# Quality of life and its influencing factors among centenarians in Nanjing, China: A cross-sectional study

**Xin Xu[1, 3, 4], Yuan Zhao[1, 2, 3, 4, 5]*, Siyou Xia[1, 3, 4], Panpan Cui[1, 3, 4], Wenmin Tang[1, 3, 4], Xiaoliang Hu[1, 3, 4]**

[1] School of Geographic Science, Nanjing Normal University, Nanjing, China;

[2] Ginling College, Nanjing Normal University, Nanjing, China

[3] Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, Nanjing, China

[4] Key Laboratory of Virtual Geographic Environment (Nanjing Normal University), Ministry of Education, Nanjing, China

[5] International Center for Aging and Health Studies (Nanjing Normal University), Nanjing, China

* Corresponding author

E-mail: zhaoyuan@njnu.edu.cn (YZ)

# Abstract

**Purpose** As centenarians are the most vulnerable social group among the elderly, their quality of life (QoL) is of great significance for the realization of healthy aging and a harmonious society. The purpose of this cross-sectional study was to examine the determinants of QoL of centenarians in Nanjing.

**Methods** An exploratory factor analysis and structural equation modelling were performed to discuss the complex relationship between physical health, mental health, family support, socioeconomic factors and other dimensions and the quality of life of centenarians. In-depth interviews were conducted.

**Results** The quality of life (QoL) of centenarians in Nanjing is in the middle level as a whole, and the distribution pattern of the central urban area, the suburbs and the far suburb is decreasing step by step. Four major factors related to QoL emerged from the responses of the participants: (a) psychological support, (b) socioeconomic status, (c) physical health, and (d) sensory ability. Specifically, we found that socioeconomic conditions and physical health have significant effects on QoL, which is manifested in disposable income, retirement wages, cognitive function and leisure social activities. Additionally, psychological support and sensory ability have no significant impact on QoL; however, the latter can improve QoL indirectly by changing the physical health of centenarians.

**Conclusions** This paper provides a good empirical case for deeply understanding quality of life in centenarians and provides evidence for policies supporting healthy aging and active aging.



**Keywords** Centenarians • Quality of life • Factor analysis • Structural equation modelling • Nanjing


# Introduction

Centenarians, as a special group of the oldest-old people, have emerged as an important feature of the “age of longevity” (Magnolfi et al. 2009). According to the United Nations Population Division, the number of centenarians will remarkably increase by approximately 18 times, from 18,000 in 2000 to 3.2 million by 2050 (United Nations 2019). As they are regarded as a model of successful or healthy aging (Gu and Feng 2015; Gu and Feng 2018), information about their health status is important for predicting their medical needs and designing effective services and health care programs (Selim et al. 2005). Numerous previous studies have confirmed that multiple factors, such as socioeconomic status (Gu and Zeng 2001; Zhao et al. 2018; Kim and Kim 2016), environment (Liu et al. 2014), lifestyle (Pes et al.

2013), education (Bossuyt et al. 2004), and even political atmosphere (Xinming et al. 2010), are important to longevity. However, some scholars have noted that living longer does not mean living well, and in some countries, health tends to decline while life expectancy increases (Crimmins & Hiram 2011). Indeed, the social reality in China of "getting old before getting rich" has spurred policy measures to improve the quality of life (QoL) of elderly individuals lacking material security. Therefore, how to address the socio-economic impact of aging, improve the QoL of centenarians, and achieve healthy aging and active aging have become the focus of social attention (Qiao 2009; Engberg et al. 2009).

The concept of quality of life (QoL) first appeared in the American economist Galbraith's "The Affluent Society" as a way to conceptualize people's enjoyment of life, access to service facilities and spiritual enjoyment and fun (Feng & He 1992). Since then, the study of QoL has gradually attracted attention in sociology, psychology, economics and other disciplines. In terms of a theoretical framework, the American economist Rostow first elaborated a theoretical system for QoL in his book "Politics and the Stages of Growth", arguing that when economic growth satisfies material needs and then produces demand for intangible products (services and spiritual life), which is the process of improving QoL (Yi 1998). Lawton proposed a theoretical framework for "the good life" and attempted to assess four aspects of life that can be evaluated objectively (behavioral competence and the external environment) and subjectively (perceived quality of life and psychological well-being). This conception is consistent with the breadth of the World Health Organization's (WHO) definition of health as "a state of complete physical, mental, and social well-being, not merely the absence of disease or infirmity" (Lawton 1983). As the research deepens, some scholars began to focused on QoL and its determinants in older people. For example, Farquhar reported that older people identified health, family relationships, physical activities, living standards, and other social contacts as important to improving their QoL (Farquhar 1995). Studies by Gallicchio have shown that poor social networks are associated with poor physical and mental health; other factors, such as insufficient funds and poor housing conditions were also important factors in the deterioration of QoL (Gallicchio et al. 2007). In addition, scholars have noted that the activities of daily living (ADL), physical health and social skills of centenarians are weaker than those of elderly individuals in general, especially in terms of adaptability, resistance and self-care ability, which greatly affects their QoL (Gu and Feng 2015; Gu and Feng 2018). For instance, Takayama reported for a Japanese centenarian sample that approximately one-third of the centenarians were totally physically dependent,

and a quarter of the centenarians in their study functioned independently (Takayama 2007). The Georgia Centenarian Study also indicated that centenarians have much lower levels of activities of daily living functioning than younger age groups (Martin 1996). Non-centenarian studies have shown that the QoL of elderly individuals with somatic chronic disease is lower in all dimensions than in those without somatic disease (Jia et al. 2004). Sensory impairment is common among the oldest-old population; for instance, the Georgia Centenarian Study reported that 75% had some level of visual impairment (Toyoshima et al. 2017). Cimarolli and Jopp provided evidence that having a vision impairment alone and having vision and hearing impairment were powerful predictors of functional disability (Cimarolli & Jopp 2014). Furthermore, substantial decline is also prominent in the cognitive domain among centenarians. The prevalence of cognitive impairment among centenarians ranges from 40% to 60% (Andersen-Ranberg et al. 2001; Gondo et al. 2006). The above studies show that physical and mental health have an important impact on the QoL of centenarians, and studied of centenarians in China have reached similar conclusions (Wu et al. 1998; Zhen & Jiang 1998; Wang et al. 2017). These studies undoubtedly provide us with a basis for research on the QoL of centenarians.

It is concluded that in terms of the perceived quality of life (QoL) of centenarians, no authoritative definition has been established that is generally accepted by the theoretical community. At present, the research on QoL studies objective quality of life, focusing on social conditions and material levels, and subjective quality of life, focusing on human attitudes, feelings, and expectations (Tian et al. 2015). Such research is limited to evaluation by survey reports and scoring forms. Quality of life has not been explored in depth by constructing a comprehensive multi-dimensional indicator system. The standards of QoL for centenarians in different regions, of different genders and from different cultures are also very different. With changes in social and economic structures, the connotation of QoL for centenarians will also change accordingly. Jiangsu Province became an aging society in 1986, four years ahead of the rest of China. According to the “Jiangsu Province 2017 elderly population information and status report on the development of the elderly”, at the end of 2016, Jiangsu had a total of 6,026 centenarians, an increase of 535 over the previous year, or 7.72 per 100,000 people. Nanjing has a registered population of 6.8197 million, of whom 320 are centenarians. As the country’s first capital to become an aging society, Nanjing has the economic and social development conditions to better cope with the challenges of population aging and promote healthy aging and active aging. In view of this, based on the data of the “Nanjing Centenarians Survey” conducted in 2018, this paper constructs a comprehensive evaluation index system

for QoL in centenarians and uses factor analysis and structural equation modelling to analyze the logical relationship between factors in different dimensions. To enrich the research results on QoL and health and longevity, this study provides policy recommendations for a society characterized by healthy aging and active aging.

