The effect of healthy lifestyles and social determinants on independent life expectancy and sex differences in China: evidence from a 13-year cohort study

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Summary

Background Functional independence is the basis for healthy ageing and quality of late life. However, evidence on how healthy lifestyle factors and social determinants of health affect longevity in independence remains limited, particularly regarding sex differences. We aimed to examine the associations of these factors with life expectancy with and without dependency, and to assess whether such effects differ by sex.

Methods This cohort study used data from the nationally representative Chinese Longitudinal Healthy Longevity Study (CLHLS), which collected data from 2008 to 2021. Participants aged 65–100 years were included if they had at least one follow-up or death record. Healthy lifestyle factors (ie, diet, physical activity, smoking, and alcohol use) and social determinants of health (ie, financial status, education, health-care access, built environment, and social context) were assessed at baseline. Functional independence was determined by self-reported need for assistance with activities of daily living and instrumental activities of daily living at each survey wave. A continuous-time three-state Markov model was applied to estimate hazard ratios and 95% CIs between independence, dependence, and death, yielding total and independent life expectancy by sex, adjusted for covariates.

Findings 11 804 participants were included in the study. At age 65 years, females had longer total life expectancy than males (18·18 years [95% CI 17·74–18·49] *vs* 15·50 years [15·10–15·89]) but shorter independent life expectancy (10·35 years [10·13–10·55] *vs* 11·29 years [11·05–11·54]). The gain in independent life expectancy was greater for males with 3–4 healthy lifestyle factors versus males with 0–1 healthy lifestyle factors (2·45 years [2·24–2·67]) compared with females with 3–4 healthy lifestyle factors versus females with 0–1 healthy lifestyle factors (2·09 years [1·90–2·29], p=0·015). However, females had greater gains in independent life expectancy from favourable social determinants of health. Those with 4–5 positive social determinants of health indicators lived 1·95 (1·74–2·16) more years independently compared with those with 0–1, surpassing the 1·67 year (1·49–1·85) gain observed in males (p=0·047). The combination of both favourable lifestyle behaviours and supportive social conditions produced the largest improvement in independent life expectancy, with gains of 3·94 (3·73–4·15) years for males and 3·89 (3·68–4·11) years for females.

Interpretation Pathways to healthy ageing differ between sexes in China: males benefit more from lifestyle modifications whereas females gain more from improved social conditions. These results underscore the importance of sex-specific public health strategies that focus on reducing unhealthy behaviours among males and improving social support for females.

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For the Chinese translation of the abstract see **Online** for appendix 1

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Introduction

Functional independence, defined as the ability to perform daily activities without assistance, represents the cornerstone of healthy ageing and quality of life.[1] Independent life expectancy, measuring the expected years of life spent functionally independent, provides an important metric for evaluating healthy ageing. With age, maintaining independence becomes increasingly difficult, especially for females. Although females live longer than males, they spend less years without morbidity and dependency, a phenomenon known as the male–female health-survival paradox.[2–4] For example, in the UK in 2015, males aged 65 years were expected to live a further 11·1 years independently and 7·6 years with dependency, whereas females of the same age were expected to live a further 10·7 years independently and 10·6 years with dependency.[3] Such disparities reduce quality of life, increase economic costs, and place additional psychosocial burdens on older females.[5] Addressing this difference and developing sex-specific interventions are essential for healthy ageing and social equity. This challenge is particularly acute in low-income

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Research in context

Evidence before this study

On July 1, 2025, we searched PubMed, Web of Science, Embase, and Google Scholar for studies published in English using keywords including ("independent life expectancy" OR "disability-free life expectancy" OR "functional independence") AND ("healthy lifestyle" OR "social determinants of health" OR "socioeconomic status") AND ("older adults" OR "aging") AND ("China" OR "Asia") from database inception to June 30, 2025. Previous studies consistently show that healthy lifestyle behaviours and favourable social determinants of health are associated with reduced disability and mortality among adults aged 65 years and older. However, most research has focused on disease-based outcomes or total life expectancy. Few studies have directly quantified the effect of lifestyle and social determinants of health on independent life expectancy, particularly in low-income and middle-income countries. Furthermore, the sex-specific contributions of lifestyle and social conditions to independent life expectancy, and their combined effects, remain poorly understood. No previous research has applied multi-state models to estimate functional transitions and independent life expectancy in a large, nationally representative cohort of older adults.

Added value of this study

To the best of our knowledge, this study provides the first sex-specific estimates of independent life expectancy in older Chinese adults (ie, those aged 65 years and older) using 13-year nationwide longitudinal data. We show that gains to functional independence differ by sex; males benefit more from healthy lifestyles whereas females benefit more from social support. The combination of both favourable lifestyle behaviours and supportive social conditions could extend functional independence by up to 3·9 years per person.

Implications of all the available evidence

Current evidence highlights the need for integrated behavioural and structural interventions to promote healthy ageing and challenges universal intervention approaches. In China, strategies should focus on reducing unhealthy behaviours among older males and improving social conditions for older females. Because gains in life expectancy are not always accompanied by proportional gains in healthy years, independent life expectancy should be considered a key indicator for ageing policies. Tailored, sex-specific approaches could help extend years of independence, reduce long-term care needs, and promote greater equity in older populations.

and middle-income countries, which are home to the majority of the world's older population. In these settings, gains in longevity have not been accompanied by commensurate improvements in healthy life expectancy. According to data from the Global Burden of Disease study, between 2010 and 2019, life expectancy in the UK increased from 80·6 to 81·4 years, with an additional 0·2 years lived in poor health. In China, life expectancy rose from 74·6 to 77·3 years, but unhealthy years increased by 0·7 years.[6] As China now accounts for more than one quarter of the world's older population,[7] the projected expansion of years lived with dependency is expected to place substantial pressure on health and long-term care systems.

