Multi-State Analysis of the Impact of Childhood Starvation on the Healthy Life Expectancy of the Elderly in China

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Abstract

Background: Child malnutrition is not only common in developing countries, but also an important issue faced by developed countries. This study aimed to explore the influence and degree of childhood starvation on the health of the elderly, which providing a reference for formulating health-related policies under the concept of full-life cycle health.

Methods: Based on Chinese Longitudinal Healthy Longevity Survey (CLHLS) in 2008, 2011 and 2014, this paper took a total of 13,185 elderly people aged 65-99 years as the target population. By IMaCH software, with age, gender, and income level as the control variables, and the average life expectancy and healthy life expectancy of the elderly was measured. The x^2 test was used to explore the differences in socio-economic status of elderly people with or without starvation in childhood. The paired *t* test was used to analyze the difference both average life expectancy and healthy life expectancy.

Results: (1) Transition probabilities in health-disability, health-death, and disability-death all showed an upward trend with age($P<0.05$), where the elderly who experienced starvation in childhood were higher than those without such an experience($P<0.05$). However, the probability of disability-health recovery showed a downward trend with age($P<0.05$), whereas the elderly who experienced starvation in childhood were lower than those without starvation($P<0.05$).(2) For the elderly who experienced starvation in childhood, the health indicators of the average life expectancy, healthy life expectancy, and healthy life expectancy proportion accounted for the remaining life were lower than those of the elderly without childhood starvation ($P<0.05$).

Conclusions: The negative impact of childhood starvation on health through the life course till old age, has a persistent negative cumulative effect on the quantity and quality of life for the elderly. Therefore, it is important to pay attention to the nutritional status of children in poor families from the perspective of social policy-making.

Keywords: the Elderly; Healthy Life Expectancy; Childhood Starvation; Life Course

Background

Since the 1900s, China have entered a violently turbulent modern society. During this period, people's lives were generally difficult, and hunger caused a large number of deaths. After the establishment of the People's Republic of China in 1949, the country experienced a "three-year difficult period" from 1959 to 1961, which caused a nationwide "famine”. The number of deaths caused by starvation had risen, and the lack of nutrition greatly affected the health of the population. In recent years, some studies analyzed the impact of the "Great Famine" in childhood on the health and economic status of their adulthood, and found that infants and children who have grown up in the period had shorter life longevity and poorer health in old age [1]. The factors show that the health status of the elderly is not only affected by elements of the old stage, but also earlier life experiences especially childhood.

Life course theory has gradually become an important paradigm for the study of elderly health, emphasizing the long-term impact of life events in critical periods on the health outcomes of elderly. Existing research [2] show that childhood is a critical period of growth and development. At this time, negative nutrition and health shocks experienced may change the original development track of the individual and thus affect the health trajectory of their entire life course. The elderly who experienced starvation during childhood as a health disadvantaged group, have current disadvantages that may depend on the previous unfavorable socioeconomic status. From a policy perspective, it is necessary to understand the long-term effects of malnutrition in earlier life, because child malnutrition is not only common in developing countries, but also an important issue faced by developed countries. Data show that there are approximately 1 billion people in the world who are malnourished, including 140 million preschool children under the age of 5, which will lead to permanent damage to their physical and cognitive development and even death due to nutritional diseases [3].

In recent years, the economics has begun to pay attention to the long-term effects of life experiences in the fetus or early childhood on health, education, and labor market conditions, especially the health and nutritional status before the age of 5 [4]. These studies generally used negative external shocks as an identification event, such as war, famine, rainfall, flu, etc. [5-7]. Schellenberg J A, Victora C G and other studies of low-

income or middle-income countries such as Brazil, India, and South Africa have found that malnourished children had shorter height in adulthood, fewer years of education, and diminished labor productivity [8].Epidemiology and health economics in China are increasingly concerned about the impact of childhood health and developmental status on their health in adult period. Scholars such as Chen and Zhou [9] analyzed the long-term effects of China's "Great Famine" on the health of those who experienced famine. Studies found that babies and children born or raised during this period had a lower height, poorer health, and economic status in adulthood.

Despite there are many literatures on widely acknowledged links between childhood hunger and a range of adverse health outcomes late in life, the reliability of research results and research conclusions are different because of different measurement indicators. A comprehensive evaluation of long-term impacts of hunger on individual's health capital is empirically difficult to conduct. Earlier investigation of this issue was hindered by several challenges including data restrictions. To determine the long-term consequences, we need both information about whether a person experienced hunger several decades ago as well as information about health status. Data tracking individual experiences for such a long period are not often available even in developed countries [10-11]. The most frequent method in the previous literature is to use exposure to shocks defined at a more aggregated level [12], taking famine as an indicator of having childhood starvation [13-15]. But the problem is exposure to famine and exposure to hunger are not equivalent. The famine and hunger belong to different levels of variables. Therefore, identification strategies that only exploit macro-level variations may obtain inconsistent estimates of the long-term effects of hunger.

