

Transitions in Depressive States and Depression-Free Life Expectancy Among Older Adults with Arthritis

Shengyuan Zheng

Second Hospital of Jilin University

Ziyuan Liu

Second Hospital of Jilin University

Yingqiao Sun

Second Hospital of Jilin University

Zehao Yu

Second Hospital of Jilin University

Xiongfeng Tang

Second Hospital of Jilin University

Yanguo Qin

qinyg@jlu.edu.cn

Second Hospital of Jilin University

Research Article

Keywords: arthritis, depression, multi-state model, depression-free life expectancy

Posted Date: June 8th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9548265/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Objective

This study aimed to examine transitions between depressive states among individuals with arthritis and evaluate their associations with life expectancy (LE) and depression-free life expectancy (DFLE).

Methods

Using data from the China Health and Retirement Longitudinal Study (CHARLS), we included older adults with arthritis who had available depressive status and follow-up information. A multi-state model was used to estimate transitions among no depression, mild depression, moderate-to-severe depression, and death. Multi-state life tables were constructed to estimate LE, DFLE, mild depression life expectancy, and moderate-to-severe depression life expectancy at age 60 by baseline depressive status. Stratified analyses were conducted by sex and educational attainment. The Health and Retirement Study (HRS) was used to examine the consistency of the findings.

Results

At age 60, LE differed only modestly across baseline depressive states, ranging from approximately 20.4 to 20.8 years. However, DFLE varied substantially. Individuals without depression at baseline were expected to live about 12.4 years free of depression, compared with about 9.5 years among those with mild depression and fewer years among those with moderate-to-severe depression. Years lived with depression increased as baseline depressive severity worsened. Transition analyses showed that no depression was relatively stable, mild depression involved both recovery and progression, and moderate-to-severe depression was more likely to persist or transition to death. Women and individuals with lower education had a lower proportion of DFLE and spent a greater proportion of remaining life with depression.

Conclusions

Depression among individuals with arthritis is associated with a substantial reduction in depression-free years and a shift toward longer survival with depression. Long-term arthritis management should incorporate mental health screening and integrated interventions, particularly for women and socioeconomically vulnerable groups.

1 Introduction

Arthritis is one of the most common chronic conditions among older adults. It is characterized by high prevalence, prolonged disease course, and substantial disability burden [1, 2]. Osteoarthritis (OA) and rheumatoid arthritis (RA) are the most common forms of arthritis. Patients often experience persistent joint pain, stiffness, and functional limitation, which impair daily activities, reduce quality of life, and impose a considerable long-term care burden on families and society [3, 4]. With rapid population ageing, the burden of arthritis continues to increase and has become an important public health and economic concern [5].

Depression is another major public health issue and a common mental health problem in later life, contributing substantially to disease burden [6]. Among individuals with arthritis, depression deserves particular attention. Chronic pain, sleep disturbance, impaired mobility, and reduced social participation may increase the risk of depression [7–9]. In turn, depression may worsen arthritis-related outcomes by reducing physical activity, impairing self-management, and aggravating inflammatory and stress-related responses [10–12]. Thus, arthritis and depression may not simply coexist, but may form a mutually reinforcing cycle. For individuals with arthritis, depression is not only a common psychological comorbidity but also a potential determinant of disease progression and long-term health outcomes.

Nevertheless, mental health problems among individuals with arthritis remain insufficiently addressed in clinical practice. Previous studies have mainly focused on the prevalence and risk factors of depression in arthritis, or on its associations with single adverse outcomes [10, 13, 14]. Less is known about how depression shapes subsequent health trajectories over the life course. For chronic and long-lasting conditions such as arthritis, patients may experience both physical and psychological burdens for many years. Therefore, mortality risk or total life expectancy alone may not fully capture the long-term health loss associated with depression. Depression-free life expectancy (DFLE), developed within the framework of health expectancy, estimates the expected number of remaining years lived without depression [15, 16]. Compared with measures based solely on depression prevalence or mortality risk, DFLE provides a more intuitive assessment of the combined impact of depression on both length and quality of life. By decomposing survival time into different depressive states, DFLE and related state-specific life expectancies can more comprehensively characterize the long-term health trajectories of individuals with arthritis and inform clinical screening, risk stratification, and integrated interventions.

Based on this rationale, the present study used multi-state models and multi-state life tables to distinguish mild depression from moderate-to-severe depression and to examine dynamic transitions among no depression, mild depression, moderate-to-severe depression, and death in individuals with arthritis. We further estimated total life expectancy, depression-free life expectancy, and life expectancy lived in different depressive states, aiming to provide epidemiological evidence for mental health screening, risk identification, and integrated management in this population.

