

# 3-D Health Trajectories and Related Childhood Predictors Among Older Adults in China

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## Research Article

**Keywords:** Older adults, 3-D health, Multi-trajectory modeling, Childhood predictors

**Posted Date:** February 2nd, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-154765/v1>

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## 3-D health trajectories and related childhood predictors among older adults in China

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### **Abstract**

**Objectives:** This study aimed to identify the multi-trajectories of 3-D health of older adults in China and to explore whether the childhood predictors are associated with 3-D health trajectory.

**Methods:** Data came from five waves of the China Health and Retirement Longitudinal Study (CHARLS, 2011 to 2018). A multi-trajectory modeling approach was carried out to jointly estimate the trajectories of 3-D health. A multinomial regression model was used to investigate the relationship between childhood predictors and the joint trajectories.

**Results:** We identified three typical joint 3-D health trajectories. Female, childhood health, maternal and paternal educations, childhood friendships, family and neighborhood predictors could all affect disability trajectories of older adults directly or indirectly through adults variables.

**Discussion:** The 3-D health trajectories showed increasing trends, thus the government should perform more interventions toward the childhood predictors for better health of older adults.

**Keywords:** Older adults; 3-D health; Multi-trajectory modeling; Childhood predictors

### **Introduction**

Facing rapid aging in China, nearly 40 million and 180 million older adults had a disability and chronic disease in 2019; and nearly 22.7% had depression<sup>1</sup>. Preventing disability, chronic disease and depression can be a great benefit for the improvement of health, life predictors of old adults, and reducing the huge burden for the national support system<sup>1-3</sup>. Older adults may own different health trajectories: Some may maintain good health, while others may become ill at an early age. Interventions that do not consider the various trajectories of illnesses among older adults could be ineffective.

As chronic and non-communicable diseases become the dominant diseases in China, early predictors will play more critical roles in the health of older adults<sup>4,5</sup>. The interventions of early

health determinants can promote the health of old adults and largely reduce the old-age care burden<sup>6</sup>. The Chinese government has issued many policies to promote health aging such as the “Actively Responding to Aging” strategy and the “Healthy China 2030” plan. “Actively Responding to Aging” strategy means to prevent disease rather than treating it after illness, and the “Healthy China 2030” plan puts forward the concept of “life-cycle health management”, and those policies strengthen the critical role of the early interventions in promoting the health of older adults. However, the precise implementation of interventions requires understanding which early factors will affect the health of older adults.

In this paper, we proposed a 3-D health trajectory model, which assumes that the trajectories of disability, disease and depression are related to each other. And by using the 3-D health trajectory model, we tried to better explore the health trajectories of older adults. The paper also explored whether the early predictors such as childhood friendship, family, and neighborhood predictors will influence the later 3-D health trajectories and the indirect effects of those earlier variables on the 3-D health trajectories through adults variables.

### **Literature review**

As the multidimensional nature of health and aging<sup>7</sup>, recently more researches have paid attention to the relationship between diseases, such as chronic diseases, disability, and depression, and indicated that estimating one direction of the interrelationship between diseases may be misleading<sup>8-10</sup>. Several studies have explored disease, disability or depression trajectories among older adults, but they were estimated separately as if three independent processes<sup>7,11</sup>. To our knowledge, none of the studies examined the disability, depression and disease trajectories jointly and how the three components evolved over time.

Though the change of the human disease spectrum makes early social determinants more critical for later human health, studies focusing on earlier social predictors of health are still not enough<sup>12</sup>. Several researches have explored the predictors of health trajectories of older adults by considering the predictors at baseline<sup>13,14</sup> and a few included childhood variables, such as childhood health or childhood socioeconomic status, but they did not focus on the childhood predictors<sup>15</sup>. Previous studies also showed that those who have more advantages in childhood will also be healthier in later life than those who do not have the advantages, which means that childhood risk factors can affect the later health through adult variables<sup>16-18</sup>. While previous

studies showed that childhood friendship, family and neighborhood predictors playing critical roles in health <sup>17,19-21</sup>, we are unaware of any studies that focused on the direct or indirect effects through adults variables of those variables on 3-D health trajectories of older adults.

## Results

### Health trajectories of older adults

Table 1 shows the results from the best-fitting base model, which was divided into three groups. In the 3-D health model, time was modeled with quadratic specifications for all three disability and depression groups, linear specifications for all three disease groups. Maximum likelihood estimation assigned 42.57%, 38.07%, and 19.36% for the low, middle and high 3-D health group, respectively. The final average posterior probabilities were 0.96 for the low and high groups, 0.94 for the middle group and all well above the 0.7 criterion.

