Is China Moving Towards Healthy Aging? —A tracking study based on 5 phases of CLHLS data

Yinan Yang
South China University of Technology

Yingying Meng (yingyingmeng@whu.edu.cn)
Wuhan University

Research

Keywords: health, comprehensive assessment, latent variable, second-order factor model, structural mean model

Posted Date: May 6th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-26297/v1

Abstract

Background

Most of the countries are entering an aging society in the world. China has the largest number of elderly people in the world and “healthy aging” is the key way for China to cope with the challenges of population aging. This paper aims to investigate whether there is a trend of "healthy aging" in China using the longitudinal data.

Methods

The data used in this study were from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) data of 2002, 2005, 2008, 2011 and 2014. A second-order factor model including four dimensions of physical health, functional status, mental health and social health was constructed to measure a latent variable, “Health_elders” and the structural mean model was further used to the examine the significance of the mean differences in “Health_elders” across five periods.

Results

The results showed that, with the exception of 2008, the Health_elders in 2002, 2005, 2011 and 2014 displayed an upward trend, and the mean differences in Health_elders across five periods were significant. These findings indicate that on the whole, compared with older people in the past, older people in more recent periods are healthier, which supports the trend of "healthy aging" in China. In terms of groups, the health levels of male, town-residing elderly populations are higher, but the healthy aging trends among female elderly people and rural and urban elderly populations are stronger. Regarding the physical health of the elderly population, the health levels of the 60-74 years old cohort are decreasing, and the participation of elderly individuals in social activities is low, which is the weakness in the healthy aging process in China

Conclusion

The health status of the elderly population is generally on the rise, indicating that China's aging is moving towards healthy aging. So the government should take more measures to encourage the medical and health system to adapt to the aging situation and requirements as soon as possible.

Introduction

Health is the key to the aging problem, and solving health problems can essentially resolve the negative impact of aging[1, 2]. Havighurst first proposed the concept of "healthy aging"[3]. In 1990, the first World Assembly on Aging officially introduced the strategy of "healthy aging" to its member nations. The strategy called for enhancing or maintaining the internal abilities of elderly individuals and improving supportive environments to realize the functions required for the healthy life of elderly people[4]. China

has the largest number of elderly people in the world, some scholars have pointed out that healthy aging is the key way for China to cope with the challenges of population aging[5–7].

"Healthy aging" is the overall changing trends in the health of all elderly individuals in a society[1, 8]. China was recognized as an aging society in 1999, and by 2019, elderly individuals over 60 years old accounted for 18.1% of the total population and those over 65 years old accounted for 12.6%. In the past 20 years, has China moved towards healthy aging, sub-healthy aging or even diseased aging? According to the Healthy China Action Promotion Committee, in 2018, China's average life expectancy was 77 years, of which the healthy life expectancy was 68.7 years; that is, elderly individuals lived with diseases for approximately 8.3 years, including 40 million half-disabled elderly individuals and 20 million completely disabled elderly individuals, and 180 million elderly people with one or more chronic diseases, accounting for 75% of this population. In addition to the above officially disclosed data, researchers have also carried out a rich exploration and assessed the changing trends in the health status of the elderly population in China. Some of them have found that the elderly population is getting healthier[9–11], while some have reached opposite conclusions[12–14]. In addition, some of the studies have been positive for some indicators and negative for other indicators, without consistent results[15].

These annual statistical indicators and research literature studies are primarily based on cross-sectional data in a certain year. These measurement results can only reflect the static level of elderly health at that time point while cannot describe the long-term changes. Individual longitudinal research studies based on multistage data often compare only the measurement results in each stage but do not test the significance of the differences between measurement values across the periods. Therefore, whether the changes across time periods show statistical significance has not been tested. Most of the measurement tools use one or several indicators, which are often separately measured in operation. A single or a small number of indicators are not enough to reflect the whole picture of the health of the elderly population, leading to one-sidedness and uncertainty[16]. However, due to different research methods and variables used in the construction of indicator systems, most of the results lack comparability[17, 18]. These shortcomings obviously affect the accurate understanding of the overall characteristics and trends in aging health in China and may be the main cause of the inconsistencies in the existing research results.

In this paper, improvements over previous studies will be made: using 5 phases of longitudinal data, the "overall health" of elderly individuals will be measured with the four dimensions of physical health, functional status, mental health and social health, and statistical test methods will be used to test the significance of the difference across the 5-phase measurement results of the average health in the elderly population. Based on the results of these dynamic measurements and tests, the trends in healthy aging in China will be judged.

LITERATURE REVIEW

In response to the challenges of population aging, Havighurst first proposed the concept of "healthy aging"[3], which was defined as prolonging life span and increasing life satisfaction. However, longevity

reflects only the quantity of life, not the quality of life. In 1987, the World Health Assembly extended the definition of "healthy aging" as postponing biological aging and social aging through a series of positive measures at the same time as the unstoppable calendar aging continues. Rowe and Kahn defined healthy aging as an "active disease-free state". These definitions ignore the inevitable aging process in the process of life, and it is not realistic to expect elderly individuals to have no disease[19]. In view of this, in 2016, the World Health Organization no longer emphasized the lack of "disease" in its global report on aging and health but defined "healthy aging" as "the process of developing and maintaining the functions required for healthy life of the elderly" based on the perspective of "function"[4]. This definition mainly depends on older people's internal abilities, supportive environment and their interaction.

The concept of "healthy aging" based on functional performance is widely accepted, but its measurement indicators, statistical analysis methods and models are still very limited[20, 21]. This is because measuring healthy aging is not simply equivalent to measuring the health of elderly individuals. There are two large differences in measuring healthy aging: first, the health of elderly individuals is the result of the gradual development of people across the whole life process[22]. Individuals' choices at different time points and environmental interventions during the life process will change their internal abilities and function and ultimately affect the changing trajectory of healthy aging[23]. Therefore, we should dynamically investigate or intervene in healthy aging based on the whole life course[4]; second, although healthy aging should be based on individual's health and longevity, it focuses on the overall situation or average level in the elderly population[24]. The healthy life span of a few people has little effect on improving the average healthy life span of the group[25]. Xiong & Dong[26], Wu & Jiang[1] and Zhong & Chen[27] pointed out that "healthy aging" can be considered from two aspects: first, healthy life expectancy is increasing, the corresponding period of disease is shortening, and the best goal is to "end without disease"; second, the proportion of healthy and long-lived elderly people accounts for the majority and is increasing. It can be seen that healthy aging is based on the measurement of the overall health level of the elderly population and then the trends in the dynamic changes.

The most commonly used indicators of elderly health include life expectancy, health expectancy, quality-adjusted life expectancy (QALE), disability-adjusted life expectancy (DALE, which was renamed HALE in 2001), years of life lost (YYL), incidence rate, disability rate and other indicators[28]. In research studies, some researchers will use a single indicator, while others will use multiple indicators.

