Heterogeneous trajectories of depressive symptoms in the aging process: A sequence analysis within nine-year follow-ups of Chinese cohorts

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Abstract

Objective: Depression in later life has increasingly become alarming with the progressive population aging worldwide, but the dynamics of depression may vary across individuals in the aging process. This study aims to address heterogeneity in the trajectory of depression among Chinese cohorts transitioning to older courses and examine demographic and socioeconomic factors associated with different types of the trajectory.

Methods: Using data from the 2011-2020 China Health and Retirement Longitudinal Study (CHARLS), the study employed sequence analysis to address heterogeneity in the trajectories of depressive symptoms for Chinese cohorts aged 45-64 years (n = 6161) in 2011 and conducted multinomial logistic regression to examine factors associated with the trajectory membership.

Results: 43% of respondents did not report depressive symptoms over the study period. Additional eight types of trajectories of depressive symptoms were identified for respondents who experienced the emergence, persistence, or remission of depression over time. Better socioeconomic conditions were associated with decreased risks for following depression trajectories. Age was not necessarily linked to the presence of depression; yet, age-related events, such as the loss of spouse, diminishing family connections, and declining physical health, played significant roles in developing and sustaining depressive symptoms as people aged.

Conclusions: Trajectories of depressive symptoms were heterogeneous across populations entering older ages. Improving socioeconomic conditions, encouraging social connections, and promoting physical health matter for depression prevention and control in the aging population.

Keywords: Depression; Healthy aging; Social determinants of health; Sequence analysis

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Introduction

Depression is prevalent among populations entering their middle to late life (Hu et al., 2022; Zenebe et al., 2021), elevating morbidity and mortality in multiple related diseases (Meng et al., 2020; Rodda et al., 2011). With the progressive population aging worldwide, the threat of depression has become further alarming, necessitating better research understanding of the developmental pattern of depression to promote healthy later lives. The long-established literature has documented variations in the association between age and depression across aging populations: The risk of depression may increase (Ge et al., 2025; Lei et al., 2014; Li et al., 2016; Stordal et al., 2003) or decrease (Fan et al., 2021; Xu et al., 2024) with age, or display a non-linear pattern over the life course, with relative peaks of the risk arising in the middle and the latest life (Best et al., 2021; Snowdon, 2001; Xu et al., 2024).

Age-related risk factors may be accountable for the association between age and depression among older people. Ill physical conditions and other stressful and adverse life events arise as people age, such as labor market status transitions and bereavement. These events may provoke and fuel depressive symptoms (Blazer & Hybels, 2005; Fan et al., 2021; Kendler et al., 1999; Lei et al., 2014; Li et al., 2016; Li et al., 2021; Stordal et al., 2003; Zenebe et al., 2021). Yet, people from different sociodemographic backgrounds typically experience heterogeneous life trajectories, and socioeconomic advantages offer safeguards against the onset and persistence of depressive disorders in the aging process (Blazer & Hybels, 2005; Fan et al., 2021; Lei et al., 2014; Li et al., 2016; Lorant et al., 2003). As such, individuals may maintain stable mental health or go through a rise, decline, or fluctuation in depressive symptoms, subject to their aging experiences and conditions. In other words, the trajectories of depressive symptoms of individuals across their life cycles are heterogeneous.

Studies to date have drawn on longitudinal data and primarily used group-based trajectory models to fit curvilinear trajectories of depressive symptoms over time at the population level, showing distinct trajectory patterns varying in the severity and stability of symptoms within a population (Agustini et al., 2022; Musliner et al., 2016; Xie et al., 2023). This approach simplifies the typology of the trajectory specific to individuals. However, originating from complex interactions between individuals and environments with advancing age (Blazer & Hybels, 2005), the symptoms may not always emerge in a curvilinear manner as assumed, but investigations in this regard are not adequate.

This present study aims to enhance the knowledge about the heterogeneous trajectories of depressive symptoms in the course of aging. Instead of modeling growth curves, I defined the trajectory of depressive symptoms by the discrete sequence of depressive states for each individual over an observational window. I conducted sequence analysis to holistically depict the trajectory over a nine-year period from 2011 to 2020 for Chinese cohorts aged 45-64 years at baseline of the China Health and Retirement Longitudinal Study (CHARLS) and identified the typology of the trajectory. I further explored the sociodemographic factors linked to the trajectory membership for the study population.

China has the largest amount of older population growing at an unprecedented pace (Han et al., 2020), having confronted increasing burdens of psychological health similar to many other aging and aged countries (Ying et al., 2024). An explicit understanding of the heterogeneous patterns and the social determinants of depression among people transitioning into later life provides implications for early recognition and intervention in the global era of aging.

Methods

Study population

Data were drawn from the CHARLS, a nationally representative dataset of middle-aged and older people sampled in the Chinese mainland, collecting wealthy information on individual socioeconomic backgrounds and health outcomes (Zhao et al., 2023; Zhao et al., 2014). The baseline survey was mostly conducted in July and August 2011 and lasted until March 2012. Subsequent follow-ups were completed in 2013, 2015, 2018, and 2020. Each wave of the CHARLS was approved by the Institutional Review Board at Peking University (IRB00001052-11015), and all participants signed informed consent. De-identified data and associated documentation are publicly accessible at https://charls.charlsdata.com/.

This study included the CHARLS participants who were aged 45-64 years at baseline (born between 1946 and 1966) and participated in four subsequent waves of follow-ups. Participants who did not complete the depression survey module, answered "don't know," or refused to answer more than one out of the ten items of the depression scale in any survey wave were excluded from the analysis. A flowchart of sample selection is presented in Figure A1 in Appendix 1. The analytic sample included 6161 participants, whose depressive symptoms were repeatedly assessed five times between 2011 and 2020. Of these participants, 53.3% were women, and the mean age at baseline was 54.3 years.

Measures

Depressive symptoms were measured by the short form of the Centre for Epidemiologic Studies Depression Scale (CES-D), which consists of ten descriptive statements of moods and somatic symptoms (detailed in Table A1 in Appendix 1) and has been established as a valid screening tool (Andresen et al., 1994). Each item was assessed on a four-point scale in terms of the frequency of the symptom during the last week before the interview, ranging from "rarely or none of the time (less than 1 day)" to "most or all of the time (5-7 days)." The CES-D score was obtained as the sum of scores for 10 items, ranging from 0 to 30, with a higher score indicating a greater degree of depressive symptoms. Three depressive states were defined using the cut-off points of 12 and 18, where 12 was shown to be a suitable diagnostic threshold of depression for older Chinese people (Cheng & Chan, 2005), and 18 represented the 75th percentile of the score. Scores below 12 were classified as "no symptoms," scores between 12 and 17 as "depression," and scores equaling or above 18 as "major depression." The sequence of categorical depressive states at five survey waves defined the trajectory of depressive symptoms.

A series of sociodemographic variables was selected to examine the associated factors of the trajectory of depressive symptoms. These factors included basic demographics, such as gender, baseline age, and birth cohort, time-invariant socioeconomic factors, such as years of schooling, parents' highest years of schooling as a proxy of childhood socioeconomic background, and residence locality, measured by the urban/rural dichotomy and geographic regions with distinct economic features.

Time-varying demographic factors, such as marital status, employment status, intergenerational relation, and physical health status, were categorized based on changes in the status at five sequential waves to capture experiences and role transitions that had occurred as individuals aged. I also included a count variable to measure the degree of social connections, which was calculated as the cumulative number of the survey waves in which individuals had frequently connected with their communities. Table A2 in Appendix 1 displays descriptive summaries of the study sample. Definitions and classifications of these variables are detailed in Appendix 2 of the supplementary material.