# Methods

## Participants

The baseline 2018 "Nanjing Centenarian Survey" included 185 elderly people aged 100 years and older with identity cards from 11 municipal districts in Nanjing (Xuanwu District, Qinhuai District, Jianye District, Gulou District, Pukou District, Qixia District, Yuhuatai District, Jiangning District, Luhe District, Lishui District, Gaochun District). Before the formal household survey, we used a qualitative research method based on in-depth interviews. Several pre-surveys were conducted from November 2017 to March 2018 to examine whether the questionnaire had any ambiguity or meaning omissions for the interviewees, and to modify and supplement it. The official household survey period was from June to September 2018. The inclusion criteria for participating in the study where: currently living in Nanjing and household registration showing an age of 100 years old or older (referred to as centenarians) by April 30, 2018. Ultimately, 275 elderly people aged 100 and older were registered. As a group with abnormal physical function, centenarians are at risk of sudden death or natural death, coupled with other social factors. During the investigation, 90 elderly people failed to complete the survey due to death (19), migration (23), poor health (48), and the actual number of surveys collected was 185 (There are 36 people in Qinhuai District, 30 in Gulou District, 20 in Luhe District, 27 in Xuanwu District, 15 in Qixia District, 12 in Jianye District, 11 in Jiangning District, 8 in Gaochun District, 8 in Pukou District, 6 in Lishui District and 4 in Yuhuatai District) (Table 1).

**Table 1** Individual and family attribute characteristics of the sample (*N*=185)

| Variable | Option | Number of people | Ratio/% | Variable | Option | Number of people | Ratio/% |
|---|---|---|---|---|---|---|---|
| Sex | Male (1) | 46 | 24.86 | Education level | Primary and below (1) | 141 | 76.22 |
| | Female (2) | 139 | 75.14 | | Junior high school (2) | 13 | 7.03 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Age | 100-105 (1) | 175 | 94.59 | | Secondary (3) | 11 | 5.95 |
| | >105 (2) | 10 | 5.41 | | Undergraduate (4) | 18 | 9.73 |
| Nation | Han nationality (1) | 182 | 98.38 | | Postgraduate and above (5) | 2 | 1.08 |
| | Non-Han nationality (2) | 3 | 1.62 | Marriage | Unmarried (1) | 3 | 1.62 |
| Household type | Rural (1) | 40 | 21.62 | | Getting married (2) | 7 | 3.78 |
| | Urban (2) | 145 | 78.38 | | Divorce (3) | 3 | 1.62 |
| Living arrangement | Living alone (1) | 16 | 8.65 | | Widowed (4) | 172 | 92.97 |
| | Living with a spouse/children (2) | 138 | 74.59 | Annual income | <10000 CNY (1) | 67 | 36.22 |
| | Living with others (3) | 16 | 8.65 | | 10000-30000 CNY (2) | 59 | 31.89 |
| | Living in an institution (4) | 15 | 8.11 | | >30000 CNY (3) | 59 | 31.89 |

Note: assignment in parentheses

# Index system and variable measurement

The World Health Organization (WHO) first proposed the concept of "healthy aging" at the Copenhagen Conference in September 1990, identifying three criteria for healthy aging: physical health, mental health, and social adaptation (Wu & Jiang 1996). Subsequently, in response to the emerging challenges of population aging, the idea of "active aging" was put forward in 1999, namely, older groups and older individuals could realize their potential for physical, social, and mental well-being throughout the life course and could participate in society according to their needs, desires, and capacities and receive adequate protection, security, and care when they required assistance (Yang 2009). Based on a theoretical framework incorporating "healthy aging" and "active aging", this study considers the group specificity of centenarians and, by selecting scientific, comparable and accessible indicators, a comprehensive multi-dimensional evaluation index system for the quality of life of centenarians is constructed with four dimensions: physical health (PH), cognitive and psychological health (CPH), family social relations (FSR), and socioeconomic security (SE) (Table 2) (Feng & He 1992; Zeng & Gu 2002; Tian et al. 2013).

**Table 2** Evaluation index system of quality of life for centenarians

| Target layer | Latent variable | Observation variables | Variables | Variable range |
|---|---|---|---|---|
| Quality of life in centenarians (QOL) | Physical health (PH) | Life self-care ability (ADL) | $X_1$ | Needing assistance in any one of the six tasks (1), needing some help (2), needing no assistance in any of the six tasks (3) |
| | | Self-rated health | $X_2$ | Poor body (1), general body (2), good body (3) |
| | | Hearing | $X_3$ | Major obstacles (1), some obstacles (2), and no obstacles (3) |
| | | Vision | $X_4$ | Major obstacles (1), some obstacles (2), and no obstacles (3) |

| | | | |
|---|---|---|---|
| Cognitive and Psychology health (CPH) | Cognition function | $X_5$ | Unable to answer (1), partial can (2), can answer (3) |
| | Loneliness | $X_6$ | Always/often (1), sometimes (2), seldom/almost never (3) |
| | Depression levels | $X_7$ | Always/often (1), sometimes (2), seldom/almost never (3) |
| Family social relations (FSR) | Leisure activities | $X_8$ | Low (1), medium (2), high (3) |
| | Whom do you want to tell in advance | $X_9$ | No one (1), others (2), family members (3) |
| | Who helps you solve problems | $X_{10}$ | No one (1), others (2), family members (3) |
| | Living arrangement | $X_{11}$ | Others (1), living with family members (3) |
| Socioeconomic security (SE) | Disposable income | $X_{12}$ | Low (1), medium (2), high (3) |
| | With or without retirement | $X_{13}$ | Without (1), With (3) |
| | A major occupation before 60 years old | $X_{14}$ | Unemployed (1), business and service personal, agriculture, forestry, animal husbandry and fishermen, production workers (2), professionals/ doctors/ teachers, administration and staff, military personnel (3) |
| | Education level | $X_{15}$ | No upper school (1), primary school (2), junior high school and above (3) |

The measurement criteria for each dimension of quality of life are as follows:

(1) Physical health. Physical health includes activities of daily living, self-rated health and sensory ability. Activities of daily living (ADL) are measured by the self-reported ability to perform six daily activities (bathing, dressing, toileting, indoor transferring, continence, and eating). Following the common practice in the field, we weighted the average score of the six questions, divided the interviewees into three categories, and assigned values according to the results obtained (needing no assistance in any of the six tasks=3, needing some help=2, and needing assistance in any one of the six tasks=1) (Gu et al. 2017). Sensory ability includes both hearing and visual function. It was divided into three groups (major obstacles=1, some obstacles=2, and no obstacles=3). Self-rated health was measured by the question “What is your overall assessment of your own health compared to the past year?”. Responses were given on a 5-point Likert scale ranging from 1-5, and there was an “unanswerable” option. To retain as many samples as possible, the analysis does not eliminate “unanswerable” responses but treats them as missing values and interpolates them by linear interpolation in multiple imputation, which assumes that people with the same demographic and social characteristics in terms of economic status, family and social support, and health behaviors give similar responses. After imputation, as the following codes were applied: 1-2 for poor health=1; 3 for general health=2, and 4-5 for good health=3.

(2) Cognitive and psychological health. Cognitive function was measured by a validated Chinese version of the Mini-mental State Examination (MMSE), which includes six domains of cognition (orientation, reaction, calculation, short-term memory, naming, and language). According to whether the

168 respondent can answer the presented questions, they are divided into three categories (unable to
169 answer=1, partially can=2, and can answer=3). Psychological health includes loneliness and depression
170 levels. Loneliness and depression levels are measured by “Did you feel lonely?”, and “Did you feel
171 depressed last month?”, respectively. Responses are given on a 5-point Likert scale ranging from 1-5,
172 with an “unanswerable” option. “Unanswerable” responses were treated similarly to those of self-rated
173 health.