Researchers often measure the health of elderly individuals from different dimensions according to the definition of health from the World Health Organization. The measurement of physical health mainly includes the activities of daily life (ADL) scale, Barthel Index (BI) scale, instrumental ADL (IADL) scales and so on. Subjective well-being, a comprehensive dimension, is commonly used in the assessment of mental health of elderly individuals and includes life satisfaction, positive emotions, negative emotions, etc.[29]. These scales mainly include happiness scales (e.g., Memorial University of Newfoundland Scale of Happiness; MUNSH), loneliness scales (e.g., the UCLA loneliness scale), depression scales (e.g., Center for Epidemiological Studies Depression scale; CESD), the Life Satisfaction Index A scale, the Mini-Mental State Examination (MMSE), life significance scales (e.g., Meaning of Life Questionnaire; MLQ), etc[30].

Assessments of social health often use social adaptation, social participation, social role, social support and other indicators. The scales include the earliest Berle Index of social support, social relationship scale (SRS), social support questionnaire (SSQ), social adaptation scale (SAS), social adaptation self-test scale (SAS-SR), and the social maladjustment questionnaire (SMS)[31].

It is difficult to reflect the overall health status of elderly individuals with only a single indicator or a single dimension. Measurement errors often lead to the illusion that elderly individuals suffer from group diseases or functional problems[18, 32]. Therefore, currently, researchers have measured the health of elderly individuals from three dimensions of physical health, mental health and social health[28]. When elderly individuals are asked about themselves, they think that healthy aging should include four aspects: physical, mental, psychological and social[33]. In recent years, more emphasis has been placed on the comprehensive evaluation of the health of elderly individuals based on the concept of overall health including physiological health, physical function, mental health, role function, self-assessment health and other dimensions, as well as health-related quality of life assessment (HRQOL), comprehensive geriatric assessment (CGA), etc[34, 35]. A developed comprehensive assessment scale includes the Duke University Older Americans Resources and Services (OARS) assessment scale, the Comprehensive Assessment and Referral Evaluation (CARE), the Frailty Index (FI), and the Grade Membership of Health Status[28]. Compared with traditional measurement methods, the comprehensive assessment of elderly health as a predictor of elderly health is much better, which can provide a more appropriate entry point for public health policy[4, 18].

It can be seen that the measurement of elderly health has experienced a development process from a single indicator to multiple indicators and from a single dimension to multidimensional to a comprehensive evaluation. The same process also stands for the research on the measurement of elderly health in China. Zhong & Chen[27] and Qiang & Zhe[36] used the Sullivan method to measure the healthy life expectanc y of Chinese elderly individuals. Wu et al.[37]proposed measuring the health of Chinese elderly individuals with three indicators: life span, self-care ability evaluations and self-assessed health. Rao[5]selected four indicators to measure the social effect of healthy aging, including the Chinese elderly individuals' life independence, spiritual pleasure, social interaction and social contribution. In fact, these studies all use single indicators for the measurement. Jiao K [18] made a contribution in measuring the overall health of elderly individuals by using the ADL, IADL, MMSE and self-reported measures of chronic diseases and used a latent class model to classify the Chinese elderly participants into four categories: healthy, mild disability, cognitive impairment and mostly unhealthy. Based on the four dimensions of life independence, spiritual pleasure, social interaction and participation, and social contribution, Qian J [38]found that China's healthy aging has achieved some results, but there is still much room for improvement, especially focusing on the health status of the elderly population in rural areas. These researchers have tended to understand healthy aging as a measurement of aging health and attempt to reflect trends in healthy aging from the results of cross-sectional data from a particular year. Obviously, the static measurement results have difficulty reflecting long-term trends in healthy aging in China.

Some researchers have realized that we should judge trends in healthy aging in China from the perspective of dynamic change. Mu G [39] proposed a set of eight indicators including the change in proportion of healthy elderly in the total population and the change in proportion of healthy elderly in the total elderly population to reflect health changes in the elderly population in China, but the data were not used to conduct specific measurement work. Zhe T, Xiang M and Fang X [12]used ADL scores to track 12-year survey data from Beijing elderly individuals, which showed that the ratio of healthy life expectancy (ALE/LE) decreased in recent years. A study from the World Health Organization found that the gap between the average life expectancy and the healthy life expectancy of elderly individuals in China increased with increasing age in the period from 2000 to 2012[40]. Zeng Y and Feng Q [14]showed that cognitive function and physical function of Chinese elderly individuals significantly decreased from 1998 to 2008 compared with 10 years ago. The increase in life expectancy per capita was accompanied by a decline in the health level of elderly individual. In contrast to the conclusions of these studies, other studies found that Chinese elderly individuals are becoming healthier and healthier[9–11]. Yu Y and Feng J [15], based on the data of the China Nutrition and Health Survey (CHNS) in 1991–2009, using a random effect model, found that indicators of daily behavioral abilities gradually improved between generations, but the indicators of chronic disease and health risk gradually deteriorated and was more severe in rural areas. These studies have focused on dynamic measurements of healthy aging, but their shortcomings are that they also examined a single health indicator, or a small number of health indicators, and the empirical results were not consistent.

From the perspective of measurement research on healthy aging in China, the existing problems are that the measurement indicators are too few, the dimensions are single, and the results are not consistent. In addition, most of these studies were aimed at static measurements of cross-sectional data at a particular period of time or lack statistical tests assessing the significance of difference between measures across multiple periods of data. These shortcomings have limited judgments regarding trends in healthy aging in China.

Study Design

Data Source

The data used in this paper are from the Chinese Longitudinal Healthy Longevity Survey (CLHLS). The project covers 23 provinces and is the largest set of survey data of the elderly population in China. This paper selects five longitudinal datasets from 2002, 2005, 2008, 2011 and 2014. We removed 135 individuals who were under 60 years old from the sample and finally obtained 65,064 observations, with the minimum of 60 years old and the maximum of 120 years old. Among them, 16,064 observations were made in 2002, with an average age of 86, 15,638 in 2005, with an average age of 86, 6445 in 2008, with an average age of 87, 9749 in 2011, with an average age of 86, and 7168 in 2014, with an average age of 85.