Analytical strategies

The study used sequence analysis, which has been increasingly applied in interdisciplinary spheres of social sciences to study life trajectories (Cornwell, 2015; Studer & Ritschard, 2016), to depict the individual trajectory of depressive symptoms over the nine-year span and identify between-individual dissimilarities in their trajectories. The longitudinal CHARLS data provide discrete, repeated measures of psychological health states, forming a sequence of depressive symptoms for each individual defined as a trajectory. The approach enables the visualization of individual-specific trajectories of the symptoms and the identification of typical patterns of the trajectory across individuals through clustering sequences.

The method of optimal matching of spells (OM spell) was adopted to compare trajectories by compressing the sequences of depressive states into sequences of spells, where a spell represents a consecutive period during which an individual spent in the same state across survey waves (Cornwell, 2015; Studer & Ritschard, 2016). The method accordingly treats the spell as an independent element and integrates the optimal matching algorithm to compute minimal distances, namely edit costs, between pairwise sequences, in terms of insertion/deletion (*indel*) and substitution transformations, required to transform one sequence into another (Studer & Ritschard, 2016). The cost parameter settings seek to balance the distinct dimensions of sequences to understand how sequences differ from each other (Lesnard, 2010; Studer & Ritschard, 2016). In this study, the sequence dissimilarity arose primarily from the order in which depressive states occurred. The analysis accordingly set a low indel cost to reduce the impact of the timing of states. Substitution costs were assigned to account for the likelihood of transitions between states: a low substitution cost was adjusted between "no symptoms" and "depression," compared to that between "depression" and "major depression." Meanwhile, a low expansion cost was set to compress the cost of spell length, reduce relative sensitivity to the state duration, and accordingly highlight the order of states across the five survey waves.

Ward's hierarchical cluster analysis was conducted to create clusters of trajectories based on the optimal matching distance matrix, classifying individual trajectories into typical heterogeneous groups. The study obtained a cluster membership for each trajectory and used it as the explained variable in the multinomial logistic regression to examine its associated factors. Continuous variables were standardized in the regression model. The major analysis was conducted by TraMineR (Gabadinho et al., 2011), WeightedCluster (Studer, 2013), and related packages in R.

Results

Typology of the trajectories of depressive symptoms

Figure 1 plots the nine-year trajectory of depressive symptoms for each individual and the state distributions in each wave. While in each survey wave, around 73% of the study samples did not report depressive symptoms, 43% of the samples did not present any salient depressive symptoms over the nine-year spans. However, the remaining individuals displayed rather distinctive sequence patterns: People who had undergone evident psychological fluctuations experienced heterogeneous trajectories of the symptoms as they aged.

[Figure 1]

Results from sequence analysis using the OM spell method provide hints for understanding the patterns. As shown in Figure 2 (Figure A2 in Appendix 1 depicts the associated state distribution for each cluster), nine clusters, representing nine typical trajectory patterns, were identified across the study populations based on the tradeoff in the cluster quality measures (Studer, 2013): (1) stable non-depressed (43.0%), (2) transient depression (10.4%), (3) transient major depression (6.7%), (4) emerging depression (7.2%), (5) emerging major depression (7.0%), (6) recurrent depression (12.6%), (7) persistent depression with fluctuating severity (3.6%), (8) persistent depression with episodes of major depression (3.3%), and (9) remission of depression (6.2%). Individuals who had ever reported depressive symptoms at any point during the study window experienced varying trajectories, characterized by worsening, improvement, or recurrent depressive conditions.

[Figure 2]

Factors associated with the type of trajectory

Table 1 shows the relative risk ratios (RRR) estimated from the multinomial logistic regression. The base category was the trajectory of stable non-depressed states. Holding other variables constant, baseline age, as well as birth cohort membership, were not consistently associated with depression trajectories in a single direction. However, the results highlighted two leading attributions in terms of factors associated with the trajectory membership. First, better socioeconomic positions in middle and later life were associated with a greater likelihood of following the trajectory of stable non-depressed states. Second, experiencing any stressful or

adverse event in the aging process was generally related to trajectories therein the emergence or persistence of depressive symptoms.

[Table 1]

Specifically, compared to following the stable non-depressed trajectory, the relative risk of experiencing any depressive symptoms with aging was consistently higher for females, who were particularly likely to follow the trajectory of persistent depression with episodes of major depression (trajectory 8: RRR = 4.97, 95% CI = 3.32 – 7.44). Individual education, as a key indicator of socioeconomic status, significantly reduced the relative risk of experiencing depressive symptoms. In particular, higher-educated middle-aged and older people had lower risks of developing and sustaining major depression as age increased (trajectory 5: RRR = 0.62, 95% CI = 0.54 – 0.70). After controlling for individual education, parental education was slightly associated with a reduced risk of depression among middle-aged and older adults. In terms of residential locality, residing in urban areas compared to rural areas was linked to decreased relative risks of developing and sustaining depressive symptoms over the study periods (trajectory 4: RRR = 0.58, 95% CI = 0.45 – 0.74; trajectory 6: RRR = 0.58, 95% CI = 0.47 – 0.72; trajectory 7: RRR = 0.58, 95% CI = 0.40 – 0.84; trajectory 8: RRR = 0.57, 95% CI = 0.38 – 0.86). Similarly, living in more economically developed regions, especially the eastern-costal region of the mainland, compared to western inland regions, was consistently associated with lower risks of experiencing depressive symptoms, and the relative risk of sustaining major depression was significantly reduced (trajectory 8: RRR = 0.19, 95% CI = 0.12 – 0.30).

On the other hand, being single or widowed, experiencing unstable employment or transition to retirement, having weak connections with children, and suffering physical illness were strongly associated with the increased relative risks of membership in any trajectories characterized by depressive symptoms, as opposed to membership in the non-depressed trajectory. Compared to stably partnered people, prolonged widowhood significantly elevated the relative risk of persistent depression (trajectory 7: RRR = 5.01, 95% CI = 2.91 – 8.61; trajectory 8: RRR = 3.48, 95% CI = 1.89 – 6.41), and the occurrence of widowhood also increased the relative risk of developing depression and major depression (trajectory 3: RRR = 1. 95, 95% CI = 1.33 – 2.85; trajectory 4: RRR = 1.60, 95% CI = 1.08 – 2.36; trajectory 5: RRR = 2.00, 95% CI = 1.36 – 2.94). Despite the small number of single participants in the sample, being single significantly increased the expected risk of emergence and persistence of depression and major depression over the study period (In particular, for trajectory 8: RRR = 8.81, 95% CI = 2.61 – 29.78).

Compared to individuals engaged in non-agricultural employment during the study period, those working in agriculture were more likely to follow various trajectories of depression rather than the non-depressed trajectory (trajectory 3: RRR = 2.00, 95% CI = 1.32 – 3.03; trajectory 6: RRR = 1.92, 95% CI = 1.42 – 2.59; trajectory 8: RRR = 2.21, 95% CI = 1.04 – 4.69), and those working intermittently also particularly had higher relative risks for developing major depression with aging (trajectory 3: RRR = 2.02, 95% CI = 1.33 – 3.06; trajectory 5: RRR

= 1.85, 95% CI = 1.23 – 2.78). In addition, the transition from work to retirement was associated with an increased relative risk of developing major depression (trajectory 5: RRR = 1.64, 95% CI = 1.05 – 2.56) but also experiencing transient major depression (trajectory 3: RRR = 1.99, 95% CI = 1.27 – 3.11). However, long-term retirement did not have evident associations with membership in the depression trajectories.