We deal with this problem by exploiting retrospective data on individual-level occurrence of hunger episodes during childhood, collected by the survey of Chinese Longitudinal Healthy Longevity Survey (CLHLS). This kind of measurement method is more effective, which can conduct a micro-analysis of how the dilemma in the early life is transformed into the negative results in the later life. There is a growing literature taking advantage of this self-reported measure to examine long-term consequences of childhood hunger associated with World War II and several famines happened in European countries [16-18].

In summary, some researchers have done a lot of exploration in this field, but there are still many limitations. First, the above-mentioned studies have paid more attention

to the lasting impact of severe nutrition and health shocks on the health of economically active people(people who have not yet reached the old age).Second, in most previous research literature, self-assessed health status of the elderly was used as the dependent variable, by which body function of the elderly cannot be reflected effectively due to stronger subjectivity. As for the measurement of healthy life expectancy, most international literature adopts the multi-state life table method based on cohort data, which can reflect the true health level of the study population, and the research conclusions are more reliable [19-20]. Third, Due to the lack of high-quality cohort data in China, most previous studies were based on cross-sectional data to measure the relationship between child hunger and health, and cannot make statistical inferences. Therefore, this paper takes life course theory as the analysis framework based on strict cohort data, whether to have the childhood starvation as independent variables, to measure healthy life expectancy of the elderly in China, trying to give answer to the question: to what extent does the accumulated disadvantage formed by childhood starvation affect the health of the elderly?

Methods

Research data

The data come from Chinese Longitudinal Healthy Longevity Survey (CLHLS). This research project has conducted surveys for 8 times in 23 provinces in China. This study used baseline data of 2008, follow-up 2011 and 2014, with a total of 13,185 people aged 65-99 years as samples. Since the survey did not select samples with equal probability, it was necessary to weigh the samples according to the actual composition of age, gender, and residence in the 23 provinces to represent the general population of the elderly in the country. Therefore, before calculating the relevant indicators, the paper weighed the data according to the weight coefficients provided by the project team, after which the sample size was 16,200 people.

Variables setting

The explained variable in this article is the health status of the elderly. The CLHLS database uses the ADL to determine the health status of the elderly. The scale includes 6 measurement items for eating, dressing, indoor activities, going to the toilet, bathing, and controlling toilet. For the above 6 measurement items, if the research subjects select "can be completed", they are judged as "healthy"; if any one of the items is selected as "unable to complete", the sample is judged as "disabled"[21]. The question about income

in the original questionnaire was, "Compared with the local people, what is your life?", There are five options. The options are set to "very rich", "relatively rich", "average", "more difficult" and "very difficult". This study combined "very wealthy" and "relatively wealthy" into "rich" as a high-income group, and combined "average", "relatively difficult" and "very difficult" into "difficult" as a low-income group. The core explanatory variable of this article is "Did you experience starvation in childhood", to which the answer is "yes or no". In the questionnaire of CLHLS, the exact age at which starvation occurred is not asked. Therefore, this article draws on the definition of children's physiological age in the Medicine, Education and Labor Legislation field and defines childhood age from 0-12 years old [22-23].

Preparation and calculation of multi-state life table

IMaCh software is used for the estimation of healthy life expectancy in this study, which is an abbreviation of Interpolated Markov Chain and one of the first batch of software to provide multi-state life table estimation. Its main advantage is the direct use of the original survey data, and the use of multi-period (≥2 times) different longitudinal data at intervals, in which processing different health status is considered such as improvement, reduction, no change and death. In this study, State1 and State2 are healthy and disabled respectively, and State3 is dead [24].

In the multi-state life table, the initial state of the cohort (2008) is "healthy" and "unhealthy"; the end state (2014) is "healthy", "unhealthy" and "death". Each state at the beginning of the period can be transited to any state at the end of the period. In this paper, "whether childhood is Starving" is defined as a binary variable, and "gender" and "income level" are included as control variables to calculate the multi-state healthy life expectancy of the elderly with or without starvation in childhood. The calculation formula of the main variables is as follows (Lievre, A, 2003):

(1) Let X(x) denote the state of an individual aged x. After time h this individual is in state X(x+h). Assume that X(x) is a non-homogeneous discrete parameter Markov chain on these three states with transition probabilities:

$$ {}_{h}p_{x}^{jk} = Pr(X(x+h) = k \ / X(x) = j) \qquad (1) $$

(2) If this individual is observed only once more at timet_3,and noted to be in state l, then a further contribution to the likelihood is$({}_{d2}p_{x2}^{kl})$. In this case the component of the total likelihood due to individual i is:

$$L^{(i)} = ({}_{d1}p_{x1}^{jk}) \times ({}_{d2}p_{x2}^{kl}). \qquad (2)$$

One observes that the formation of the likelihood is no trivial matter since there is no simple analytical expression for the higher order transition probabilities.

(3) If θ denotes the vector of parameters and $\hat{\theta}$ its maximum likelihood estimator, then standard theory tells that for a large sample of size N the MLE $\hat{\theta}$ is approximatively normally distributed with mean θ and covariance matrix V ($\hat{\theta}$):

$$\lim_{N\to\infty} E(\hat{\theta}) = \theta \qquad (3)$$

$$V(\hat{\theta}) = \frac{1}{N} I^{-1}(\theta) \qquad (4)$$

where I(θ) is the information matrix computed at the true value θ. This implies the asymptotic normality of the estimates of the transition probabilities and health expectancies.