Health Dimensions And Indicator Variables

The CLHLS data investigated the health status of elderly individuals from multiple dimensions. The measurements included the following:

Table 1
Four Health Dimensions and Measurement Indicators

Health Dimension	Indicator variables
Functional status	ADL: reflecting the abilities of self-care, including bathing, dressing, indoor activities, going to the toilet, eating, and controlling urination and defecation. Three points were given to those who did not need help, 2 points were given to those who needed help for one part, and 1 point was given to those who needed help for more than two parts. The scores of the 6 items of respondents were summed with a maximum of 18 points and a minimum of 6 points. IADL: Eight items in total, including whether the individual could visit their neighbor's house, lift 5 kg of weight, wash clothes, cook, etc. Three points were given to those who could do it, 2 points were given to those who had certain difficulties, and 1 point was given to those who could not do it. The scores for the 8 items of the respondents were summed with a minimum of 8 points and a maximum of 24 points. ADS: Measure body function limitations: whether the hand could touch the back waist, whether the hand could touch the neck root, whether the individual could stand up from the chair, whether the individual could pick up a book from the ground, the steps required to rotate in situ, and whether the arm could be lifted. Completing the task with both hands received 3 points, one hand received 2 points, and neither hand received 1 point. After summing the scores, the maximum value was 18 points, and the minimum value was 6 points.
Physical health	Diseases: Number of serious diseases in the previous two years. Serious disease referred to the need for hospitalization or being bedridden at home. Chronic: Number of chronic diseases; each elderly person was required to report whether they had the listed chronic diseases.
Mental health	MMSE: Measured cognitive function in elderly individuals and included five aspects: orientation ability (general ability), response ability, attention and calculation abilities, recall ability, and language, understanding and self-coordination abilities, for a total of 24 questions. Seven points were given to the question, "How many food names can you say in one minute?" One point was given to the other 23 correctly answered questions, and 0 points were given to the incorrectly answered questions. The total score was 30. Loneliness: the elders were asked, “Do you often feel lonely?” Values of 1–5 represented always, often, sometimes, rarely and never.
Social health	Outdoor: Participation in outdoor activities, values 1–5 represent never, occasionally, at least once a month, at least once a week, and almost every day. Social: Participation in organized social activities, values 1–5 represent never, occasionally, at least once a month, at least once a week, and almost every day.

To reflect the overall health of the elderly population and reduce the measurement error, this paper selected all four dimensions. Among them, functional state, mental health and social health were all

positive measures of the health of elderly individuals, while physical health was a negative measure of the health of elderly individuals. The descriptive statistical results of the nine indicators are shown in Table 2.

Table 2
Descriptive statistics of indicator variables (5 periods pooled data)

Variables	Frequency	Mean	S.D.	Minimum	Maximum
ADL	64317	16.89	2.490	6	18
IADL	64770	18.05	6.100	8	24
ADS	64025	15.76	2.880	6	18
MMSE	63946	20.67	8.720	1	30
Loneliness	57542	3.940	1.010	1	5
Outdoor	64839	3.140	1.830	1	5
Social	64812	1.280	0.820	1	5
Chronic	65055	1.120	1.340	0	21
Diseases	63465	0.280	0.780	0	30

Table 2 uses the summary data from the 5 phases. We also calculated the average trend in the 9 health indicators over the five periods of data. In general, the five health indicators of ADL, IADL, ADS, MMSE and loneliness had high five-stage total mean values. The average values across the five periods rose, which showed that the functional status and mental health of elderly individuals were improving.

Regarding the physical health indicators, the total mean scores across the 5 stages for chronic diseases was 1.12, and the total mean scores across the 5 stages for serious diseases over the previous 2 years was 0.28. Among them, the number of chronic diseases was 1.15 in 2002, 1.21 in 2005, 1.0 in 2008, 1.15 in 2011 and 1.13 in 2014. In the previous two years, the number of serious diseases was 0.24, 0.28, 0.24, 0.35 and 0.38 in these five periods, respectively, showing a slight upward trend in general. In terms of the ratios, the ratio of patients with more than one chronic disease was 61.66% in 2002, 61.65% in 2005, 56.63% in 2008, 58.86% in 2011 and 60% in 2014 (the average of the 5 periods was 60%). The incidence of more than one serious disease was 12.45% in 2002, 14.35% in 2005, 11.76% in 2008, 14.37% in 2011 and 14.5% in 2014 (the average of the 5 periods was 13.23%). This is close to the results of Guo et al. (2019) using the fifth national health service survey data in 2013[41]. They found that the prevalence of chronic diseases in elderly individuals was 56.4%, and the annual hospitalization rate was 16.8%. According to the data released by the Health China Action Promotion Committee, 75% of elderly individuals suffered from one or more chronic diseases in 2018.

The total average value for the 5 periods regarding social activities was 1.28, which corresponded to "occasionally participate", and this value was low. However, the average value across each period slightly

increased, indicating that the participation of elderly individuals in social activities has improved. The number of outdoor activities for elderly individuals slightly decreased, but the total average value for the five periods was still 3.14, corresponding to "at least once a month", which was generally optimistic. Although regular moderate physical activity can delay the decline in physical function, a high proportion of the elderly live an inactive life in most countries [42]. Li Z and Gao G [30] found that the self-organization of social participation of elderly individuals in Chinese cities was not high, and the passive tendencies in the willingness and ways to participate were very obvious. The fifth survey on the living conditions of elderly individuals in urban and rural areas in 2015 showed that 49.4% of elderly individuals never exercise [43].

In general, six of the five-period averages for the nine indicators showed a dynamic upward trend from 2002 to 2014. However, the two indicators serious diseases and outdoor activities showed a trend towards deterioration, while the number of chronic diseases has remained stable.

Measurement model and method

1. Second-order factor model. We used factor models to measure the health of the elderly population. According to the definition of health from the World Health Organization, it is composed of four dimensions: functional state, physical health, mental health and social health. A second-order factor model was appropriate for this analysis. The second-order factor model believes that there is a common second-order factor that explains the correlations between the first-order factors; compared with the first-order factor model, the second-order factor model has a better theoretical framework, and the model is more simplified, which can release more degrees of freedom[44, 45]. That is, a second-order common factor, Health_elders, was measured by the four first-order factors. Health_elders is a continuous latent variable obeying a normal distribution. The matrix equation of the second-order factor model is as follows:

$$\eta = \Gamma \xi + \zeta \qquad (1)$$

$$X = \Lambda_x \eta + \varepsilon \qquad (2)$$

Equation (1) is the second-order factor measurement model, ξ is the second-order factor for Health_elders, η is the first-order factor vector (functional status, physical health, mental health, social health), γ is the load coefficient of four first-order factors in the second-order factor, and ζ is the second-order factor residual. Eq. (2) is the measurement model of the four first-order factors, X is the vector of the nine indicator variables, Λ_x is the load coefficient of the nine indicators in the four first-order factors, and ε is the measurement error of indicator variables. The specific model is shown in Fig. 1.

2. Structural means model. After the second-order factor model was estimated, we set up a structural mean model whose second-order factor mean is not equal to 0 and continued to test the significance of the differences of the mean of Health_elder across five stages (the intercept of the second-order factor is 0 by default). The matrix equation is shown in Eq. (3):

$$\eta = \mu + \Gamma \xi + \zeta \qquad (3)$$

The structural mean model in formula (3) can estimate the new parameter, namely, the latent variable mean μ. When comparing multiple groups, it will set the latent variable mean value μl of the reference group to 0 and then test whether the difference between the mean value of the other groups and the reference group was significant[44]. We conducted four tests for 2002-2005-2008-2011-2014 (base group 2002), 2005-2008-2011-2014 (base group 2005), 2008-2011-2014 (base group 2008) and 2011–2014 (base group 2011) to observe whether the changes in latent variable mean values in each group were significant and to study and judge the trends in the changes regarding healthy aging.