Compared to individuals who maintained close connections with their children, those with less frequent contact with children had higher relative risks of experiencing transient or recurrent symptoms, or persisting in depression (trajectory 3: RRR = 1.37, 95% CI = 1.09 – 1.73; trajectory 6: RRR = 1.34, 95% CI = 1.11 – 1.61; trajectory 7: RRR = 1.44, 95% CI = 1.04 – 1.99). Having no child or lacking in-person contact raised the relative risk of persistent depression characterized by fluctuating severity over time (trajectory 7: RRR = 2.70, 95% CI = 1.57 – 4.64). Conversely, engagement in grandchildren care could somewhat reduce the relative risk of following the trajectory of transient depressive symptoms (trajectory 2: RRR = 0.78, 95% CI = 0.63 – 0.96).

Membership in any depression trajectory was strongly related to changes in physical health. In particular, the relative risks of persisting in depression or major depression were substantially elevated for individuals who experienced intermittent functional limitations (trajectory 7: RRR = 9.28, 95% CI = 6.29 – 13.70; trajectory 8: RRR = 8.70, 95% CI = 5.66 – 13.37), newly developed limitations (trajectory 7: RRR = 8.42, 95% CI = 5.30 – 13.38; trajectory 8: RRR = 8.47, 95% CI = 5.16 – 13.92), and suffering long-term limitations (trajectory 7: RRR = 99.23, 95% CI = 38.18 – 257.91; trajectory 8: RRR = 106.95, 95% CI = 39.61 – 288.74) during the study period. Similarly, worsening chronic conditions significantly raised the relative risk of persisting in depression over time (trajectory 8: RRR = 25.22, 95% CI = 3.34 – 190.20).

The results also indicated that frequent social connection could serve as an intervention tool to reduce the relative risk of following depression trajectories. In particular, frequent participation in social activities significantly reduced the relative risk of experiencing persistent depression and major depression over time (trajectory 8: RRR = 0.60, 95% CI = 0.50 – 0.72).

Figure 3 depicts the marginal effects of each variable estimated from the model (see detailed results in Table A3 in Appendix 1), revealing consistent findings regarding factors associated with the trajectory membership.

[Figure 3]

Discussion

Although age appears to be a strong predictor of depression among the aging population in some studies, age *per se* should not be the attribution to older-age depression. Using a nationally representative Chinese sample over a nine-year period from 2011 to 2020, this study conducted sequence analysis to present strong heterogeneity in the trajectory of depressive symptoms across middle-aged and older Chinese, showing that over 43% of individuals did not

report depressive symptoms over nine years. However, others experienced occasional or persistent symptoms to varying degrees.

Findings from multinomial logistic regression suggest that socioeconomic conditions have an enduring imprint on individual health trajectories: People of higher socioeconomic status and residing in more-developed regions are more likely to follow a trajectory with no depressive symptoms as they age; however, on the other hand, age-related life events, such as changes in marital status, employment instability or role transitions, and physical illness, elevated the likelihood of developing and sustaining depressive symptoms over time. This study also suggests the importance of social connections in mid-to-later life to maintain psychological health. While long-run efforts should be made to improve economic security and reduce socioeconomic inequalities for people entering older ages, family and community support may offer more immediate ways to encourage active social engagement for older people to prevent and mitigate psychological risks.

Study limitations may be further addressed. The study sample included cohorts who participated in all subsequent rounds of survey follow-ups, but sample attrition may underestimate the severity of depression in middle-aged and older people, as depression may likely be prevalent among those who did not respond in the follow-ups. Yet, a longer-term follow-up study may be more favorable for examining the trajectories and understanding the patterns. In addition, the study did not target older-old people, who may also experience wide variations in the trajectory of psychological health (Best et al., 2021; Luppa et al., 2012). An additional concern is cohort differences across populations. As the birth cohort locates unique experiences of individual development (Elder, 1975), the patterns of health trajectories may be further featured by historical experiences specific to the cohorts. Evidence has indicated that people in more recent cohorts appear to exhibit greater risks of depression (Xu et al., 2024). Moreover, while the prevalence of older-age depression is high on a global scale (Zenebe et al., 2021), cultural differences may also explain the potential heterogeneity in trajectories of depressive symptoms among mid-to-older people from different countries and regions.

Still, this study contributes to the literature by highlighting the heterogeneous features of depression study among older people. Aging accompanies numerous potentially depressed events, but inherent socioeconomic advantages and acquired social support serve as protectors. Yet, current socioeconomic inequalities may, in turn, play a role in the variations. I call on continuing longitudinal studies to track psychological health in older people and pay special attention to people with socioeconomic disadvantages in the coming age of population aging. With the increasing longevity worldwide, the threshold of being older appears to become blurry depending on people's psychological, subjective conditions (Alonso Debreczeni & Bailey, 2021; Fan et al., 2021). Heterogeneity may become an increasingly remarkable characteristic of people's health at older ages.

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Table 1. Relative risk ratios of factors associated with trajectory membership.

	Type of trajectory, base outcome (1)							
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female (ref: male)	1.529***	1.653***	1.406***	2.067***	2.012***	2.590***	4.974***	1.596***
	(4.119)	(3.798)	(2.791)	(5.365)	(6.897)	(5.314)	(7.799)	(3.813)
Baseline age (standardized)	1.515**	1.044	0.965	1.114	1.118	0.558*	1.490	0.842
	(2.153)	(0.183)	(-0.156)	(0.457)	(0.604)	(-1.943)	(1.185)	(-0.753)
Birth cohort (ref: 1945-49)								
1950-54	1.151	0.940	0.879	1.000	0.992	0.835	1.333	0.989
	(0.691)	(-0.261)	(-0.515)	(-0.001)	(-0.043)	(-0.533)	(0.859)	(-0.044)
1955-59	2.030**	1.486	0.972	1.626	1.153	0.675	1.271	0.751
	(2.133)	(0.978)	(-0.071)	(1.181)	(0.448)	(-0.761)	(0.408)	(-0.718)
1960-64	3.400**	1.766	1.062	2.287	1.718	0.542	3.165	0.767
	(2.431)	(0.926)	(0.100)	(1.337)	(1.119)	(-0.765)	(1.311)	(-0.435)
1965-	4.044**	1.510	1.263	2.003	1.382	0.407	3.551	0.490
	(2.264)	(0.553)	(0.318)	(0.920)	(0.544)	(-0.925)	(1.171)	(-0.961)
Years of schooling (standardized)	0.891**	0.683***	0.844***	0.617***	0.768***	0.707***	0.720***	0.915
	(-2.151)	(-5.636)	(-2.692)	(-7.254)	(-5.001)	(-3.849)	(-3.421)	(-1.369)
Parents' years of schooling (standardized)	0.914*	0.928	0.969	0.934	0.912*	0.894	0.909	1.002
	(-1.856)	(-1.212)	(-0.591)	(-1.146)	(-1.886)	(-1.372)	(-1.160)	(0.042)
Urban residency (ref: rural residency)	0.909	0.850	0.580***	0.785*	0.582***	0.577***	0.568***	0.778*
	(-0.942)	(-1.247)	(-4.359)	(-1.880)	(-5.039)	(-2.907)	(-2.679)	(-1.889)
Region (ref: western)								
Central	0.883	0.755**	0.886	0.975	0.899	0.809	0.539***	0.767*
	(-1.091)	(-2.055)	(-0.880)	(-0.184)	(-0.966)	(-1.167)	(-3.291)	(-1.849)
Northeast	0.552***	0.436***	0.744	0.597**	0.502***	0.381***	0.253***	0.623**
	(-3.084)	(-3.342)	(-1.348)	(-2.186)	(-3.574)	(-2.657)	(-3.458)	(-2.005)
Eastern	0.550***	0.420***	0.690***	0.518***	0.546***	0.415***	0.190***	0.615***
	(-5.114)	(-6.011)	(-2.742)	(-4.592)	(-5.378)	(-4.348)	(-7.078)	(-3.476)
Marital status (ref: married or partnered)								
Widowed	1.140	2.523***	1.524	2.168***	1.973***	5.006***	3.477***	2.373***
	(0.491)	(3.825)	(1.478)	(2.935)	(3.129)	(5.822)	(3.993)	(3.380)
Became widowed	1.227	1.948***	1.600**	2.004***	1.145	1.654*	1.704*	0.814
	(1.106)	(3.432)	(2.369)	(3.567)	(0.759)	(1.728)	(1.939)	(-0.763)
Single or became single	1.085	1.728	2.548**	4.074***	3.046***	5.158***	8.810***	3.035**
	(0.154)	(0.968)	(1.962)	(2.944)	(2.607)	(2.980)	(3.502)	(2.303)
Employment status (ref: non-agricultural work)								
Agricultural work	1.497***	1.996***	1.562**	1.706**	1.919***	1.679*	2.214**	1.501**
	(2.783)	(3.250)	(2.529)	(2.572)	(4.259)	(1.792)	(2.072)	(2.354)