Table 1 Maximum Likelihood Estimates of disability, disease and depression from best base model

Parameter	The low 3-D health group	The middle 3-D health group	The high 3-D health group
<b>Disability</b>			
Intercept	-1.567(0.062)***	-0.755(0.099)***	1.313 (0.022)***
Linear scaled time	-0.055(0.034)	0.069(0.024)**	-0.009(0.012)
Quadratic scaled time	0.033(0.004)***	-0.013(0.003)***	0.007(0.002)**
<b>Chronic disease</b>			
Intercept	0.619(0.041)***	1.645(0.046)***	2.326(0.060)***
Linear scaled time	0.207(0.009)***	0.236(0.010)***	0.287(0.014)***
<b>Depression</b>			
Intercept	1.479(0.016)***	2.367(0.012)***	2.687(0.011)***
Linear scaled time	-0.031(0.009)***	-0.043(0.006)***	-0.029(0.007)***
Quadratic scaled time	0.005(0.001)***	0.008(0.001)***	0.006(0.001)***
Group membership	42.57	38.07	19.36
Average posterior	0.96	0.94	0.96

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probability

BIC

-99839.10

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Note: Standard errors are in parentheses; \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Figure 1, figure 2 and figure 3 show the joint trajectories of 3-D health. The average disability trajectories were 0.21, 0.47, and 3.72 points at the baseline which finally had risen to 0.72, 1.46, and 4.95 points in 7 years. This corresponded with 1.09, 1.84 and 2.42 points of disease trajectories at the baseline which then developed to 2.19, 3.33, and 4.34 points in 8 years, and corresponded with 4.39, 10.67 and 14.69 points of depression trajectories at baseline which then developed to 4.43, 11.65 and 16.06 points in 7 years.

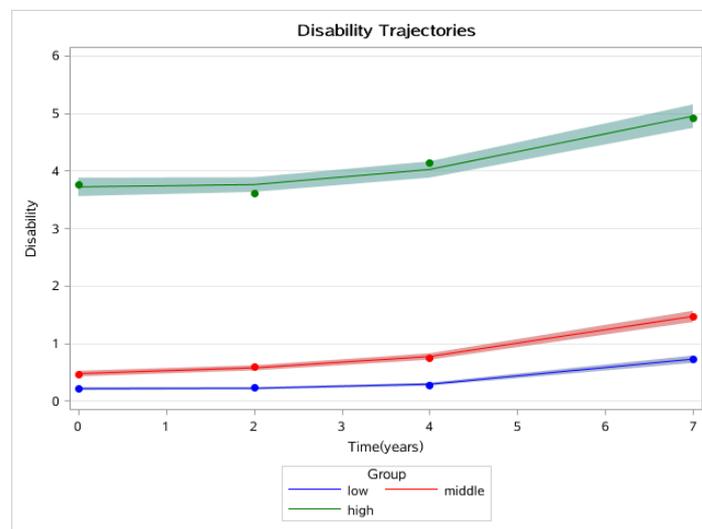


Figure 1 Disability trajectories among a sample of older individuals that survived a 7-year period in China.

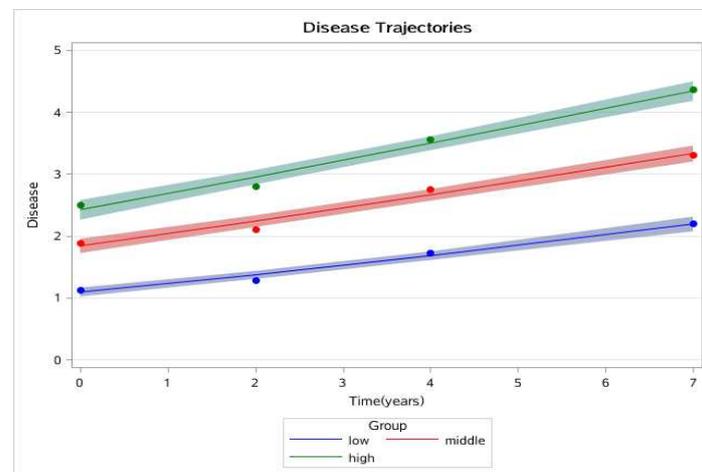


Figure 2 Disease trajectories among a sample of older individuals that survived a 7-year period

in China.

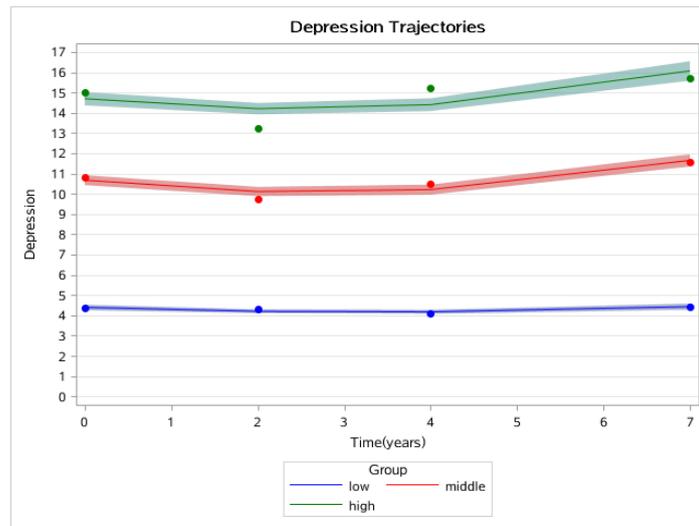


Figure 3 Depression trajectories among a sample of older individuals that survived a 7-year period in China.