Mounting evidence identifies two key modifiable pathways: healthy lifestyle behaviours (eg, diet, physical activity, smoking, and alcohol use)[8–11] and social determinants of health (eg, education, financial security, health-care access, housing, and social connections).[12,13] Both pathways substantially reduce mortality, prevent diseases, and lower disability risk in later life.[14] Evidence also suggests that the effects of healthy lifestyles and favourable social factors on mortality can differ by sex,[15] which could partly account for the observed gap in life expectancy between females and males. However, a crucial knowledge gap remains: whether these factors not only extend life expectancy but also compress the years lived with dependency, and whether such effects differ by sex.[16] Addressing this question is essential for developing targeted interventions. Moreover, in modern ageing, functional trajectories are shaped not only by biological and behavioural factors but also by the health-care environment and assistive technologies, which exert complex influences on transitions between independence, dependency, and death. A comprehensive approach that captures these dynamic transitions is therefore required.[17]

We aimed to address these crucial gaps with a 13 year nationwide longitudinal cohort, using sophisticated continuous-time Markov models to track transitions between functional states. By examining how healthy lifestyle and social determinants differentially affect independent life expectancy in males versus females, we reveal sex-specific pathways to healthy longevity.

Methods

Study design and participants

We used the five most recent waves (2008, 2011, 2014, 2018, and 2021) of the Chinese Longitudinal Healthy Longevity Study (CLHLS), a nationally representative cohort of adults aged 65 years and older, covering 23 provinces and representing approximately 85% of China's older population.[2,18] The CLHLS adopted a targeted random-sample design to ensure representativeness, even distribution across sex and age, and sufficient sub-sample size of the oldest-old (ie, those aged ≥80 years), plus compatible young-old (ie, those aged 65–79 years). In each household, only one older adult aged 65 years or older was interviewed, and couples were not jointly recruited. Those younger than 65 years and older than 100 years were excluded (to reduce heterogeneity from exceptional longevity). Those without mortality or follow-up information and those with missing core variables or irreparable data inconsistencies were also excluded. Further information about CLHLS can be found in appendix 2 (p 2). The 2008 wave served as our baseline. The Peking University Biomedical Ethics Committee approved the CLHLS (IRB00001052-13074), and all participants provided written informed consent.

Procedures

Healthy lifestyle and social determinants of health factors were operationalised using standardised self-reported questionnaire information from participants. We assessed four modifiable lifestyle factors recommended by WHO: healthy diet, smoking status, alcohol consumption and physical activity.[19] Diet was assessed using a validated food frequency questionnaire. Participants were classified as having a healthy diet if they belonged to the top 40% of the baseline population in terms of healthy food consumption frequency, which corresponded to consuming at least five of 11 food items on a daily basis (including fresh vegetables, fruits, legumes, bean products, garlic, nuts, tea, meats, fish, dairy products, eggs, mushrooms, and algae).[20] Participants were categorised as having a healthy lifestyle in smoking status if participants never smoked or had quit for more than 10 years.[21] A healthy lifestyle in alcohol consumption was similarly defined if participants never drank or had quit drinking for 10 years.[22] Physical activity was defined as engaging in daily exercise such as jogging, Tai Chi, or square dancing every day or doing daily household chores. Detailed information on the healthy lifestyle assessment is shown in appendix 2 (p 2). Participants were categorised into three groups based on their cumulative healthy lifestyle factors: 0–1, 2, and 3–4 healthy lifestyle factors.

We structured social determinants of health according to the five-dimensional framework of Healthy People 2030: financial status, education, health-care access and quality, neighbourhood and built environment, and social and community context (appendix 2 p 4).[12,13,23] Financial status was considered favourable if participants had pension benefits and a self-reported ability to meet living expenses. Educational opportunity was defined as a self-reported receipt of any form of formal education. Health-care access and quality was determined by four criteria: having health insurance, having the ability to go to hospital when ill, residing in a city in the top 40% nationwide for doctors per capita, and residing in a city in the top 40% nationwide for tertiary hospitals per capita. Neighbourhood and built environment were considered favourable if participants had their own separate bedroom and house. Social and community context was assessed using four indicators: being married, not living alone, absence of loneliness, and having social contact at least once weekly. A favourable social environment was defined as meeting at least three of the four criteria, which represented the top 40% of the study population. Based on the number of social determinants of health factors rated as favourable, participants were categorised into three groups: 0–1, 2–3, or 4–5 favourable social determinants of health factors.

See Online for appendix 2

Independence was defined using participants' self-reported need for assistance with activities of daily living and instrumental activities of daily living, following Isaacs and Neville's needs theory.[24,25] Participants were