	Type of trajectory, base outcome (1)							
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intermittent work	1.470***	2.019***	1.689***	1.850***	1.729***	1.764*	1.676	1.114
	(2.616)	(3.321)	(3.022)	(2.967)	(3.474)	(1.910)	(1.350)	(0.595)
Newly retired	1.165	1.988***	1.480*	1.641**	1.198	1.356	1.630	1.049
	(0.888)	(3.019)	(1.956)	(2.181)	(0.987)	(0.934)	(1.192)	(0.232)
Retired	0.915	1.621*	0.960	1.119	1.235	1.116	1.321	0.929
	(-0.398)	(1.719)	(-0.148)	(0.392)	(0.968)	(0.273)	(0.610)	(-0.278)
Parent-child relationship (ref: highly connected)								
Moderately connected	1.139	1.374***	1.278**	1.147	1.337***	1.438**	1.386*	1.329**
	(1.348)	(2.685)	(2.218)	(1.194)	(3.115)	(2.196)	(1.904)	(2.376)
Minimally connected	1.209	1.482*	0.931	0.891	1.422*	2.702***	1.376	1.515*
	(0.970)	(1.720)	(-0.279)	(-0.434)	(1.892)	(3.609)	(1.013)	(1.770)
Care for grandchildren (ref: no)	0.779**	0.860	1.119	0.961	0.927	1.075	0.725*	1.079
	(-2.326)	(-1.098)	(0.834)	(-0.290)	(-0.692)	(0.392)	(-1.737)	(0.549)
Functional limitation (ref: non-limited)								
Intermittent-limited	2.111***	3.222***	2.278***	3.961***	3.816***	9.284***	8.697***	3.047***
	(6.619)	(9.011)	(6.257)	(10.452)	(12.637)	(11.226)	(9.862)	(8.406)
Incident-limited	1.490**	2.413***	2.260***	5.534***	3.222***	8.422***	8.472***	2.007***
	(2.496)	(5.064)	(4.887)	(11.262)	(8.577)	(9.024)	(8.438)	(3.746)
Persistent-limited	5.525***	8.589***	3.653**	15.432***	10.803***	99.231***	106.946***	7.709***
	(3.400)	(4.118)	(2.066)	(5.580)	(5.337)	(9.434)	(9.220)	(3.801)
Chronic conditions (ref: no conditions)								
Incident conditions	1.924***	2.092***	1.197	1.854**	1.611**	2.113*	7.028*	0.943
	(3.455)	(2.788)	(0.960)	(2.341)	(2.304)	(1.654)	(1.877)	(-0.291)
Persistent conditions	1.982***	1.771**	1.120	1.113	2.331***	2.122	7.734*	0.838
	(3.344)	(1.967)	(0.537)	(0.354)	(3.884)	(1.558)	(1.942)	(-0.758)
Worsening conditions	2.753***	3.490***	1.475**	3.366***	3.796***	4.757***	25.220***	1.431*
	(5.568)	(4.936)	(2.152)	(4.825)	(6.817)	(3.603)	(3.131)	(1.907)
Frequency of social connection (standardized)	0.930	0.814***	0.891**	0.774***	0.815***	0.767***	0.600***	0.857***
	(-1.616)	(-3.532)	(-2.208)	(-4.340)	(-4.385)	(-3.181)	(-5.390)	(-2.631)

Note: Ref = reference group. Relative risk ratios are exponentiated coefficients estimated from multinomial logistic regression, with t statistics in parentheses. The base outcome (1) is the trajectory with stable non-depressed states. Outcomes 2–9 correspond to depression trajectories: (2) transient depression, (3) transient major depression, (4) emerging depression, (5) emerging major depression, (6) recurrent depression, (7) persistent depression with fluctuating severity, (8) persistent depression with episodes of major depression, and (9) remission of depression. * p<0.05, ** p<0.01, *** p<0.001. Number of observations is 6161.

Figures

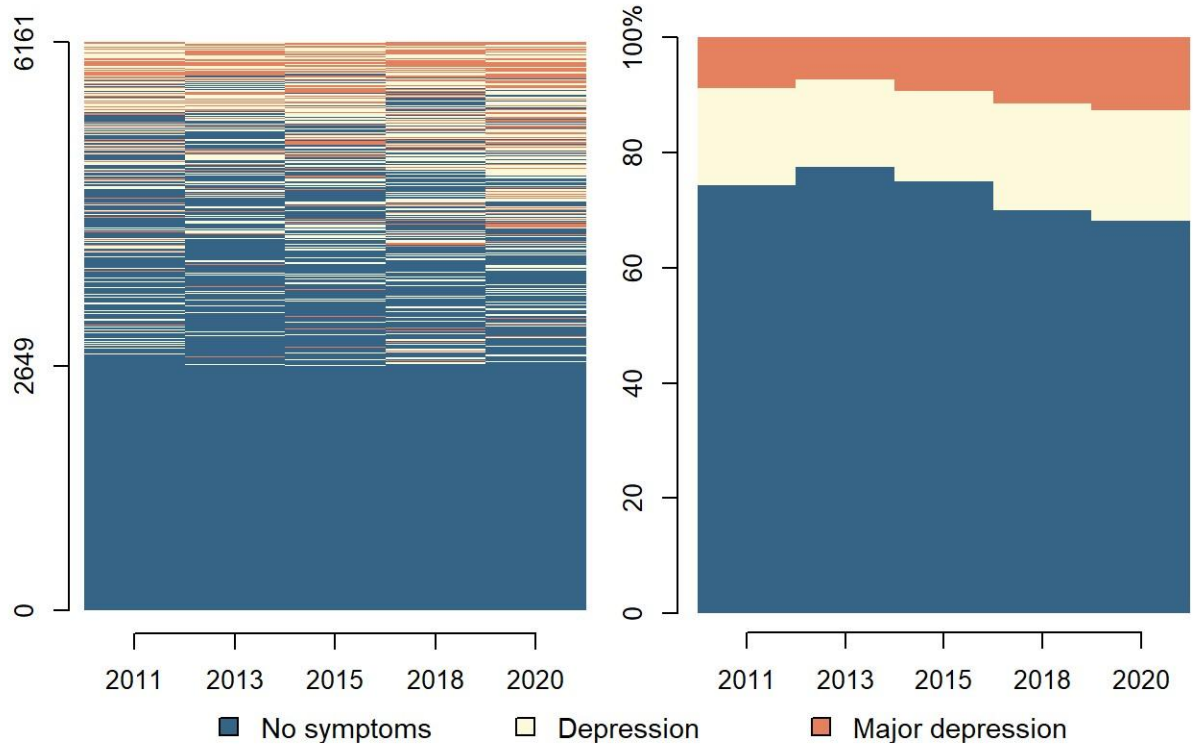

Figure 1. Individual trajectories of depressive symptoms (left panel) from 2011 to 2020 and the state distributions (right panel).