### Childhood characteristics of older adults on 3-D health trajectory groups

Table 2 shows all childhood variables that significantly differed among the three trajectory groups. One-way ANOVA or chi-squared test was used to examine the significances of childhood variables among trajectories. The results show that male older adults had a higher probability to be in the low 3-D health group. Older adults with better economic status during childhood had the same tendency to follow the lower 3-D health group. Older adults whose mother and father had higher education levels were more likely to be on the low 3-D health group. Older adults who had better neighborhood safety, a more helpful neighborhood, better neighborhood cleanliness, better health, lower loneliness, playing more with friends, and bullied less by kids during childhood had a higher probability of following the low 3-D health group.

Table 2 Childhood characteristics of older adults on three disability trajectory groups

Variables	N	Group1	Group2	Group3	$\chi^2/F$	p-value
female	4310	695(37.96)	850(52.15)	533(62.78)	159.39	<0.001
Childhood health	4310	2.51(0.96)	2.76(0.98)	2.80(0.99)	38.95	<0.001
Maternal education	4310	1.16(0.69)	1.09(0.48)	1.04(0.29)	16.35	<0.001
Paternal education	4310	1.99 (1.50)	1.80 (1.34)	1.70 (1.33)	15.22	<0.001
Economic status	4310	3.39(0.93)	3.56(0.99)	3.70(1.01)	33.24	<0.001
Parent relationship	4310	2.46(1.17)	2.67(1.23)	2.70(1.26)	17.04	<0.001

Neighborhood Safety	4310	1.54(0.67)	1.67(0.77)	1.70(0.80)	21.66	<0.001
Neighborhood Helping	4310	1.65(0.76)	1.81(0.86)	1.92(0.94)	33.34	<0.001
Neighborhood Cleanliness	4310	2.23(0.74)	2.30(0.79)	0.37(0.85)	9.03	<0.001
Loneliness	4310	3.73(0.72)	3.52(0.93)	3.40(1.03)	49.88	<0.001
Playing with friends	4310	1.74(1.11)	2.03(1.23)	2.21(1.27)	53.80	<0.001
bullied by kids	4310	3.74(0.63)	3.61(0.81)	3.56(0.86)	53.	<0.001

Note: Continuous variables are shown as mean (SD) and categorical variables are shown as frequency (%).

### Childhood predictors and 3-D health trajectories

Table 3 shows the association of childhood demographic variables, family, neighborhood, and friendship predictors with joint 3-D health trajectory group memberships. Model 1 included all childhood variables. The results showed that being female made older adults 88.8% and 199.6% more likely to be in the middle and high 3-D health groups compared with the low 3-D health group. For every point of children's health score reduction, the probabilities of being in the middle and high 3-D health groups were 22.3% and 24.1% higher than that of the low 3-D health group. Every grade increment in maternal education level made older adults 30.4% lower probability to be in the high 3-D health group than in the low 3-D health group. Every grade increment in paternal education level made older adults 5.4% and 7.5% lower probabilities to be in the middle and high 3-D health groups than in low 3-D health group. Childhood economic level decreasing every grade made older adults 7.8% and 19.3% more likely to be in the middle and high 3-D health groups than in low 3-D health group. Parent relationship level decreasing every grade made older adults 9.8% and 9.1% higher probabilities to be in the middle and high 3-D health groups compared with the low 3-D health group.

The neighborhood safety score during childhood decreasing every point made older adults 16.3% and 13.1% more likely to be in the middle and high 3-D health groups than in the low 3-D health group. Neighborhood helping score during childhood decreasing every point made older adults 15.6% more likely to be in the high 3-D health group than in the low 3-D health group. Neighborhood cleanliness score during childhood decreasing every point made older adults 16.8% more likely to be in the high 3-D health group than in the low 3-D health group.

Every point decrement of loneliness score during childhood made older adults 19.3% and 24.5% less likely to be in the middle and high 3-D health groups than in low 3-D health group. Every point of increment of playing with friends score during childhood older adults made older adults 14.8% and 24.3% less likely to be in the middle and high 3-D health groups than in low 3-D health group. Every point decrement of bullied by kids score during childhood made older adults 17.2% and 20.2% less likely to be in the middle and high 3-D health groups than in low 3-D health group.

To explore the mediate effects of adulthood variables, model 2 included the childhood variables plus adulthood variables. The significances of maternal education, paternal education, family economic status, neighborhood safety, neighborhood helping, and playing with friends were vanished or decreased after added adulthood variables, while the impacts of other variables on group memberships of 3-D health trajectory were changed only a little.

