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Association of low socioeconomic status with cognitive decline among older persons in underdeveloped areas in China – a data analysis of the Gansu aging study

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Abstract

Background Individuals with low socioeconomic status (SES) bear a disproportionate share of the cognitive impairment (CI) burden, there are growing evidence focusing on socioeconomic inequalities in CI among older persons. However, data in the underdeveloped regions is limited. This study aims to measure socioeconomic inequalities in CI among individuals aged 65 years or older in Gansu, China, and determine the contributions of socioeconomic factors to the inequalities.

Methods Data from the Gansu Aging Study in 2022 including 3241 participants. Participates' SES was assessed by using education, income, and occupation. Multivariate logistic regression was conducted to identify the associated between SES and CI, and decomposition analysis was further applied to decompose the contribution of each determinant to the observed inequalities in CI. The SES inequalities in CI were illustrated and quantified by the concentration curve index.

Results Overall, 24.2% of participants suffered from CI in the study. The likelihood of CI was lower among those with a medium SES (OR = 0.04, 95% CI:0.03, 0.07), good SES (OR = 0.06, 95% CI: 0.04, 0.09) compared to those with lower levels of SES. Older adults with mild depression (OR = 3.66, 95% CI:2.70,4.95), moderate-severe (OR = 2.82, 95% CI:2.05,3.88) were more likely to have CI in comparison to those with no depression and regular social activities were protective factors for CI (OR = 0.28, 95% CI:0.11,0.75). The concentration index indicated that CI was more concentrated in households with poor SES. Subsequently, SES explained 34.65% of socioeconomic inequality in CI.

Conclusion This study suggested that, approximately one-quarter of older persons suffered from CI in Gansu, China. Low SES was substantially associated with risk of CI. Although interventions to modify traditional risk factors may decrease the risk of CI, disparities by SES may remain without addressing SES itself.

Keywords Socioeconomic status, Cognitive decline, Cognitive impairment, Older persons, Underdeveloped areas, Dementia, China

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Introduction

With rapid demographic aging, the health and well-being of the older persons population have become important public health issues [1]. In particular, the burden is attributable to cognitive dysfunction, which is considered a key component of geriatric healthy life expectancy [2]. According to the World Alzheimer Report, around 55 million people suffered from dementia, in 2019, and this number is estimated to surge to 152 million by 2050 [3]. China has become an aging society with 14% of the population aged 65 years or older in 2021, which is expected to increase to 27.9% in 2050 [4]. Notably, China has the highest number of people with dementia in the world, accounting for a quarter of the world's total dementia population [5]. Cognitive impairment (CI), which is associated with an increased risk of disability, increased health expenditures, and progression to dementia, is a significant risk factor for ill-health status among older persons individuals [1]. Worldwide, CI (ranges from mild to severe) affect dozens of millions of people and cause significant distress to patients and caregivers and a financial burden to families and healthcare systems [6, 7]. Currently, no drugs have been developed to effectively treat or slow the progression of CI. Therefore, for decades, the interest in identifying and analyzing the factors linked to cognitive performance in older persons has been growing in all fields [8–10].

Socioeconomic status (SES), defined as a person's combined economic (e.g., material goods, monetary income) and social (e.g., formal education, work prestige) status, is a composite indicator of an individual's social status [10]. Evidence suggest that lower SES is associated with greater social isolation, unhealthy living conditions, psychosocial stress [11], fewer ties to potential sources of social support (e.g., family and friends), and more frequent experiences of interpersonal conflict [12, 13]. Perhaps as a consequence, SES status is considered to play an important role in the development of health outcomes [14–16]. A systematic review that explored the potential effect of SES on the risks of cognitive dysfunction revealed that low SES substantially increased the risk of dementia and cognitive dysfunction [17]. From this perspective, differences of cognitive performance at different levels of SES would be expected to the extent that life is more challenging for people living with lower SES [12]. Low SES may affect cognitive function through a variety of mechanisms. For example, financial stress may lead to chronic stress, affecting brain health. In addition, individuals with low SES may lack access to high-quality medical and educational resources, which further exacerbates the risk of cognitive dysfunction [18]. Indeed, those challenges are manifold and well-documented. For example, people residing in deprived SES communities had worse cognitive function than their counterparts living in more advantaged communities [19–22]. Living in a low SES community is independently associated with cognitive impairment in Asian society [19, 21, 23]. Studies in India found those illiterates, with poor economic status, and without social support, are more likely to develop CI [24]. A study from Macau reported that among the risk factors, SES accounted for 76.74% inequality of CI [25]. A study in Finland demonstrated that dementia is among the most important contributors to socioeconomic inequalities in overall mortality at older ages [26].

SES is a multidimensional construct related to both adequacies of financial resources and educational attainment [19]. Therefore, the meaning and effects of SES on cognitive functioning might vary according to context. Although some data on the socioeconomic gradients in cognitive functioning exist in China, so far mainly concentrated on more developed regions of eastern coastal China. Compared with domestic developed areas, those underdeveloped show lower economic, social, and living standards [27]. Furthermore, in comparison with the older persons from developed cities, those from underdeveloped are facing more serious health care problems because of lower income, insufficient health awareness, and lack of resources in primary medical institutions [28]. Especially in some remote areas in northwest China [29].