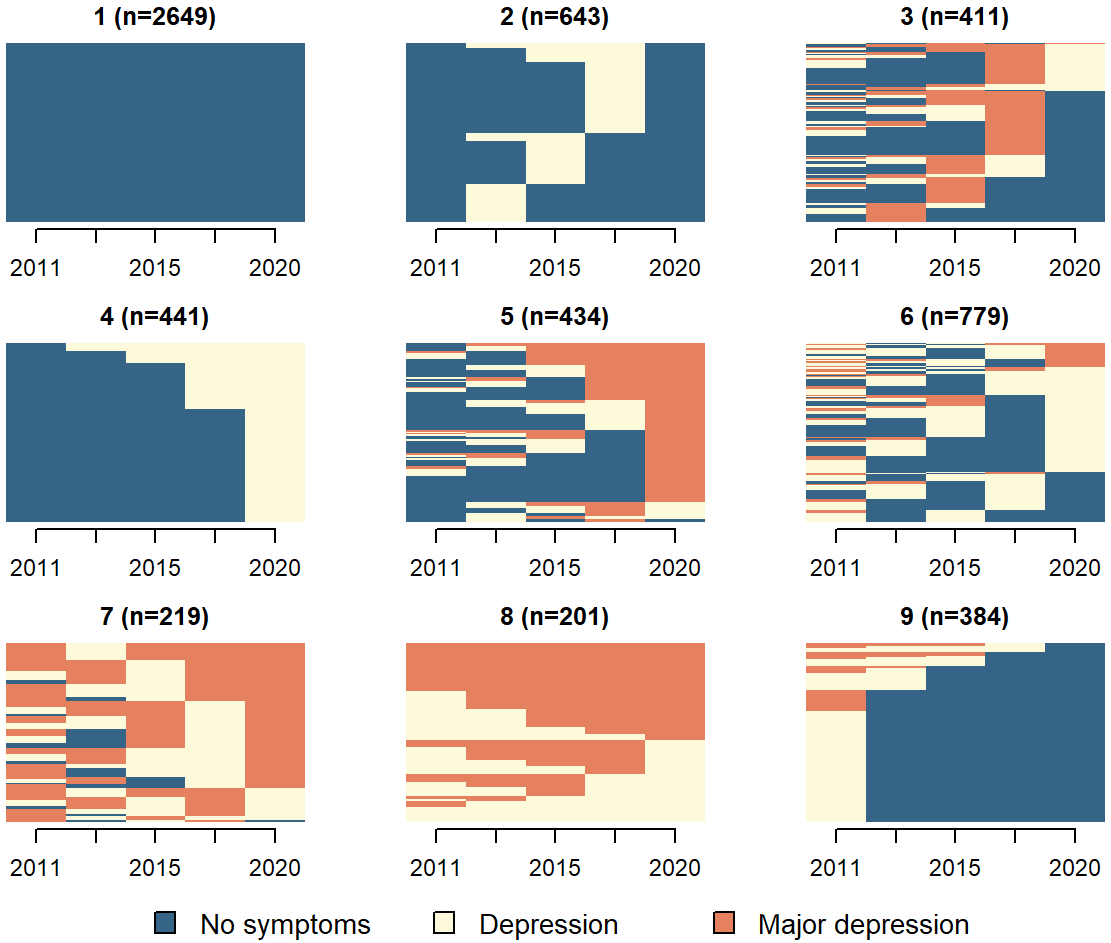

Figure 2. Typology of the trajectories of depressive symptoms.

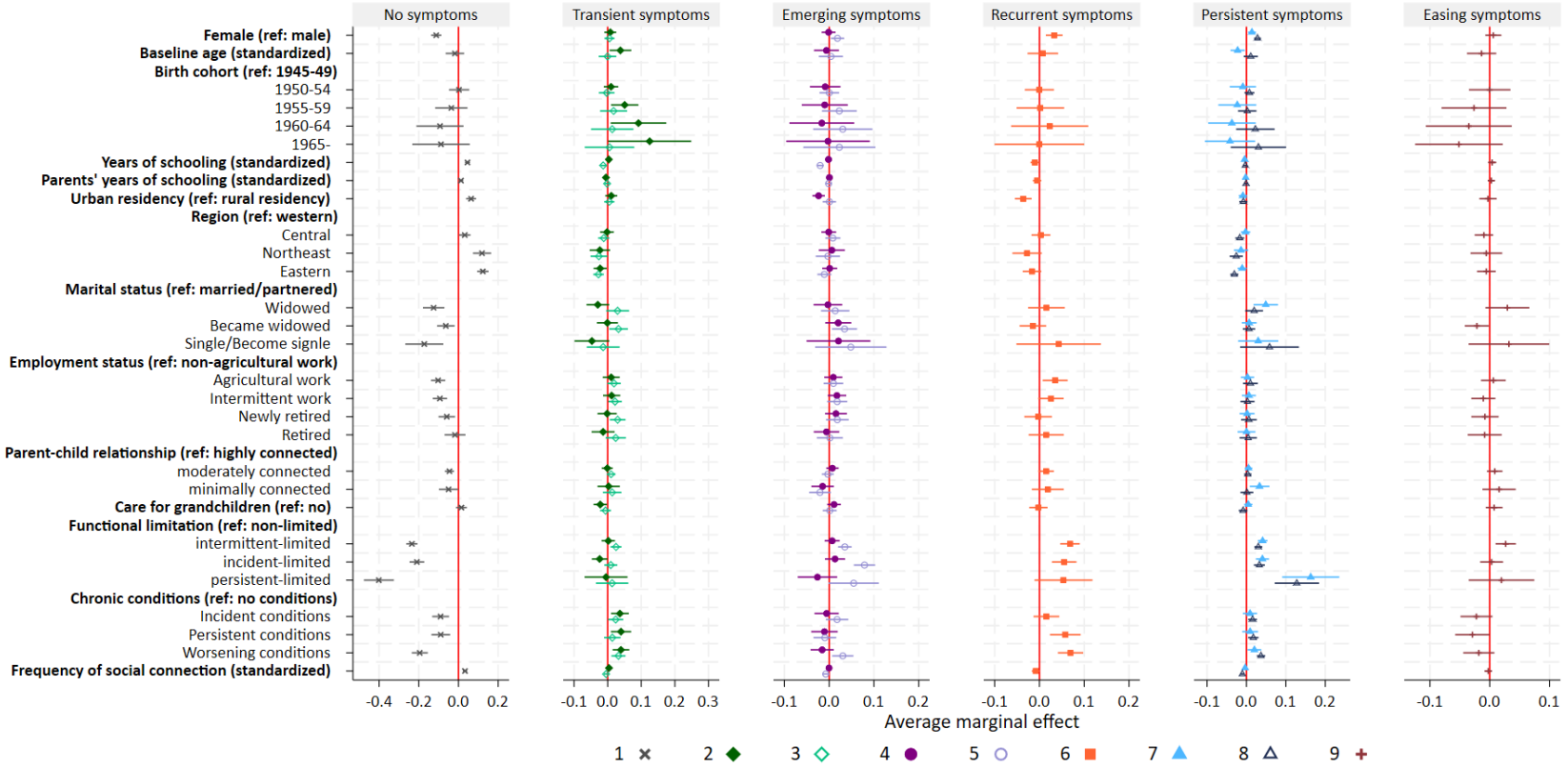

Figure 3. Average marginal effects (along with 95% confidence intervals) of selected factors on the type of trajectory.