Empirical Results

Second-order Factor Model Estimation Results

We used the CLHLS 2002, 2005, 2008, 2011 and 2015 data to estimate the second-order factor model of formula (1). Specifically, we used the structural equation model (SEM) in Stata to estimate the target factor model. The use of SEM has more advantages, such as isolating measurement errors to obtain better estimation coefficients and predicted values, reporting model fitting indicators, and conducting more follow-up tests[45]. The parameter estimation method was maximum likelihood estimation. The estimated results are shown in Table 3.

Table 3
Second-order factor model estimation results

Dimensions and indicators		(1)	(2)	(3)	(4)	(5)
		2002	2005	2008	2011	2014
Elderly Health (second order)	Functional Status	1.000	1.000	1.000	1.000	1.000
	Physical Health	-0.078***	-0.089***	-0.063***	-0.044***	-0.068***
		(-13.28)	(-14.47)	(-10.23)	(-3.44)	(-4.44)
	Mental Health	0.195***	0.196***	0.191***	0.204***	0.170***
		(21.65)	(20.25)	(20.16)	(16.77)	(11.77)
	Social Health	0.192***	0.221***	0.180***	0.203***	0.195***
		(26.24)	(26.26)	(23.31)	(18.81)	(14.44)
Functional Status	ADL	1.000	1.000	1.000	1.000	1.000
	cons.	17.174***	17.293***	17.420***	17.232***	17.310***
		(1155.00)	(1131.16)	(1209.35)	(829.82)	(703.74)
	IADL	4.906***	4.664***	4.920***	4.518***	4.706***
		(107.83)	(98.21)	(97.07)	(72.01)	(61.23)
	cons.	18.726***	18.952***	18.970***	19.181***	19.404***
		(406.73)	(404.59)	(400.27)	(311.01)	(257.15)
	ADS	1.493***	1.506***	1.796***	1.366***	1.444***
		(83.74)	(85.77)	(89.81)	(63.22)	(54.26)
	cons.	16.197***	16.199***	16.074***	16.322***	16.323***
		(831.41)	(806.63)	(758.67)	(647.92)	(523.72)
Physical Health	Serious illness	1.000	1.000	1.000	1.000	1.000
	cons.	0.233***	0.269***	0.228***	0.351***	0.398***
		(41.07)	(47.71)	(40.02)	(30.16)	(27.96)
	Chronic disease	2.334***	2.084***	1.317***	1.542***	0.823***

Note: The z value is reported in parentheses, * * * represents a significance level of 0.1%.

		(11.90)	(12.24)	(7.17)	(3.00)	(2.77)
	cons.	1.126***	1.177***	0.982***	1.176***	1.185***
		(101.44)	(99.68)	(96.43)	(74.41)	(62.64)
Mental Health	Lonely feeling	1.000	1.000	1.000	1.000	1.000
	cons.	3.933***	3.959***	3.939***	3.985***	3.945***
		(459.47)	(458.21)	(453.11)	(368.46)	(302.53)
	MMSE	20.444***	22.208***	21.856***	21.899***	24.200***
		(21.96)	(20.57)	(20.20)	(16.94)	(11.91)
	cons.	22.752***	22.956***	22.341***	23.046***	23.523***
		(439.16)	(412.91)	(428.45)	(316.10)	(278.18)
Social Health	Social activities	1.000	1.000	1.000	1.000	1.000
	cons.	1.299***	1.333***	1.278***	1.310***	1.330***
		(185.78)	(174.80)	(181.33)	(132.93)	(106.89)
	Outdoor activities	5.155***	4.290***	4.780***	4.399***	4.538***
		(25.96)	(26.29)	(23.30)	(18.45)	(14.41)
	cons.	3.441***	3.304***	3.224***	3.256***	3.243***
		(233.20)	(221.89)	(212.26)	(159.01)	(128.81)
Goodness of fit indices	N	14149	13855	13961	7860	5216
	RMSEA	0.056	0.058	0.047	0.049	0.044
	CFI	0.968	0.965	0.975	0.974	0.980
	TLI	0.951	0.945	0.960	0.959	0.968
	SRMR	0.055	0.044	0.031	0.047	0.039
	R^2	0.943	0.907	0.966	0.909	0.916

Note: The z value is reported in parentheses, * * * represents a significance level of 0.1%.

According to the fitting indices of the data in the 5 periods shown in Table 3, RMSEA, CFI, TLI and SRMR were all above the acceptable critical values, and R^2 exceeded 0.9, indicating that the fitting effect of the second-order factor model was good enough to accept. From the results of the parameter estimation, the

load coefficients of the second-order factor to the first-order factors were all significant at the 1% level (the load coefficients of the functional state were automatically set to 1 by the program), the load coefficients of the first-order factor to the index variables were also significant at the 1% level (the load coefficients of the first index were automatically set to 1 by the program), and the parameter estimation results were relatively close, which showed that the measurement effect was good. This showed that the measurement coefficients of the two-order factor model in the 5 phases were robust and met the basic requirements of measurement invariance[45]. The model can be used to measure the latent variable Health_elders in the five periods.

Multiperiod Comparative Test Of The Structural Mean Model

Based on the 5-stage measurement results of latent variable Health_elders in Table 3, how does the health values in the elderly population change in each stage? Is the trend going towards greater health, or vice versa? If the elderly health value in each period increased, but the change was small but not significant, it would not be enough to support the conclusion that the elderly population in China is generally healthier. Therefore, we continued to use the structural mean model to test the mean differences in the five latent variables. When multiple groups were compared, the latent variable mean of the reference group was set to 0, and then the difference between the mean of other groups and the reference group were tested. We carried out 4 tests in total. The results are shown in Table 4.

Table 4
Significance test of latent variable mean differences based on a multiple-group structural mean model

Results	Period	Five periods	Four periods	Three periods	Two periods
Mean differences test of Health_elders(latent variable)	2002	0.000			
	2005	0.033**	0.000		
		(2.41)	(.)		
	2008	-0.011	-0.049***	0.000	
		(-0.80)	(-3.45)	(.)	
	2011	0.065***	0.029*	0.078***	0.000
		(4.03)	(1.80)	(4.89)	(.)
	2014	0.119***	0.082***	0.131***	0.055***
		(6.41)	(4.38)	(7.04)	(2.65)
Measurement model estimation results	second order	omitted	omitted	omitted	omitted
	first order	omitted	omitted	omitted	omitted
Goodness of fit indices	N	55041	40892	27037	13076
	RMSEA	0.064	0.063	0.062	0.057
	CFI	0.934	0.937	0.939	0.953
	TLI	0.931	0.933	0.933	0.945
	SRMR	0.055	0.051	0.048	0.055
	R^2 (CD)	0.920	0.917	0.922	0.931

In column (1) of Table 4, the average Health_elders in 2002 was taken as the base group (set as 0). The results showed that the mean value for Health_elders in 2005 was significantly higher (3.3%) than that in 2002. The mean difference in 2008 was negative but not significant. In 2011, it was significantly higher than 6.5% at the 1% level in 2002, while in 2014, it was significantly higher than 11.9% at the 1% level in 2002. Column (2) was based on the average Health_elders in 2005. The test results showed that in 2008, the level of 1% was significantly lower than that in 2005 by 4.9%. In 2011, it was 2.9% higher at 10% than in 2005, while in 2014, it was 8.2% higher at 1%. Column (3) was based on the average Health_elders in 2008. The test results showed that the level of 1% in 2011 was 7.8% higher than that in 2008, while the level of 1% in 2014 was 13.1% higher than that in 2011. Column (4) takes the average Health_elders in 2011 as the reference frame. The test results showed that in 2014, it was 5.5% higher than that in 2011.