	Total population (N=11 804)	Males (n=5514)	Females (n=6290)
Independent states			
Independent	5616 (47·6%)	3157 (57·3%)	2459 (39·1%)
Dependent	6188 (52·4%)	2357 (42·7%)	3831 (60·9%)
Mean follow-up time, years	5·33 (4·01)	5·35 (4·00)	5·31 (4·03)
Death during follow-up	8269 (70·1%)	3880 (70·4%)	4389 (69·8%)
Mean age, years	84·52 (9·92)	83·05 (9·58)	85·82 (10·04)
Age group, years			
65–74	2506 (21·2%)	1345 (24·4%)	1161 (18·5%)
75–84	2883 (24·4%)	1491 (27·0%)	1392 (22·1%)
≥85	6415 (54·3%)	2678 (48·6%)	3737 (59·4%)
Resident			
Urban	4361 (36·9%)	2046 (37·1%)	2315 (36·8%)
Rural	7443 (63·1%)	3468 (62·9%)	3975 (63·2%)
Lifestyle factors			
Healthy diet	3280 (27·8%)	1676 (30·4%)	1604 (25·5%)
Never or quit smoking	7510 (63·6%)	1980 (35·9%)	5530 (87·9%)
Never or quit alcohol consumption	7922 (67·1%)	2562 (46·5%)	5360 (85·2%)
Daily exercise	7230 (61·3%)	3453 (62·6%)	3777 (60·0%)
Numbers of healthy lifestyle factors			
0–1	2818 (23·9%)	2266 (41·1%)	552 (8·8%)
2	4212 (35·7%)	1981 (35·9%)	2231 (35·5%)
3–4	4774 (40·4%)	1267 (23·0%)	3507 (55·8%)
Social determinants of health factors			
Good financial status	1911 (16·2%)	1368 (24·8%)	543 (8·6%)
Good educational opportunity	4747 (40·2%)	3524 (63·9%)	1223 (19·4%)
Good health-care access and quality	3296 (27·9%)	1706 (30·9%)	1590 (25·3%)
Good neighbourhood and built environment	10 188 (86·3%)	4796 (87·0%)	5392 (85·7%)
Good social and community context	4079 (34·6%)	2630 (47·7%)	1449 (23·0%)
Numbers of social determinants of health factors			
0–1	4224 (35·8%)	1141 (20·7%)	3443 (54·7%)
2–3	5623 (47·6%)	3158 (57·3%)	2465 (39·2%)
4–5	1597 (13·5%)	1215 (22·0%)	382 (6·1%)
Mini-Mental State Examination score	24·12 (6·46)	25·46 (5·74)	22·94 (6·83)
Sleep duration, normal	7519 (63·7%)	3661 (66·4%)	3858 (61·3%)
Obesity, yes	329 (2·8%)	137 (2·5%)	192 (3·1%)
Number of diseases	0·99 (1·17)	0·99 (1·21)	0·99 (1·15)
Other chronic diseases, yes	5844 (49·5%)	2727 (49·5%)	3117 (49·6%)
Metabolic risk diseases, yes	2833 (24·0%)	1259 (22·8%)	1574 (25·0%)

Data are n (%) or mean (SD). Due to rounding, the total percentage may not equal 100%.

Table: **Baseline characteristics**

classified as dependent if they reported needing assistance with any activities of daily living or required help with cooking, lifting a 5 kg weight, or shopping.

Covariates were selected based on previous research and cohort data availability. Questionnaire data included age, sex, education, residence, sleep duration, Mini-Mental State Examination score, and history of 16 major chronic diseases (ie, hypertension; diabetes; coronary heart disease; stroke and cerebrovascular disease; bronchitis, emphysema, asthma, and pneumonia; tuberculosis; cataract; glaucoma; cancer; Parkinson's disease; arthritis; dementia; cholecystitis and gallstones; dyslipidaemia; rheumatism and rheumatoid arthritis; and chronic kidney disease). Sleep was categorised as normal (ie, 6–9 hours per day) or abnormal.[26] Physical exams were performed by a professional team, with BMI calculated as weight divided by height squared and anything more than 28 kg/m² was defined as obese. Hypertension, diabetes, hyperlipidaemia, and obesity were classified as metabolic risk diseases, and the remaining 13 conditions as other chronic diseases.

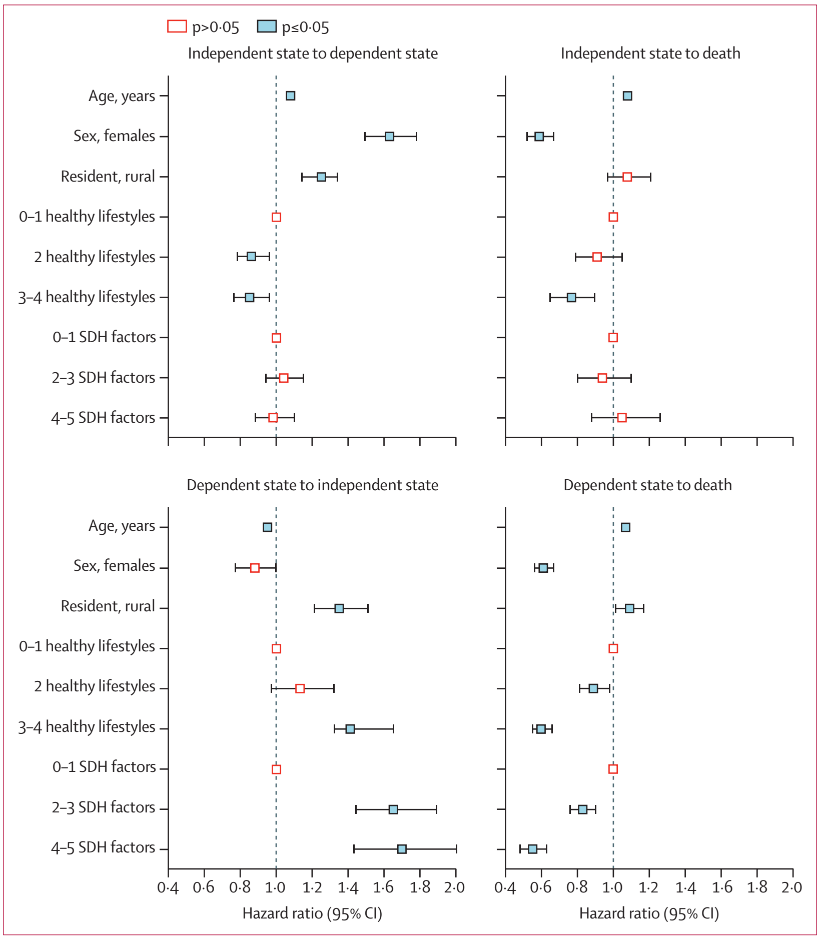

Figure 1: **Adjusted hazard ratio of healthy lifestyle and SDH factors across each dependency state transitions**
This model was adjusted by Mini-Mental State Examination score, sleep duration, and the number of metabolic diseases and non-metabolic diseases. SDH=social determinants of health.