Gansu Province is located in a rather remote region in northwest China with a dry climate and lack of water resources. Moreover, most areas of Gansu are plateaus and mountains, with an average altitude of above 1,000 m. The per capita GDP in Gansu was 102,433 Chinese Yuan in 2021, ranking 27 out of 31 provinces in China [30]. Till 2021, there were 317 Million residents aged 65 and above, representing 12.58% of the total population in Gansu [31], suggesting a high prevalence of CI [32]. At present, there is a shortage of full-time prevention and control personnel for mental health in the province, and to date, data on the CI of older persons in this region remain to be unexplored. In this paper, we used data from a prospective cohort study of older persons in Gansu province to systemically explore the association between SES and cognitive function, and to identify which SES variables had the strongest relationship with cognitive function which has more research significance in analyzing the data in economically underdeveloped regions.

Methods

Study participants and study design

The current analysis is based on data from the Gansu Aging Study (N=7500), which examined demands on the combining service of medical and solder persons care, and its influencing factors in old age, including health conditions, medical endowment insurance, and older

persons' knowledge and demands for the combination of medical care. Briefly, the Gansu Aging Study was enrolled in 2022 as a continuation of the population-based health Study in Gansu, initiated in 2019, including older persons adults from rural and urban areas of Gansu province. The study was approved by the Ethics Review Committee of Gansu Provincial Hospital. Written informed consent was obtained from all participants included in the study. Based on the Medical and Health Service System Planning (2016–2020), Gansu Province is divided into four medical zones (Lanzhou, Tianshui, Wuwei, and Pingliang) [33]. The study uses a multistage stratified sampling method. Within each region, nine subdistricts/townships were selected randomly as the second level (township). Then three were randomly selected as the third level (village). The following inclusion criteria were used to recruit participants: (1) 65 years and above by the time of the interview; (2) older persons who lived at home for more than 6 months (permanent residents); (3) volunteering to participate and providing written informed consent; (4) able to cooperate to complete data collection; (5) able to communicate with the interviewers. The following exclusion criteria are used: (1) those were institutionalized (e.g., people in nursing homes) and (2) having severe mental diseases (3) having life-threatening diseases or hearing or vision loss. Detailed baseline information has been described in the previous reports [27]. In 2022, all surviving participants (43.2%, $N=3241$) returned for a 3-year follow-up visit. The current study included participants who had relevant follow-up examinations including cognitive tests and SES. The detailed censoring process is shown in Fig. 1.

Procedures

Five investigators were formed for each site, consisting of one junior neurologist, three medical students, and one social worker. All information was obtained in participants' homes through face-to-face interviews using internationally compatible questionnaires. The spouse or other family member was instead interviewed when the participants were unable to answer questions, while questions about the cognitive function can only be answered by the participants themselves. Any missing or unclear items within the questionnaire were supplemented with a follow-up telephone call to minimize deviation and impact on the study results.

To minimize inconsistencies, interviewers and experts received the same week-long training on all necessary knowledge and skills, and a retraining course every 1 month. Inter-rater reliability for the assessment of questionnaires from individuals with cognitive decline was required to exceed 0.92. Any missing or unclear items within the questionnaire were supplemented with a follow-up telephone call to minimize deviation and impact