174 (3) Family and social relationships assessed by asking respondents who they want to tell in advance,
175 who help them solve problems or difficulties, what their living arrangements are, and what leisure
176 activities they participate in. Responses to the first questions are divided into three groups (no one=1,
177 others=2, and family members=3). Living arrangements are divided into two types (living with family
178 members=3 and others=1). Leisure activities are measured by the sum frequency scores for 12 activities
179 (no participation=1, sometimes=2, at least once a month=3, at least once a week=4, and everyday=5),
180 including doing housework, exercising, visiting the garden, planting flowers and grass, and reading
181 newspapers. All samples were divided into three groups: low (<12), medium (12-18), and high (>18).

182 (4) Socioeconomic security include education level, disposable income, major occupation and
183 retirement wages. Education level is divided into no upper school=1, primary school=2, and junior high
184 school and above=3. Disposable income in the previous year was divided into three groups: low
185 (<10000CNY), medium (10000-30000CNY), and high (>30000CNY). There are 9 occupational types:
186 professionals/doctors/teachers, administration and staff, business and service personnel, agricultural
187 workers, forestry workers, animal husbandry and fishery workers, production workers, military
188 personnel, other laborers difficult to classify, and unemployed. Among them, unemployed=1; business
189 and service personnel, agricultural workers, forestry workers, animal husbandry and fishery workers, and
190 production workers=2; and professionals/doctors/teachers, administration and staff, and military
191 personnel=3.

192 In addition to the above 15 exogenous observed variables, 4 endogenous observed variables, life
193 satisfaction, happiness, economic satisfaction, and housing satisfaction, were measured by items
194 assessing “your overall life satisfaction”, “your happiness”, “your family financial situation”, and “your
195 housing satisfaction”. The response categories for these items were always, often, sometimes, seldom,
196 almost never and never.

# Methods

## Exploratory factor analysis

We first use factor analysis to comprehensively evaluate the quality of life of centenarians. The basic steps are as follows: (1) According to the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity, it is judged whether the observed variable is suitable for factor analysis. The principle is to compare the correlation coefficient between the observed variables and the relative magnitude of the partial correlation coefficient. The range of the value is [0, 1], and when the KMO value is large, it is suitable for factor analysis. (2) The feature variables are extracted from the correlation matrix, the variance contribution rate of each variable in each factor is determined by rotation, and the number of factors and the variables loading on the same factor are determined. (3) Factor rotation is performed according to the maximum variance method; the common factor is extracted with an eigenvalue greater than 1 as the standard, and the items with factor loadings less than 0.5 or extraction common degrees less than 0.4 are excluded. (4) Finally, the weighted average of the main factor variance contribution rate is determined to obtain a comprehensive evaluation model of life quality for centenarians.

## Structural equation modelling (SEM)

Considering that quality of life is a multi-dimensional concept, its influencing factors include several variables that are not directly observable and measurable but can be measured indirectly through other observed variables. The structural equation model is a complex multivariate relationship modelling tool for comprehensive analysis of variance, regression analysis, path analysis and factor analysis. It allows measurement errors between independent variables and dependent variables to effectively overcome traditional research methods. Thus, based on the results of factor analysis, this paper uses structural equation modelling to model and analyze the factors affecting quality of life.

The structural equation model includes two parts: the measurement model and the structural model. The measurement model reflects the relationship between the latent variable and the observed variable. The expression is:

$$y = \Lambda_y \eta + \varepsilon \tag{1}$$

$$x = \Lambda_x \xi + \delta \tag{2}$$

where $y$ is an endogenous relational variable group. $\Lambda_y$ is the factor loading matrix of endogenous observed variables on endogenous latent variables, reflecting the relationship between endogenous observed variables and endogenous latent variables. $\eta$ is an endogenous latent variable. $x$ is an exogenous relational variable group. $\Lambda_x$ is the factor loading matrix of exogenous observed variables on exogenous latent variables, reflecting the relationship between exogenous observed and exogenous latent variables. $\xi$ is an exogenous latent variable. $\varepsilon$ and $\delta$ are the residual terms of the measurement model, that is, the parts that cannot be explained by the latent variables.

The structural model reflects the relationship between latent and observed variables. The expression is:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

where $B$ is the relationship between endogenous latent variables. $\Gamma$ is the relationship between exogenous latent variables. $\zeta$ is the residual term of the equation.

# Qualitative research

Qualitative research is an activity in which researchers use themselves as research tools, adopt a variety of data collection methods in a natural context to conduct a holistic study of social phenomenon, and interact with research objects to obtain an interpretative understanding of their behavior and meaning construction (Chai 2010). This method focuses on the narrative as the material, the inductive method as the argumentation step, and the constructivism as the premise. The strength of this method lies in the importance of individual experience and feelings, and its material source is more reliable, real, rich and vivid, with strong explanatory power and credibility. In this paper, based on qualitative research, the in-depth interview method is used to obtains relevant data and uses it as a supplementary material to explain the quantitative results, so as to achieve the complementary combination of quantitative research and qualitative research.

# Results

## Quality of life evaluation

### Factor analysis

To ensure the authenticity and reliability of the questionnaire data, the reliability and validity of the 15 variables affecting the quality of life of centenarians were first tested. The reliability test yielded a Cronbach's α coefficient of 0.683, which is close to the criterion of greater than 0.700, indicating that the internal consistency of the data was acceptable. The KMO test and Bartlett's test of sphericity were used to test the validity. The results showed that the KMO value was 0.716, which is greater than 0.700. Bartlett's test of sphericity yielded 0.000, which is less than 0.050, indicating that the data correlation was good and suitable for factor analysis.

The initial factor analysis showed that the cumulative variance contribution rate was 61.062%, and the loading of "self-rated health" on each factor was less than 0.5. To improve the factor analysis results, this item was deleted. The KMO test and Bartlett's tests of sphericity were performed on the remaining variables, and the results were 0.717 and 0.000, respectively, indicating suitability for factor analysis. The principal component extraction common factor was used, the maximum variance method was selected for factor rotation, and eigenvalues greater than 1 were used to extract 5 principal factors. The cumulative contribution rate reached 63.769%. The factor component matrix was then rotated to obtain a factor loading matrix to illustrate the importance and contribution of each indicator to the principal factor (Table 3) (Tian et al. 2015).

**Table 3** Rotating factor load matrix

| Objective variables | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Who helps you solve problems $X_{10}$ | 0.856 | -0.030 | -0.007 | -0.047 |
| Whom do you want to tell in advance $X_9$ | 0.835 | 0.033 | 0.104 | 0.040 |
| Loneliness $X_6$ | 0.829 | 0.054 | 0.027 | -0.013 |
| Depression levels $X_7$ | 0.775 | 0.025 | -0.026 | 0.059 |
| Living arrangement $X_{11}$ | 0.554 | -0.114 | 0.071 | -0.526 |

| | | | | |
|---|---|---|---|---|
| Disposable income $X_{12}$ | 0.031 | 0.802 | 0.055 | 0.019 |
| With or without retirement $X_{13}$ | 0.148 | 0.797 | -0.011 | 0.014 |
| A major occupation before the age of 60 $X_{14}$ | 0.001 | 0.752 | -0.032 | 0.002 |
| Education Level $X_{15}$ | -0.130 | 0.712 | 0.018 | 0.112 |
| Life self-care ability $X_1$ | 0.084 | -0.047 | 0.828 | -0.222 |
| Leisure activities $X_8$ | -0.070 | 0.088 | 0.760 | 0.092 |
| Cognition function $X_5$ | 0.037 | 0.081 | 0.694 | 0.358 |
| Vision $X_4$ | 0.130 | -0.176 | 0.517 | 0.399 |
| Hearing $X_3$ | 0.044 | 0.113 | 0.180 | 0.833 |

Table 3 shows that "Who help you solve problems ($X_{10}$)", "Whom do you want to tell in advance ($X_9$)", "Loneliness ($X_6$)", "Depression levels ($X_7$)", and "Living arrangement ($X_{11}$)" are heavily loaded on the principal component $F_1$, which was therefore called psychological support. "Disposable income ($X_{12}$)", "With or without retirement ($X_{13}$)", "A major occupation before the age of 60 ($X_{14}$)", and "Education level $X_{15}$" heavily loaded on the principal component $F_2$, which was named socioeconomic security. "Life self-care ability ($X_1$)", "Leisure activities ($X_8$)", and "Cognition function ($X_5$)" heavily loaded on the principal component $F_3$, which was named physical health. "Vision ($X_4$)" and "Hearing ($X_3$)" loaded heavily on the principal component $F_4$, which was named sensory ability.