(4) The initial state was i, The proportion of outcome status was 1 (health) and 2 (disability).The prevalence ${}_tW^{i1}(x)$ among survivors at age x and in state 1 from a cohort of individuals in state i at age x - t (t years earlier) reads:

$${}_tw^{i1}(x) = \frac{{}_tp_{x-t}^{i1}}{{}_tp_{x-t}^{i1} + {}_tp_{x-t}^{i2}} \qquad (5)$$

and the prevalence ${}_tW^{i2}(x)$:

$${}_tw^{i2}(x) = \frac{{}_tp_{x-t}^{i2}}{{}_tp_{x-t}^{i1} + {}_tp_{x-t}^{i2}} \qquad (6)$$

(5) Calculate the incidence rate of individual ending status j(the stable disability rate in the state j)

$${}_yp_x^{\cdot j}(\theta) = {}_yp_x^{1j}(\theta) + w^2(x,\theta)\left({}_yp_x^{2j}(\theta) - {}_yp_x^{1j}(\theta)\right) \qquad (7)$$

(6) Over the interval (x,x+y), given the initial state i at age x, with y as the upper limit in the sums：

$${}_ye_x^{ij} = \sum_{u=1}^{y} {}_up_x^{ij} \qquad (8)$$

(7) Total life expectancies respective of the initial state are：

$$e_x^{i\cdot} = e_x^{i1} + e_x^{i2} \qquad (9)$$

Statistical analysis

Firstly, SPSS17.0 software was used to describe the frequency of different health statuses of the elderly. It analyzed the distribution of health status by age, gender, residency, education level, income level, and whether hungry or not. Secondly, x^2test was used to explore the differences in socio-economic status of elderly people with or without starvation in childhood, taking α=0.05 as the inspection standard. Thirdly, by IMaCh software, the multi-state life table method was used to measure the average life expectancy and healthy life expectancy of the elderly people who have childhood starvation or not. Fourthly, the paired *t* test was used to analyze the difference both average life expectancy and healthy life expectancy.

Results

Data quality assessment

Taking the sex-age structure of the elderly over 65 years in the sixth census in China as a reference, the data after weight adjustment of the cohort in the CLHLS database from 2008 to 2014 were compared. The results showed that the weighted adjusted data fitted well with the sixth census data of China (figure1).

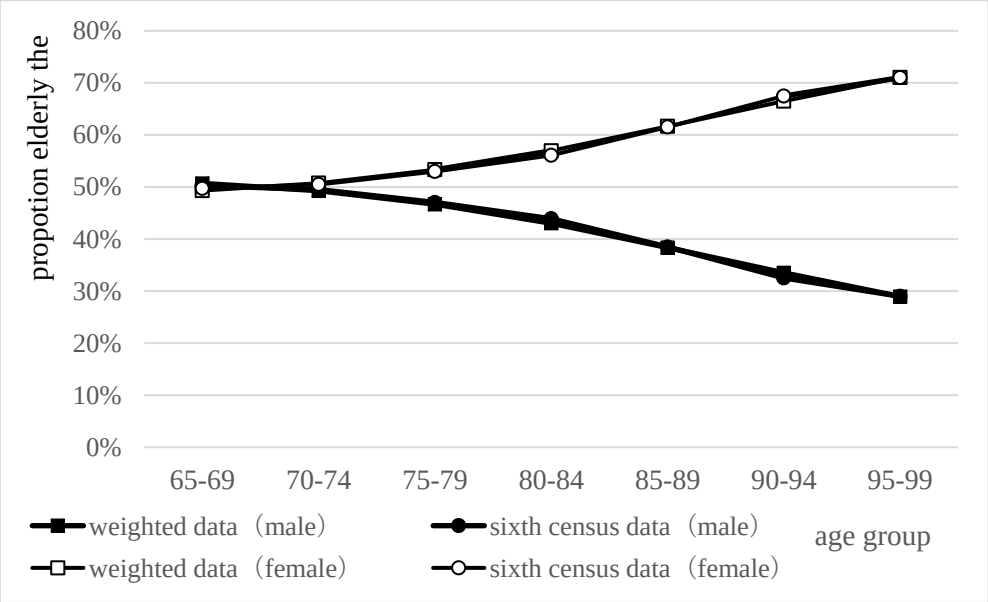

Figure 1 Comparison between the sixth census data of China and weighted survey data by sex-age structure

Descriptive analysis

With the weighted adjustment of the raw data, the baseline number in 2008 was 16,200. The remaining number in 2011 was 14,405 and the survivors in 2014 was 12,876. In 2008, the proportion of elderly people under 80 years old accounted for

83.51%. In 2011 and 2014, the proportion under 80 years old increased to 86.01% and 88.05% respectively. The proportion of female elderly was higher than 50%, which was slightly higher than the male elderly. More than 60% of the elderly were farmers or unemployed; Over 80% were primary and lower in education, and lower- income, which presented a declining trend over time. The proportion of elderly people with hunger in 2008 was 66.1%, rising to 65.9 % in 2011 and 65.6% in 2014 respectively. From the perspective of health status, the proportion of healthy elderly decreased year by year during the follow-up period. Meanwhile the proportion of disabled and dead elderly showed an upward trend. (table1).

