states were calculated by applying the corresponding

cross-sectional age–sex specific prevalence rates in 2002 to the person-years lived in different age categories derived from period life tables from 2002 to 2005.

Statistical analysis

Two sex-specific models were fit for all the dependent variables including mortality and the five health outcomes. Model I controlled for age and air pollution level (APL) only and Model II added a number of socioeconomic controls, marital status, health practice variables, and per capita GDP at the contextual level (i.e., county or city district). In the survival analysis of the longitudinal data of the CLHLS from 2002 to 2005, where death was the outcome variable, age was categorized into seven five-year groups to account for the nonlinearity of the age effect on mortality. For the five health outcomes, multilevel logistic regression analyses of the cross-sectional data of the CLHLS in 2002 were performed to estimate the prevalence rates and effects of the predictors. Given that the sampling weight variable in the CLHLS dataset is calculated based on the age-sex-urban/rural residence-specific distribution of the population and does not capture other important compositional variables (e.g., marital status, living arrangement, etc.), we did not apply sample weights in the regression analyses. Research has indicated that inclusion of variables related to sample selection in the regression produces unbiased coefficients without weights; additionally, weighted regression results are likely to enlarge the standard errors[43, 44]. All analyses were conducted using STATA 10.1.

RESULTS

Sample statistics are shown in Table 1. The overall death rate in the three-year follow-up is 14%. The average air pollution level (APL) across all the prefectures and cities is 3.3, indicating slight pollution (see Appendix). Table 2 presents results of survival analysis. Air pollution is a significant risk factor of mortality for women with one higher level of air pollution corresponding to a 13% increase in mortality risk, independent of individual-level socio-demographic factors or community-level per capital GDP (see Model II). Air pollution did not appear relevant for men's mortality risk. Table 3 shows coefficients of multilevel logistic models of health conditions. For both men and women, air pollution strongly increases odds of having health problems.

For example, in women one level higher in air pollution is associated with an 11% increase in the odds of being IADL-disabled, 47% for ADL disability, 15% for cognitive impairment, 17% for self-rated poor health, and 7% for having at least one chronic condition. The corresponding figures in men are 15%, 42%, 23%, 10%, and 8%, respectively (see Model II in Table 3). The effects are all positive and net of multi-level controls.

(Tables 1, 2, 3 about here)

Table 4 illustrates sex-specific LEs estimated by survival analyses for each age stratum. Two areas of different pollution levels were compared, one with an APL of 2 representing areas of relatively good air quality and an APL of 6 denoting moderately heavily polluted areas. Based on Model I, in the absolute value, LEs in women in areas of good air quality (APL=2) were from 0.9 year at age 100 to 3.8 years at age 65 greater than those living in moderately heavily polluted areas (APL=6). The corresponding figures were much smaller in men: 0.9 years at age 65 and 0.2 year at age 100, respectively. However, proportionally speaking, the detrimental effects of air pollution were greater in groups older than 85 years of age. These patterns continued to hold after other socio-demographic covariates were accounted for (see Model II).

(Table 4 about here)

Table 5 shows reductions in HEs linked to air pollution. For example, in the absolute value, the gap in HEs for ADL in women between areas with good air quality and moderately heavily polluted areas was 5.2 years at age 65 and 2.8 years at age 85. Reductions in HEs related to air pollution based on other outcomes were smaller although also notable. Reductions in men's HEs attributable to air pollution were much smaller as compared to those for women. These patterns are graphically illustrated in Figures 2 and 3, where the stronger effects of air pollution on women are apparent for most outcomes. Our *ad hoc* analyses further showed that these effects were net of demographics, psychosocial factors, health practice, and community-level per capital GDP (data not shown).

(Table 5 and Figures 2 and 3 about here)

DISCUSSION

Although the link between air pollution and health is well-recognized[45], quantifying prospective health consequences of air pollution has been difficult[7]. Most epidemiological studies of air pollution rely on

ecological data focusing on mortality and cardiovascular, respiratory and pulmonary conditions. Hence, causality in this link remains elusive and pollution effects on other health outcomes are largely unknown. The literature is particularly thin in China—a rapidly developing country that has been exhibiting large-scale environmental deterioration concomitant with an unprecedented continued economic miracle.