According to the score coefficient matrix of each factor (Table 4), the formulas for psychological support factor $F_1$, socio-economic factor $F_2$, physical health factor $F_3$, and sensory ability factor $F_4$ can be obtained as follows:

$$F_1 = -0.031X_1 + 0.062X_3 + 0.045X_4 + 0.000X_5 + 0.272X_6 + 0.262X_7 - 0.058X_8 + 0.274X_9 + 0.281X_{10} + 0.145X_{11} + 0.001X_{12} + 0.043X_{13} - 0.005X_{14} - 0.044X_{15} \quad (4)$$

$$F_2 = 0.008X_1 - 0.019X_3 - 0.102X_4 + 0.013X_5 + 0.016X_6 - 0.002X_7 + 0.040X_8 + 0.004X_9 - 0.018X_{10} - 0.009X_{11} + 0.336X_{12} + 0.332X_{13} + 0.315X_{14} + 0.291X_{15} \quad (5)$$

$$F_3 = 0.479X_1 - 0.066X_3 + 0.189X_4 + 0.300X_5 - 0.026X_6 - 0.066X_7 + 0.392X_8 + 0.004X_9 - 0.041X_{10} + 0.108X_{11} + 0.034X_{12} - 0.006X_{13} - 0.008X_{14} + 0.003X_{15} \quad (6)$$

$$F_4 = -0.336X_1 + 0.659X_3 + 0.259X_4 + 0.162X_5 + 0.037X_6 + 0.106X_7 - 0.081X_8 + 0.069X_9 + 0.024X_{10} - 0.408X_{11} - 0.058X_{12} - 0.041X_{13} - 0.053X_{14} + 0.024X_{15} \quad (7)$$

**Table 4** Factor score coefficient matrix

| Objective variables | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |

| | | | | |
|---|---|---|---|---|
| $X_1$ | -0.031 | 0.008 | 0.479 | -0.336 |
| $X_3$ | 0.062 | -0.019 | -0.066 | 0.659 |
| $X_4$ | 0.045 | -0.102 | 0.189 | 0.259 |
| $X_5$ | 0.000 | 0.013 | 0.300 | 0.162 |
| $X_6$ | 0.272 | 0.016 | -0.026 | 0.037 |
| $X_7$ | 0.262 | -0.002 | -0.066 | 0.106 |
| $X_8$ | -0.058 | 0.040 | 0.392 | -0.081 |
| $X_9$ | 0.274 | 0.004 | 0.004 | 0.069 |
| $X_{10}$ | 0.281 | -0.018 | -0.041 | 0.024 |
| $X_{11}$ | 0.145 | -0.009 | 0.108 | -0.408 |
| $X_{12}$ | 0.001 | 0.336 | 0.034 | -0.058 |
| $X_{13}$ | 0.043 | 0.332 | -0.006 | -0.041 |
| $X_{14}$ | -0.005 | 0.315 | -0.008 | -0.053 |
| $X_{15}$ | -0.044 | 0.291 | 0.003 | 0.024 |

## Comprehensive evaluation model construction

To investigate the quality of life of centenarians in Nanjing, quantitative analysis and comprehensive analysis were carried out, and the composite index was calculated by weighting the contribution rate of each common factor:

$$F = 0.221F_1 + 0.174F_2 + 0.148F_3 + 0.095F_4 \quad (8)$$

where $F$ is the comprehensive score of the quality of life and $F_1$, $F_2$, $F_3$, and $F_4$ are the common factor scores calculated by formulas (4), (5), (6), and (7). The higher the F value, the better the quality of life of the centenarians.

## Overall evaluation of quality of life

The average quality of life of centenarians in Nanjing was 1.518. Among the 185 centenarians, 94 had a higher quality of life index than the average, and 91 were below the average. This shows that the quality of life of centenarians in Nanjing was generally at a medium level. The highest score was 2.020, and the lowest score was 0.917. The centenarians with the highest scores have urban hukou (registered permanent residence) and received a good education from an early age. Their cognitive state is very good, and they can perceive time, temperature and space clearly and quickly. Their hearing and eyesight are very good and they love to read newspapers, watch TV, and chat with people, and they care about national

events. In terms of life activities, they can get ready for bed, dress, and eat independently. They have a retirement salary of nearly CNY 10,000 per month, their medical expenses are fully reimbursed, and the family provide a caregiver. The overall quality of life is very high for such centenarians. The centenarians with the lowest scores have a rural hukou (registered permanent residence). They have lived in a house provided by the church for more than 30 years. They have serious hearing impairment and cannot communicate with others. They have no friends and cannot take care of themselves. They rely on the old-age subsidy provided by the government, and their overall quality of life is very poor.

By using the ArcGIS10.0, the average quality of life of centenarians in 11 districts of Nanjing was calculated and found to be gradually decreasing from the central city to the periphery. Among them, the quality of life in Jianye District is the highest (1.625), and the quality of life in Lishui District is the lowest (1.317). There are 7 districts higher than the city's average, namely Jianye District (1.625), Jiangning District (1.589), Yuhuatai District (1.566), Xuanwu District (1.558), Qinhuai District (1.554), Qixia District (1.530), Gulou District (1.526), both of which are the central urban area with 5 kilometer circle and the suburbs with 15 kilometer circle. The quality of life in six districts of Luhe District (1.465), Gaochun District (1.384), Pukou District (1.352), and Lishui District (1.317) was lower than the city's average (Figure 1).

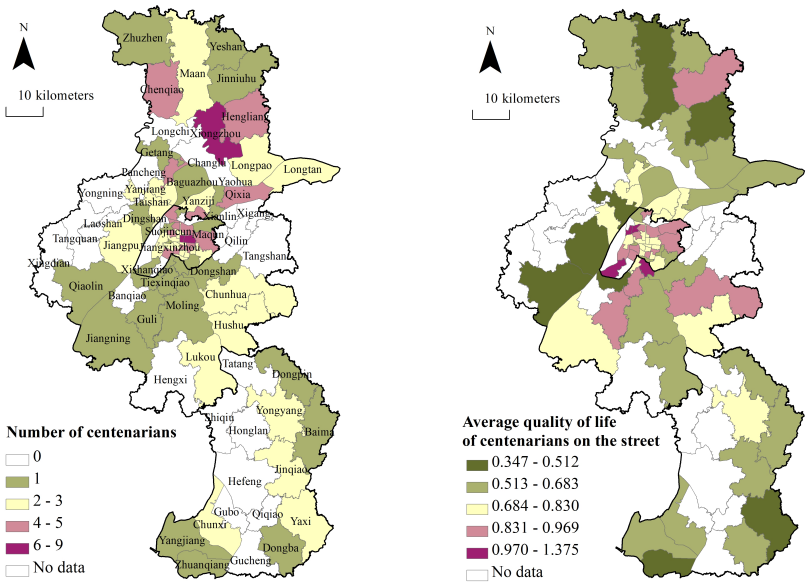


**Fig. 1** Spatial distribution of quality of life of centenarians in streets, 2018

# Analysis of the factors influencing quality of life

The above exploratory factor analysis shows that there are four dimensions factors influencing quality of life: psychological support, socioeconomic status, physical health, and sensory ability. Based on this, an initial model of quality of life among centenarians was constructed. The model consisted of 5 latent variables, 14 exogenous observed variables, and 4 endogenous observed variables (Figure 2). Therefore, this study proposes the following hypotheses:

$H_1$: Good psychological support has a significant positive impact on quality of life;

$H_2$: Good socioeconomic security has a significant positive impact on quality of life;

$H_3$: Good physical health has a significant positive impact on quality of life; and

$H_4$: Good sensory ability has a significant positive impact on quality of life.