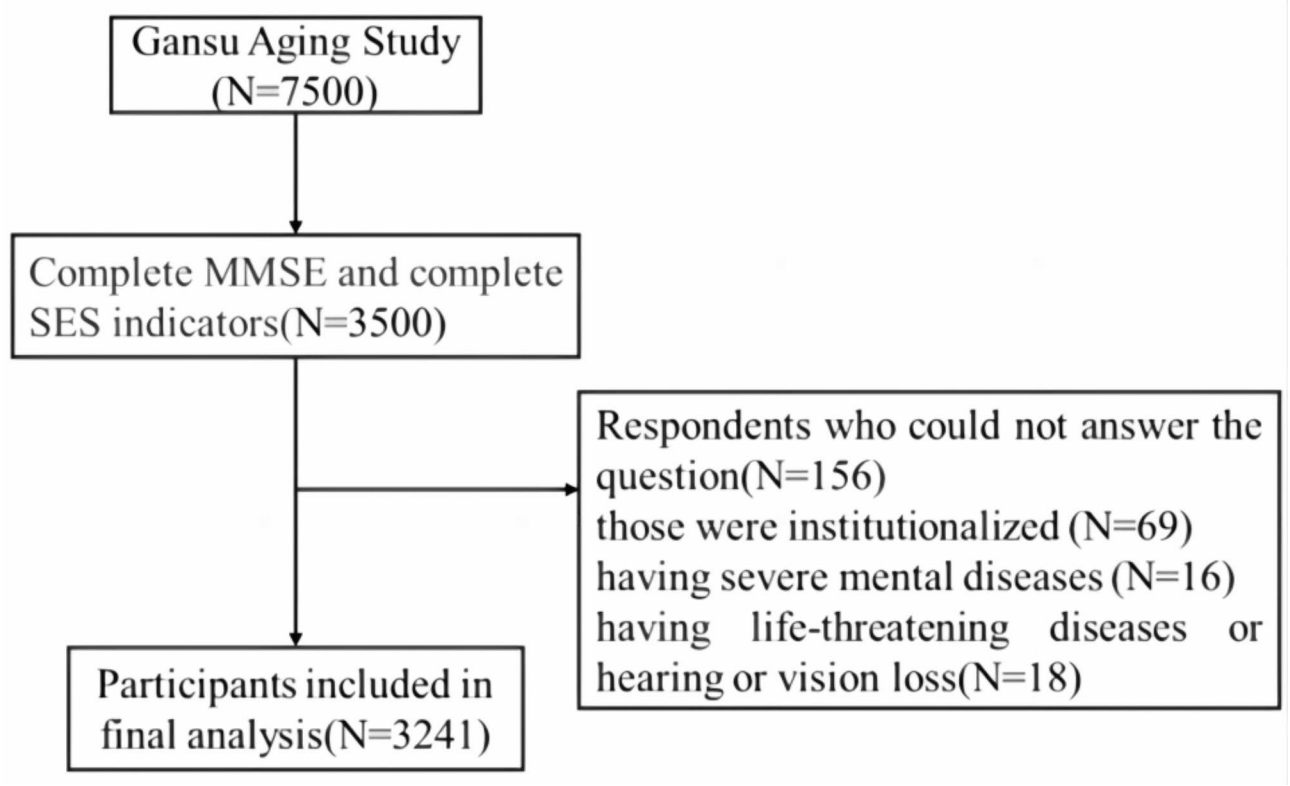

Fig. 1 Flow chart of participant selection; MMSE: Mini-Mental State; Examination; SES, socioeconomic status

on the study results. Data were stored on a secured server that only allowed authorized personnel access. For quality control, monitors did daily computer-based logic checks for item non-response and survey data outliers.

Measures

Covariates

Demographic factors include age, according to the WHO classification, participants were classified as elderly (≥75 years) or non-elderly (<75 year) [34]. gender (male or female), living arrangement (alone, With spouse, With children), marital (other, married), and residence (urban, rural), For residence we take the location of household registration as the division of urban and rural, if the location of household registration is rural, it will be rural population, if the location of household registration is in the city, it will be urban population.

Health related factors include drinking (yes or no), smoking (yes or no), regular exercise (yes or no), regular cognitive activities (yes or no), regular social activities (yes or no), body mass index (BMI), and psychological factors such as depression. Regular exercise was defined as engaging in at least 30 min of physical activity, such as Tai Chi, running, climbing, and jogging, etc. at least three times a week. Regular cognitive activities should be performed at least 3 times a week, including playing chess, playing mahjong, matching games, etc. Regular social activities were defined as taking part in social activities regularly at least 3 times a week, such as group activities, shopping, playing, sports, etc. The height and weight of the subjects were measured by professional medical staff, and the subjects were required to take off their shoes and wear thin clothing. BMI was calculated by dividing weight by height squared (Kg/m^2). According to the Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults published in 2006, the standards are as follows: underweight: BMI<18.5, normal : BMI 18.5∼23.9, overweight or obese: overweight: BMI 24.0∼27.9 [35]. Hamilton Depression Scale (HAMD-24) was used to estimate the presence of depressive symptoms [36]. The scale mainly includes 24 items. Each item uses a 5-level scoring method ranging from 0 to 4 points. The higher the score, the more serious the degree of depression. The rating of the scale: Normal: <8, mild: 8∼19; moderate: 20∼34, severe: ≥35.

Cognitive impairment

The dependent variable in this study was cognitive impairment, which was assessed by using the Chinese version of the Mini-Mental State Examination (MMSE) [37]. MMSE tests 24 items from five aspects of cognitive function. The total score ranged from 0 to 30, and the higher score indicated better cognitive ability. A single cutoff is widely used to screen for cognitive impairment [38, 39]. We used single cutoff points of MMSE to define those with cognitive impairment: < 24 abnormal. Participants were categorized as cognitively normal or impaired according to cognitive level, the MMSE score<24 indicated cognitive impairment, and ≥24 indicated cognitively normal.

The level of SES

Socioeconomic status is a complex structure with multiple dimensions [19], and this study mainly wants to explore the influence of individual economic status on their cognitive level imbalance. Thus, based on the questionnaire, in this study the participates' education level (percentage with less than a high school education), the per capita monthly income in the previous year, and pre-retirement occupation were used together to measure the level of participates' SES in current study. Education level was divided into five groups: illiterate, elementary school, junior high school, senior high school, and bachelor degree and above. According to the previous pre-survey, although there is a clear classification of economic income status [40] and occupation type [41] in China, the economic status is divided into five levels(<1000, 1000–2999, 3000–4999, ≥5000) and the occupation is divided into five categories(government staff, public institution staff, enterprises staff farmer, peasant-worker, self-employment and freelancing) We first computed standardized values for education, occupation, and per capita monthly income variables, and then summed them into an overall index was formed, which represented SES, with a mean value of zero and SD of 1.613. The full range of SES was from −2.77 to 2.43, with higher scores suggesting a higher level of SES.