To our knowledge, the present study is the first to report prospective and contextual effects of outdoor air pollution on LE and HE in China, using a recently collected nationally representative sample of older adults. Net of a range of control variables, exposure to outdoor air pollution led to a reduction of LE and greater reductions of HE. These detrimental pollution effects seemed to be stronger for women than men although for men the pollution effect on LE was in the same direction and the pollution effects on HEs were remarkable as well. The largest gap in LE between areas with good air quality and moderately heavily polluted areas was about four years for women of age 65; and the corresponding largest gap in HE was five years based on ADL for women of age 65. Proportionally speaking, the pollution effects were greater among the oldest old (age 85 or older). Adding up to the population level, these human and health costs can be tremendous. Clearly, the detrimental health effects of environmental pollutions in China need to be urgently addressed.

The stronger contextual effect of outdoor air pollution on women's health is consistent with evidence that women's health and behavior are more responsive to a host of residential environmental factors reported in the neighborhood effects on health research[46]. It is also consistent with growing evidence of interaction between gender and air pollution in affecting respiratory health [47]. The finding from the present study indicates that women's greater susceptibility to air pollution is not limited in respiratory health but also applicable to a wide range of conditions prevalent among the elderly. Both biological and non-biological mediators of this gender/sex gap have been proposed. For example, women's smaller lung size and airway diameter may lead to increased airway reactivity and exacerbate particulate deposition[48, 49]. As to non-biological factors, gender differences in socioeconomic status and stress experiences[50, 51] and other socio-demographic factors such as marital status[52] may help explain the gendered responses to air pollution[47]. In addition, residence-based

pollution exposure may be captured more accurately for women than for men considering that women tend to spend more time near home being more likely to be caregivers and less likely to have full-time jobs[46, 53]. These explanations remain largely speculative, however. Most studies in the neighborhood effects on health literature have not specifically investigated gender modification of neighborhood effects; rather, they simply control for gender in regression analyses[54, 55]. Arguably, compared to adjustment for gender/sex, reporting gender/sex-stratified results can better reveal different associations in the pollution-health link between men and women. Air pollution epidemiology should incorporate more detailed gender/sex analysis in the future[47].

Another modification factor of the pollution-health link is age. It is not surprising that older elders are more vulnerable to air pollution compared to younger elders due to their impaired physiological functioning and cumulative exposure to air pollution[17]. The same pattern may well hold true when older adults are compared to younger and middle-aged adults. Therefore, in a society aging fast, the dire health consequences of air pollution observed today likely gets exacerbated over time. In other words, the human and health costs of air pollution currently experienced likely foreshadow a more devastating picture in the near future.

Among health outcomes examined, ADL stuck out showing the largest pollution-induced reductions in HE for both men and women. This finding is novel. Compared to other health conditions, ADL is the most debilitating condition that entails daily care-giving and is often shortly followed by mortality. Mechanisms underlying the particularly strong ADL-pollution link need to be elucidated.

This study is limited in several ways. Misclassification of pollution exposure is unavoidable given uncounted residential mobility which may underestimate the pollution effects. With a relatively short follow-up period (i.e., 3 years), this study cannot detect longer-term pollution effects. In addition, relative impacts of the five different components of air pollution on individuals' mortality risk and health outcomes were not distinguished. A study conducted in the USA showed that particulates were the most damaging pollution, while ozone and other pollutants had much smaller effects[56]. This finding seems to suggest air quality standards should be

more targeted on controlling the ambient particulate levels. It can be expected that this pattern also holds in China. However, evidence is not readily available on this hypothesis and the present study is not equipped to examine this issue either. In other words, this study cannot provide evidence-based policy recommendation as to which aspect of air pollution should be prioritized to ameliorate. That said, insofar as many pollutants are highly correlated and often share common sources[56, 57], mandatory significant reductions in emissions from many sources should be implemented to reduce air pollution in densely populated and rapidly developing China.