2 Methods

2.1 Study Design and Data Sources

This study used a two-cohort design. Data were obtained from the China Health and Retirement Longitudinal Study (CHARLS) and the Health and Retirement Study (HRS). CHARLS was used as the primary analytical cohort to systematically evaluate transitions between depressive states among individuals with arthritis and their impact on remaining life expectancy. HRS was used as an external validation cohort to examine the consistency of the direction and pattern of the findings. Detailed descriptions of the two cohorts are provided in Supplementary File 1.

To improve comparability between the two cohorts, we selected five follow-up waves with similar time structures for analysis: CHARLS waves 1–5, conducted from 2011 to 2020, and HRS waves 10–14, conducted from 2010 to 2018. Given differences in the observation structure and measurement framework between the two databases, cohort-specific multi-state models were fitted according to the characteristics of each dataset. In both cohorts, the fitted models were used to generate age-specific state transition probability matrices, which were subsequently incorporated into multi-state life table estimation.

2.2 Variable Definitions

In the primary analysis, arthritis status was defined using self-reported information. In CHARLS, participants were asked during standardized interviews whether a doctor had ever diagnosed them with arthritis. Those who answered “yes” were classified as having arthritis. Similarly, in HRS, participants were asked whether they had ever had arthritis or whether a doctor had ever told them that they had arthritis. Participants who answered “yes” were defined as having arthritis.

The health state variable was defined according to each participant’s depressive status at each follow-up wave. Depressive symptoms were assessed using standardized depression scales in both cohorts. In CHARLS, depressive symptoms were measured using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10), with a total score ranging from 0 to 30. Depressive status was categorized into three levels: no depression (State 1, CES-D score < 10), mild depression (State 2, $10 \leq$ CES-D score < 15), and moderate-to-severe depression (State 3, CES-D score ≥ 15) [17]. In HRS, depressive symptoms were assessed using the eight-item CES-D scale (CES-D-8), with a total score ranging from 0 to 8. Following previous studies, depressive status was categorized as no depression (State 1, CES-D-8 score 0–1), mild depression (State 2, CES-D-8 score 2–3), and moderate-to-severe depression (State 3, CES-D-8 score > 3) [18].

Because comparable variables were limited across the two cohorts, the models included only age, sex, and educational attainment. These variables were incorporated as covariates in the multinomial logit transition models and were also used for stratified analyses. To ensure comparability between the two data sources, educational attainment was classified according to the highest completed level of education as lower education, defined as below high school, and higher education, defined as high school or above.

2.3 Multi-state Model Framework

In this study, we used a multi-state Markov model (MSM) to describe changes in depressive status among individuals with arthritis during follow-up [19]. At any given time, each participant could occupy one of four mutually exclusive health states (Fig. 1): no depression (State 1), mild depression (State 2), moderate-to-severe depression (State 3), and death (State 4). Death was treated as an absorbing state, meaning that no further transitions were possible once this state was reached.

Multi-state models have been widely used to characterize dynamic transitions between multiple health states and to estimate quantities such as state occupancy probabilities, transition probabilities, and life expectancy [20]. In this study, the process was assumed to satisfy the Markov property. That is, conditional on the current state and covariates, the future state depends only on the current state and not on the previous state history. Based on this framework, we estimated age-specific state transition probability matrices, which were subsequently used in the multi-state life table analysis.

Because health states in both CHARLS and HRS were observed primarily at discrete follow-up waves, we adopted a discrete-time multi-state Markov modelling approach in both cohorts. Transitions were defined as changes in state between two adjacent observations, and the outcome state at the next observation was predicted according to age, the starting state, and covariates [21]. In CHARLS, follow-up intervals were not completely uniform and mainly consisted of 2-year and 3-year intervals. Therefore, transition probabilities were estimated separately for different interval lengths and then combined according to the observed interval structure. In contrast, the main HRS analysis was based on adjacent waves with a fixed 2-year interval, and transition probabilities were estimated using a common 2-year step.

For model estimation, separate multinomial logit transition models were fitted for each of the three non-death starting states. Age-specific state transition probability matrices were then derived from model-based predictions. Overall estimates were obtained by weighting sex- and education-specific subgroup estimates. Confidence intervals were estimated using individual-level bootstrap resampling. Details on the integration of different observation intervals in CHARLS, the fixed-step approach in HRS, the specification of initial states, and the life table recursion formulas are provided in Supplementary File 1.

2.4 Multi-state Life Table and Life Expectancy Estimation

After obtaining age-specific state transition probability matrices, we constructed multi-state life tables to estimate total life expectancy (LE) among individuals with arthritis. LE was further decomposed into depression-free life expectancy (DFLE), mild depression life expectancy (MDLE), and moderate-to-severe depression life expectancy (SDLE). Based on state transition probabilities at different ages, the multi-state life table recursively estimates the expected time spent in each health state over the remaining lifetime. The sum of all state-specific life expectancies equals total LE.

