Supplementary Materials

Health-Adjusted Life Expectancy (HALE)

The method was developed by the Global Burden of Diseases Study (GBD) was used in the calculations of HALE[1]. First, years of life lost (YLLs) were calculated based on the all-cause death dataset of residents in Guangzhou.

$$YLLs = N \times L$$

N is the number of people in a certain age group and gender group who die from a certain cause, and L is the value of life lost in a certain age group (the life expectancy value corresponding to this age group in the life table). This study used the reference life table obtained from the GBD 2019, which was based on the lowest mortality observed in all age groups globally, to construct the standard life expectancy from the highest value of life expectancy in each age group globally (Supplementary Table S1).

Supplementary Table S1. GBD 2019 reference life table

Age group	Life expectancy
0–	88.87
1–	88.00
5–	84.03
10–	79.05
15–	74.07
20–	69.11
25–	64.15
30–	59.20
35–	54.25
40–	49.32
45–	44.43
50–	39.63
55–	34.91
60–	30.25
65–	25.68
70–	21.29
75–	17.10
80–	13.24
85–	9.99
90–	7.62
95–	5.92

Second, we calculate the years lived with disability (YLDs). It is extremely difficult to calculate accurate YLDs because of the lack of basic data necessary to calculate them. The World Health Organization (WHO) has studied the internal relationship between YLDs and YLLs in various regions of the world and an indirect method for calculating YLDs was developed[2-6].

$$YLDs_{\text{study area } ij} = \frac{YLDs_{\text{reference area } ij}}{YLLs_{\text{reference area } ij}} \times YLLs_{\text{study area } ij}$$

i, j is gender and age group respectively. The reference area for this study is China. The YLDs-YLLs ratios of China from 2010 to 2019 were obtained from the public database of GBD, and the 2020 estimate uses the 2019 reference value.

Third, we used Sullivan's method to incorporate YLDs into life tables, HALE is calculated by taking into account the loss of life due to disease or disability in each age group.

$$HALE_{i,j,x} = \frac{1}{l_{i,j,x}} \sum_{1}^{w} L_{i,j,x} \times (1 - YLD_{i,j,x})$$

$l_{i,j,x}$ is the number of people in the life table at the age of x; $L_{i,j,x}$ is the number of survivors in the age group of $[x, x+5)$, and w is the last age group in the life table.

Multilevel Model

The null model (Model I) with the GAP as the dependent variable was fitted, and the Intra-Class Correlation (ICC) was 0.849, indicating that 84.9% of the total variation in the GAP was attributed to districts. That is, there was an interclass correlation and the multilevel model analysis is reasonable. The fixed effect of the random intercept model (Model II) with the GAP as the dependent variable and time as the independent variable showed the GAP increasing by 0.040 years per year. In the models with random intercept and slope (Model III) with the GAP as the dependent variable and time as the independent variable, both AIC and BIC increased compared with Model II. Furthermore, four principal components, produced by GPCA, were included in Model II as the independent variables to fit the multilevel model (Model IV) with a controlled principal component based on Model II. The results showed that the fixed effect (districts, years, and four principal components) and random effect (districts and residual) could explain 83.6% of the variation in the GAP, and the GAP increased by 0.089 years per year. (Supplementary Table S2)

Supplementary Table S2. Parameter estimates of mixed effect model (standard error)

Parameter	Model I[a]	Model II[b]	Model III[c]	Model IV[d]
Fixed parameters				
β_1 (Intercept)	7.357 (0.252)***	7.118 (0.258)***	7.118 (0.256)***	6.826 (0.218)***
β_2 (Years)	–	0.040 (0.009)***	0.040 (0.013)*	0.089 (0.021)***
β_3 (PC1)	–	–	–	0.146 (0.051)**
β_4 (PC2)	–	–	–	−0.111 (0.054)*
β_5 (PC3)	–	–	–	−0.226 (0.087)*
β_6 (PC4)	–	–	–	−0.015 (0.083)
Random parameters				
σ_1^2 (Districts)	0.688 (0.830)	0.690 (0.830)	0.683 (0.826)	0.334 (0.578)
σ_2^2 (Years)	–	–	0.001 (0.031)	–
σ_3^2 (Residual)	0.123 (0.350)	0.106 (0.326)	0.097 (0.311)	0.101 (0.317)

Note. $^{***}P < 0.001$, $^{**}P < 0.01$, $^{*}P < 0.05$. Conditional $R^2 = 0.836$; Marginal $R^2 = 0.292$. [a]The null model with the GAP as the dependent variable. [b]The random intercept model with the GAP as the dependent variable and time as the independent variable. [c]The random intercept and slope model with the GAP as the dependent variable and time as the independent variable. [d]The multilevel model with controlled principal component based on Model II. PC = principal components.

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