In conclusion, this study highlights the prospective and contextual effects of exposure to outdoor air pollution on morbidity, mortality, LE and HE in China. Evidence is clear to support policies and programs developed and implemented to address high-levels of air pollution in China to reduce pollution-induced burden of morbidity and mortality. Despite its remarkable economic growth and overarching improvement in standard of living in the reform era, China has suffered significant environmental degradation, growing health disparities, and mounting public dissatisfaction with equity issues in recent years[2, 58]. To halt this downward trend, perhaps one viable solution is to ameliorate air quality to impede one pathway leading to slower health gain and greater health inequality recently looming large in China.

References

1. Zhang, J.F., et al., *Environmental health in China: progress towards clean air and safe water.* Lancet, 2010. 375(9720): p. 1110-1119.
2. Tang, S.L., et al., *Health system reform in China 1: Tackling the challenges to health equity in China.* Lancet, 2008. 372(9648): p. 1493-1501.
3. Cann, C.W., M.C. Cann, and S. Gao, *China's road to sustainable development*, in *China's Environment and the Challenge of Sustainable Development*, K.A. Day, Editor 2005, M. E. Sharpe Inc: New York, NY. p. 3-34.
4. Wang, X.P. and D.L. Mauzerall, *Evaluating impacts of air pollution in China on public health: Implications for future air pollution and energy policies.* Atmos Environ, 2006. 40(9): p. 1706-1721.
5. Kan, H.D. and B.C. Chen, *Air pollution and daily mortality in Shanghai: A time-series study.* Arch Environ Health, 2003. 58(6): p. 360-367.
6. Kan, H.D., et al., *An evaluation of public health impact of ambient air pollution under various energy scenarios in Shanghai, China.* Atmos Environ, 2004. 38(1): p. 95-102.
7. Mead, R.W. and V. Brajer, *Valuing the adult health effects of air pollution in chinese cities.* Living in a Chemical World: Framing the Future in Light of the Past, 2006. 1076: p. 882-892.
8. Brook, R.D., et al., *Air pollution and cardiovascular disease - A statement for healthcare professionals from the expert panel on population and prevention science of the American Heart Association.* Circ J, 2004. 109(21): p. 2655-2671.
9. Dockery, D.W., et al., *An association between air pollution and mortality in six U.S. cities.* N Engl J Med, 1993. 329(December): p. 1753-1759.
10. Pope, C.A., et al., *Particulate air-pollution as a predictor of mortlaity in a prospective-study of U.S. adults.* Am J Respir Cri Care Med, 1995. 151(3): p. 669-674.
11. Schikowski, T., et al., *Does respiratory health contribute to the effects of long-term air pollution exposure on cardiovascular mortality?* Respiratory Research, 2007. 8: p. 20.
12. Sun, R. and D. Gu, *Air pollution, economic development of communities, and health status among the elderly in urban China.* Am J Epidemio, 2008. 168(11): p. 1311-1318.
13. Dockery, D.W. and P.H. Stone, *Cardiovascular risks from fine particulate air pollution.* N Engl J Med, 2007. 356(5): p. 511-513.
14. Kunzli, N., et al., *Public-health impact of outdoor and traffic-related air pollution: a European assessment.* Lancet, 2000. 356(9232): p. 795-801.
15. Pope, C.A., M. Ezzati, and D.W. Dockery, *Fine-particulate air pollution and life expectancy in the United States.* N Engl J Med, 2009. 360(4): p. 376-386.
16. Schindler, C., et al., *Short-term variation in air pollution and in lung function among never-smokers - The Swiss study on air pollution and lung diseases in adults (SAPALDIA).* Am J Respir Crit Care Med, 2001. 163(2): p. 356-361.
17. Sandstrom, T., et al., *The need for a focus on air pollution research in the elderly.* Eur Respir J, 2003. 21: p. 92S-95S.
18. Alberini, A., et al., *Valuing health effects of air pollution in developing countries: The case of Taiwan.* J Environ Econ Manage, 1997. 34(2): p. 107-126.
19. Alberini, A. and A. Krupnick, *Cost-of-illness and willingness-to-pay estimates of the benefits of improved air quality: Evidence from Taiwan.* Land Econ., 2000. 76(1): p. 37-53.
20. Krupnik, A. and A. Alberini, *Air pollution and acute respiratory illness: Evidence from Taiwan and Los Angeles.* American Journal of Agricultural Economics, 1997. 79: p. 1620-1624.
21. Tabaku, A., et al., *Effects of air pollution on children's pulmonary health.* Atmos Environ, 2011. 45(40): p. 7540-7545.
22. Turner, M.C., et al., *Long-term ambient fine particulate matter air pollution and lung cancer in a large cohort of never-smokers.* Am J Respir Cri Care Med, 2011. 184(12): p. 1374-1381.
23. Watts, J., *Doctors blame air pollution for China's asthma increases.* Lancet, 2006. 368(9537): p. 719-720.