All-cause mortality was ascertained from family members (children or spouses) or primary caregivers' records, with death certificates used for verification. For missing death data, verification was conducted through community committees. Follow-up time was calculated as the interval between the first interview and either the last interview or date of death.

Statistical analysis

Missing data were imputed using the random forest method (appendix 2 pp 9–10). Throughout the study, each participant was classified into one of three states at each survey wave: functional independence, functional dependence, and death. We allowed transitions between the independent and dependent state and from either to death (appendix 2 p 27). A continuous-time three-state Markov model was applied to estimate age-specific transition intensities between states and to calculate functional independence-related life expectancy stratified by sex. Transition intensities were modelled as hazard ratios (HRs) with 95% CIs, adjusted for sampling weight, age, sex, residence, healthy lifestyle factors, social determinants of health factors, Mini-Mental State Examination score, sleep duration, and the number of metabolic and other chronic diseases. Healthy lifestyle and social determinants of health factors were incorporated as covariates to assess their effect on independent-related life expectancy across different exposure levels. The package msm[27] in R is used to fit continuous-time Markov models for muti-state processes observed at arbitrary times (panel data). The package elect[28] in R is an extension of msm designed to compute state-specific and marginal life expectancies using the Gompertz distribution, a commonly used parametric model for mortality rates (appendix 2 p 6). Multi-categorical variables were incorporated into the model as dummy variables. Throughout the study, following the restrictions when the multi-state life table was developed, participants' ages were considered to start at 65 years and end at 110 years.[29] We used a Monte Carlo simulation with parametric bootstrapping (step method) to estimate 95% CIs for life expectancy. Independent and dependent state life expectancy was analysed and fitted separately by sex for each healthy lifestyle factor group and social determinants of health group. All analyses were performed in R software (version 4.3.0).

We stratified analyses by sex to compare the effects of healthy lifestyle groups across social determinants of health factor groups on independent and total life expectancy. We also examined each lifestyle and social determinants of health factor on state transitions and life expectancy, estimating 95% CIs from group means and SDs under normality assumptions.

Sensitivity analyses included: (1) Cox models using baseline data to assess associations of each lifestyle and social determinants of health factor with mortality, generating weighted lifestyle and social determinants of health scores categorised into tertiles; (2) re-estimating life expectancy with the “Middle Riemann” method;[28] (3) assuming the 15th of the participants birth month as the birthdate to calculate ages in months and re-analysing transition probabilities; (4) excluding 2021 data to address COVID-19 effects; and (5) redefining dependency after age 75 years as needing help only with activities of daily living, and recalculating fitted results.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, writing of the report, or the decision to submit the manuscript.

Results

From 16 952 respondents, we excluded 391 individuals younger than 65 years and 2537 older than 100 years (appendix 2 p 8). Among the remaining 14 024 potential participants, we excluded 2151 without mortality or follow-up information and 69 with missing core variables or irreparable data inconsistencies. 11 804 participants with a mean baseline age of 84·52 years (SD 9·92), of whom 6290 (53·3%) were female and 5514 (46·7%) were male and 7443 (63·1%) resided in rural areas (table). At baseline, 3831 (60·9%) females and 2357 (42·7%) males had dependent status.

Regarding healthy lifestyle factors, 2266 (41·1%) males reported only 0–1 healthy lifestyles, whereas 3507 (55·8%) females most commonly reported 3–4 healthy lifestyles (table). For social determinants of health factors, 3158 (57·3%) males were in the 2–3 social determinants of health group compared with 2465 (39·2%) females, while 3443 (54·7%) females had only 0–1 social determinant of health factors versus 1141 (20·7%) males. Overall, males showed more favourable social determinants of health factors, particularly in education and financial status, whereas females tended to adopt healthier lifestyles, especially in terms of smoking and alcohol use.

The transition probability analysis revealed that females had both higher risk of becoming dependent (hazard ratio [HR] 1·63, 95% CI 1·49–1·78) from independent and lower probability of death from both independent (0·59, 0·52–0·67) and dependent state (0·61, 0·56–0·67) compared with males, after adjustment for all covariates (figure 1; appendix 2 p 11). Based on these transitions, despite females having longer total life expectancy (18·18 years, 95% CI 17·74–18·49 *vs* 15·50 years, 15·10–15·89), males had higher independent life expectancy (11·29 years, 11·05–11·54 *vs* 10·35 years, 10·13–10·55) at age 65 years (appendix 2 p 12). This resulted in a substantial difference in years spent in dependency: 7·83 years (95% CI 7·58–8·11) for females compared with 4·21 years (4·01–4·44) for males (figure 2; appendix 2 p 12).

Healthy lifestyle factors and social determinants showed distinct patterns of influence on functional