Heterogeneous trajectories of depressive symptoms in the aging process: A sequence analysis within nine-year follow-ups of Chinese cohorts

Appendix 1. Supplementary material

Table A1. The CHARLS measurement of depression, scoring criteria, and classification of depressive states.

10-item short form of the Centre for Epidemiologic Studies Depression (CES-D) Scale		Scoring criteria for the CES-D score, ranging from 0 to 30	Classification of the depressive state
Item	The frequency of the statement during the last week		
1	I was bothered by things that don't usually bother me	*For items except for 5 and 8:* 0 = Rarely or none of the time (less than 1 day) 1 = Some or a little of the time (1-2 days) 2 = Occasionally or a moderate amount of the time (3-4 days) 3 = Most or all of the time (5–7 days) *For items 5 and 8:* The scoring is reversed	CES-D score 0-11 = No symptoms 12-17 = Depression 18-30 = Major depression
2	I had trouble keeping my mind on what I was doing		
3	I felt depressed		
4	I felt everything I did was an effort		
5	I felt hopeful about the future		
6	I felt fearful		
7	My sleep was restless		
8	I was happy		
9	I felt lonely		
10	I could not get going		

Table A2. Characteristics of the study sample.

Variable[1]	Mean (SD)	Baseline depressive state[2]		
		No symptoms	Depression	Major depression
Female	53.3	63.1	69.5	*69.5*
Baseline age	54.3 (5.6)	54.0 (5.6)	54.8 (5.6)	54.9 (5.6)
Birth cohort				
1946-49	14.1	13.4	16.5	15.2
1950-54	27.1	25.9	29.5	32.5
1955-59	24.9	25.5	22.8	23.5
1960-64	26.0	26.7	25.2	21.8
1965-66	7.9	8.5	6.0	7.0
Years of schooling	5.8 (4.1)	6.2 (4.1)	5.0 (3.9)	3.9 (3.7)
Parents' years of schooling	2.8 (3.5)	2.9 (3.6)	2.5 (3.4)	2.5 (3.4)
Urban residency	34.6	37.7	27.2	22.0
Region[3]				
Western	31.6	29.0	38.4	39.8
Central	29.7	29.2	31.0	30.8
Northeast	7.0	7.6	6.1	4.2
Eastern	31.8	34.2	24.6	25.1
Marital status				
Married or partnered	87.6	89.2	84.5	80.2
Widowed	4.3	3.2	6.4	10.1
Became widowed	6.9	6.6	7.2	8.4
Single or became single	1.2	1.0	1.8	1.3
Employment status				
Non-agricultural work	17.2	20.0	9.9	8.3
Agricultural work	30.3	27.9	37.5	36.7
Intermittent work	29.4	28.9	30.9	31.2
Newly retired	14.9	15.2	14.2	13.2
Retired	8.2	8.1	7.5	10.6
Parent-child relationship				
Highly connected	50.1	51.9	46.4	41.8
Moderately connected	43.6	42.4	46.8	47.9
Minimally connected	6.3	5.7	6.7	10.3
Care for grandchildren	76.5	76.4	77.9	74.5
Functional limitation				
Non-limited	60.5	68.7	41.9	27.5
Intermittent-limited	25.3	19.7	37.1	49.5
Incident-limited	12.3	10.9	16.5	16.0
Persistent-limited	2.0	0.8	4.4	7.0
Chronic conditions				
No conditions	9.6	11.2	5.8	3.7
Incident conditions	25.7	28.3	18.9	16.5
Persistent conditions	13.5	14.4	12.4	8.8
Worsening conditions	51.2	46.1	62.9	71.0
Frequency of social connection	1.8 (1.5)	1.9 (1.5)	1.6 (1.4)	1.6 (1.4)
Number of observations	6161	4576	1040	545

Note: [1] These variables were included in the regression analysis examining factors associated with the type of the trajectory of depressive symptoms. Definitions of categorical variables are detailed in the Appendix 2. [2] The grouping is based on the depressive state in 2011. [3] Among the study regions at the province level, western regions include inland, relatively less-developed provinces, such as Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunan, Shannxi, Gansu, Qinghai, and Xinjiang. Central regions include Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan. Northeast regions include Heilongjiang, Jilin, and Liaoning. Eastern regions, which are coastal and relatively developed, including Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Shandong, Fujian, Guangdong, and Hainan.

Table A3. Average marginal effects of factors associated with trajectory membership.

	Type of the trajectory of depressive symptoms								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female (*ref*: male)	-0.112***	0.008	0.005	-0.001	0.019*	0.033***	0.014**	0.028***	0.006
	(-8.511)	(0.855)	(0.697)	(-0.155)	(2.456)	(3.456)	(2.773)	(6.352)	(0.892)
Baseline age (standardized)	-0.018	0.038*	-0.001	-0.006	0.004	0.008	-0.022*	0.011	-0.014
	(-0.759)	(2.285)	(-0.047)	(-0.418)	(0.288)	(0.432)	(-2.410)	(1.204)	(-1.085)
Birth cohort (*ref*: 1945-49)									
1950-54	0.003	0.010	-0.003	-0.009	0.000	-0.000	-0.009	0.008	-0.000
	(0.113)	(0.904)	(-0.261)	(-0.505)	(0.033)	(-0.007)	(-0.528)	(1.180)	(-0.001)
1955-59	-0.036	0.051*	0.018	-0.010	0.023	0.002	-0.023	0.002	-0.026
	(-0.868)	(2.432)	(0.863)	(-0.371)	(1.150)	(0.074)	(-0.942)	(0.176)	(-0.948)
1960-64	-0.093	0.092*	0.014	-0.016	0.030	0.023	-0.037	0.023	-0.035
	(-1.538)	(2.170)	(0.419)	(-0.443)	(0.902)	(0.520)	(-1.194)	(0.911)	(-0.955)
1965-	-0.088	0.125*	0.005	-0.003	0.023	-0.000	-0.042	0.030	-0.051
	(-1.192)	(1.980)	(0.142)	(-0.053)	(0.556)	(-0.001)	(-1.279)	(0.849)	(-1.378)
Years of schooling (standardized)	0.045***	0.003	-0.013***	-0.001	-0.020***	-0.010*	-0.004	-0.003	0.004
	(6.900)	(0.732)	(-3.479)	(-0.346)	(-5.129)	(-2.054)	(-1.605)	(-1.116)	(1.151)
Parents' years of schooling (standardized)	0.013*	-0.005	-0.002	0.001	-0.001	-0.005	-0.002	-0.001	0.003
	(2.217)	(-1.209)	(-0.488)	(0.199)	(-0.321)	(-1.128)	(-0.734)	(-0.448)	(0.886)
Urban residency (*ref*: rural residency)	0.063***	0.011	0.005	-0.024***	0.001	-0.036***	-0.009	-0.008	-0.003
	(4.886)	(1.161)	(0.608)	(-3.316)	(0.068)	(-3.783)	(-1.655)	(-1.482)	(-0.388)
Region (*ref*: western)									
Central	0.032*	-0.002	-0.012	-0.001	0.008	0.003	-0.002	-0.017**	-0.010
	(2.173)	(-0.204)	(-1.366)	(-0.106)	(0.976)	(0.300)	(-0.335)	(-2.938)	(-1.221)
Northeast	0.119***	-0.023	-0.026*	0.006	-0.003	-0.028	-0.014	-0.026**	-0.006
	(5.063)	(-1.492)	(-2.048)	(0.407)	(-0.203)	(-1.642)	(-1.470)	(-3.011)	(-0.416)
Eastern	0.123***	-0.022*	-0.027***	0.001	-0.011	-0.017	-0.011	-0.031***	-0.006
	(8.477)	(-2.243)	(-3.389)	(0.149)	(-1.354)	(-1.584)	(-1.784)	(-5.812)	(-0.703)
Marital status (*ref*: married or partnered)									
Widowed	-0.125***	-0.029	0.030	-0.003	0.014	0.016	0.049**	0.020	0.030
	(-4.522)	(-1.699)	(1.704)	(-0.165)	(0.839)	(0.744)	(3.100)	(1.705)	(1.579)
Became widowed	-0.064**	-0.001	0.032*	0.020	0.034*	-0.015	0.007	0.007	-0.021*
	(-2.822)	(-0.052)	(2.275)	(1.373)	(2.410)	(-0.970)	(0.725)	(0.830)	(-2.081)