In Table 4, only 2008 was lower (not significant) than 2002, and 2008 was significantly lower than 2005. Compared with other years, the disasters in 2008 were more serious in China. At the beginning of 2008, there was a snow and rain disaster in the south, another Wenchuan earthquake with magnitude 8 in May, and a global subprime financial crisis in September. The GDP growth rate in that year dropped from 14.23% in 2007 to 9.65% in China. Zhu H and Huang X [46]used the CLHLS data to measure active aging, they also found that active aging in 2008 was at a low point. Using the "consistent index" compiled by the China Economic Climate Monitoring Center, they found that the trend in aging attitude was consistent with the macroeconomic environment. Elderly individuals are more dependent on the environment, but in the case of natural disasters, technological disasters and man-made conflicts, the elderly population is most likely to be ignored[4]. After 2008, elderly health in 2011 and 2014 proceeded to improve significantly.

Predicted Mean Values Of The Latent Variables

After the model fitting, we used the predict command of Stata to estimate the prediction value of the second- order factor, elderly health, and the 4 first-order factors. As these predicted values are standardized values, for ease of comprehension, we used the efficacy coefficient method to convert the predicted values to a 100-point scale. Figure 3 reports the average of their predictions.

According to Fig. 2a, the predicted mean values for functional status, mental health and social health among the first-order factors continued to rise in the other four periods, with the exception of the decrease in 2008. The predicted mean value for physical health rose, but because physical health was measured in the reverse direction, this indicated that elderly physical health was declining, which is contrary to the trends observed with the other three first-order factors. Zhe T, Xiang M and Fang X [12], Zhang W and Du P [13], Zeng Y and Feng Q [14]and other researchers found that the reason why the elderly population in China becomes unhealthy is largely because they still regard disease-free as the judgment standard of health. The corresponding health indicators collected were mostly limited to physiological health indicators such as disease, common disease, death, disability, and epidemiological methods[24]. However, health is multidimensional, and elderly health is more special and mainly includes noninfectious diseases such as chronic diseases, and many health problems that cannot be diagnosed as a certain disease, such as weakness, incontinence, falls, mental disorders, syndromes, etc., and often cannot be completely cured[4]. Even if these diseases exist, they cannot account for the actual impact on elderly individuals because these people can still maintain good function and enjoy a high level of health through drug inhibition, appliance assistance, environmental support, etc[47]. For this reason, the latest definition of "healthy aging" from the World Health Organization no longer distinguishes healthy and unhealthy by the presence of disease but emphasizes the function exertion required in the healthy life of elderly individuals. It is believed that the effect of comprehensive evaluation results of function exertion in elderly individuals as the prediction index is much better[4]. This is also the reason why this paper chose a four-dimensional second-order factor model for comprehensive measurement.

The trend that the physical health dimension in elderly individuals tended to decrease deserves attention. China's existing medical and health services are aimed at the treatment of acute infectious diseases and symptoms. The main characteristics of elderly patients are chronic diseases, comorbidities, physical deficiencies and so on. The course of disease is long, fluctuates with time, and is difficult to cure[4]. Although elderly individuals can also use the current medical and health system, it usually does not meet their needs well, and the effects are not good. However, the number of specialized medical and health institutions, rehabilitation hospitals and nursing homes for elderly individuals is limited and unevenly distributed. There is a serious lack of institutions such as dementia care and hospice care. Combining medical and nursing services has just started, and the number of personnel engaged in elderly health services is also insufficient. If we continue to passively deal with these issues all the time, it will only increase the burden on the government and society and will fall into an increasingly passive situation[24].

In general, with the exception of 2008, the results from the other years showed that the average Health_elders in China is rising, and the rising change was statistically significant. Combined with the predicted trend in Fig. 2B, it can be seen that compared with older people in the past, older people in more recent periods have better health levels. This strongly supports the notion that the trajectory of China's aging is towards healthy aging. This is due to obvious improvements in living conditions, such as better nutrition, medical and health services, and improvements in the health literacy of elderly individuals brought about by China's economic and social development. Fogel’s study of the United States also showed that older people do have better health than their grandparents and great-grandparents[48]. According to the fourth national survey on the living conditions of elderly populations in urban and rural areas, the proportion of self-rated elderly health in 2015 increased by 5.5% compared with that in 2000, including 1.4% in rural areas and 7.0% in urban areas[43].

Further Subgroup Results

We further divided the population by gender, urban and rural residential areas, and age groups to report the group differences underlying the overall trends in the changes shown in Fig. 3. Regarding age groups, we divided elderly individuals by the ages suggested by the World Health Organization. The age groups were 60–74 years old (young elderly), 75–89 years old (middle-aged elderly), and over 90 years old (long-lived elderly). The results are shown in Fig. 3:

Figure 3 shows that the average health predictions for the male and female elderly groups showed an overall upward trend, and the average health prediction for the male elderly group was higher than that for the female elderly group. However, from 2002 to 2014, the average health prediction for the female elderly had a larger increase, indicating that the healthy aging trend in the female elderly group was stronger. From the perspective of residential separation, the average health predictions for the elderly individuals in towns was higher, with a higher health level of the elderly group; the second was the average health prediction for elderly individuals in rural areas, and the lowest was in the average health prediction for the elderly individuals in urban areas. Old people in rural villages had many problems, such as inconvenient

access to medical treatment and medical and health resources. The elders in cities had to afford a high cost of living, bore greater psychological pressures, lived with fewer social interactions, and suffered great health loss from work. These reasons are also why an increasing number of old people are choosing to leave cities, especially large cities, to go to some small towns and characteristic pension counties and towns to live as they age.