Table 1 Basic situation and health transition of the elderly

	2008Year		2011Year		2014Year	
	N	Proportion (%)	N	Proportion (%)	N	Proportion (%)
Explanatory variable						
Age group						
65-69	5590	34.51	5351	37.16	5097	39.59
70-74	4696	28.99	4266	29.62	3870	30.06
75-79	3242	20.01	2770	19.23	2369	18.40
80-84	1755	10.83	1401	9.73	1109	8.61
85-89	696	4.30	495	3.44	352	2.73
90-94	184	1.14	106	0.74	66	0.51
95-99	37	0.23	16	0.11	13	0.10
Gender						
male	7754	47.86	6780	47.08	5976	46.41
female	8447	52.14	7622	52.93	6899	53.58
Residency						
urban	10033	61.9	8764	65.1	7758	60.3
Rural	5135	38.1	4695	34.9	4251	39.7
Education level						
primary schools and below	13234	81.69	11657	80.95	10349	80.37
above primary school	2943	18.17	2721	18.89	2507	19.47
Economic level						
low income	14115	87.1	12507	86.85	11136	86.49
high income	2086	18.3	1876	13.03	1721	13.37
Starvation						

yes	10709	66.1	9489	65.9	8442	65.6
no	5492	33.9	4912	34.1	4434	34.4
Health condition						
health	15405	95.09	10331	63.77	8024	49.53
disability	796	4.91	1393	8.60	4627	28.56
death	0	0	1800	11.11	3325	20.52
missing visits	0	0	2677	16.52	225	1.39

Single factor analysis

Explore the differences in the socioeconomic status of the two groups of elderly above. The results showed that there was a statistically significant difference in age, gender, residency, education level, and income level between the groups with or without starvation (P<0.05). Specifically, the main features of the elderly with starvation experience were as follows: mainly over 80 years old, female (74.7%), rural (77.4%), lower education level with primary schools and below (74.9%), and mainly low-income (75.1%). (Table 2).

Table2 Analysis on the differences in social attributes of childhood hunger

Variable		childhood hunger		χ^2	P
		yes	no		
Age	65-69	4219(75.5%)	1366（24.5%）	19.74	0.003
	70-74	3512(74.9%)	1180（25.1%）		
	75-79	2316(71.4%)	927(28.6%)		
	80-84	1303(74.3%)	451(25.7%)		
	85-89	519(74.5%)	178(25.5%)		
	90-94	140(76.1%)	44(23.9%)		
	95-99	27 (73.0%)	10 (27%)		
Gender	male	6240(74 %)	2197(26%)	11.31	0
	female	5796(74.7%)	1958(25.3%)		
Residence	urban	1436(68.9%)	649(31.1%)	23.42	0
	rural	10883(77.4%)	3172(22.6%)		

Education level	primary schools and below	9901 (74.9%)	3321 (25.1%)	11.20	0
	above primary school	2130 (71.9%)	832 (28.1%)		
Economic level	low income	10599 (75.1%)	3506 (24.9%)	37.44	0
	high income	1320 (60.8%)	766 (39.2%)		

Risk transition probability

Health-disability and disability-health transition probability

In general, the health-disability transition probability showed a linear upward trend with age (male:95%CI (0.1244,0.2715), female: 95%CI (0.1245,0.2893), P<0.05), whether male or female, whereas the difference between the two groups gradually increased with age. On the contrary, the disability-health transition probability was linearly decreasing with age for all the elderly (male:95%CI (0.094,0.1716), female: 95%CI (0.0921,0.1746), P<0.05).

For the elderly males, the disability-health transition probability of the elderly who experienced starvation in childhood was lower than those without childhood starvation (*t=0.440, P<0.05*), especially for those over 80 years old. The difference between the two groups gradually widened with age. However, as for health-disability transition probability, the elderly who experienced starvation in childhood were higher than those without starvation (*t=0.526, P>0.05*). For the female elderly, the disability-health probability of the elderly with starvation in childhood was lower than those without childhood starvation *(t=3.279, P<0.05*). Meanwhile, for the probability of health-disability transition, the situation of the two groups was just the opposite(*t=0.999, P>0.05*).In addition, not only the health-disability but also the disability-health transition probability, displayed differences presented by age which show an increase among female seniors were greater than males (Figures 2 and 3).