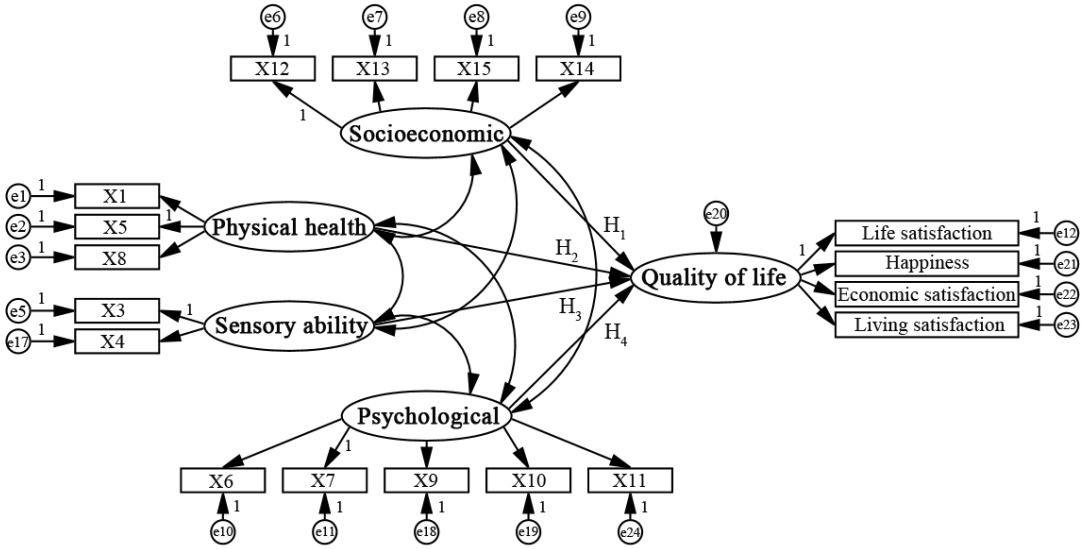


**Fig. 2** Initial model of quality of life

# Model fitting and correction

We use AMOS 21.0 to perform confirmatory factor analysis on the initial model. The results show that, except for the satisfaction with the living environment, the normalized loading of all the other observed variables is between 0.455 and 0.851, which satisfies the standard of more than 0.400, indicating that the impact of the observed variables in the quality of life model on specific structural variables is significant and can explain the corresponding potential variables well. The maximum

likelihood estimation method is used to test the fitness of the hypothesized model (Table 5). The results show that the goodness-of-fit index (GFI), modified goodness-of-fit index (AGFI), norm-fit index (NFI), comparative-fit index (CFI), and incremental-fit index (IFI) do not reach the ideal value (0.900). According to the modification index (MI), we found that by increasing the relationship between latent variables e8 and e9, e10 and e17, e22 and e23, and e8 and e22, we can reduce the chi-square values of 22.289, 15.732, 13.595, and 12.006, respectively, and increase the *P* value to yield a more ideal structural model. After the correction, though the GFI, the AGFI and the NFI were slightly lower than 0.900, the chi-square degrees of freedom ratio ($x^2$/df), approximate root mean square residual (RMSEA), CFI, and IFI reached the standard of 0.900, indicating that the overall goodness of fit of the model is acceptable. Thus, it was taken as the final model (Figure 3).

**Table 5** Quality of life structural model fit test

| Fitting index | $x^2$/ *df* | *GFI* | *RMSEA* | *AGFI* | *NFI* | *CFI* | *IFI* | *ACI* | *CAIC* |
|---|---|---|---|---|---|---|---|---|---|
| Ideal value | 1~3 | >0.900 | <0.100 | >0.900 | >0.900 | >0.900 | >0.900 | The smaller the better | The smaller the better |
| Hypothetical model | 2.178 | 0.858 | 0.080 | 0.806 | 0.766 | 0.854 | 0.858 | 364.307 | 558.443 |
| Modified model | 1.680 | 0.890 | 0.061 | 0.844 | 0.825 | 0.919 | 0.921 | 303.305 | 514.323 |

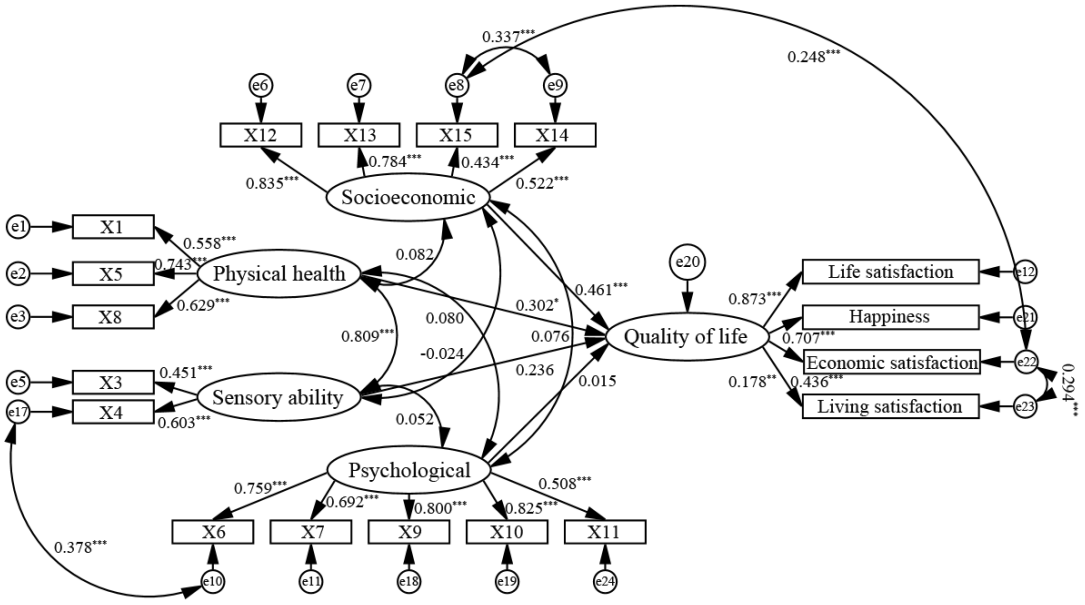


**Fig. 3** Results of structural equation model in quality of life

## Reliability and validity test

The results showed that the overall reliability of the 14 exogenous observed variables was Cronbach's α = 0.667, which is close to the criterion of greater than 0.700, indicating that the overall validity of the questionnaire is acceptable. The reliability test is carried out for each of the four latent variables. Except for that of the sensory ability latent variable, the Cronbach's α value of the other latent variables ranged from 0.686 to 0.820, which is greater than 0.5, indicating that each measurement item is credible (Qian 2014). With sensory ability included, the combined reliability is slightly lower than the standard value (0.600), and other observed variables can explain the corresponding potential variables more effectively. Although the average variation of the three latent variables of psychological support, socioeconomic security, and physical health is less than the 0.5 threshold, it is close to 0.5, so the model is acceptable (Fornell & Larcker 1981) (Table 6).

