Supplementary materials

A Health Economic Approach to Estimate the Burden of Cardiovascular Diseases Associated with Fine Particulate Matter: The Case of Beijing and Its Implications

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Authors: Yawen Jiang, Shan Jiang, and Weiyi Ni

Corresponding Author: Yawen Jiang

Sun Yat-sen University School of Public Health (Shenzhen)

Corresponding Email: jiangyw26@mail.sysu.edu.cn;

Part 1. Cardiovascular event risk equation

The cardiovascular risk equation was extracted from a previous epidemiology study in China.[1]

10-year integrated probability of AMI and stroke for Chinese male=

$$1 - 0.9835^{\exp(\sum \beta_i X_i)},$$

where $\sum \beta_i X_i = 0.0656 \times age_i - 0.5488 \times I(SBP_i < 120) + 0.4011 \times I(130 \leq SBP_i \leq 139) + 0.8073 \times I(139 < SBP_i \leq 159) + 1.7041 \times I(159 < SBP_i \leq 179) + 2.5327 \times I(SBP_i > 179) + 0.2864 \times I(BMI_i \geq 24) - 0.007 \times I(3.62 \leq TC_i < 5.17) + 0.304 \times I(TC_i \geq 5.17) + 0.7082 \times SMOKING_i + 0.0651 \times DIABETES_i - 3.5951.$

10-year integrated probability of AMI and stroke for Chinese female=

$$1 - 0.9948^{\exp(\sum \beta_i X_i)},$$

where $\sum \beta_i X_i = 0.0851 \times age_i - 0.8267 \times I(SBP_i < 120) + 0.2294 \times I(130 \leq SBP_i \leq 139) + 0.7970 \times I(139 < SBP_i \leq 159) + 1.3674 \times I(159 < SBP_i \leq 179) + 1.8483 \times I(SBP_i > 179) + 0.6762 \times I(BMI_i \geq 24) - 0.0866 \times I(3.62 \leq TC_i < 5.17) + 0.2654 \times I(TC_i \geq 5.17) + 0.4699 \times SMOKING_i + 0.9599 \times DIABETES_i - 3.8780.$

In the equations above, I(·) is an indicator function of whether the condition in the parentheses is true, SBP_i is the systolic blood pressure (mm Hg) of the simulated individual, TC_i is the total cholesterol (mmol/L), BMI is the body mass index (kg/m^2), $SMOKING_i$ is an indicator of smoking, and $DIABETES_i$ is an indicator of having diabetes.

Part 2. The DEALE method and transferring 10-year probability to 1-year probability

The DEALE method assumes an exponential distribution of time to event and allows algebraic calculation of 1-year probability from 10-year probability.[2] Specifically, the following formulas were used:

$$r_{1year} = -\left(\frac{1}{10}\right) \cdot \ln\left[1 - \left(p_{10year}\right)\right],$$

$$p_{1year} = 1 - e^{-r_{1year}}$$

where r_{1year} is the 1-year rate, p_{1year} is the 1-year probability, and p_{10year} is the 10-year probability.

Part 3. Proportions of AMI and stroke

The respective proportions of AMI and stroke out of total AMI and stroke events were calculated using numbers from the cardiovascular risk equation estimation study [1]. The numbers of AMI and stroke events were 66 and 158 among men, and were 39 and 108 among women. Using these numbers for calculation, the proportions of AMI and stroke were 29.46% and 70.54% among men, and were 26.53% and 73.57% among women. The proportions were not age-varying because the source data did not allow age-varying data extraction.

As such, the 1-year probability of AMI was calculated as $p_{AMI} = p_{AMI\&stroke} \times 29.46\%$ and the 1-year probability of stroke was calculated as $p_{stroke} = p_{AMI\&stroke} \times 70.54\%$ for men. The probabilities for women were calculated using the same approach.

Part 4. Angina to stroke ratio

We calculated angina-stroke incidence ratio by age group (Table S1) using age group specific angina and stroke prevalence data.[3]

Table S1. Angina-stroke incidence ratio

	Self-reported prevalence (%)		Incidence in the corresponding period (%)		Incidence ratio
	stroke	angina	stroke	angina	Angina/stroke
<59	1.5	4.4	1.5	4.4	2.93
60-69	3.4	9.0	1.9	4.6	2.42
70-79	5.3	13.1	1.9	4.1	2.16
>80	7.1	14.5	1.8	1.4	0.78

Part 5. Diabetes prevalence to incidence conversion

The diabetes prevalence rate of Chinese children is 0.11%.[4] The exact prevalence rate of 18 years old Chinese people was not available. Diabetes prevalence rates of Chinese adults were obtained from a Chinese epidemiology study.[5] We calculated 10-year incidence rates of diabetes (Table S2) using prevalence rates and transferred 10-year incidence rates to 1-year probabilities using the aforementioned DEALE method. Age group 70-79 incidence rate was extrapolated to age group 80-89.