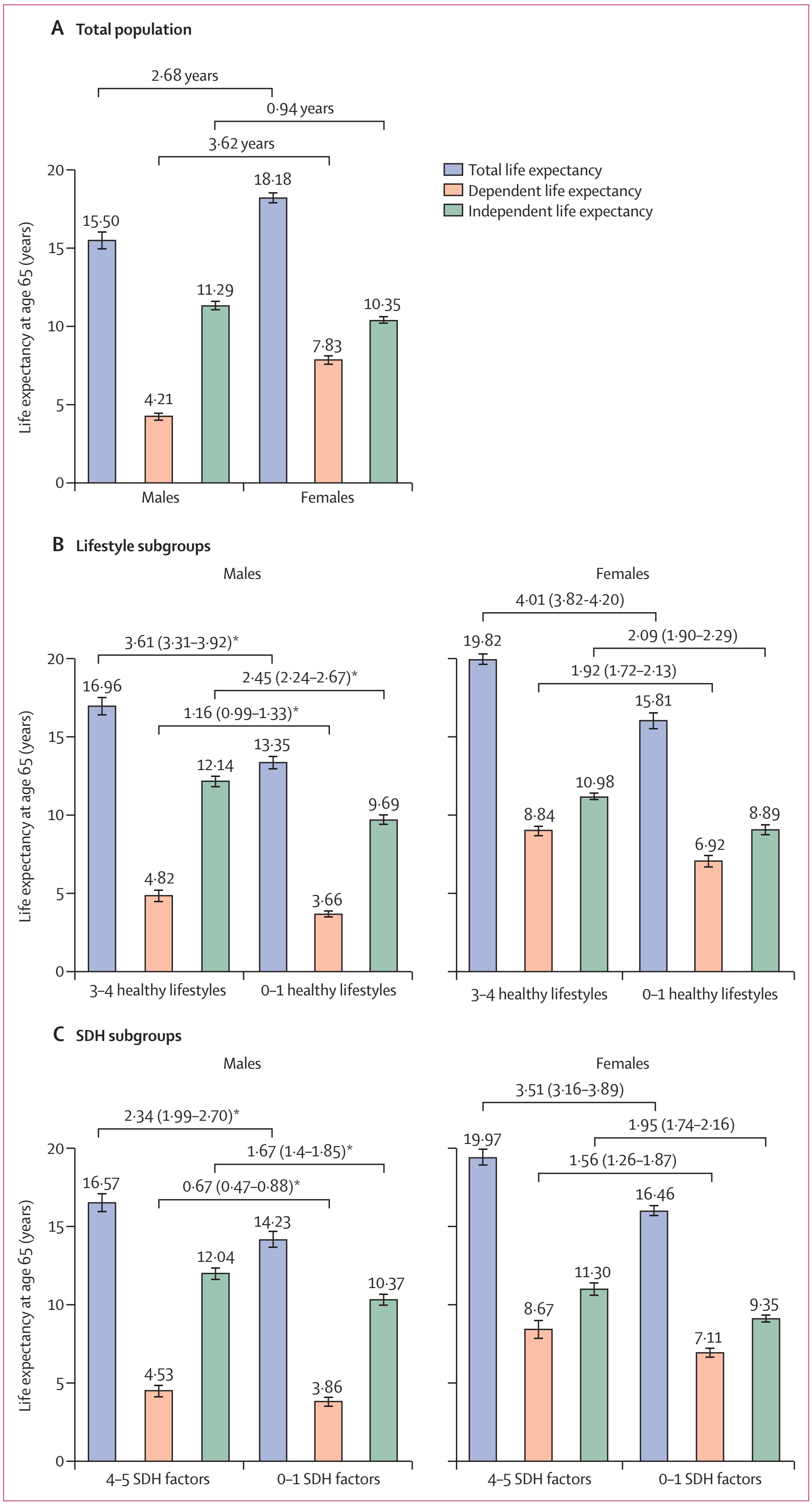

Figure 2: **Effect of different healthy lifestyles and SDH factors on life expectancy for males and females at age 65 years**

(A) Total and independence-related life expectancy at age 65 years in males and females among the study population. (B) Male and female independent-related life expectancy at age 65 years across 0–1 and 3–4 healthy lifestyle factors. (C) Male and female independent-related life expectancy at age 65 years across 0–1 and 4–5 SDH factors. SDH=social determinants of health. *p<0·05 compared with females.

Figure 3: **Joint effects of healthy lifestyle and SDH factors on the percentage of independent life expectancy across males and females at age of 65 years among study population**
SDH=social determinants of health.

transitions (figure 1). Healthy lifestyle factors primarily protected against loss of independence (HR for 3–4 *vs* 0–1 factors 0·85, 95% CI 0·76–0·96) and reduced mortality from both independent (0·77, 0·65–0·90) and dependent states (0·60, 0·55–0·66). In contrast, favourable social determinants exerted their strongest effects on recovery from dependency (HR for 4–5 *vs* 0–1 factors 1·70, 1·43–2·00) and survival after becoming dependent (0·55, 0·48–0·63).

The impact of lifestyle and social factors on independent life expectancy showed marked sex differences (figures 2). Males with 3–4 healthy lifestyle factors gained 2·45 (95% CI 2·24–2·67) additional years of independent life compared with those with 0–1 factors, slightly exceeding the female gain of 2·09 years (1·90–2·29, p=0·015). However, females with 4–5 favourable social determinants of health factors gained 1·95 (1·74–2·16) additional years of independent life expectancy compared with those with 0–1 factors, exceeding males who gained 1·67 years (1·49–1·85, p=0·047).

The joint effect of healthy lifestyle and social determinants of health factors on the independent life expectancy of males and females are shown in figure 3 and appendix 2 (p 13). Compared with the group with the lowest life expectancy (0–1 healthy lifestyle and 0–1 favourable social determinant of health factor), improvements in both the lifestyle subgroup and the social determinants of health subgroup significantly increased life expectancy (p<0·05). Males with 3–4 healthy lifestyles and 4–5 favourable social determinants of health factors can extend their independent life expectancy by 3·94 years (95% CI 3·73–4·15) and their total life expectancy by 5·78 years (5·51–6·06), meanwhile females with the same factors can increase their independent life expectancy by 3·89 years (3·68–4·11) and total life expectancy by 7·41 years (7·08–7·76); however, we observed that the proportion of independent life expectancy differed only slightly across groups. Under the same healthy lifestyle subgroup, as favourable social determinants of health factors increase, the difference in independent life expectancy between males and females decreases. In all subgroups with 4–5 favourable social determinants of health factors, the sex gap in independent life expectancy was smaller than that observed in the overall population.

This sex-differential response remained consistent across individual components of most domains (appendix 2 pp 14–16, 28). Males gain substantial increases in independent life expectancy from diet, smoking cessation, and exercise, whereas females gain substantial improvements from smoking cessation, exercise, neighbourhood and built environment, and social and community context. In terms of reducing sex differences in independent life expectancy, daily exercise and all social determinants of health factors provide some benefit. At the same time, daily exercise, health-care access and quality, and social and community context contribute more substantially to increasing sex differences in dependent life expectancy than other factors.