In terms of age, the health prediction values for the younger people was higher and that of the long-lived people was the lowest. However, the health prediction values for young and old people decreased over the years. The young and old people in 2014 were more unhealthy than the young and old people in 2002. This shows that with the faster pace of work and the greater pressures of life, the health loss in retired old people was greater than that in retired old people of the same age in the past, resulting in the lower average value of group health. However, middle-aged and long-lived elderly people now have higher mean health predictions than the old people of the same age. In the past decade, China's social security system has been improved, including medical insurance, pension service subsidies, old age allowance, and life preference. In 2002, only 42.23 million old people were able to receive pensions, 24.74 million old people participated in medical insurance, and almost all the old farmers and residents had no pension or a very low-level pension. In 2014, 85.93 million retired employees were able to receive pensions, 143.13 million older people in urban and rural areas were able to receive pensions, 72.55 million retired employees participated in basic medical insurance, and 31.45 million urban residents were able to receive pension basic medical insurance (elderly individuals account for the majority of this population). As previously demonstrated, old people in the past had better health endowments, coupled with better medical and health conditions and social security systems, and the health status of the middle-aged and old people is better than those of middle-aged and old people in the past.

Conclusions

Health is the basic resource to ensure independence of and social participation among the elderly population. Healthy aging has changed people's traditional view of aging, which can create rich new opportunities for elderly individuals, families and society[4]. In the future, the elderly population in China will exceed 1/3 of the total population, account for more than 1/4 of the whole life cycle, and account for more than 40% of the total medical expenses of the whole population[5]. This has determined a focus on the construction of "healthy China" is the health of the elderly population. Without "healthy aging", it is impossible to achieve "healthy China".

Is China's aging healthy? This is a very important issue for system reform, optimization and policy implementation. In view of the inconsistency in the existing empirical evidence, this paper improves the existing measurement research of "healthy aging" from the perspective of overall health, dynamic measurements over five periods of data and testing for significant differences. The second-order factor model, which consists of nine indicators of functional status, physical health, mental health and social health, showed that, with the exception for lower levels in 2008, the predicted mean value of the other four phases of the latent variable Health_elders showed an upward trend and has passed the significance test

for the difference in the mean values of the latent variable. These results showed that the health status of the elderly population is generally on the rise, indicating that China's aging is moving towards healthy aging. Compared with the older people in the past, older people are healthier now. In terms of groups, the health levels of the male elderly and town-residing elderly populations were higher, but the healthy aging trends in the female elderly, rural elderly and urban elderly populations were stronger. Regarding the physical health of the elderly population, the health levels of 60-74-year-old (young elderly) people was decreasing, and the participation of elderly individuals in social activities was also low, which was the weak point in the healthy aging process in China.

In this paper, the measurement results from 5 stages of the CLHLS data showed that the proportion of chronic diseases in the elderly population in China has been as high as 60%, and physiological health indicators such as chronic diseases and serious diseases have declined. As a matter of urgency, China should establish a relatively independent comprehensive elderly health service system including health care, prevention, treatment, rehabilitation, nursing care and hospice care as soon as possible, build a number of high-level specialized hospitals for elderly individuals, or take the second option and set up specialized geriatric departments in large-scale general hospitals, while providing professional teaching and training of gerontology and gerontology for health practitioner training and encouraging the medical and health system to adapt to the aging situation and requirements as soon as possible.

In addition, the study also found that the social participation of elderly individuals in China is low. Old age produces a change in a person's social role, which inevitably leads to negative thoughts such as "useless". Especially in rural areas, there are few social activities and few spiritual and cultural activities. China's 13th five-year plan for the development of the national aging cause and the construction of an elderly care system proposes to "vigorously support the elderly to participate in social development". We should develop voluntary services for elderly individuals, guide the development of social organizations at the grassroots level, and actively promote mutual support and pension modes such as time banks, Internet plus pensions and smart pensions.

Finally, limited by the variables in CLHLS data, only nine indicators are used in the four dimensions of this study. Especially, the physical health, mental health and social health can only be measured by two indicators. If more measurement indicators can be obtained, the test results of China's healthy aging trend will be more accurate.

Declarations

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the the Chinese Longitudinal Healthy Longevity Survey (CLHLS) data of 2002, 2005, 2008, 2011 and 2014 repository (from https://sites.duke.edu/centerforaging/programs/chinese-longitudinal-healthy-longevity-survey-clhls/) .

Ethics approval and consent to participate

The study was exempt from human subjects approval (non-identifiable data; not human subjects).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

This research was funded by the National Social Science Foundation (project 14CJY015 and 16CGL046).

Authors' Contributions

The empirical analysis and the draft were primarily written by Yinan Yang. Yingying Meng was responsible for writing the literary and revising the manuscript. All authors jointly read and approve the final version of the manuscript.

Acknowledgements

References

1. Wu C, Jiang X: **on the strategy of "healthy aging**. *China Social Sciences* 1996:52–64.
2. Britta B, Anjana B, Abou TH, Javier V, Rebekah T. **The Right to Health of Older People**. *Gerontologist* 2016:Suppl_2.
3. Havighurst RJ. **Successful Aging**. *Gerontologist* 1961, 1:8–13.
4. WHO. **World Report on Aging and Health**. WHO Press; 2016a.
5. Rao K. Research on healthy aging and elderly health support system. Chinese journal of health management. 2013;007:149–50.
6. Chen X, Smith J, Strauss J, Wang Y, Zhao Y. *China Health and Retirement Longitudinal Study (CHARLS)*. 2017.
7. Liu L. China geriatric health research report(2018). Beijing: social sciences literature press; 2019.
8. Wang X. **review and Prospect of research on "healthy aging**. *population research* 1996:71–75.

9. Gu L, Qiao X. **analysis of the influencing factors of the self-assessment of the health of the elderly in China**. *Journal of population* 2006:27–31.
10. Guo W. **the change of self-care life expectancy of the elderly in China**. *population and development* 2013, 1.
11. Li C, Liu H, Liang y, Wang H, Li Q. **international comparison of healthy life expectancy and prediction of healthy life expectancy in China**. *China Population Science* 2018.
12. Zhe T, Xiang M, Fang X. **healthy life expectancy and its changes of the elderly in Beijing**. *Chinese Journal of epidemiology* 2005, 12.
13. Zhang W, Du P. Regional Disparity in Healthy Life Expectancy for the Chinese Elderly:Expansion or Compression. Population research. 2009;33:25–34.
14. Zeng Y, Feng Q. Trends of Disability and Mortality among the Oldest-Old in China. population research. 2017;041:22–32.
15. Yu Y, Feng J. the dynamic change of China's elderly health and its implications for healthy aging. world economic literature. 2017;000:1–16.
16. Song Y: *comprehensive assessment of the elderly (2nd Edition)*. Beijing: China Union Medical University Press; 2019.
17. Kenneth Rockwood ABM, MacKnight C. Some mathematical models of frailty and their clinical implications. Reviews in Clinical Gerontology. 2002;12:109–17.
18. Jiao K: *health status and social economic factors of the elderly*. world book publishing company; 2014.
19. Rowe JW, Kahn RL. Successful aging. Aging. 1997;10:142.
20. Baltes PB, Lindenberger U. Emergence of a powerful connection between sensory and cognitive functions across the adult life span: A new window to the study of cognitive aging? Psychol Aging. 1997;12:12–21.
21. WHO. **global strategy on people-centered and integrated health services**. World Health Organization; 2015.
22. Bowling A, Dieppe P. **What is successful ageing and who should define it?** *Bmj British Medical Journal* 2005.
23. Du P, Dong T. **promoting healthy aging: concept change and policy innovation**. *scientific research on aging* 2015, 12.
24. Wen Y. Research on the development strategy of healthy aging. Shanghai: Shanghai Science and Technology Press; 2017.
25. Wu C: *the scientific and social significance of healthy aging, in achieving healthy aging, edited by China Society of Gerontology*. China Labor press; 1995.
26. Xiong B, Dong Z. **healthy aging: the golden autumn project across the century**. *medicine and society* 1995:18–22.