**Table 6** The results of the reliability and validity of model

| Latent variables | Observation variables | Standardized factor load | Reliability | Combinational reliability (CR) | Average variation extraction (AVE) |
|---|---|---|---|---|---|
| Psychological support | Who helps you solve problems | 0.711 | 0.820 | 0.803 | 0.450 |
| | Whom do you want to tell in advance | 0.736 | | | |
| | Loneliness | 0.690 | | | |
| | Depression levels | 0.605 | | | |
| | Living arrangement | 0.602 | | | |
| Socioeconomic security | Disposable income | 0.648 | 0.743 | 0.696 | 0.365 |
| | With or without retirement | 0.657 | | | |
| | A major occupation before the age of 60 | 0.567 | | | |
| | Education level | 0.536 | | | |
| Physical health | Cognitive function | 0.618 | 0.686 | 0.692 | 0.431 |
| | Leisure activities | 0.598 | | | |
| | Self-care ability | 0.744 | | | |
| Sensory ability | Vision | 0.741 | 0.471 | 0.546 | 0.387 |
| | Hearing | 0.474 | | | |

Note: Combinational reliability $(CR)=\left((\sum\lambda)^2\right)/\left((\sum\lambda)^2+\sum\delta\right)$, Average variation extraction $(AVE)=\left(\sum\lambda^2\right)/n$, where $\lambda$ and $\delta$ are the factor load amount and error variation, respectively, and $n$ is the number of measurement indicators.

## Model result interpretation

The model results show that socioeconomic factors have a significant positive impact on quality of life ($P < 0.001$), and their impact effect is the largest (Figure 2). For every unit increase in social and economic conditions, the quality of life will increase by 0.461 units; thus, $H_2$ is established. Socioeconomic conditions are an important prerequisite for improving the quality of life of centenarians. Most centenarians were born in the early twenties of the last century, with a relatively low level of social occupation and a relatively small amount of retirement pay, which has a certain impact on their consumption structure and consumption level. Studies have shown that older people require five times more special care and medical support than the average older person, and their per capita medical costs are nearly three times higher than those of younger adults (Yang & Wen 2014). Adequate social and economic support can enable centenarians to obtain more social support resources, such as medical care, health care, and entertainment, which contribute to the improvement of quality of life. Among the socio-economic factors, retirement wages, disposable income and major income sources have the greatest impact, with interpretation values of 0.835, 0.784, and 0.522, indicating that retirement wages and income sources are the key factors affecting the quality of life of centenarians in Nanjing. Therefore, the satisfaction of the living needs of centenarians must be based on social conditions and is an important guarantee for improving their quality of life. The quality of life of interviewees A and C was high, and the quality of life of interviewee B was poor. The following statement were made by them or their children:

*"I was born in Yizheng, graduated from junior high school, and worked at Luhe Middle School in Yangzhou in 1958. Now I have a pension of 4000 yuan a month, plus a subsidy of 5000 yuan a month, there is no burden in life, and I am still satisfied with my own life."*

*——(Interviewee A) daughter answered*

*"I was born in the countryside and never went to school. I worked in agriculture all my life. I have no job, no pension, daily mainly rely on the government's old age subsidy, but the church provides me with rice and oil, life can basically be self-sufficient. If I were rich, I would choose to spend my money on food and clothing."*

*——(Interviewee B) daughter answered*

*"I had a job when I was young, and I did not retire until the age of 80. I have always had a stable income. Now that I am retired, I have a pension of nearly 10,000 RMB a month, and I also enjoy a special allowance from the State Council. I also give appropriate subsidies in the community. At ordinary times, I also speculate in stocks, manage financial management and daily living expenses, and I am not worried about my livelihood."*

*——(Interviewee C) daughter-in-law answered*

Physical health also has a positive effect on quality of life ($P < 0.1$), and the impact effect is second only to that of socioeconomic security. For each additional unit of physical health, quality of life increases by 0.302 units; thus, $H_3$ is established. Older people with good physical health have stronger resilience and adaptability, can quickly sense and cope with emergencies encountered in life, have reduced risk of disease and death, and have better quality of life. In the physical health dimension, cognitive function has the greatest impact on quality of life, with an explanatory power of 0.743, followed by leisure activities (0.629) and self-care ability (0.558). Cognitive impairment is common among centenarians. Older people with good cognitive function can positively perceive their surroundings, which is crucial in terms of the psychological and physiological effects of old age, thereby reducing the risk of disease, disability and mortality, and improving their quality of life. Leisure and physical activities imply regular commitments, membership and sense of belonging, and social integration, which may stimulate multiple bodily functions (e.g., cognitive, cardiovascular, and neuromuscular), protect against cognitive decline, bolster active coping strategies, and, in turn, lower the risk of mortality. Furthermore, leisure activities can cushion the negative impact of certain unfortunate events and provide opportunities to successfully meet the challenges of daily life (Von 2016; Wolff et al. 2014). In contrast, no leisure activities may lead to a sense of loneliness, abandonment and a negative perception of aging, which reduces quality of life. Centenarians with strong self-care ability can cope with unexpected events in daily life. In turn, they have stronger adaptability, resistance and resilience and effectively reduce the probability of disability. Studies have shown that the incidence of dementia in elderly individuals between 65 and 85 has risen sharply. Most centenarians have moderate to severe cognitive impairment, which affects their physiological functions to varying degrees, thus affecting their quality of life (Jopp et al. 2016). Interviewees A and D had high quality of life and were engaged in physical health activities:

*"The old man is usually very strong, for nearly 20 years has not had a physical examination, and*

*in his current life is fully able to take care of himself. Usually likes to watch the news, cares about current events, likes to clean things up. Now the cognition is also very good, knows that he usually cannot use the gas stove at home, because he is old, in case he forgets to turn off the fire it will be very dangerous, cannot be self-made to ask the nurse or son for help."*

*——(Interviewee A) daughter answered*

*"The old man cares about national affairs, current affairs, politics and bridge news, loves Beijing Opera, does not deliberately exercise, and still maintains a strong enthusiasm for learning in his later years. Although he is in bed and his hearing is not good, he knows that he is unwilling to trouble his children and has hearing aids, but only for those who seem important people will he wear them."*

*——(Interviewee D) son answered*

Sensory ability and psychological support have a weak effect on quality of life and are not significant. Thus, $H_3$ and $H_4$ are not established, indicating that centenarians with good sensory ability and strong psychological support do not necessarily have a higher quality of life. Related studies have also shown that although centenarians complain that they do not exercise enough or are unable to take care of themselves, few centenarians exhibit depression and anxiety (Buono et al.1998). Because centenarians mostly live with other people or have special care, they are better adapted to the surrounding environment and have a good attitude, their probability of depression or loneliness is low, and their difficulties in life can be solved for them in a timely manner. Among them, "Whom do you want to tell in advance" and "who helps you solve problems in advance" had the greatest impact on psychological support, with explanatory power of 0.800 and 0.825, respectively, indicating that these two items had a significant effect on the psychological support of the elderly. It is very important for centenarians to be able to effectively relieve psychological stress and solve living difficulties when necessary. The following interviewees showed similar psychological characteristics:

*"The old man has a very good state of mind and is proud to be able to live over 100 years of age. Usually likes to be alone, keeps himself clean, but also likes it lively and is particularly happy when someone comes to see him."*

*——(Interviewee E) daughter-in-law answered*

*"The old man used to be a soldier driving tanks in the army, and when he came back as a soldier, he was driving for a bus company, but his state of mind was particularly good. His friends were not many,*

*and when he was upset, he never said anything about himself. He is not afraid to die, he is not forced to die, and his state of mind is better."*

*——(Interviewee F)*

*"The old man has been living with his children, has no good friends, does not like to chat and go out. Encounters things more openly, rarely feels lonely, afraid, nervous. He feels like he is doing well, not a burden."*

*——(Interviewee G) daughter-in-law answered*

In addition, we found a significant positive effect between physical health and sensory ability (0.863, P <0.01), that is, the sensory function of centenarians was significantly associated with cognitive impairment, self-care ability and leisure activities. Hearing and visual function are manifestations of sensory abilities and are powerful predictors of functional disability (Davey et al. 2013). A centenarian with good sensory ability can perceive time, space and the environment well and has good control over his or her own health, effectively reducing the risk of disability and mental illness and improving his or her quality of life. The vast majority of centenarians in this study had visual or hearing impairments, which may be one of the reasons why very few of them still maintained leisure activities.