Our sensitivity analyses supported the robustness of our findings. Grouping participants by healthy lifestyle and social determinants of health scores (appendix 2 pp 17–19), using the Middle Riemann method (appendix 2 p 20), and applying monthly transition rates (appendix 2 p 21) all yielded results consistent with the main analyses. Life expectancy estimates excluding 2021 data (appendix 2 p 22) were slightly higher, and the age-specific independence analysis (appendix 2 p 23) confirmed that the differential effects of healthy lifestyles and social determinants of health on independent life expectancy remained.

Discussion

To the best of our knowledge, this study is the first to estimate independent life expectancy among Chinese adults aged 65 years and older. Our findings reveal distinct pathways to healthy longevity between males and females, offering three key insights. First, although older Chinese females live longer than males, they have fewer independent life expectancy years, confirming the persistence of the male–female health-survival difference in functional independence. Second, both healthy lifestyle behaviours and favourable social determinants of health independently and synergistically contribute to gains in independent life expectancy. Third, the gains of independent life expectancy from improving those factors appear to differ by sex: males benefit more from healthy lifestyle improvements, whereas females benefit more from favourable social conditions. These findings provide important evidence for understanding the sex differences and for developing sex-specific strategies to reduce care dependency in ageing populations.

Our study found that among the Chinese older population males have an additional independent life expectancy of 0·9 years compared with females (11·3 years *vs* 10·4 years). Compared with a British population study in the same period,[25] this difference is similar but relatively smaller (UK males 11·2 years *vs* UK females 9·7 years). Notably dependent life expectancy in China is lower, and the sex difference between males and females is smaller (UK males 6·5 years *vs* UK females 10·8 years; Chinese males 4·2 years *vs* Chinese females 7·8 years). These differences could be attributed to various reasons such as the differences in regional economic and health-care systems.[30] Compared with UK older adults aged 60 years and older, Chinese older adults might be disadvantaged in education and socio-economic status, likely due to the later timing of educational reforms and economic development in China compared with the UK.[31] With economic growth, Chinese older adults might experience longer dependent states, which will accelerate care needs. This potential disparity in dependent life expectancy further underscores the necessity of ongoing monitoring and adjustment of care strategies.

Consistent with previous studies, we found that adherence to healthy lifestyle behaviours[9,10] and having favourable social determinants of health[12] were both associated with longer independent life expectancy and total life expectancy. Notably, our findings suggest that the pathways through which lifestyle factors and social determinants of health influence independent life expectancy might differ. Healthy lifestyle factors had a positive effect on all transitions leading to independence, while favourable social determinants of health mainly influenced recovery from dependence and reduced mortality among those who were already dependent. Several mechanisms could explain this difference. Healthy lifestyle factors have well established multidimensional benefits in older adults, including delaying the onset of chronic diseases, promoting psychological wellbeing, and preventing functional decline.[29,32] In contrast, the social determinants of health framework focus on structural conditions such as income, education, and access to health care. Previous research has shown that socioeconomic conditions can influence health outcomes indirectly by shaping individual behaviours.[33] In the independent state, social determinants of health could operate primarily through this behavioural mediation pathway. However, among those who were already dependent, social determinants of health might exert direct effects through greater access to medical and rehabilitative services, improved care coordination, and enhanced social support. Evidence from studies in Europe and North America indicates that higher education, financial resources, and stronger social networks are associated with greater resilience to health challenges, more successful recovery trajectories, and better access to rehabilitation among older adults.[34,35] These findings suggest that effective strategies to extend functional independence in ageing populations should combine behavioural interventions at the individual level with broader social policies aimed at improving structural determinants of health. However, neither healthy lifestyle behaviours nor favourable social determinants of health were associated with a compression of dependent life expectancy. One possible explanation is that the life expectancy of older adults in China has not yet approached a biological or societal ceiling. According to Fries' theory of compression of morbidity,[36] improvements in population health and longevity should ideally lead to a shorter duration of morbidity, provided that the onset of chronic disease or disability is delayed more than the increase in life expectancy. Building on this concept, the emerging theory of compression of dependency extends the focus from morbidity to functional independence—emphasising a reduction in the years lived with dependency rather than merely disease. In the context of global population ageing, characterised by growing care needs and an expanding duration of dependent life expectancy, healthy lifestyles and favourable social determinants of health remain pivotal in promoting such compression of dependency. Further longitudinal research is warranted to identify strategies to achieve this goal, encompassing not only behavioural interventions but also system-level investments in geriatric care, community rehabilitation, and social protection.

After accounting for sex differences, we found that gains in independent life expectancy were greater for males through lifestyle modification, whereas females benefited more from improvements in social conditions, even when transition rates associated with lifestyle and social determinants of health were the same between sexes. This finding suggests that biological differences between males and females, such as hormonal profiles, immune responses, and disease susceptibility, might not only independently contribute to the sex differences but also amplify the effects of social and behavioural exposures. Consistent with previous findings[11,37] and our data, males tend to exhibit more adverse health behaviours, including smoking, alcohol consumption, and physical inactivity, whereas females are more likely to occupy structurally disadvantaged social positions. Biological sex-related factors could further magnify the life-expectancy losses associated with these behavioural and structural exposures, thereby reinforcing sex disparities in ageing trajectories.