Table 3 Effects of early factors on the 3-D health trajectory model among a sample of older adults survived 8 years in China

Variables	Model 1		Model 2	
	OR		OR	
	Group 2	Gtoup3	Group 2	Gtoup3
	Vs	vs	Vs	vs
	Group 1	Group1	Group 1	Group1
Female	1.888***	2.996***	1.959***	2.713***
Childhood health	1.233***	1.241***	1.236***	1.242***
Maternal education	0.896	0.696**	0.948	0.800
Paternal education	0.946*	0.925*	0.975	0.976
Family economic status	1.078*	1.193***	1.045	1.149**
Parent relationship	1.098**	1.091*	1.095**	1.100*
Neighborhood Safety	1.163**	1.131*	1.156**	1.098
Neighborhood Helping	1.075	1.156**	1.073	1.108
Neighborhood cleanliness	1.055	1.168**	1.074	1.200**
Loneliness	0.807***	0.755***	0.836***	0.793***

Playing with friends	1.148***	1.243***	1.102**	1.141***
Bullied by kids	0.828***	0.798***	0.815***	0.767***
Age			1.007	1.047***
Education			0.941**	0.809***
Residence			1.612***	1.533***
Marriage status			0.91	0.854
Smoking			1.073	1.152
Drinking			1.140	1.088
Medical insurance			0.766	0.698
Pension			0.849*	0.722***
BIC		8756.69		8564.09

Note: Statistics are shown as OR and 95% confidence interval. OR=odds ratio; CI=confidence interval; BIC= Bayesian Information Criterion; \*p <0.05, \*\*p <0.01, \*\*\*p <0.001.

## Discussions

In this study, we identified three joint trajectories of 3-D health according to the model fit indexes and explanation of the results. The results were not coincident with other studies. Martin et al. found a more rapid increment of disability trajectory<sup>15</sup> and Liang found four depression trajectories<sup>11</sup>. We also tried to use four trajectories of 3-D health, but the results were hard to explain so finally we used the three trajectories of 3-D health. Our results showed that the 3-D health trajectories had increasing trends and the disease had the most obvious increment over time than disability and depression, which means effective interventions are necessary for better 3-D health.

Being female was fragile to have a higher 3-D health trajectory (see model 1 in table 3), which was coincident with other studies that used depression as the outcome variable<sup>11,14</sup>. But the result was different from the study that used disability as outcome variables, which found weaker association between sex and disability trajectories<sup>15</sup>. Model 2 in table 3 showed that the significant level of female was not changed compared with model 1 which means that female is more likely to be associated with joint health trajectory directly. The thought of “male-first” in traditional China causes being female to have fewer resources than being male to maintain their health in childhood, which suggests more attention should be paid to the health of female during

childhood.

Worse childhood health was associated with a higher 3-D health trajectory (see model 1 in table 3), which means that improving childhood health is important to the better 3-D health of old adults. A previous study found childhood health could affect disability trajectories indirectly through adult variables<sup>15</sup>. In this study, we used 3-D health trajectories as dependent variables and found different results. Model 2 in table 3 showed that the significant level of childhood health was not changed compared with model 1, which means that childhood health is more likely to be associated with 3-D health trajectory membership directly. The inclusion of disease and depression as a dependent variable in our study may strengthen the direct effect of childhood health. So the government and society should pay more attention to the health of children.

A previous cross-section study showed maternal education could affect the health of Chinese old adults indirectly through adult variables, while paternal education could not affect the health of Chinese old adults by using CHARLS data<sup>22</sup>. In this study, we used 5 waves of CHARLS data, and found that higher maternal and paternal educations were both associated with lower 3-D health trajectories (see model 1 in table 3). Model 2 in table 3 showed that the significant levels of maternal and paternal educations were vanished compared with model 1, which means that maternal and paternal educations are more likely to be associated with group memberships of joint health trajectory indirectly through adult variables. So, the Chinese government should improve the education level of parents for better health of later life of their children.

Previous studies showed the result of the association between childhood family economic status and later health was still inconsistent<sup>5,22</sup>. The study found that better childhood family economic status was associated with better 3-D health (see model 1 in table 3). When compared with model 2 in table 3, the significant level of childhood family economic status in model 2 reduced but still significant, which meant childhood family economic status can affect the 3-D health trajectory membership both directly and indirectly through adult variables. Based on the result, the government should pay more attention to the children who are from poor economic family.

Previous studies found that the childhood parent-child relationship could affect later health<sup>17</sup>. But when we added the childhood parent-child relationship variable to model 1, we did not find the relationship (result not shown). Instead, we found better parent relationship during childhood was related to better 3-D health trajectories of older adults (see model 1 in table 3), and when

added the adult variables to model 2 in table 3, the significant levels of the OR values were not changed, which meant that parent relationship during childhood was more likely to be associated with group memberships of 3-D health trajectory directly. A harmonious family atmosphere during childhood should be created for the health of older adults.

Better safety of neighborhood was associated with better 3-D health trajectories of older adults (see model 1 in table 3), and when added the adult variables to model 2 in table 3, the significant level of the OR values vanished on high group versus low group and the significant level of the OR values was not changed on middle group versus low group compared with model 1, which mean that safety of neighborhood could be associated with 3-D health trajectory membership both directly and indirectly through adult variables. So, it is necessary to improve the safety of the neighborhood since childhood for the health of older adults.