Statistical analysis

The Stata 16.1 software and the SPSS.25.0 software were used for the data analysis.SPSS 25.0 software is used to study the general description and single factor analysis, regression analysis and principal component, and Stata 16.1 software was used for the subsequent Shapley decomposition. The analysis strategies of this study were as follows: Firstly, the basic characteristics of the subjects were described, the qualitative variables were described by frequency (n) and percentage (%), and the inter-group comparison was performed by χ^2-test or Mann-Whitney text. Secondly, the multiple binary logistic regression analysis was used to estimate the effects of the demographic, socioeconomic, social support, and health factors on CI. Thirdly, principal component analysis was used to calculate the SES score, and the concentration index was used to analyze the inequality of cognitive impairment. We used the concept of Shapley decomposition. To determine the impact of the different categories

of explanatory variables. $P<0.05$ was considered as statistically significant.

Construction of Socioeconomic Status

SES was a commonly used indicator to describe family economic level, which comprehensively described the socioeconomic status of the subjects. SES generally included three dimensions: rank, identity, and power [42]. Combined with the actual situation of this survey and prior study [43], three indicators including education level, per capita monthly household income, and occupation were adopted to reflect the SES of the subjects. The score of SES was calculated by principal component analysis. The score of each index in the first principal component was used as the corresponding weight to calculate the score of SES. In this study, according to the third quantile, the SES was divided into three groups: poor, medium, and good.

Concentration index

The concentration index was an indicator reflecting the inequity of health status caused by social and economic factors. The reliability of using the concentration index and its decomposition to measure health inequality had been fully verified in previous studies [44]. This study used the concentration index to measure the inequality of cognitive impairment among people of different SES. The value range of the concentration index was [−1,1]. If people of different economic levels had the same probability of developing cognitive impairment, the concentration index was 0; if the concentration index was negative, it indicated that the prevalence of cognitive impairment tended to be poor; if the concentration index was positive, it indicated that the prevalence of cognitive impairment tends to be rich. The calculation formula was as follows:

$$C = \frac{2}{\mu} cov\left(y_{i,} R_i\right)$$

Where, R_i represented the proportion of individual i ranked by SES; y_i represented the prevalence of cognitive impairment; μ represented the average prevalence of cognitive impairment.

The concentration index decomposition method can decompose the concentration index into the contribution of influencing factors [45]. The equation for logistic distribution is:

$$l_n \frac{\pi}{(1-\pi)} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n$$

Where, $X_{1,}$ X_2, X_3,... X_n are explanatory variables and β_1,β_2, β_3, ... β_n are regression coefficients.

To determine the impact of the different categories of explanatory variables, we used the concept of Shapley decomposition [46, 47]. which is quite well-known. We applied the simplest type of Shapley decomposition to determine the impact of different variables on the inequality of the CI among older adults. The Shapley value decomposition is useful in regression-based methods as it does not require the regression model to be linear. The Shapley value decomposition method relies on iteratively removing explanatory variables to determine how much each contributed to overall inequality.

Results

Baseline socioeconomic and demographic characteristics

A total of 3241 subjects were surveyed in this study, and the prevalence of CI was 24.2% with 52.1% among females. About 42% of the older adults are 75 years or older, with 10% living alone. Taking regular exercise, regular cognitive activities, and regular social activities were 51.8%, 60.9%, and 49.9%, respectively. More than half lived in rural areas. About 35.2% reported smoking, and 35.4% drank alcohol regularly. The older persons with mild and moderate-severe depression were 41.6% and 15.0%, respectively (Table 1).

Nearly 26.0% of older adults had poor SES. Nearly a quarter of the population is illiterate. The per capita monthly income of the older persons were <1000, 1000–2999, 3000–4999, and ≥5000 accounting for 19.7%, 24.0%, 31.5%, and 24.8%, respectively (Table 2).

Individual risk factors for cognitive impairment

The binary regression results for cognitive impairment and its determinants are presented in Fig. 2. After adjusting for confounding factors finding that the likelihood of cognitive impairment was lower among older adults with a medium SES (OR=0.04, 95% CI:0.03,0.07), good SES (OR=0.06, 95% CI: 0.04,0.09) compared to those with lower levels of SES. And compared with the normal elderly, the older adults with mild depression (OR=3.66, 95%CI: 2.70,4.95) and moderate to severe depression (OR=2.82, 95%CI: 2.05,3.88) were more likely to develop CI. Similarly, the elderly with regular social activities had better CI (OR=0.28, 95%CI: 0.11,0.75).

Relationship between SES and cognitive impairment

In this study, we used education level, income, and occupation to describe SES, and the first principal component of each indicator were 0.893∼0.982 (Table 3). According to the tertiles, the SES was further divided into three groups: poor, medium and good.