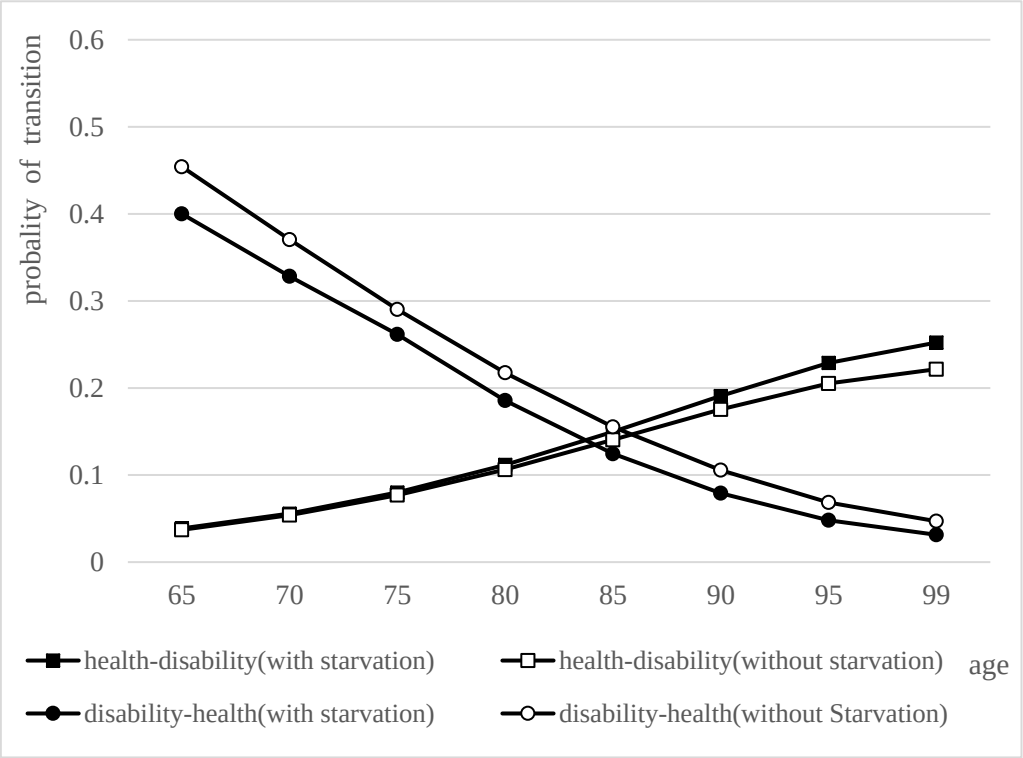

Figure 2 Comparison of the probability curves of disability and health transition among elderly males

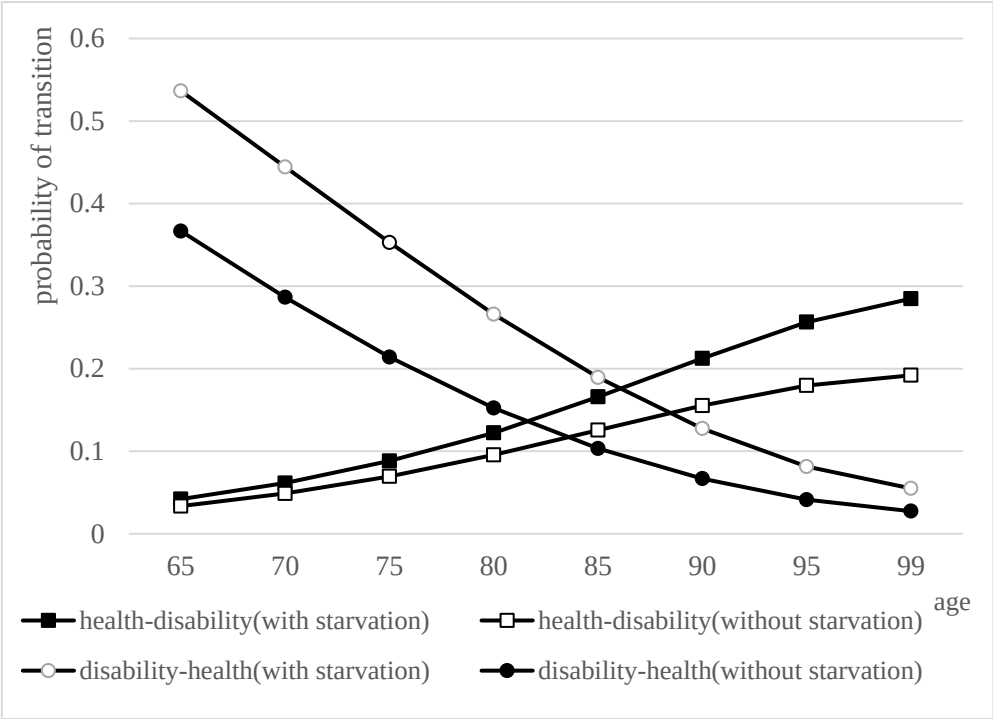

Figure3 Comparison of the probability curves of disability and health transition among elderly females

Health-death and disability-death transition probability

Overall, not only health-death(male:95%CI (0.0988,0.2480),female: 95%CI (0.0973,0.2534), P<0.05) but also disability-death transition probability(male:95%CI (0.2516,0.4789),female: 95%CI (0.2526,0.4717), P<0.05) of the elderly with or without starvation in childhood have both shown an linear upward trend, whereas the difference between the two groups gradually expanded with age. Specifically, for male elderly people who experienced starvation in childhood, the probability of disability-death transition ($t=8.140, P<0.05$) and health-death transition probability ($t=2.079, P>0.05$) were both higher than the elderly without experience of starvation. Similarly, as for the probability both of disability-death ($t=8.135, P<0.05$) and health-death ($t=1.873, P>0.05$)，the female elderly who experienced starvation in childhood, were higher than those without experience of starvation. In addition, as for differences between starvation and or not, male elderly people were higher than female on disability-death transition probability, while female elderly people were greater than male ones on health-death transition probability (Figure 4 and Figure 5).