More neighborhood helping during childhood was associated with better 3-D health trajectories of older adults (see model 1 in table 3), and when added the adult variables to model 2 in table 3, the significant level of the OR values was vanished, which meant that childhood neighbor helping was more likely to affect group membership of joint health trajectory indirectly through adult variables. So the government should advocate for neighborhoods helping for better health of older adults.

Better cleanliness of childhood neighborhood was associated with better 3-D health of older adults (see model 1 in table 3), and when added the adult variables to model 2 in table 3, the significant level of the OR values was not changed compared with model 1, which meant that cleanliness of childhood neighborhood was more likely to be associated with joint health trajectory membership directly. The Chinese ministry of health should improve the cleanliness of neighborhoods to improve the health of older adults.

Every level decrement of childhood loneliness and bullied by kids scores and every level increment of playing with friends score were all associated with the better 3-D health trajectories of older adults (see model 1 in table 3), and when added the adult variables to model 2 in table 3, the significant levels of the OR values were nearly no change compared with model 1, which means that childhood loneliness, playing with friends, bullied by kids are more likely to affect the memberships of joint health trajectory group directly. The results indicate the importance of friendships and more interventions should be performed to improve the friendship during

childhood for improving the health of later life.

### **Limitations**

Several important limitations persistently haunting the field of trajectory modeling and disability researches were still unavoidable. First, we did not include the time-varying indicators when we have estimated the multi-trajectory, which might alter our findings. So, further studies are needed.

Second, the variables we used were from self-reported surveys, which may cause bias. However self-reported data (e.g., disease, depression, disability) is commonly used in health trajectory researches of older adults and it can reflect personal status interacting with the real world more accurately<sup>23</sup>.

Third, it may lose some information as we used the summative scores to represent the disability, disease and depression. However, previous studies widely used the summative scores in the health researches of older adults and proved the results of summative scores are acceptable and consistent<sup>8,9,24,25</sup>.

### **Conclusions**

This study contributes to the existing research in three respects: first, a large five-wave national representative panel data is used and allows for a better investigation of 3-D health trajectories and its childhood predictors of older adults.

Second, it is the first paper to carry out the joint trajectory model to explore the trajectory of 3-D health of older adults and find an increasing trajectory of joint health trajectory. The results are meaningful for understanding the course of 3-D health of older adults.

Third, it is the first paper focusing on the childhood predictors of the health trajectory of older adults. The paper can provide a new perspective for the Chinese ministry of health to precisely issue the intervention policies for "Actively Responding to Aging" and "life-cycle health management" strategies and finally improve the health of older adults.

### **Materials and methods**

#### **Study population and measurements**

CHARLS is a longitudinal survey that aims to be representative of the residents in mainland China aged 45 and older, with no upper age limit. The national baseline survey was conducted in 2011-12, with wave 2 in 2013, wave 3 in 2014, wave 4 in 2015 and wave 5 in 2018. Wave 4 was a

life history survey. To ensure sample representativeness, the CHARLS baseline survey covered 150 countries/districts, 450 villages/urban communities, across the country, involving 17,708 individuals in 10,257 households, reflecting the mid-aged and older Chinese population collectively. More details of CHARLS were described in the study of Ferraro et al. <sup>26</sup>. In this study, the data of 2011, 2013, 2014, 2015 and 2018 waves were used and the individuals older than 60 were included. After excluded the missing data and the individuals younger than 60, the number of each wave was: wave 2011, n=4310; wave 2013, n=4106; wave 2015, n=4046; wave 2018, n=3588. Since wave 2014 is a life history survey, the participants were the same as wave 2011.

Attrition is a particular concern in analyzing longitudinal data. In this paper, intermittent missing data was assumed as missing at random (MAR) and Maximum Likelihood was applied to handle it. A total of 51% attrition by the end of the survey was caused by mortality. Because the attrition due to death was ignorable, we used a multi-trajectory model to modeled mortality as a joint part of the disability trajectories <sup>27</sup>, which allowed calculating trajectory-specific attrition rates due to death and adjusting the trajectory group membership probabilities.

### **Dependent variables**

The degree of disability was measured by ADL and IADL. ADL was measured by a 6-item summary, which includes bathing, dressing, eating, getting in/out of bed, using the toilet, and controlling urination. IADL included managing money, taking medications, shopping for groceries, preparing meals, cleaning house. Disability was dichotomized into no difficulty (0) and some difficulty (1) in performing the tasks. As recommended by previous studies <sup>24,25</sup>, we combined ADL and IADL disabilities in a simple sum to enhance the sensitivity of scaling. So the total score of the severity of disability was 0 to 22.

Depression was measured by the CES-D-10 scale and composed of ten questions including “feeling depressed”, “feeling that everything was an effort”, “whether the respondent’s sleep was restless”, “feeling lonely” and so on <sup>9</sup>. The code was from never (0) to all of the time (3). So the total score of depression ranged from 0 to 30, with higher scores indicating the respondent felt more depressed.

According to other studies <sup>8</sup>, disease was assessed by a sum of 13 different chronic diseases. Each chronic disease was reported by asking “Have you been diagnosed with the following conditions by a doctor”, these chronic diseases were: hypertension, diabetes, cancer, chronic lung

disease, heart disease, stroke, emotional problem, arthritis, dyslipidemia, liver disease, kidney disease, digestive disease, and asthma. The answer to each question was coded “no” (0) or “yes” (1). So the total score of disease ranged from 0 to 13.