# Discussion

Based on the data of the "Nanjing Centenarian Survey" conducted in 2018, the overall quality of life of centenarians was evaluated via exploratory factor analysis and structural equation modelling, and the complex relationship among the influencing factors was explored. The results show the following:

The overall quality of life of centenarians in Nanjing is at a medium level. The elderly individuals with the best and worst quality of life show significant differences in hukou (registered permanent residence) type, education level, self-care ability, sensory function, social and economic security, and leisure social activities. The quality of life of the centenarians in Nanjing shows a decreasing trend from the central city to the periphery. There are 7 districts in which the average quality of life is higher than the city's average; Jianye district has the highest average quality of life and Lishui district the lowest.

There are four factors influencing quality of life: psychological support, socioeconomic status, physical health and sensory ability. According to the size of the influence, the order of the influencing factors is socioeconomic status > physical health > sensory ability > psychological support. Social and

economic security and physical health have a significant impact on quality of life, which is embodied in disposable income, retirement wages, cognitive function, and leisure social activities. Psychological support and sensory abilities have little effect on quality of life, but this does not mean that these variables are meaningless for improving quality of life. The study found that there is a significant correlation between sensory ability and physical health, that is, sensory ability can affect quality of life by changing the physical health of the elderly. Furthermore, the role of psychological support factors has not been highlighted, to some extent, reflecting that centenarians receive better family and social support. There is no difference between the samples.

This paper systematically examines the complex relationship between socioeconomic status, physical health, sensory ability and psychological support factors and the quality of life of centenarians. The study confirms the importance of socioeconomic status and physical health for improving the quality of life of centenarians. At present, the government should give the most effective social support while reasonably assessing the socioeconomic status and physical health of the elderly to relieve the old-age burden on the elderly caused by low income and poor health. Second, the government should focus on the improvement of the urban and rural medical security system, the establishment of community and home care services and elderly care measures, and the development of the elderly family service industry. Encouraging the development of the home care industry from a policy perspective will provide psychological and spiritual comfort to the elderly, improving all aspects of the quality of life of centenarians and promoting the realization of social aging. However, there are still some shortcomings in the research. First, the number of survey samples is limited. Only centenarians in Nanjing were selected for in-depth interviews. Whether the research conclusions represent all the centenarians requires further follow-up research. Second, the influencing factors do not take into account geographical and biological factors, such as the natural environment and genetics. In the future, more sample data on centenarians are needed to conduct interdisciplinary research in the fields of sociology, geography and biology to explore the cross-effects of these mechanisms on quality of life. In addition, due to the particularity of the physiological and psychological state of the survey sample, the reliability and effectiveness of short-term tests may be affected by fatigue or sensory and cognitive impairments in the centenarians, which should be considered in the measurements. Moreover, the validity of using surrogate answers when centenarians are unable to answer directly should be considered (Poon et al. 2010). Finally, this study of the quality of life of centenarians is based on subjective evaluation. In follow-up research,

the scientific combination of a subjective evaluation system and an objective evaluation system of quality of life, such as one assessing the level of social service supply, home care, or the community environment. These factors will be more helpful in excavating and comprehensively revealing the factors influencing the quality of life of centenarians, providing suggestions for the improvement of public policy regarding pensions.

**Acknowledgments** The authors would like to thank all participants and collaborating staff who took part in the research.

**Author contribution** XX and YZ initiated, participated in the design of the study and helped in the drafting and editing of the article. XX, SX, PC, and WT prepared the database and performed the statistical analysis. XX drafted the manuscript. YX, SX, PC, WT and XH critically revised the manuscript. All the authors have read and approved the final version of the manuscript.

**Funding** This study was supported by the Key Project of the National Natural Science Foundation of China (Grant No.41430635); and National Social Science Foundation of China (Grant No. 18BRK031); Graduate Research and Innovation Projects of Jiangsu Province (Grant No. KYCX19_0758).

# Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

# References

Andersen-Ranberg, K., Vasegaard, L., & Jeune, B. (2001). Dementia is not inevitable: A population-based study of Danish centenarians. *Journal of Gerontology Series B: Psychological Sciences and Social Sciences*, 56(3), 152–159. https://doi.org/10.1093/geronb/56.3.p152.

Bossuyt, N., Gadeyne, S., Deboosere, P., & Van, O. H. (2004). Socio-economic inequalities in health expectancy in Belgium. *Public*

*Health*, 118(1), 3-10. https://doi.org/10.1016/S0033-3506(03)00130-6.

Buono, M. D., Urciuoli, O., & De, L. D. (1998). Quality of life and longevity: A study of centenarians. *Age & Ageing*, 27(2), 207-216. https://doi.org/10.1093/ageing/27.2.207.

Chai, Y. (2010). *The activity space of the elderly in Chinese cities*. Science Press, 24-26. [In Chinese]

Cimarolli, V. R., & Jopp, D. S. (2014). Sensory impairments and their associations with functional disability in a sample of the oldest-old. *Quality of Life Research*, 23(7), 1977-1984. https://doi.org/10.1007/s11136-014-0657-0.

Crimmins, E. M., & Hiram, B. (2011). Mortality and morbidity trends: Is there compression of morbidity. *Journals of Gerontology*, 66(1), 75-86. https://doi.org/10.1093/geronb/gbq088.

Davey, A., Dai, T., Woodard, J. L., Miller, L. S., Gondo, Y., Johnson, M. A., et al. (2013). Profiles of cognitive functioning in a population-based sample of centenarians using factor mixture analysis. *Experimental Aging Research*, 39(2), 1-20. https://doi.org/10.1080/0361073X.2013.761869.

Engberg, H., Oksuzyan, A., Jeune, B., Vaupel, J. W., & Christensen, K. (2009). Centenarians—a useful model for healthy aging? A 29-year follow-up of hospitalizations among 40,000 Danes born in 1905. *Aging Cell*, 8(4), 270-276. https://doi.org/10.1111/j.1474-9726.2009.00474.x.

Farquhar, M. (1995). Elderly people's definitions of quality of life. *Social Science & Medicine*, 41(10), 1439-1446. https://doi.org/10.1016/0277-9536(95)00117-P.

Feng, L., & He, J. (1992). Analysis of macroscopic method of measuring the quality of life of the population (Part 2)——Human development index. *Population & Economics*, (3), 30-37. [In Chinese]

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39-50. https://doi.org/10.2307/3151312.

Gallicchio, L., Hoffman, S. C., & Helzlsouer, K. J. (2007). The relationship between gender, social support, and health-related quality of life in a community-based study in Washington County, Maryland. *Quality of Life Research*, 16(5), 777-786. https://doi.org/10.1007/s11136-006-9162-4.

Gondo, Y., Hirose, N., Arai, Y., Inagki, H., Masui, Y., Yamamura, K., et al. (2006). Functional status of centenarians in Tokyo, Japan: Developing better phenotypes of exceptional longevity. *The Journal of Gerontology Series A: Biological Sciences and Medical Sciences*, 61(3), 305-310. https://doi.org/10.1093/gerona/61.3.305.

Gu, D., Dupre, M., & Qiu, L. (2017). Self-perception of uselessness and mortality among older adults in China. *Archives of Gerontology and Geriatrics*, 68, 186-194. https://doi.org/10.1016/j.archger.2016.10.015.