Our findings have important implications for global healthy ageing strategies. WHO's Decade of Healthy Ageing (2021–30)[38] highlights functional ability, rather than the mere absence of disease. In rapidly ageing societies such as China, our findings indicate that comprehensive policy frameworks addressing both individual-level behaviours and broader structural social factors are essential to achieving longer functional independence for older adults. Approaches tailored to sex-specific needs could be particularly effective. For males, promoting healthier lifestyle behaviours could yield substantial benefits, whereas for females, strengthening community-level social support systems could offer advantages. The synergistic effect observed in our study, in which combined improvements in lifestyle and social determinants resulted in the greatest gains in independent life expectancy, suggests that fragmented or isolated health promotion strategies might be insufficient. In high-income countries, addressing the sex distribution of social determinants might also help narrow the difference. The stronger influence of social conditions on the functional independence of females highlights the need for sex-sensitive policies that address structural inequities to promote healthy ageing and health equity.

This study has several strengths, including its large, nationally representative cohort with long follow-up, comprehensive assessment of lifestyle and social determinants, and the use of a dynamic modelling approach. Nonetheless, some limitations should be noted. First, lifestyle and disease data were self-reported, which could introduce recall bias, although strict assessments and low levels of inconsistent or missing data (1–3%)[39] suggest the effect is limited. Second, independence was assessed at long intervals (ie, 2–4 years), which could underestimate lifestyle effects; however, the use of monthly transitional rates and robustness checks indicate this bias is minor. Third, a healthy volunteer effect cannot be excluded, but refusal rates were low (about 2%)[39] and mortality was comparable to national statistics. Fourth, we defined a healthy lifestyle as abstaining from both alcohol and smoking for at least 10 years, and we further verified potential reverse causality using a dynamic regression model (appendix p 24). Fifth, lifestyle behaviours earlier in life could have cumulative effects, which we could not capture; life-course studies are needed to address this. Sixth, genetic factors were not included due to high missingness. Seventh, sleep was not included as a core lifestyle factor because only some self-reported indicators were available; future studies should adopt more comprehensive and multidimensional assessments of lifestyle. Eighth, the absence of data on disease progression and related biomarkers limits our understanding of underlying mechanisms. Sex differences in disease patterns and biomarkers might contribute to disparities in independent life expectancy. Future research integrating clinical biomarkers and detailed disease profiles is needed to elucidate the biological and behavioural pathways underlying sex differences in healthy longevity.

For the **Chinese Longitudinal Healthy Longevity and Happy Family Study** see https://opendata.pku.edu.cn/dataverse/CHADS

This study show that both healthy lifestyle factors and favourable social determinants extend independent life expectancy among older Chinese adults, with notable sex differences in their effects. Males' greater benefit from lifestyle modifications and females' responsiveness to social improvements points to targeted strategies for extending healthy, independent years. As populations age globally, these sex-specific pathways offer hope for more equitable and effective approaches to healthy longevity. Future studies should translate these insights into policies and programmes that help all older adults maintain independence and dignity in their later years.

Contributors

YY and LR conceptualised and designed the study, completed the statistical analyses, drafted the initial manuscript, and reviewed and revised subsequent drafts of the manuscript. YZho, KL, YZe, and ED contributed to the conceptualisation and design of the study, supervised the data collection, statistical analyses, initial drafting of the manuscript, and reviewed and revised subsequent drafts of the manuscript. HZ, SL, YH, KS, YJ, YW, and MY contributed to interpretation of the data and extensive revision of the manuscript. JH, JL, YZha, JS, BH, THL, and DB assisted with the data interpretation and reviewed and revised subsequent drafts of the manuscript. Only the core team (LR, YH, SL, YZe, and YY) had access to and verified the data as the 2021 data are not yet publicly available. YZe, ED, and YY were responsible for the decision to submit the manuscript. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

Declaration of interests

We declare no competing interests.

Data sharing

The data that support the findings of this study are available from Peking University Open Research Data. The data access requires the completion of a detailed application form from the website. The Chinese Longitudinal Healthy Longevity data from the 2008 to 2018 waves are fully publicly available. The 2021 wave data will be released and made publicly available in due course. Researchers interested in accessing the 2021 wave data can contact the corresponding author for further information. For more information on accessing the data, see the Chinese Longitudinal Healthy Longevity and Happy Family Study.

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References

1 WHO. Healthy ageing and functional ability. Oct 26, 2020. https://www.who.int/news-room/questions-and-answers/item/healthy-ageing-and-functional-ability (accessed July 1, 2025).

2 Zeng Y, Feng Q, Hesketh T, Christensen K, Vaupel JW. Survival, disabilities in activities of daily living, and physical and cognitive functioning among the oldest-old in China: a cohort study. *Lancet* 2017; **389:** 1619–29.

3 Kingston A, Comas-Herrera A, Jagger C, et al. Forecasting the care needs of the older population in England over the next 20 years: estimates from the Population Ageing and Care Simulation (PACSim) modelling study. *Lancet Public Health* 2018; **3:** e447–55.

4 Vaupel JW. Biodemography of human ageing. *Nature* 2010; **464:** 536–42.

5 Stewart Williams J, Norström F, Ng N. Disability and ageing in China and India—decomposing the effects of gender and residence. Results from the WHO study on global AGEing and adult health (SAGE). *BMC Geriatr* 2017; **17:** 197.

6 Ferrari AJ, Santomauro DF, Aali A, et al. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet* 2024; **403:** 2133–61.

7 Chen X, Giles J, Yao Y, et al. The path to healthy ageing in China: a Peking University–*Lancet* Commission. *Lancet* 2022; **400:** 1967–2006.

8 Chinese Center for Disease Control and Prevention. Health tips for older adults. March 7, 2022. https://en.chinacdc.cn/in_focus/202203/t20220307_257489.html (accessed Oct 14, 2025).

9 Li Y, Schoufour J, Wang DD, et al. Healthy lifestyle and life expectancy free of cancer, cardiovascular disease, and type 2 diabetes: prospective cohort study. *BMJ* 2020; **368:** l6669.

10 Li Y, Pan A, Wang DD, et al. Impact of healthy lifestyle factors on life expectancies in the US population. *Circulation* 2018; **138:** 345–55.