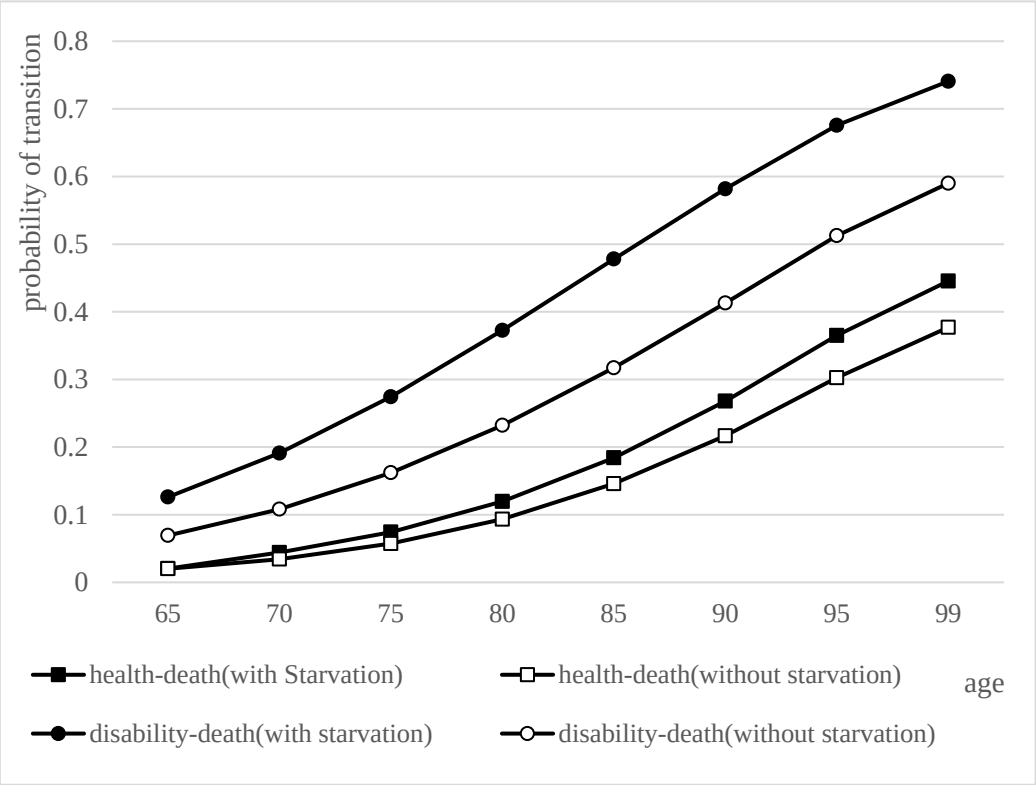

Figure 4 Comparison of health and death transition probability curves of male elderly

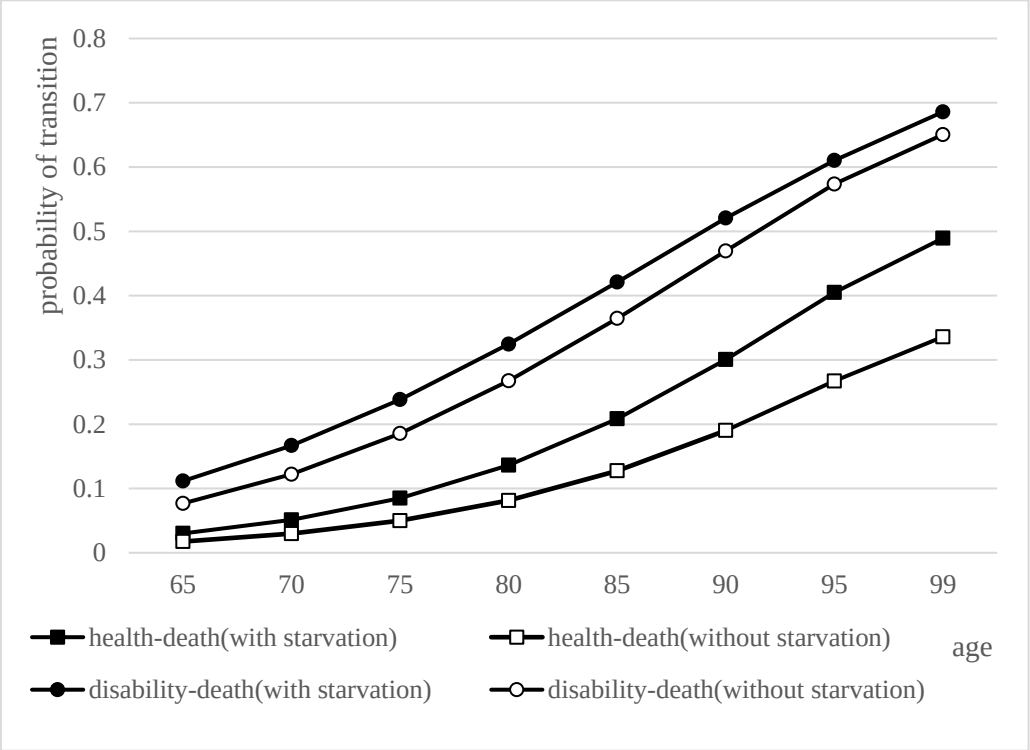

Figure 5 Comparison of health and death transition probability curves of female elderly