27. Zhong J, Chen Y: **a preliminary analysis of the healthy life expectancy of some urban residents**. *medicine and society* 1998:209–211.
28. Feng Y. aging and global health. Beijing: people's Health Press; 2018.
29. Wu Z. **the connotation, evaluation and research of mental health in the elderly**. *China Journal of Gerontology* 2003:1–3.
30. Li Z, Gao G. An Empirical Study on social participation of urban elderly in the context of active aging. learning practice. 2009;12:116–23.
31. Yang Y, Jia H. **research on national social health measurement and its influencing factors - Empirical Evidence Based on mimic structural equation model**. *China health policy research* 2018:28–36.
32. Zheng X. Health Evaluation of Aging Population in China. Journal of Peking University. 2000;037:144–51.
33. Phelan JC, Link BG, Diez-Roux A, Kawachi I, Levin B. Fundamental Causes of Social Inequalities in Mortality: A Test of the Theory. J Health Soc Behav. 2004;45:265–85.
34. Rajeev K, Varshney, and, Kamel, Chabane, and, Prasad S, Hendre: **Comparative assessment of EST-SSR**, **EST-SNP and AFLP markers for evaluation of genetic diversity and conservation of genetic resources using wild**, **cultivated and elite barleys**. *Plant Science* 2007.
35. Thanakwang K, Soonthorndhada K. Mechanisms by Which Social Support Networks Influence Healthy Aging Among Thai Community-Dwelling Elderly. Journal of Aging Health. 2011;23:1352–78.
36. Qiang L, Zhe T. Application of multi state life table method in the study of healthy life expectancy of the elderly. China Population Science. 2002;01:40–8.
37. Wu C. **Some Thoughts on methodology of research on healthy aging**. *China Population Science* 2001:101–106.
38. Qian J. **measurement research on four dimensions of social effects of healthy aging of the elderly population in China**. *scientific research on aging* 2013:75–81.
39. Mu G. health problems in the process of population aging, in achieving healthy aging, edited by China Society of Gerontology. Beijing: China Labor press; 1995.
40. WHO. **China country assessment report on ageing and health**. WHO Press; 2016b.
41. Guo B. study on the influencing factors of health service utilization of the elderly in rural areas from the perspective of healthy aging. Chinese medical ethics. 2019;32:105–9.
42. WHO. Active Ageing: A Policy Framework. Aging Male. 2002;5:1–37.
43. Dang J: **survey report on the living conditions of the elderly in urban and rural areas of China**. social sciences literature press; 2018.
44. Hou J. Structural equation model and its application. Beijing: Education science press; 2004.
45. Wang M, Bi X, Ye H. Growth hybrid model: analysis of individual development trends in different categories. Sociological Studies. 2014;029:220–41.
46. Zhu H, Huang X. **positive aging attitude: individual difference, group effect, and time change**. *social security research* 2013:32–39.

47. Young Y, Frick KD, Phelan EA. Can Successful Aging and Chronic Illness Coexist in the Same Individual? A Multidimensional Concept of Successful Aging. J Am Med Dir Assoc. 2009;10:87–92.
48. Fogel RW. Supplement: Aging, Health, and Public Policy || Changes in the Process of Aging during the Twentieth Century: Findings and Procedures of the Early Indicators Project. Population Development Review. 2004;30:19–47.