The concentration curve of cognitive impairment among older persons is shown in Fig. 3. The concentration curve falls above the line equality, with the negative value of the concentration index of −0.144 ($P<0.001$)

Table 1 Demographic and health related characteristics of subjects with non-cognitive impairment vs. cognitive impairment

Variable	Total	Cognitive Impairment	Non-cognitive impairment	χ^2/Z	*P*
Total, n(%)	3241	784(24.2)	2457(75.8)		
Demographic Factors					
Age, year				5.317	0.021*
< 75	1994(61.5)	455(58.0)	1539(62.6)		
≥ 75	1247(42.0)	329(42.0)	918(37.4)		
Gender, n (%)				31.093	< 0.001**
Male	1544(47.9)	308(39.3)	1246(50.7)		
Female	1687(52.1)	476(60.7)	1211(49.3)		
BMI, Kg/m^2, n (%)				-2.371	0.001**
Underweight	721(22.2)	154(19.6)	567(23.1)		
Normal	1204(37.1)	336(42.9)	868(35.3)		
Overweight or obese	1316(40.6)	294(37.5)	1022(41.6)		
Marital status, n (%)				19.020	< 0.001**
Others	455(14.0)	147(18.8)	308(12.5)		
Married	2786(86.0)	637(81.3)	2149(87.5)		
Home location, n (%)				2.057	0.152
Urban	1519(46.9)	350(44.6)	1169(47.6)		
Rural	1722(53.1)	434(55.4)	1288(52.4)		
Living arrangement, n (%)				133.170	< 0.001**
Live alone	326(10.1)	144(18.4)	182(7.4)		
With spouse	1633(50.4)	274(34.9)	1359(55.3)		
With children	1282(39.6)	366(46.7)	916(37.3)		
Health related Factors					
Depression, n (%)				-2.579	0.01*
Normal	1406(43.4)	313(39.9)	1093(44.5)		
Mild	1348(41.6)	335(42.7)	1013(41.2)		
Moderate-severe	487(15.0)	136(17.3)	351(14.3)		
Smoking, n (%), Yes	1141(35.2)	238(30.4)	903(36.8)	10.656	0.001**
Drinking, n (%), Yes	1148(35.4)	196(25.0)	952(38.7)	49.099	< 0.001**
Regular exercise, n (%), Yes	1505(51.8)	406(51.8)	1099(44.7)	11.898	0.001**
Regular cognitive activities, n (%), Yes	1970(60.8)	444(56.6)	1526(62.1)	4.008	0.045*
Regular social activities, n (%), Yes	1617(49.9)	420(53.6)	1204(49.0)	4.962	0.026*

BMI, body mass index, MMSE, Mini-Mental State Examination. *$p < 0.05$; **$P < 0.01$; Other marital statuses include divorced, widowed, never married

(Table 4), indicating that SES inequalities exist in the distribution of cognitive impairment. Furthermore, the concentration index calculated from the SES dimensions was −0.482 ($P<0.001$) (Education), −0.189 ($P<0.001$) (per capita monthly income) and 0.169 ($P<0.001$) (occupation), respectively.This suggests that there are inequalities that disadvantage the poor, that is, cognitive impairment was more concentrated among older persons with lower SES.

Results of the Shapley decomposition analysis

Table 5 presents the results of the Shapley decomposition. The models explain the socioeconomic inequalities in CI among older adults shown in (Table 5). The results revealed that SES, smoking status, weight status, and gender were the significant factors that contributed to the inequality for cognitive impairment among older adults. For instance, SES among older adults explained 34.65% of socioeconomic inequality, followed by 14.19% of smoking status, 12.00% BMI, and 10.05% gender. Apart from these factors, live arrangement (1.13%), and age (1.11%) contribute the least to the total inequality.

Discussion

The present study adds to the literature on CI inequalities among old-age in economically underdeveloped regions. Our data demonstrated a higher prevalence of CI (24.2%) among older persons in Gansu, China, which is substantially higher compared with those reported in developedcities in China (18%) [7, 48]. As well as in the developed countries (16.0–22.2%) [48] and developing countries (16%) [24]. Meanwhile, it is lower than previous reports in some Western countries [49], Asian countries, such as Macau (44.35%) [25], South Korea (32.2%), and rural China [20, 50]. The differences in these results may be due to the different investigation methods and

Table 2 Socioeconomic status of subjects with non-cognitive impairment vs. cognitive impairment

Variable	Total	Cognitive Impairment	Non-cognitive impairment	χ^2/Z	*P*
Total, n (%)	3241	784(24.2)	2457(75.8)		
SES, n (%)				-8.564	< 0.001**
Poor	838(25.9)	341(43.5)	497(20.2)		
Medium	1107(34.2)	170(21.7)	937(38.1)		
Good	1296(40.0)	273(34.8)	1023(41.6)		
Education, n (%)					
Illiteracy	792(24.4)	262(33.4)	530(21.6)	11.1873	< 0.001**
Primary school	607(18.7)	227(29.0)	380(15.5)		
Junior high school	599(18.5)	100(12.8)	399(20.3)		
Senior high school	782(22.5)	134(17.1)	594(24.2)		
University Graduate or above	515(15.9)	61(7.8)	454(18.5)		
per capita monthly income, n (%)				-10.922	< 0.001**
< 1000	637(19.7)	217(27.7)	420(17.1)		
1000–2999	777(24.0)	259(33.0)	518(21.1)		
3000–4999	1022(31.5)	196(25.0)	826(33.6)		
≥ 5000	805(24.8)	112(14.3)	693(28.2)		
Occupation, n (%)				94.836	< 0.001**
Government staff	575(17.7)	78(9.9)	497(20.2)		
Public institution staff	483(14.9)	98(12.5)	385(15.7)		
Enterprises staff	334(10.3)	54(6.9)	280(11.4)		
Farmer	1011(31.2)	332(42.3)	679(27.6)		
Migrant workers	560(17.3)	147(18.8)	413(16.8)		
Self-employed, and others	278(8.6)	42(5.4)	203(8.3)		

SES, socioeconomic status. MMSE, Mini-Mental State Examination; ** $p < 0.01$

A farmer is a producer engaged only in agriculture; Migrant workers refer to people engaged in both agricultural and non-agricultural production; Other occupations include driver, tour guide, shopping guide, etc

populations studied. Moreover, Gansu province has the lowest economic GDP in China, which would substantially impact education and income compared with the highest GDP regions in China (e.g., Shanghai or Beijing) [51].