24. Gu, D. and M.E. Dupre, *General data assessment of the Chinese Longitudinal Healthy Longevity Survey in 2002*, in *Healthy Longevity in China: Demographic, Socioeconomic, and Psychological Dimensions*, Y. Zeng, D. L. Poston, D.A. Vlosky, and D. Gu , Editors. 2008, Springer Publisher: Dordrecht, Netherlands. p. 101-119.
25. Zeng, Y. and J.W. Vaupel, *Functional capacity and self-evaluation of health and life of oldest old in China.* J Soc Issues, 2002. 58(4): p. 733-748.
26. Gu, D. and M.E. Dupre, *Assessment of reliability of mortality and morbidity in the 1998-2002 CLHLS waves*, in *Healthy Longevity in China: Demographic, Socioeconomic, and Psychological Dimensions*, Y. Zeng, D. L. Poston, D.A. Vlosky, and D. Gu, Editors. 2008, Springer Publisher: Dordrecht, Netherlands. p. 101-119.
27. Zeng, Y. and D. Gu, *Reliability of age reporting among the Chinese oldest-old in the CLHLS data sets*, in *Healthy Longevity in China: Demographic, Socioeconomic, and Psychological Dimensions*, Y. Zeng, D. Poston, D.A. Vlosky, and D. Gu, Editors. 2008, Springer Publisher: Dordrecht, Netherlands. p. 61-79.
28. Cui, Y., et al., *Air pollution and case fatality of SARS in the People's Republic of China: an ecologic study.* Environmental Health 2003. 2(1): p. 15.
29. Shen, L. *Internet GIS for Air Quality Information Service for Dalian, China*. 2005 [cited 2009 March 8]; Available from: http://www.collectionscanada.gc.ca/obj/s4/f2/dsk3/OWTU/TC-OWTU-480.pdf.
30. WHO, *Air Quality and Health in Eastern Europe, Caucasus and Central Asia*, 2003, WHO Regional Office for Europe: Copenhagen, Demark.
31. China National Environmental Monitoring Center (CNEMC), *Technological Rules Concerned "Ambient Air Quality Daily Report"*, 2007, China National Environmental Monitoring Center: Beijing, China.
32. Krzyzanowsk, M. and D. Schwela, *Patterns of air pollution in developing countries*, in *Air Pollution and Health*, S.T. Holgate, J.M. Samet, and H.S. Koren, Editors. 1999, Academic Press: New York, NY. p. 105 – 113.
33. Tseo, G., F. Chen, and H. Liu, *Energy, Air Pollution and Public Health in China*, in *Air Pollution: Environmental Issues and Health Effects*, S.K. Majumdar, E.W. Miller, and J.J. Cahir, Editors. 1991, The Pennsylvania Academy of Science: Easton, PA. p. 426-443.
34. Xu, X., *Air pollution and its health effects in urban China*, in *Energizing China: Reconciling Environmental Protection and Economic Growth*, M.B. McElroy, C.P. Nielsen, and P. Lydon, Editors. 1998, Harvard University Press: Cambridge, MA. p. 267-286.
35. Chinese Academy of Sciences, *Chinese Natural Resources Database* The Institute of Geographical Sciences and Natural Resources Research, Editor: Beijing, China.
36. Preston, S., P. Heuveline, and M. Guillot, *Demography: Measuring and Modeling Population Processes*2001, London: Blackwell Publishers.
37. Folstein, M.F., S.E. Folstein, and P.R. McHugh, *Mimi-mental state - practical method for grading cognitive state of patients for clinician* J Psychiatr Res, 1975. 12(3): p. 189-198.
38. Zeng, Y., et al., *Sociodemographic and health profiles of the oldest old in China.* Popul Dev Rev, 2002. 28(2): p. 251-273.
39. Zhang, Z., *Gender differentials in cognitive impairment and decline of the oldest old in China.* J Gerontol Soc Sci, 2006. 61B: p. S107-S115.
40. Idler, E.L. and Y. Benyamini, *Self-rated health and mortality: A review of twenty-seven community studies.* J Health Soc Behav, 1997. 38(1): p. 21-37.
41. Robine, J.M., et al., *Determining Health Expectancies.* 2003, West Sussex, England: John Wiley & Sons Ltd.
42. Lamb, V.L. and J.S. Siegel, *Health demography*, in *The Methods and Materials of Demography*, J.S. Siegel and D.A. Sawnson, Editors. 2004, Elsevier Academic Press: San Diego, CA. p. 341–370.
43. Hendrikx, J., *The impact of weights on standard errors*, in *The Annual Meeting of the Association for Survey Computing.* 2002, Imperial College: London, UK.
44. Winship, C. and L. Radbill, *Sampling weights and regression analysis.* Sociol Method Res, 1994. 23: p. 230-257.