11 Ren L, Hu F, Walsh S, et al. Healthy lifestyle factors outweigh influence of APOE genetic risk on extending cognitively healthy life expectancy among Chinese older adults: evidence from a nationwide cohort study. *Alzheimers Dement* 2025; **21:** e70090.

12 Zhong J, Zhang Y, Zhu K, et al. Associations of social determinants of health with life expectancy and future health risks among individuals with type 2 diabetes: two nationwide cohort studies in the UK and USA. *Lancet Healthy Longev* 2024; **5:** e542–51.

13 Safford MM, Reshetnyak E, Sterling MR, et al. Number of social determinants of health and fatal and nonfatal incident coronary heart disease in the REGARDS Study. *Circulation* 2021; **143:** 244–53.

14 Gong J, Wang G, Wang Y, et al. Nowcasting and forecasting the care needs of the older population in China: analysis of data from the China Health and Retirement Longitudinal Study (CHARLS). *Lancet Public Health* 2022; **7:** e1005–13.

15 Lu J, Li M, He J, et al. Association of social determinants, lifestyle, and metabolic factors with mortality in Chinese adults: a nationwide 10-year prospective cohort study. *Cell Rep Med* 2024; **5:** 101656.

16 Van Oyen H, Nusselder W, Jagger C, Kolip P, Cambois E, Robine JM. Gender differences in healthy life years within the EU: an exploration of the “health-survival” paradox. *Int J Public Health* 2013; **58:** 143–55.

17 Tawiah R, Jagger C, Anstey KJ, Kiely KM. Lifecourse socioeconomic position and cohort differences in health expectancy in Australia: a longitudinal cohort study. *Lancet Public Health* 2022; **7:** e347–55.

18 Yao Y, Lv X, Qiu C, et al. The effect of China’s Clean Air Act on cognitive function in older adults: a population-based, quasi-experimental study. *Lancet Healthy Longev* 2022; **3:** e98–108.

19 Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med* 2020; **54:** 1451–62.

20 Sun Q, Hu Y, Yu C, et al. Healthy lifestyle and life expectancy free of major chronic diseases at age 40 in China. *Nat Hum Behav* 2023; **7:** 1542–50.

21 Thomson B, Islami F. Association of smoking cessation and cardiovascular, cancer, and respiratory mortality. *JAMA Intern Med* 2024; **184:** 110–12.

22 Griswold MG, Fullman N, Hawley C, et al. Alcohol use and burden for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2018; **392:** 1015–35.

23 US Department of Health and Human Services. Healthy people 2030. Social determinants of health. https://healthgov/healthypeople/priority-areas/social-determinants-health (accessed May 4, 2025).

24 Isaacs B, Neville Y. The needs of old people. The ‘interval’ as a method of measurement. *Br J Prev Soc Med* 1976; **30:** 79–85.

25 Kingston A, Wohland P, Wittenberg R, et al. Is late-life dependency increasing or not? A comparison of the Cognitive Function and Ageing Studies (CFAS). *Lancet* 2017; **390:** 1676–84.

26 Svensson T, Saito E, Svensson AK, et al. Association of sleep duration with all- and major-cause mortality among adults in Japan, China, Singapore, and Korea. *JAMA Netw Open* 2021; **4:** e2122837.

27 Jackson C. Multi-state models for panel data: the msm package for R. *J Stat Softw* 2011; **38:** 1–28.

28 van den Hout A, Sum Chan M, Matthews F. Estimation of life expectancies using continuous-time multi-state models. *Comput Methods Programs Biomed* 2019; **178:** 11–18.

29 Dhana K, Franco OH, Ritz EM, et al. Healthy lifestyle and life expectancy with and without Alzheimer’s dementia: population-based cohort study. *BMJ* 2022; **377:** e068390.

30 Liu Z, Han L, Feng Q, et al. Are China’s oldest-old living longer with less disability? A longitudinal modeling analysis of birth cohorts born 10 years apart. *BMC Med* 2019; **17:** 23.

31 Lu W, Pikhart H, Sacker A. Comparing socio-economic inequalities in healthy ageing in the United States of America, England, China and Japan: evidence from four longitudinal studies of ageing. *Ageing Soc* 2019; **41:** 1495–520.

32 Gao J, Wang Y, Xu J, Jiang J, Yang S, Xiao Q. Life expectancy among older adults with or without frailty in China: multistate modelling of a national longitudinal cohort study. *BMC Med* 2023; **21:** 101.

33 Xue X, Cheng M. Social capital and health in China: exploring the mediating role of lifestyle. *BMC Public Health* 2017; **17:** 863.

34 Weeks WB, Chang JE, Pagán JA, Aerts A, Weinstein JN, Ferres JL. An observational, sequential analysis of the relationship between local economic distress and inequities in health outcomes, clinical care, health behaviors, and social determinants of health. *Int J Equity Health* 2023; **22:** 181.

35 Jilani MH, Javed Z, Yahya T, et al. Social determinants of health and cardiovascular disease: current state and future directions towards healthcare equity. *Curr Atheroscler Rep* 2021; **23:** 55.

36 Fries JF. The compression of morbidity. 1983. *Milbank Q* 2005; **83:** 801–23.

37 Wang HY, Zhang M, Sun X. Sex-specific association between socioeconomic status, lifestyle, and the risk of frailty among the elderly in China. *Front Med (Lausanne)* 2021; **8:** 775518.

38 Michel J-P, Leonardi M, Martin M, Prina M. WHO’s report for the decade of healthy ageing 2021–30 sets the stage for globally comparable data on healthy ageing. *Lancet Healthy Longev 2021*; **2:** e121–22.

39 Zeng Y. Towards deeper research and better policy for healthy aging—using the unique data of Chinese Longitudinal Healthy Longevity Survey. *China Economic J* 2012; **5:** 131–49.