The finding that the CI mainly concentrates on older persons with lower SES is consistent with previous studies [26, 52]. Overall SES is the most important factor affecting cognitive inequality among the older persons in Gansu. This is consistent with the results from Macau and India [24]. These further illustrate that CI inequity is a problem with worldwide prevalence, and moreover, poor SES is the significant cause of CI for those populations in a relatively undeveloped region like Gansu, and prevention strategies for CI, especially among those with poor SES could have a large public health impact. Primary health services can meet the majority of the health needs of people throughout their lifetime [53]. However, the quality of the primary public health service varies greatly due to regional economic disparity in China [54–57]. Gansu is a typical poverty-stricken province in China, and so far there are still many people who live in remote mountain areas [50, 58]. It is difficult and expensive for these residents to meet the provincial hospitals' doctors due to inconvenient traffic and the heavy burden of living [59, 60]. The low-quality health resources and insufficient service capacity at the primary level undoubtedly influence the equity and efficiency of health services [61]. Furthermore, despite the demand, the lack of relevant knowledge hinders the use of care services utilization not only in China [56]. but also in some developed countries [54]. The same phenomenon was also seen in Gansu, especially among those with lower SES [62]. Since the comprehensive promotion of public health services is an important measure that affects healthcare [54]. We consider promotion strategies should be used in older persons people to reduce the incidence of CI in Gansu. In addition, the provision of care and services for older adults should focus more on the accessibility and visibility of public health services.

SES reflects the individual's ability to obtain material and social resources [63]. Better SES generally suggests higher quality of life, wider social information [64]. and greater access to health services, which leads to more cognitive stimulation and cognitive reserve to prevent or delay the onset of CI [46, 63]. Previous studies have identified consistent urban-rural differences in CI [7, 52, 53]. Our results show, however, that even among older persons people who live in urban, we did not detect a significant protective effect against CI. This was also indicated in another study in China [48]. The reason for the insignificance may lie in the possibility that although urban areas can provide a more cognition-stimulating environment than rural areas [65], they also provide an adverse environment, such as reduced social interaction. A study reported that in China, almost half of the urban older adults, even those with relatively superior education and economic conditions, did not participate in any social activities (e.g., community entertainment, group sports, internet surfing, and others) [66]. Thus, the individuals lose the possibility of social support, such that they were exposed to an increased risk of CI. Meanwhile,