### **Independent variables**

Sex was coded as “male” (0) and “female” (1). Childhood health ranged from 1 to 5, with higher score indicating a worse childhood health. Maternal and paternal educations ranged from 1 to 9, with a higher score indicating a better education level. Family economic status in childhood ranged from 1 to 5, with a higher score indicating a better economic level. Parent relationships ranged from 1 to 5, with a higher score indicating a better relationship. Neighborhood safety, neighborhood helping, neighborhood cleanliness were all ranged from 1 to 4, with a higher score indicating a worse neighborhood quality. Loneliness, friend playing, bullied by kids ranged from 1 to 4, with a higher score of loneliness and bullying by kids indicating a better friendship quality and with a higher score of playing with friends indicated a worse friendship quality. More details are shown in the supplementary material.

### **Statistical Analysis**

Two stages in the statistical analysis were performed. In the first stage, a multi-trajectory modeling was used to identify the joint trajectories of 3-D health. The approach uses maximum likelihood estimation for the trajectories with discrete groups sharing different patterns<sup>28,29</sup>. Trajectory modeling distinguishes one outcome with several trajectories and individuals in the same group have the same trajectory. Recent improvement of multi-trajectory modeling allows for joint modeling of more than two outcomes and omission caused by mortality<sup>27</sup>. Each trajectory groups is now defined by several trajectories which depend on the number of outcomes, the likelihood of multi-trajectory modeling is:

$$P(Y_1, Y_2, \dots, Y_n) = \sum_k \pi_k \prod_n f_n^k(Y_k)$$

Where  $n$  represents the number of different outcome trajectories in each trajectory group  $k$ .  $f(*)$  represents the distribution for each outcome and can be different across the outcomes. Here the zero inflation poisson distributions were used for disability and depression and censor normal distribution for diseases. Model fit was identified by BIC value and the average posterior probability of each group based on the Maximum Likelihood Estimates, which was proposed by

Nagin<sup>30</sup>. The smaller the BIC value, the better the trajectory model fit is. The threshold of the average posterior probability is 0.7 and higher than 0.7 means an acceptable model fit. As with other similar studies, we also considered the explanation of each trajectory when we chose the appropriate number of potential trajectories<sup>11,31</sup>. The PROC TRAJ option was performed for SAS 9.4 to estimate the model<sup>27-29</sup>.

The multinomial regression model was used to analyze the association of the childhood predictors and membership in trajectory groups by using the “Glimmix” procedure for SAS 9.4. Maximum likelihood estimation was applied to the model estimation. The OR values were applied to assess the probability for older adults in different trajectory groups<sup>15</sup>.

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#### **Author contributions statement**

CPP conceived, designed, and analyzed the data, and was responsible for interpretation of findings, primary drafting of manuscript, revisions. CW, BS and PGW made substantial contributions to interpretation of data and revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

#### **Competing interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

#### **Funding**

The author(s) received no financial support for the research, authorship, and/or publication of this article.