Analysis of healthy life expectancy and its differences

Overall, regardless of male and female, the elderly who experienced starvation in childhood were lower than the elderly without starvation experience on such indicators as the average life expectancy, healthy life expectancy and healthy life expectancy accounted for the remaining life, in which the difference between the two groups was gradually decreasing with age on the average life expectancy male:95%CI (4.7241,9.6559),female: 95%CI (5.8672,11.6542), P<0.05) and the healthy life expectancy male:95%CI (3.1915,7.8079),female: 95%CI (3.7217,9.0226), P<0.05) respectively.

For the elderly men, the healthy life expectancy of the elderly between 65-69 years old was 12.26±0.26 years, while the average life expectancy was 14.36±0.27 years, which meant that male elderly people between 65-69 years old were in a healthy state accounting for 85.30% of time. In the same age group, the healthy life expectancy of the elderly without hunger in childhood was 12.70±0.21 years. Meanwhile the average life expectancy was 14.78±0.23 years, indicating that 65-69 year old males without hunger had 85.92% in a healthy state for the rest of their lives. The paired *t* test found

that the healthy life expectancy of the elderly without starvation in all age groups was higher than that of the elderly with starvation, with statistically significant difference (*P<0.05*), while the proportion of life expectancy (HLE/LE) of the elderly without starvation was also higher than that of elderly people with starvation. In which the difference was statistically significant (*P<0.05*).

For the female elderly, the healthy life expectancy of those between 65-69 years-old with hunger experience was 14.06±0.30 years, while the average life expectancy was 17.06±0.33 years, which meant that the males between 65-59 years-old with hunger had 82.30% in healthy state of the rest life. In the same age group, the healthy life expectancy of the elderly without hunger in childhood was 14.48±0.22 years. Meanwhile the average life expectancy was 17.42±0.25years, indicating that the male elderly between 65-59 years-old without hunger had 83.1% in a healthy state of living (table2).The paired *t* test found that the healthy life expectancy of the elderly without starvation in all age groups was higher than that of the elderly with starvation, at which the difference was statistically significant (*P<0.05*).The proportion (HLE/LE) of the elderly without starvation was also higher than that of elderly people who experienced starvation, at which the difference was statistically significant (*P<0.05*).

Table3 Comparison of healthy life expectancy among the elderly population**(x±s)**

Age group	With starvation			Without starvation		
	LE	HLE	HLE/LE (%)	LE	HLE	HLE/LE (%)
man						
65-69	14.36±0.27	12.26±0.26	85.3	14.78±0.23	12.70±0.21	85.92
70-74	11.02±0.24	9.03±0.23	82.55	11.34±0.19	9.39±0.18	82.72
75-79	8.23±0.21	6.36±0.19	77.19	8.46±0.17	6.65±0.16	78.54
80-84	6.02±0.18	4.30±0.17	71.22	6.18±0.24	4.53±0.16	73.18
85-89	4.38±0.16	2.80±0.15	63.68	4.48±0.14	2.99±0.13	66.48
90-94	3.22±0.13	1.77±0.15	54.51	3.28±0.12	1.92±0.13	58.39
95-99	2.44±0.11	1.08±0.15	44.03	2.47±0.09	1.22±0.12	49.08
woman						
65-69	17.06±0.33	14.06±0.30	82.3	17.42±0.25	14.48±0.22	83.1
70-74	13.38±0.30	10.51±0.27	78.43	13.65±0.22	10.87±0.20	79.56
75-79	10.19±0.38	7.50±0.27	73.42	10.37±0.20	7.79±0.18	74.99
80-84	7.58±0.24	5.09±0.21	67.02	7.67±0.19	5.32±0.16	69.21
85-89	5.55±0.22	3.29±0.18	59.16	5.59±0.17	3.48±0.15	62.14
90-94	4.07±0.19	2.04±0.16	49.96	4.07±0.15	2.20±0.14	53.87
95-99	3.04±0.16	1.22±0.15	39.97	3.01±0.13	1.36±0.13	44.77

Note: ①LE: average life expectancy; ②HLE: healthy life expectancy; ③HLE/LE: healthy life expectancy accounted for the remaining life

Discussion

The life course provides an important theoretical perspective for a comprehensive analysis of the health status of the elderly. The results of this study showed that the experience of starvation in childhood had a negative cumulative effect on the health in old age, which was related to the social and historical environment of the research group. The target group was born in 1908-1942 during was a special historical period of social transformation, political turmoil, and material deprivation. During the time, many elderly people had experienced starvation before the age of 12[24]. Some scholars have studied the long-term negative effects of "great famine of China" on the health of famine-experienced people[25-27]. However, as a rare historical event, the "Great Famine" has serious, extreme, and transient characteristics, which conclusions drawn have certain limitations in terms of external validity. In contrast, the adverse effects of the childhood starvation on health in this paper are more typical and more universal.