Gu, D., & Feng, Q. (2015). Frailty still matters to health and survival in centenarians: The case of China. *BMC Geriatrics*, 15(1), 1-11. https://doi.org/10.1186/s12877-015-0159-0.

Gu, D., & Feng, Q. (2018). Psychological resilience of Chinese centenarians and its associations with survival and health: A fuzzy set analysis. *Journal of Gerontology: Social Sciences*. 73(5), 580-589. https://doi.org/10.1093/geronb/gbw071.

Gu, D., & Zeng, Y. (2001). Analysis on the health status of Chinese senior citizens. *Chinese Journal of Population Science*, (S1), 10-16. [In Chinese]

Jia, S., Feng, Z., Hu, Y., & Wang, J. Q. (2004). Survey on quality of life and influencing factors of the elderly in Shanghai. *Journal of Nurses Training*, 19(5), 420-423. [In Chinese]

Jopp, D. S., Park, M. K. S., Lehrfeld, J., & Paggi, M. E. (2016). Physical, cognitive, social and mental health in near-centenarians

and centenarians living in New York City: Findings from the Fordham Centenarian Study. *BMC Geriatrics*, 16(1), 1-10. https://doi.org/10.1186/s12877-015-0167-0.

Kim, J. I., & Kim, G. (2016). Country-level socioeconomic indicators associated with healthy life expectancy: Income, urbanization, schooling, and internet users: 2000–2012. *Social Indicators Research*, 129(1), 391-402. https://doi.org/ 10.1007/s11205-016-1295-4.

Lawton, M. P. (1983). Environment and other determinants of well-being in older people. *Gerontologist*, 23(4), 349-357. https://doi.org/10.1093/geront/23.4.349.

Liu, Y. L., Luo, K. L., Lin, X. X., Gao, X., Ni, R. X., Wang, S. B., et al. (2014). Regional distribution of longevity population and chemical characteristics of natural water in Xinjiang, China. *Science of the Total Environment*, 473, 54-62. https://doi.org/10.1016/j.scitotenv.2013.11.134.

Magnolfi, S. U., Noferi, I., Petruzzi, E., Pinzani, P., Malentacchi, F., Pazzagli, M., et al. (2009). Centenarians in Tuscany: The role of the environmental factors. *Archives of Gerontology and Geriatrics*, 48(2), 263-266. https://doi.org/10.1016/j.archger.2008.02.002.

Martin, P., Poon, L. W., Kim, E., & Johnson, M. A. (1996). Social and psychological resources of the oldest old. *Experimental Aging Research*, 22(2), 121–139. https://doi.org/10.1080/03610739608254002.

Pes, G. M., Tolu, F., Poulain, M., Errigo, A., Masala, S., Pietrobelli, Angelo., et al. (2013). Lifestyle and nutrition related to male longevity in Sardinia: An ecological study. *Nutrition Metabolism & Cardiovascular Diseases Nmcd*, 23(3), 212-219. https://doi.org/10.1016/j.numecd.2011.05.004.

Poon, L. W., Martin, P., Bishop, A., Cho, J., Rosa, G. D., Deshpande, N., et al. (2010). Understanding centenarians' psychosocial dynamics and their contributions to health and quality of life. *Current Gerontology and Geriatrics Research*, (1), 2004-2016. https://doi.org/10.1155/2010/680657.

Qiao, X. (2009). Introduction and comments on study of health expectancy. *Population & Development*, 15(2), 53-66. [In Chinese]

Qian, J., Wang, D., & Niu, Y. (2014). Analysis of the influencing factors of urban residents to use urban public bikes: A case study of Suzhou. *Geographical Research*, 33(2), 358-371. [In Chinese]

Selim, A. J., Fincke, G., Berlowitz, D. R., Miller, D. R., Qian, S. X., Lee, A., et al. (2005). Comprehensive health status assessment of centenarians: Results from the 1999 large health survey of veteran enrollees. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 60(4), 515-519. https://doi.org/10.1093/gerona/60.4.515.

Takayama, M., Hirose, N., Arai, Y., Gondo, Y., Shimizu, K., Ebihara, Y., et al. (2007). Morbidity of Tokyo-area centenarians and its relationship to functional status. *Journals of Gerontology*, 62(7), 774-782. https://doi.org/10.1093/gerona/62.7.774.

Tian, J., Guo, G., Hong, C., Wang, R., Sun, Jing., & Liu, Yu. (2013). Research progress in factors influencing quality of life of adults with advance age. *Journal of Nursing Science*, 28(9), 92-94. [In Chinese]

Tian, Y., Liu, X., Li, H., Sun, D., Tu, H., & Wen, Hua. (2015). Rural development difference based on subjective and objective evaluation of quality of life: A case of economically underdeveloped villages in Beijing mountainous area. *Progress in Geography*, 34(2), 185-196. [In Chinese]

Toyoshima, A., Martin, P., Sato, S., & Poon, L. W. (2017). The relationship between vision impairment and well-being among centenarians: Findings from the Georgia Centenarian Study. *International Journal of Geriatric Psychiatry*, 33(2), 414-422. https://doi.org/10.1002/gps.4763.

United Nations. *The World Population Prospects*; The 2019 Revision. The United Nations: New York.

Von, H. S. (2016). *Conceptual and methodological issues on the adjustment to aging. International Perspective on Aging*. New York: Springer Publisher.

Wang, S., Li, X., Wang, T., Liu, X., Cui, X. Y., & School, W. H. (2017). Analysis of quality of life of centenarians in Weihai city. *Chronic Pathematology Journal*, (11), 1211-1213. [In Chinese]

Wolff, J. K., Warner, L. M., Ziegelmann, J. P., & Wurm, S. (2014). What do targeting positive views on ageing add to a physical activity intervention in older adults? Results from a randomised controlled trial. *Psychology & Health*, 29(8), 915-932. https://doi.org/10.1080/08870446.2014.896464.

Wu, C., & Jiang, X. (1996). Discussion on the strategy of "health aging". *Social Sciences in China*, (5), 52-64. [In Chinese]

Wu, J., Liu, K., & Li, X. (1998). Assessment of quality of life in 29 Uygur centenarians. *Chinese Journal of Geriatrics*, (1), 32-34. [In Chinese]

Xinming, S., Gong, C., & Xiaoying, Z. (2010). Chinese life expectancy and policy implications. *Procedia - Social and Behavioral Sciences*, 2(5), 7550-7555. https://doi.org/10.1016/j.sbspro.2010.05.120.

Yang, C. (2009). How to promote the healthy aging and positive aging progress in Jiangsu province. *Population Journal*, (3), 60-64. [In Chinese]

Yang, Y., & Wen, M. (2014). Psychological resilience and the onset of activity of daily living disability among older adults in China: A nationwide longitudinal analysis. *Journals of Gerontology Series* B*: Psychological Sciences and Social Sciences*. 70(3), 470-480. https://doi.org/10.1093/geronb/gbu068.

Yi, S. (1998). A brief account of the development of life quality's study. *Journal of Shenzhen University(Humanities & Social Sciences)*, (1), 102-109. [In Chinese]

Zeng, Yi., & Gu, Danan. (2002). International development in quality of life of the elderly. *Chinese Journal of Population Science*, (5), 59-69. [In Chinese]

Zhao, Y., Fu, H., Guo, A., Li, C., Karen, S. L., Wu, B., et al. (2018). A comparison of perceived uselessness between centenarians and non-centenarians in China. *BMC Geriatrics*, 18(1), 1-11. https://doi.org/10.1186/s12877-018-0944-7.

Zhen, Z., & Jiang, X. (1998). Survey on the quality of life of 100 centenarians in Shanghai. *Chinese Journal of Gerontology*, (4), 193-194. [In Chinese]