# Figures

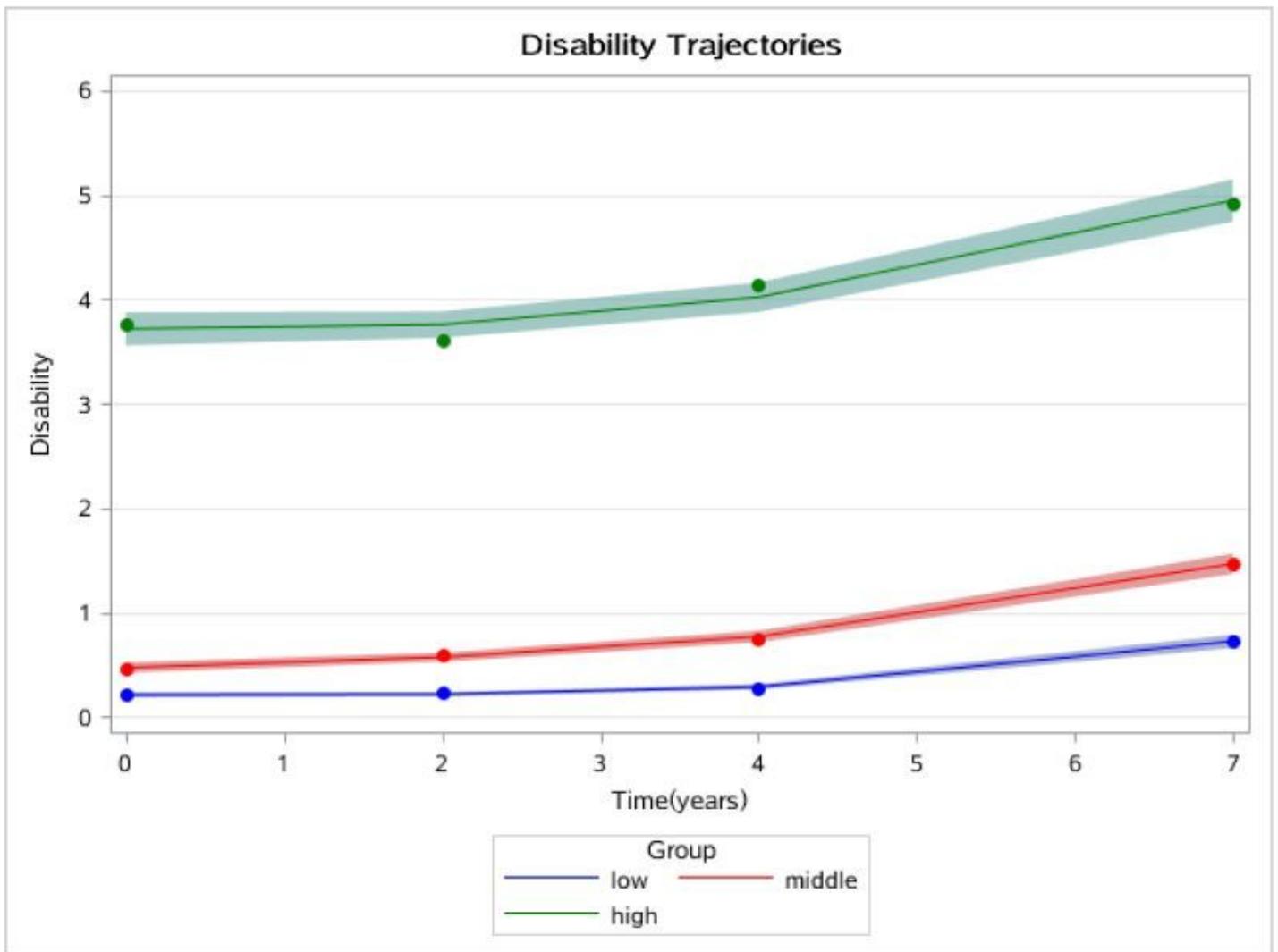
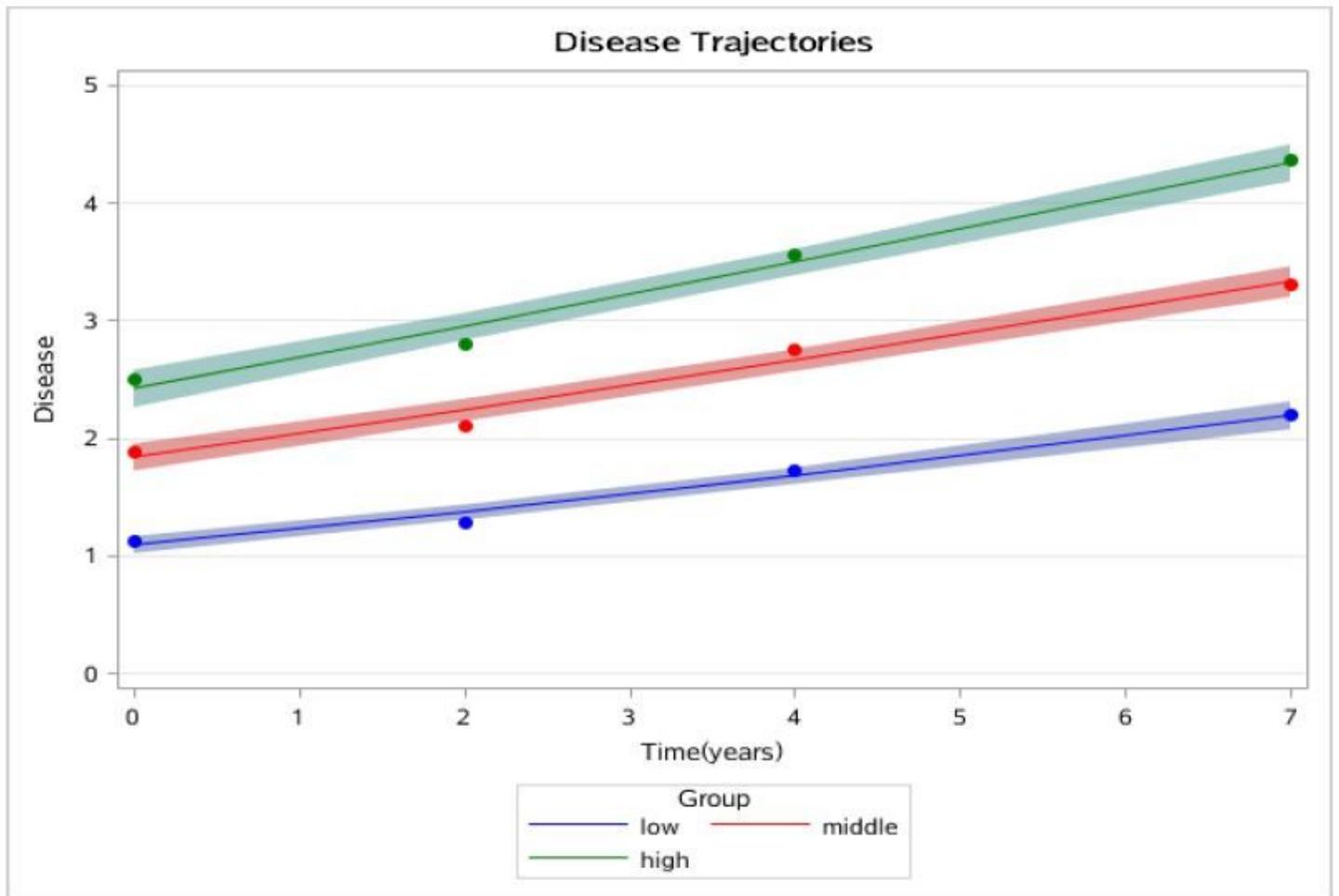