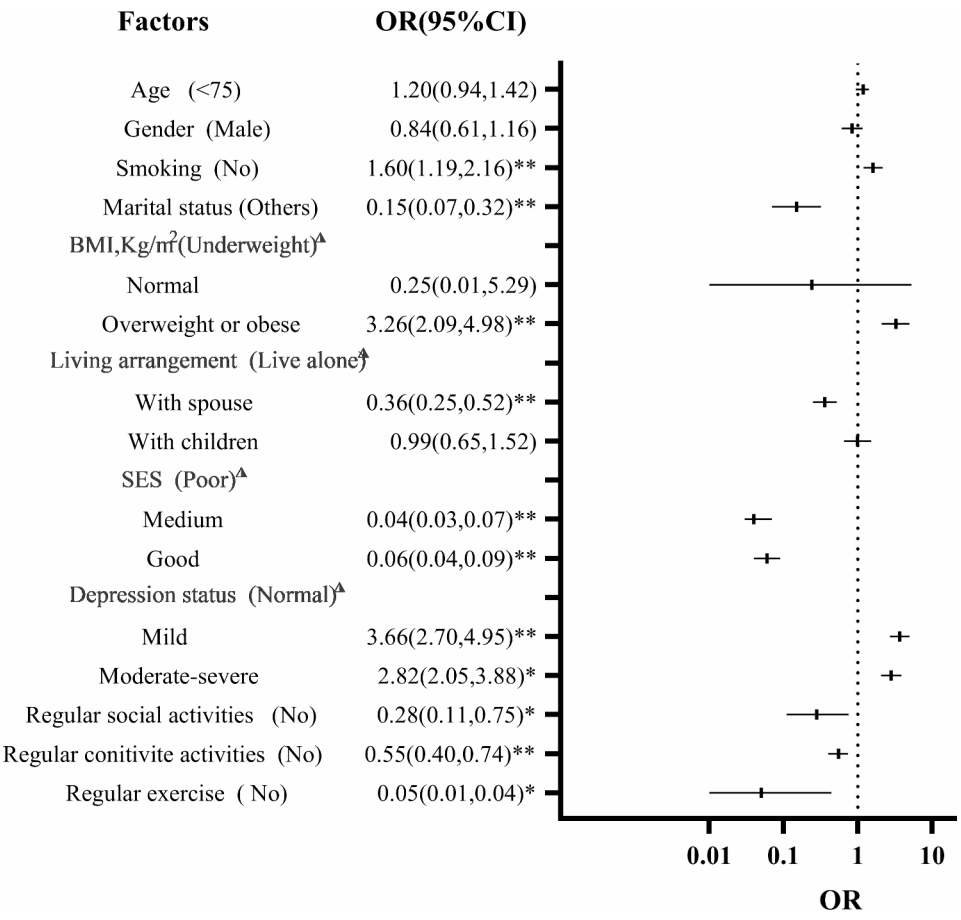

Fig. 2 Regression analysis results for cognitive impairment. ▲Reference category; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 3 First principal component weights of variables related to SES

Variables	First principal component
Occupation	0.893
Education	0.918
per capita monthly income	0.982

measures from the local authority were taken out to improve internet accessibility, including improving the infrastructure within the internet pathway via satellite, and WeChat. And strategies to improve healthcare systems in rural areas [67], thus rural residents have more access to receive cognitive stimulation than before, and the conditions for prevention and treatment of cognitive decline are more favorable.

Our study found that combined health-related behaviors (such as smoking, drinking, exercise and obesity) are another key contributor to inequality in CI. This is generally consistent with the findings of previous studies [68]. Healthy lifestyle behaviors are considered important means to reduce the burden of diseases [69]. In our study, we find that smoking has the strongest association with CI, followed by BMI, physical exercise, social contact, and cognitive activity. Although each of these behaviors contributes differently to CI, our results indicate that participants maintaining more healthy lifestyles have a significantly lower CI than those with fewer healthy lifestyles. This information could be useful in making personal choices that can help to protect against CI. Previous studies have shown that people with low SES tend to have lower adherence to healthy lifestyle behaviors [53, 70]. Although the differences in SES disparities in the distribution of health-related behaviors among older adults are not determined in this study, since the important role of such behaviors to inequality in CI, maintaining a vigorous lifestyle is needed, so as to postpone or even prevent the processes of CI and dementia.

Social engagement is a key determinant of active aging [64], especially within China's collective cultural background [23]. Previous research finds that social engagement is associated with overall cognitive performance in older adults [36]. This is also indicated in our study, which suggest that older adults with previous regular social activities have a lower e risk of CI. Furthermore, more attention should be paid to older persons with limited SES, especially those living alone which be considered