	Type of the trajectory of depressive symptoms								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Single or became single	-0.172***	-0.047	-0.013	0.021	0.048	0.043	0.030	0.059	0.032
	(-3.532)	(-1.778)	(-0.537)	(0.571)	(1.190)	(0.891)	(1.151)	(1.541)	(0.933)
Employment status (*ref*: non-agricultural work)									
Agricultural work	-0.103***	0.011	0.019	0.009	0.010	0.035*	0.003	0.010	0.006
	(-5.594)	(0.822)	(1.868)	(0.900)	(0.856)	(2.468)	(0.326)	(1.071)	(0.581)
Intermittent work	-0.093***	0.012	0.022*	0.017	0.018	0.026	0.006	0.003	-0.011
	(-5.059)	(0.903)	(2.154)	(1.654)	(1.571)	(1.783)	(0.696)	(0.303)	(-1.040)
Newly retired	-0.059**	-0.002	0.030*	0.015	0.018	-0.003	0.002	0.006	-0.008
	(-2.765)	(-0.114)	(2.472)	(1.228)	(1.429)	(-0.184)	(0.182)	(0.628)	(-0.686)
Retired	-0.018	-0.014	0.024	-0.006	0.002	0.015	0.000	0.005	-0.008
	(-0.653)	(-0.780)	(1.555)	(-0.405)	(0.107)	(0.752)	(0.017)	(0.414)	(-0.580)
Parent-child relationship (*ref*: highly connected)									
Moderately connected	-0.046***	-0.001	0.010	0.007	-0.003	0.015	0.005	0.004	0.008
	(-3.853)	(-0.147)	(1.483)	(1.048)	(-0.432)	(1.694)	(1.112)	(0.761)	(1.278)
Minimally connected	-0.050*	0.003	0.013	-0.015	-0.021	0.019	0.033**	0.001	0.016
	(-2.011)	(0.167)	(0.940)	(-1.133)	(-1.658)	(1.021)	(2.609)	(0.150)	(1.104)
Care for grandchildren (*ref*: no)	0.015	-0.022*	-0.006	0.011	0.001	-0.002	0.005	-0.008	0.007
	(1.083)	(-2.188)	(-0.783)	(1.398)	(0.168)	(-0.226)	(0.894)	(-1.498)	(1.039)
Functional limitation (*ref*: non-limited)									
Intermittent-limited	-0.235***	0.002	0.025**	0.007	0.035***	0.068***	0.041***	0.030***	0.027**
	(-16.303)	(0.179)	(3.019)	(0.783)	(4.517)	(6.146)	(6.618)	(5.942)	(3.091)
Incident-limited	-0.209***	-0.024*	0.009	0.013	0.079***	0.055***	0.041***	0.033***	0.003
	(-11.062)	(-2.015)	(0.938)	(1.145)	(6.504)	(3.940)	(4.777)	(4.613)	(0.333)
Persistent-limited	-0.401***	-0.005	0.013	-0.026	0.055	0.054	0.163***	0.128***	0.020
	(-10.383)	(-0.152)	(0.535)	(-1.162)	(1.917)	(1.624)	(4.419)	(4.454)	(0.703)
Chronic conditions (*ref*: no conditions)									
Incident conditions	-0.090***	0.036**	0.024*	-0.006	0.018	0.015	0.009	0.016**	-0.022
	(-4.151)	(2.697)	(2.080)	(-0.410)	(1.389)	(1.055)	(0.999)	(2.724)	(-1.627)
Persistent conditions	-0.089***	0.040**	0.014	-0.010	-0.010	0.058***	0.009	0.017**	-0.029*
	(-3.725)	(2.578)	(1.103)	(-0.696)	(-0.738)	(3.295)	(0.914)	(2.608)	(-1.981)
Worsening conditions	-0.195***	0.039**	0.032**	-0.016	0.031*	0.069***	0.020*	0.037***	-0.018

	Type of the trajectory of depressive symptoms								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	(-9.457)	(3.119)	(2.997)	(-1.174)	(2.522)	(4.814)	(2.315)	(6.775)	(-1.372)
Frequency of social connection (standardized)	0.033***	0.004	-0.005	-0.000	-0.008*	-0.008	-0.003	-0.010***	-0.002
	(5.855)	(1.001)	(-1.412)	(-0.096)	(-2.203)	(-1.850)	(-1.249)	(-3.854)	(-0.741)

Note: Ref = reference group. Average marginal effects estimated from multinomial logistic regression, with t statistics in parentheses. Columns 1–9 correspond to depression trajectories: (1) stable non-depressed, (2) transient depression, (3) transient major depression, (4) emerging depression, (5) emerging major depression, (6) recurrent depression, (7) persistent depression with fluctuating severity, (8) persistent depression with episodes of major depression, and (9) remission of depression. * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Number of observations is 6161.