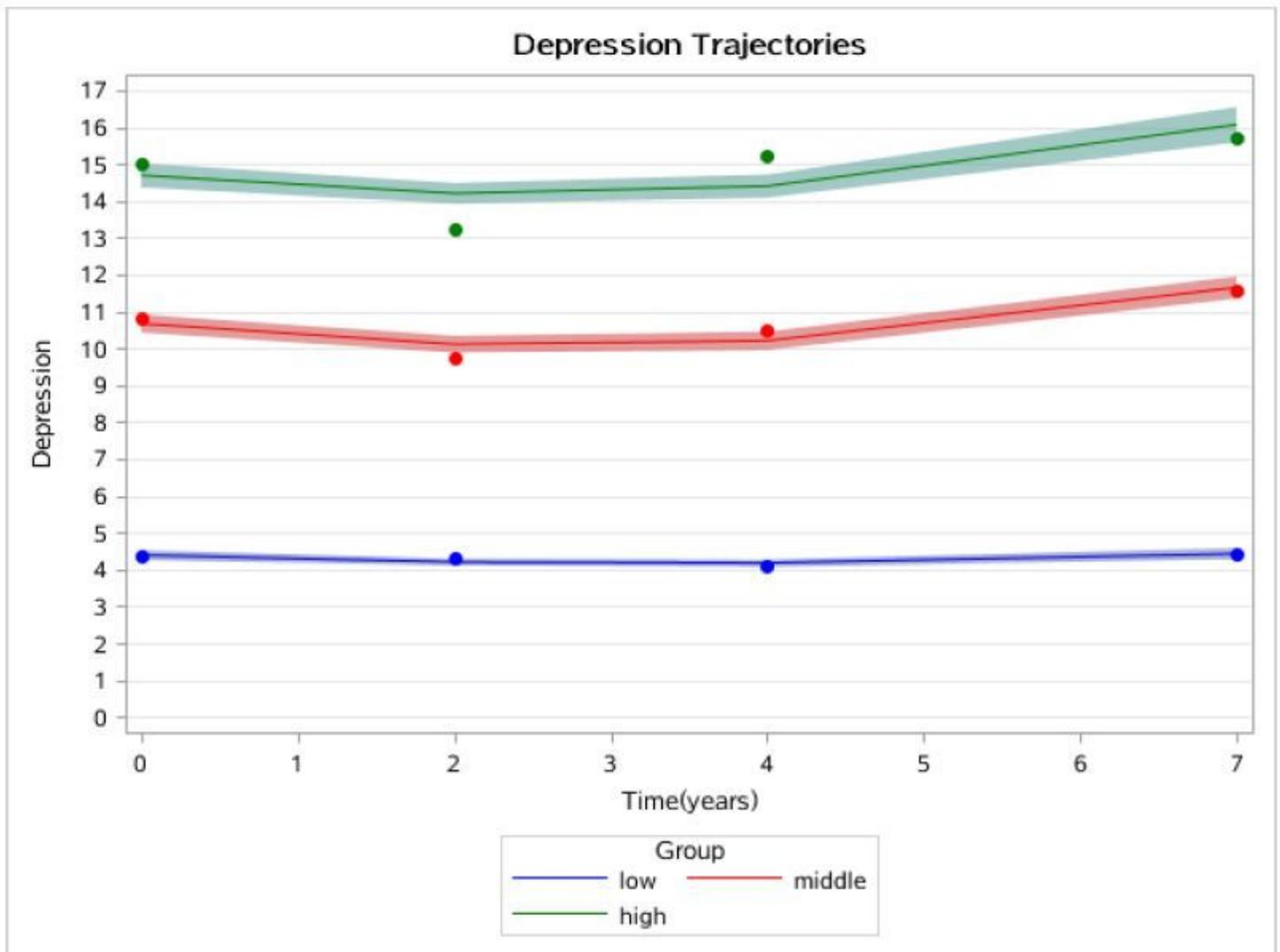
Figure 1

Disability trajectories among a sample of older individuals that survived a 7-year period in China.



**Figure 2**

Disease trajectories among a sample of older individuals that survived a 7-year period in China.



**Figure 3**

Depression trajectories among a sample of older individuals that survived a 7-year period in China.

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