Figures

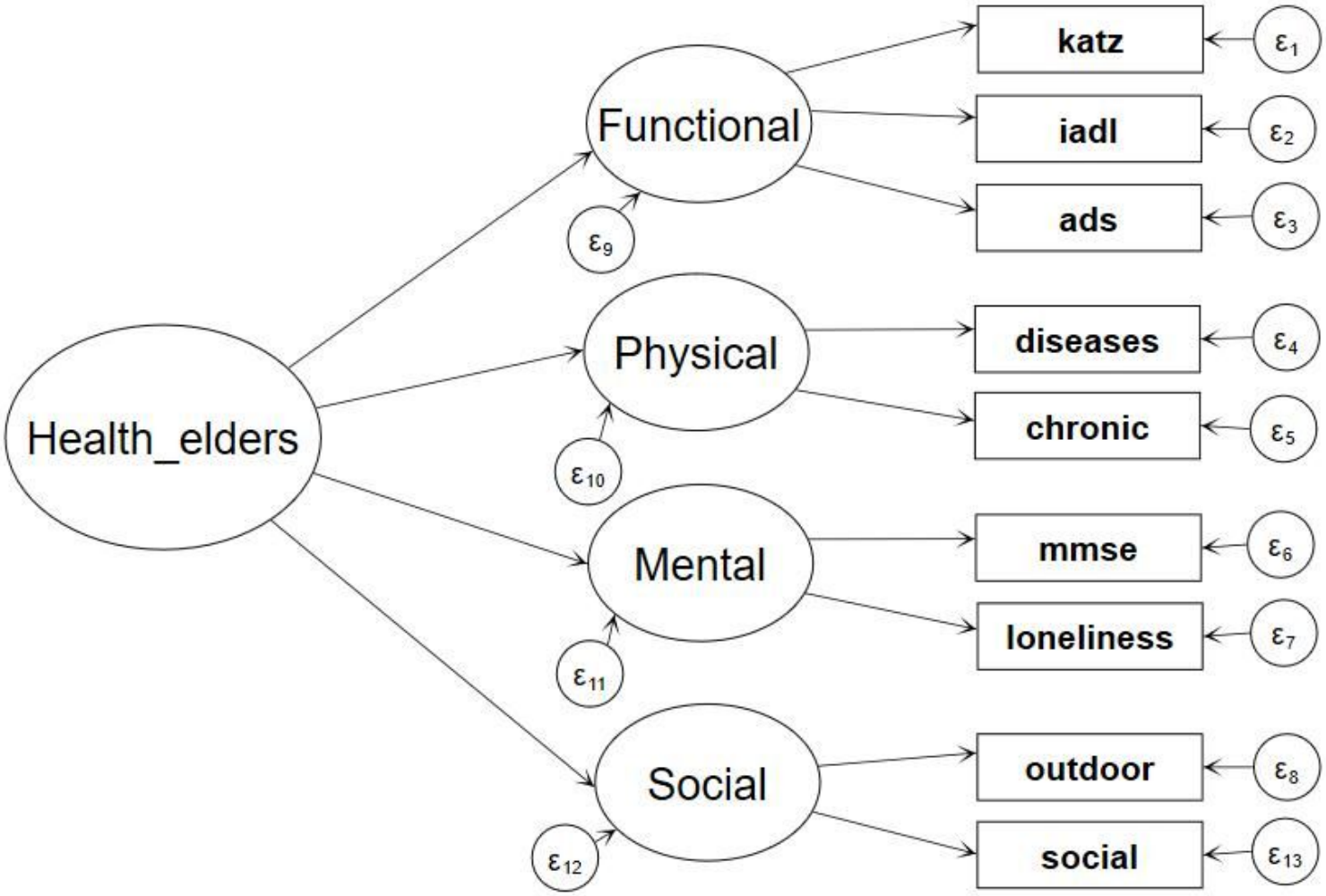

Figure 1

Theoretical Two-Order Factor Model

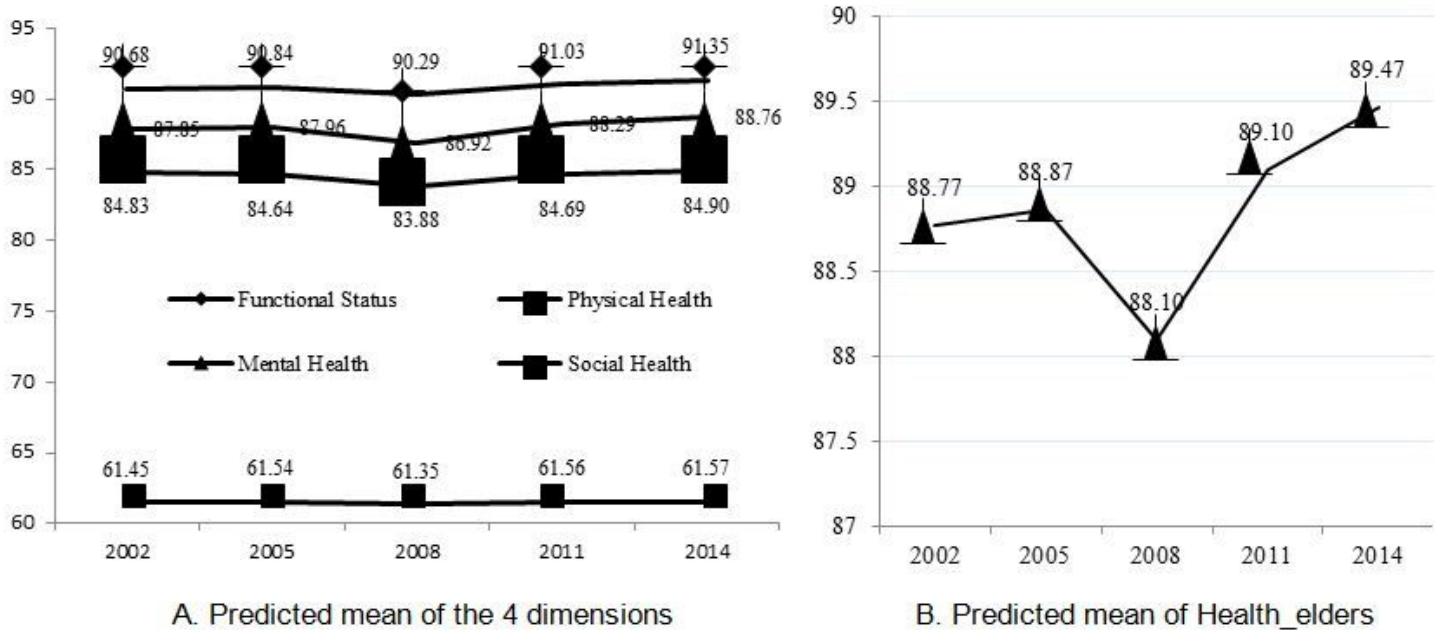

Figure 2

Predicted mean values of Health_elders and the four dimensions in 5 periods

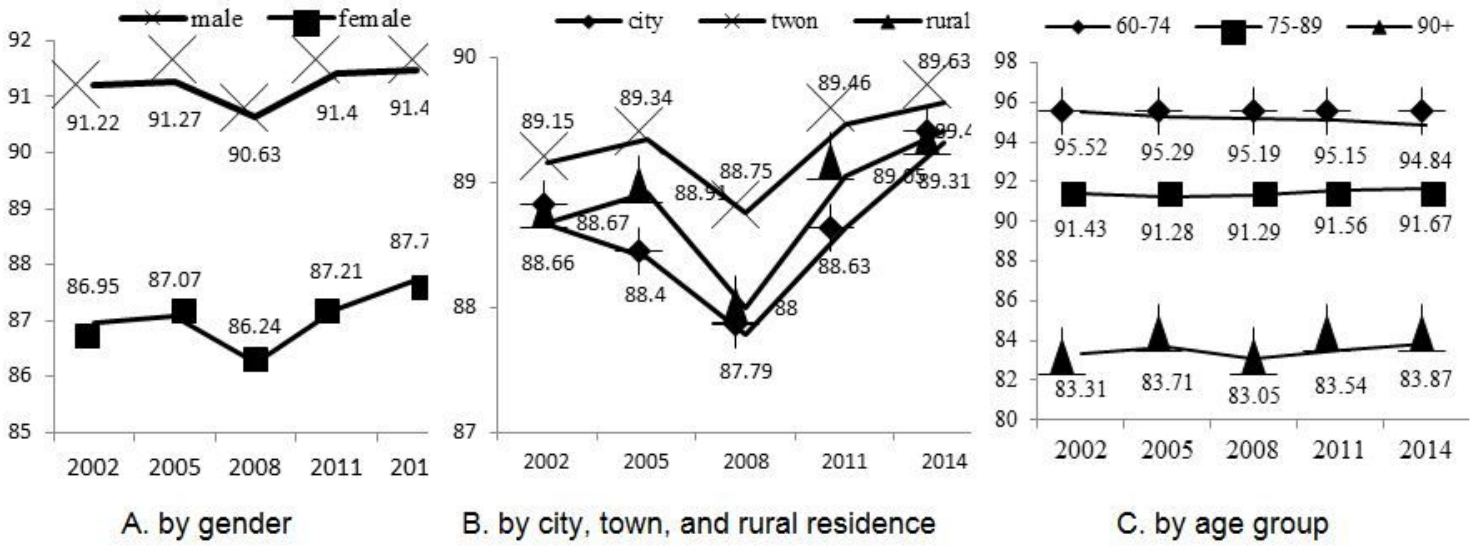

Figure 3

The predicted mean values of Health_elder in five periods