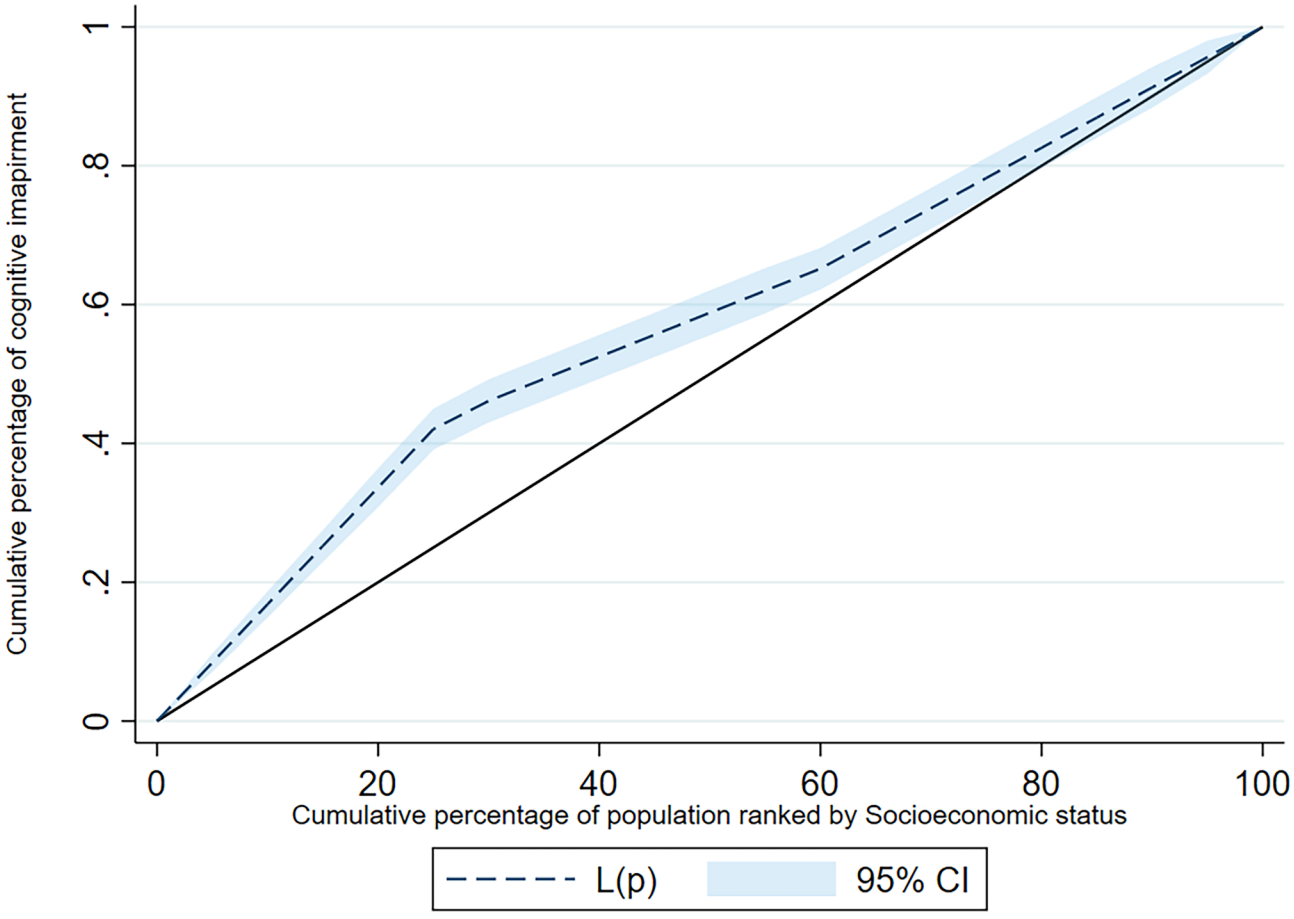

Fig. 3 Concentration curve of cognitive impairment in the older persons by SES. L(p): Concentration curve

Table 4 Concentration index of CI in the older persons under different SES indicators

Indicator	Number	Index value	SE	*p*
SES	3241	-0.144	0.017	< 0.001**
Dimensions				
Education	-	-0.482	0.015	< 0.001**
Occupation	-	0.170	0.017	< 0.001**
per capita monthly income	-	-0.180	0.017	< 0.001**

SES, socioeconomic status; **p < 0.01;SE: stander error

Table 5 Contributions of the predictor variables to the Pseudo R-square of CI in older persons (logistic regression)

Variables	Concentration index	*P*	Contribution	Contribution rate (%)
SES	-0.144	< 0.001**	0.03531	34.65
Smoking	0.093	< 0.001**	0.01446	14.19
BMI	0.055	0.001**	0.01223	12.00
Gender	0.087	< 0.001**	0.01024	10.05
Regular exercise	0.053	< 0.001**	0.00780	7.65
Depression	0.043	0.010*	0.00700	6.87
Regular social activities	0.035	0.026*	0.00655	6.43
Regular cognitive activities	-0.415	0.006**	0.00604	5.92
Live arrangement	0.014	< 0.039*	0.00115	1.13
Age	0.035	0.021*	0.00113	1.11

SES, socioeconomic status; **P < 0.01; *P < 0.05

a major risk factor for CI not only in our study but also in others [70, 71]. Moreover, we found that living with a spouse was a significant protective factor against CI, which supports prior findings [48, 71]. However, living with children had no effect on CI in the elderly. Depression, a risk factor for cognitive performance is higher in our sample than the existing research findings not only in China but also in other countries [29]. And also, findings suggest that SES has a significant positive effect on the mental health of individuals [60, 72]. Given that the coexisting of lower SES and depressive symptoms is increasing, perhaps as a consequence, those having depression

combined with lower SES, will significantly increase the risk of CI.

Limitations

There are also certain restrictions on the current investigation. Firstly, since SES and health-related information is often self-reported and only once measured, measurement error is unavoidable. Secondly, we assessed cognitive impairment using the MMSE scale. Despite the fact that the MMSE has been used in epidemiological studies and clinical practice to screen for CI and has been demonstrated to have good reliability, the use of a single scale may lead to misclassification. Future research can be done using various cognitive evaluation tools to compare whether there are differences in the results. In addition, in this study, a total of 156 people of respondents can't answer this question, because this part of the population is relatively small we no detailed introduction and analysis of this part of people, of course, this is also one of the limitations of this study. Finally, this study focused only on socioeconomic imbalances in CI, future research needs to determine how health inequalities vary across different socioeconomic classes in Gansu.

Conclusion

In conclusion, this study suggested that approximately one-quarter of older persons aged 65 years and over suffered from CI in Gansu and there is inequality in CI among the older persons in underdeveloped regions of China, and the occurrence of CI is mainly concentrated in the economically disadvantaged population. Although interventions to modify traditional risk factors may decrease the risk of CI, disparities by SES may remain without addressing SES itself.

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Author contributions

Y.F., J.Z., J.W, . wrote the main manuscript text. X.Z., J.W., H.C. and, Y.W. prepared Figs. 1, 2 and 3. All authors reviewed the manuscript. The author(s) read and approved the final manuscript.

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Data availability

All data can be offered to researchers upon request, if someone wants to request the data from this study, they can contact Jiancheng Wang (E-mail: 364954672@qq.com).

Declarations

Ethics approval and consent to participate

This study was performed according to the Helsinki Declaration, and the studies involving human participants were reviewed and approved by the Ethics Review Committee of Gansu Provincial Hospital (2021 – 168). The participants provided their written informed consent to participate in this study. Additionally, for the participants who were unable to read the informed consent form, that is, illiterate, we solicited the informed consent of their legally acceptable representatives(LARS) and investigated the participants after obtaining their consent. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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