The experience of starving in childhood affects the socioeconomic status of adulthood, which in turn affects the health outcomes of the elderly. The results of this study showed that the elderly who have experienced starvation in childhood were mainly farmers or unemployed (75.8%), mostly primary school and below in education (74.9%), and lower income level (63.3%).The literature that examined the long-term effects of fetal or childhood health as independent variables found that chronically poor health or malnutrition in childhood had a significant negative impact on the years of education during adulthood[28]. Qing He and Yuan Yan analyzed the data of CHNS to show that the overall health status during childhood had a significant positive effect on adult income[29]. Specifically, people with low socioeconomic status usually have cumulative disadvantages in terms of work environment, access to medical services, and health risks, which can affect their availability of health resources and health protection capacity[30].

The multi-state transition probability is the basis for measuring healthy life expectancy. When calculating the healthy life expectancy, the transitions between different multiple health states and the death risk could be taken to consideration, in which the result is closer to the health level of the crowd. This study found that regardless of the elderly with or without starvation in childhood, the transition

probabilities showed an upward trend on such as health-disability, health-death, and disability-death with age, while the probability of disability-health showed a downward trend. The elderly people with starvation in all age groups were lower than those who did not experience starvation in childhood. This result reflects that the impact of childhood nutrition on the health of people depends on the degree of hunger in childhood. Disability is a reversible state that can return to health or it can lead to death. It means that we should pay more attention to the problem of malnutrition in childhood, earlier detection, earlier intervention, and earlier treatment, to not cause lasting adverse health effects.

The elderly who experienced starvation in childhood are lower than those without hunger in the three indicators, such as average life expectancy and healthy life expectancy, which result is closely related to the transition probability. Older people who experienced starvation in childhood had a higher probability of health-disability, but the probability of disability-health recovery was relatively low. Therefore, the probability of disability-health recovery is the key indicator to explain the difference between the two groups above. The lower health recovery rate may reflect lower utilization of medical services, on which the social status of education and economic status affects the conditions and quality of medical service utilization [31-32].Therefore, good education and economic conditions can not only increase their utilization of health resources, but also increase awareness of preventive health care, which can effectively reduce the possibility of disability and increase the rate of disability-health recovery[33]. The elderly without childhood hunger have obvious advantages in this respect.

The policy enlightenment brought by the research is that the improvement of the material life improvement level in China under rapid economic growth in recent years, and the support of the social security system cannot completely offset negative effects on the health level of the elderly from malnutrition of childhood starvation experience. Therefore, the government should strengthen nutrition and health interventions for poor children, and effectively improve the nutrition and health status of children in poverty-stricken areas and families through the implementation of nutrition improvement programs for pre-school children. At the same time, health investment on children is an important prerequisite for the elderly people bonus. At present, the delayed retirement age has taken shape in China, but the smooth implementation of this policy depends largely on the health of the elderly. The research in this article shows that the health

problems of the elderly population should be considered from the perspective of life course, and policy makers should have a forward-looking awareness to strengthen the nutritional improvement and health promotion of vulnerable groups in the early life.

Limitations

First, due to the limitations of IMaCH model, if all the individual and family socio-economic status and environmental variables were included as control variables, it was very difficult to calculate. Therefore, this paper only took gender and age as the basic variable, and the current income level as the control variable in the model. The second is that if the nutritional status in childhood is too bad and leads to death, then these people will not appear in the sample of 2008-2014. Therefore, the estimates obtained from the sample used in this article may have survivor bias, which will underestimate the impact of childhood starvation experience on the health of the elderly. Third, although the measurement of hunger in this study avoids the limitations caused by macro-indicators (such as famine, and provincial mortality in decades after famine), it directly uses micro-level individuals' evaluation of their own childhood hunger status, but also with a certain degree of subjectivity, may bring partial bias to the results.

Conclusions

The negative impact of childhood starvation on health through life course till old age has a persistent negative cumulative effect on the elderly health. The average life expectancy and healthy life expectancy of the elderly with childhood starvation both are lower than those without childhood starvation. This study meant that for the social groups with poor early nutritional status, the upward mobility of adult social class and the improvement of material living conditions can not completely offset the negative effects of early hunger experience. Therefore, in order to achieve healthy aging, government decision makers should have a sense of foresight and take systematic intervention of all factors affecting health from early stage of life.

List of abbreviations

LE: average life expectancy;

HLE: healthy life expectancy;

HLE/LE: healthy life expectancy accounted for the remaining life

Declarations

Ethics approval and consent to participate

This was an observational study using national registry data from public platforms. The medical ethics were exempted during the investigation.

Consent for publication

Not applicable.

Availability of data and materials

The data used in this study are openly available in the Peking University Open Research Data at: https://opendata.pku.edu.cn/dataset.xhtml?persistentId=doi:10.18170/DVN/XRV2WN.

Competing interests

The authors have declared that no competing interests exist.

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Author Contributions

Conceived and designed the study: BY W; Gathered and Analyzed the data: HL D; Contributed materials/analysis tools: BY W; Wrote the paper: HL D; Reviewed/edited/approved: QH W. All authors read and approved the final manuscript.

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