Table S2. Diabetes prevalence rates and incidence rates of Chinese population

	Prevalence rate	10-year incidence rate	rate	1-year probability
male				
18-19	0.00108	NA	NA	NA
20-29	0.0261	0.02502	0.002534	0.25%
30-39	0.0521	0.026	0.002634	0.26%
40-49	0.1111	0.059	0.006081	0.61%
50-59	0.1547	0.0436	0.004458	0.44%
60-69	0.1813	0.0266	0.002696	0.27%
70-79	0.2185	0.0372	0.003791	0.38%
80-89	NA	0.0372[a]	0.003791[a]	0.38%[a]
female				
18-19	0.00108	NA	NA	NA
20-29	0.0124	0.01132	0.001138	0.11%
30-39	0.0301	0.0177	0.001786	0.18%
40-49	0.073	0.0429	0.004385	0.44%
50-59	0.1309	0.0579	0.005964	0.59%
60-69	0.2028	0.0719	0.007462	0.74%
70-79	0.2197	0.0169	0.001704	0.17%
80-89	NA	0.0169[a]	0.001704[a]	0.17%[a]

[a]: Extrapolated from the adjacent age group.

Part 6. Relationship between BMI and age
The relationship between BMI and age is as following.[6]
Male: BMI = BMI at 43.4 years old + 0.002 × 43.4^2 - 0.22 × 43.4 + 0.22 × age - 0.002 × age^2
Female: BMI = BMI at 44.3 years old + 0.002 × 44.3^2 - 0.22 × 44.3 + 0.22 × age - 0.002 × age^2

Part 7. Relationship between SBP and age
The relationship between SBP and age is as following:
Male: SBP = SBP at 43.4 years old + 0.64 × (age - 43.4)
Female: SBP = SBP at 44.3 years old + 0.64 × (age – 44.3).

The following regression equation was used to estimate the linear relationship between SBP and age of Chinese using the 2013 wave of the China Health and Retirement Longitudinal Study (CHARLS):

$$SBP = \alpha + \beta_1 age + \beta_2 I_{male} + \beta_3 I_{married} + \beta_4 BMI + \beta_5 I_{dd} + \beta_6 I_{smoke} + \beta_7 GH$$

where I_{male} is an indicator for male, $I_{married}$ is an indicator for currently married, I_{dd} is an indicator for drink daily or more often, and GH is self-reported general health (1=excellent, 5=poor). More information on CHARLS can be found at http://charls.pku.edu.cn/en.

Part 8. Angina sequelae duration
To be consistent with literature, the duration of angina sequelae varied across age and gender groups (Table S3).[7]

Table S3. Angina sequelae duration (years)

age	male	female
18-19	26	30
20-24	26	30
25-29	26	30
30-34	16	20
35-39	16	20
40-44	16	20
45-49	11	13
50-54	11	13
55-59	11	13
60-64	8	9
65-69	8	9
70-74	5	5
75-79	5	5
80-84	3	3
85-89	3	3

Part 9. Beijing population by age and sex group
The Beijing population by age group[8] and the Beijing population age-sex pyramid[9] were used to calculate the population in each age group for each sex (Table S4).

Table S4. Beijing population in 2014 by age-sex group

age	% female population in the age group out of total Beijing population	% male population in the age group out of total Beijing population	% female in this age group	% male in this age group	2014 population in age group	2014 female population	2014 male population
15-19	2.53	2.85	46.97	53.03	846,000	397,343	448,657
20-24	6.16	6.66	48.07	51.93	2,237,000	1,075,329	1,161,671
25-29	5.58	5.93	48.50	51.50	2,436,000	1,181,486	1,254,514
30-34	4.27	4.68	47.71	52.29	2,297,000	1,095,895	1,201,105
35-39	3.91	4.46	46.69	53.31	1,682,000	785,319	896,681
40-44	3.76	4.39	46.16	53.84	1,836,000	847,454	988,546
45-49	3.76	4.24	47.00	53.00	1,708,000	802,780	905,220
50-54	3.33	3.44	49.17	50.83	1,615,000	794,163	820,837
55-59	2.96	3.00	49.70	50.30	1,513,000	751,887	761,113
60-64	1.95	1.90	50.56	49.44	1,093,000	552,609	540,391
65-69	1.51	1.32	53.40	46.60	715,000	381,790	333,210
70-74	1.44	1.32	52.17	47.83	495,000	258,223	236,777
75-79	1.00	1.02	49.40	50.60	456,000	225,253	230,747
80-84	0.64	0.66	49.14	50.86	293,000	143,991	149,009
85-89	0.42	0.37	53.34	46.66	164,000	87,473	76,527

Part 10. Monetize QALYs using an alternative WTP threshold

Table S5. Population and individual expected lifetime NML using the once the GDP per capita WTP threshold

	Male	Female	Total
Population 1-year NML	$427,396,864	$431,837,990	$859,234,855
Individual expected lifetime NML	$1,329	$1,087	NA

NA, not applicable.