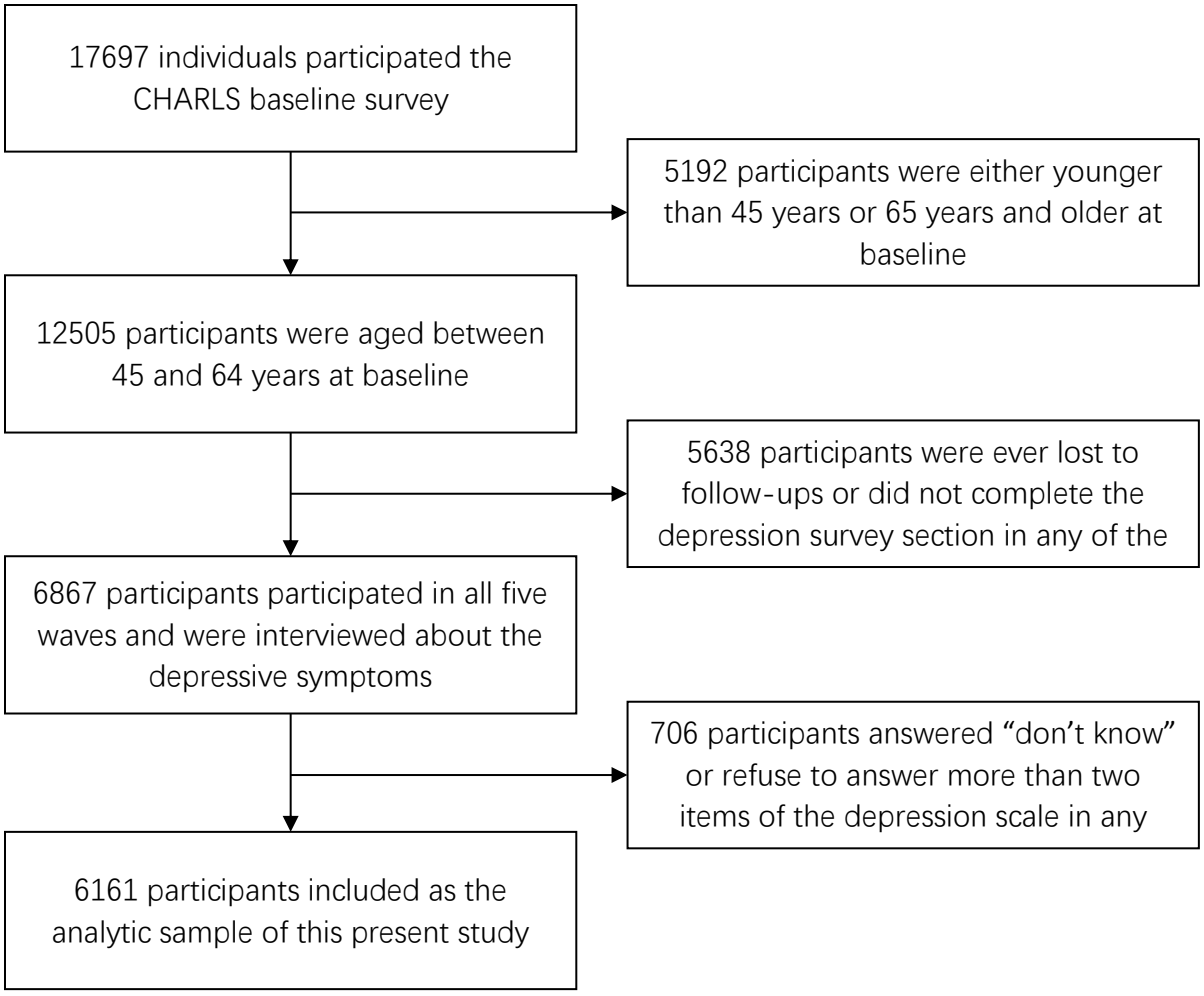

Figure A1. Study flowchart.

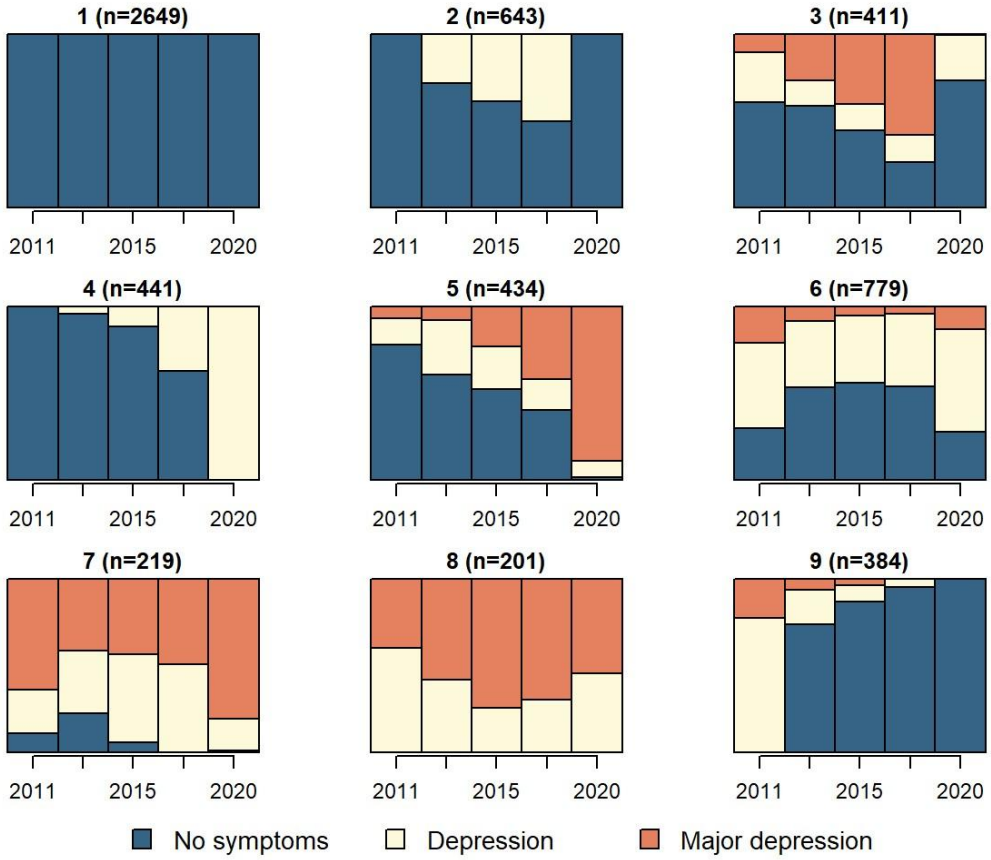

Figure A2. State distributions for each trajectory pattern.

Appendix 2. Definitions of time-varying variables associated with the trajectory of depressive symptoms

Some sociodemographic factors, such as marital status, employment status, intergenerational relations, physical health status, and social connection, might change across the study period. These original time-varying factors were regrouped and incorporated in the multinomial logistic regression to adjust for age-related factors that may concurrently influence the trajectory of depression.

Marital status was classified as follows: “married/partnered” during the study period; “widowed” if participants were widowed at the baseline survey and did not remarry, “became widowed” if participants reported widowhood at follow-ups; “single/became single” if individuals report they were single and did not remarry.

Employment status was categorized into five groups: “non-agricultural work” for participants engaged in non-agricultural employment during the study period; “agricultural work” for those who engaged in agriculture during the study period; “intermittent work” for those who reported working occasionally in some waves; “newly retired” for participants ceased working during the study period; and “retired” for those who did not work at any survey wave.

Intergenerational relations were assessed by the participant’s relationships with their children and grandchildren. The first dimension was categorized into three groups: “highly connected” for participants who co-resided or had in-person contact with their children weekly across all five survey rounds; “moderately connected” for those who did so in some survey waves; and “minimally connected” for those who had no children or did not have in-person contact with their children in any survey period. The second dimension was defined by whether the participant provided care for their grandchildren during the study period.

Physical health status was evaluated based on the degree of functional limitation and the presence of chronic conditions. Functional limitations were assessed using the Activities of Daily Living (ADL) scale, which measures difficulties in performing basic self-care tasks, including dressing, bathing, eating, transferring, toileting, and maintaining continence. Participants were categorized into four groups: “non-limited” if they reported no difficulties in performing the activities; “intermittent-limited” if they reported difficulties in some survey waves; “incident-limited” if they developed functional limitations in later waves; and “persistent-limited” if limitations were present across all waves. Likewise, individuals were grouped based on the number of ever-diagnosed chronic conditions across the five survey waves, including high blood pressure, diabetes, dyslipidemia, chronic heart problems, stroke, cancer, arthritis, and chronic diseases related to the lung, liver, and kidney: “no conditions” for participants who did not report any chronic conditions in all waves; “incident conditions” for those who developed any types of chronic condition in later waves; “persistent conditions” for those who were consistently affected by the same types of chronic conditions throughout the study period; and “worsening conditions” for those who already affected by the conditions and developed new types of conditions in later waves.

Social connection was defined based on the information about whether participants reported weekly participation in specific social activities in each survey wave. These activities encompassed general interactions with friends, team-based recreational activities (such as chess and card games), physical exercises in public spaces, volunteering, and engagement in community groups and organizations. The variable was accordingly calculated as the cumulative

frequency of survey waves in which individuals report weekly participation in any of these activities.