45. Cohen, A.J., et al., *The global burden of disease due to outdoor air pollution.* Journal of Toxicology and Environmental Health-Part a-Current Issues, 2005. 68(13-14): p. 1301-1307.
46. Wen, M. and X. Zhang, *The contextual effects of the built and the social environment of urban neighborhoods on physical activity: A multilevel study in Chicago.* Am J Health Promot, 2009. 23(4): p. 247-254.
47. Clougherty, J.E., *A growing role for gender analysis in air pollution epidemiology.* Environ Health Perspect, 2010. 118(2): p. 167-176.
48. Bennett, W.D., K.L. Zeman, and C. Kim, *Variability of fine particle deposition in healthy adults: Effect of age and gender.* Am J Reprod Im Mic, 1996. 153(5): p. 1641-1647.
49. Sunyer, J., et al., *Patients with chronic obstructive pulmonary disease are at increased risk of death associated with urban particle air pollution: A case-crossover analysis.* Am J Epidemio, 2000. 151(1): p. 50-56.
50. Davis, M.C., K.A. Matthews, and E.W. Twamley, *Is life more difficult on mars or venus? A meta-analytic review of sex differences ln major and minor life events.* Ann Behav Med, 1999. 21(1): p. 83-97.
51. Seeman, T.E., et al., *Social relationships, gender, and allostatic load across two age cohorts.* J Psychosom Res, 2002. 64(3): p. 395-406.
52. Bierman, A., *Marital status as contingency for the effects of neighborhood disorder on older adults' mental health.* J Gerontol B Psychol Sci Soc Sci, 2009. 64(3): p. 425-434.
53. Wen, M., N. Kandula, and D.S. Lauderdale, *Leisure-time walking in a multiethnic population: What difference does the neighborhood make?* J Gen Intern Med, 2007. 20(12): p. 1674–1680.
54. Cagney, K.A., C.R. Browning, and M. Wen, *Racial disparities in self-rated health at older ages: What difference does the neighborhood make?* J Gerontol B Psychol Sci Soc Sci, 2005. 60(4): p. S181-S190.
55. Keysor, J.J., et al., *Community environmental factors are associated with disability in older adults with functional limitations: The MOST Study.* J. Gerontol. A Biol. Sci. Med. Sci., 2010. 65(4): p. 393-399.
56. McCubbin, D.R. and M.A. Delucchi, *The health costs of motor-vehicle-related air pollution.* J Transp Econ Policy, 1999. 33: p. 253-286.
57. Lee, J.T., et al., *Effect of air pollution on asthma-related hospital admissions for children by socioeconomic status associated with area of residence.* Arch Environ Occup Health, 2006. 61(3): p. 123-130.
58. Zeng, Y., et al., *Associations of environmental factors with elderly health and mortality in China.* Am J Public Health, 2010. 100(2): p. 298-305.

UU IR Author Manuscript