Part 11. Model assumptions

Table S6. Summary of assumptions

Assumption category	Assumption
Population	The population have been exposed long enough to experience the full hazard of $PM_{2.5}$ pollution.
Risk calculation	Incidence ratios of angina to stroke in all groups in Beijing are the same as those in entire China
Risk calculation	Smoking status of an individual doesn't change
Risk calculation	When the data for the age group 80-89 are not available, the data from 70-79 are used (diabetes). Similarly, the data for age group 80-84 (angina sequelae duration) or 75-84 (AMI and stroke 28-day mortality) are used for age group 85-89 when the relevant data are absent.
Risk calculation	The relationships between SBP and age and between BMI and age of overall Chinese population are portable to Beijing population.
Risk calculation	Diabetes prevalence and incidence data for overall Chinese population are portable to Beijing population.
Risk calculation	Risk factors of cardiovascular diseases are not correlated.
Risk calculation	Without risk factors, the baseline hazard function of cardiovascular disease of Beijing population is the same as that of overall Chinese population.
Risk calculation	The CVD risk equation from the reference represents average individual risk at the current pollution level
Costs and QALY inputs	Unstable angina requires hospitalization.
Effect of pollution	The long-term effect of $PM_{2.5}$ pollution is represented by annual average concentration.

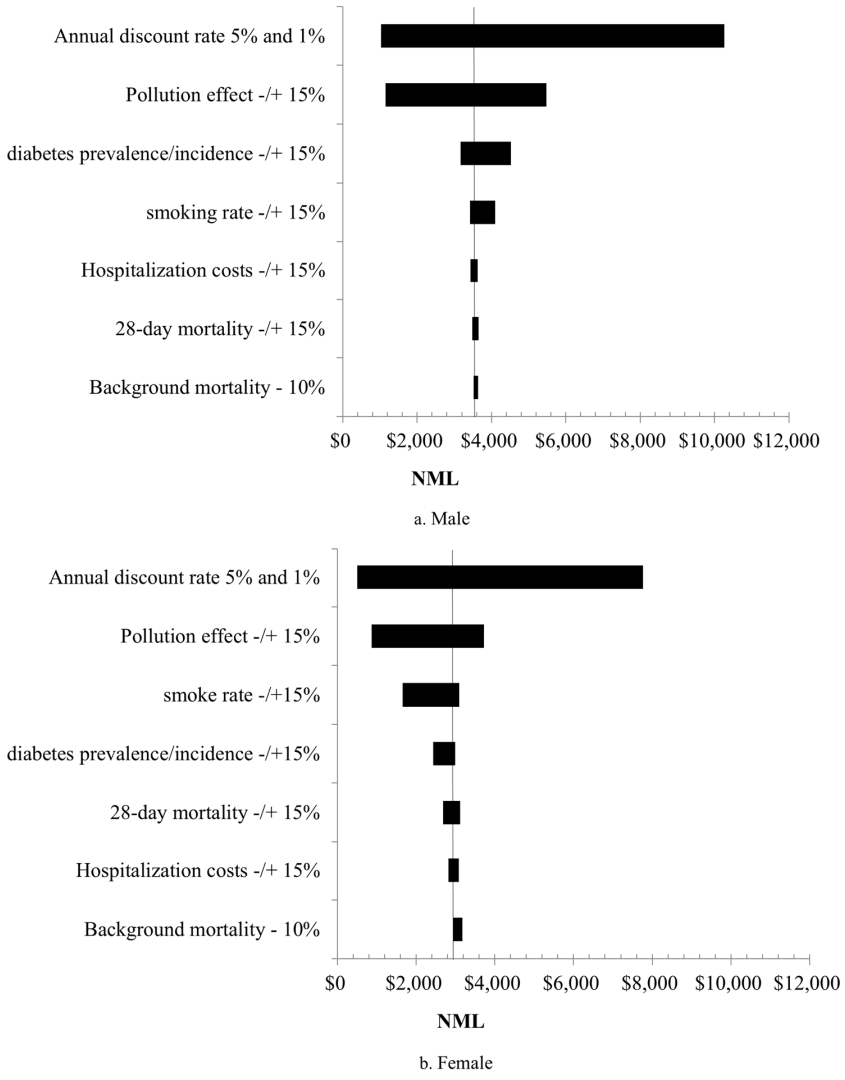

Fig S1. One-way sensitivity analyses for individual male (a) and female (b). The expected individual lifetime net monetary loss (NML) results were sensitive to changes in the annual discount rate and pollution effect.

Supplementary Materials References

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