In addition to stratified analyses, overall estimates were obtained by weighting subgroup-specific estimates according to the distribution of sex and educational attainment at the starting age. In this study, age 60 was used as the common starting point for life expectancy estimation. However, the

analytical sample was not restricted mechanically to individuals who were already aged 60 years or older at the survey baseline. The term “baseline depressive status” refers to the initial health state at the starting age of the life table, rather than the depressive status at cohort baseline. LE refers to the expected remaining years of life from the specified starting age. Further details of the calculation procedures are provided in Supplementary File 1.

All statistical analyses were performed using R software, version 4.5.2.

3 Results

3.1 Baseline Characteristics of the Study Population

In the primary CHARLS analysis, using the first entry into the analytical age window of 60 years or older as baseline, 2,037 participants were included, of whom 946 were men (46.4%). The mean age at entry into the analytical age window was 63.9 years, with an age range of 60–91 years. The sample was concentrated in younger age groups, with 70.2% aged younger than 65 years and only 4.9% aged 75 years or older. Educational attainment was generally low, with 92.7% classified as having lower education. At baseline, 50.3% of participants had no depression, 24.0% had mild depression, and 25.7% had moderate-to-severe depression. Women had a higher proportion of moderate-to-severe depression than men, whereas men were more likely to be free of depression. In the HRS analysis, 10,205 participants were included, of whom 3,717 were men (36.4%). The mean age at entry into the analytical age window was 70.5 years, with an age range of 60–99 years. The baseline age distribution was relatively balanced, with participants mainly concentrated among those younger than 65 years (32.4%) and those aged 75 years or older (31.3%). Regarding educational attainment, most participants were classified as having higher education (77.6%), with little difference in educational distribution between men and women. At baseline, 64.2% of participants had no depression, 18.8% had mild depression, and 17.1% had moderate-to-severe depression. By sex, men had a higher proportion without depression, whereas women had higher proportions of both mild and moderate-to-severe depression.

The baseline characteristics of participants included in the two cohorts are summarized in Table 1.

Table 1 Baseline characteristics of the study participants.								
Data source	Variables	Options	Male		Female		Total	
			N	%	N	%	N	%
CHARLS								
	Age	< 65	640	67.60	791	72.50	1431	70.20
		65–69	165	17.40	165	15.10	330	16.20
		70–74	85	8.99	92	8.43	177	8.69
		75+	56	5.92	43	3.94	99	4.86
	Education level	Below high	862	91.10	1026	94.00	1888	92.70
		High and above	84	8.88	65	5.96	149	7.31
	Depression status	No depression	546	57.70	479	43.90	1025	50.30
		Mild depression	211	22.30	278	25.50	489	24.00
		Moderate-to-severe depression	189	20.00	334	30.60	523	25.70
HRS								
	Age	< 65	1173	31.56	2129	32.92	3302	32.42
		65–69	578	15.55	1102	17.04	1680	16.49
		70–74	764	20.55	1247	19.28	2011	19.74
		75+	1202	32.34	1990	30.77	3192	31.34
	Education level	Below high	814	21.90	1471	22.74	2285	22.43
		High and above	2903	78.10	4997	77.26	7900	77.57
	Depression status	No depression	2575	69.28	3960	61.22	6535	64.16
		Mild depression	643	17.30	1268	19.60	1911	18.76
		Moderate-to-severe depression	499	13.42	1240	19.17	1739	17.07

3.2 Transition Probabilities Between Depressive States in CHARLS

Figure 2 presents the age-specific transition probabilities between depressive states in the overall CHARLS sample. The transition patterns differed clearly by initial depressive state. Among individuals without depression at age 60, remaining non-depressed was the most likely subsequent outcome, although this probability declined with age. Correspondingly, the probabilities of developing mild depression, moderate-to-severe depression, or dying gradually increased.

For individuals with mild depression at age 60, the main subsequent outcomes were either remaining mildly depressed or recovering to a non-depressed state. However, transitions to moderate-to-severe depression and death became more frequent at older ages, suggesting that mild depression may represent an unstable intermediate state with both potential for recovery and risk of progression.

Among individuals with moderate-to-severe depression at age 60, persistence in the same state was relatively common, whereas recovery to no depression was less likely. The probability of death also increased substantially with age and was generally higher among those with more severe baseline depression. Overall, these findings indicate that depressive states among individuals with arthritis are dynamic, and that greater depressive severity is associated with more persistent psychological burden and a less favorable subsequent health trajectory.

3.3 Life Expectancy Among Older Adults With Arthritis in CHARLS

Table 2 shows life expectancy at age 60 according to baseline depressive status in the 2011–2020 CHARLS primary analysis. Total LE differed only slightly across baseline depressive states, whereas the composition of state-specific life expectancy varied substantially. At age 60, individuals without depression were expected to live 20.4 years, including 12.4 years free of depression. Among those with mild depression, total LE was 20.8 years, but DFLE decreased to 9.46 years. Among those with moderate-to-severe depression, total LE was 20.4 years, with DFLE further reduced to 8.26 years. In contrast, SDLE increased with greater baseline depressive severity, from 4.27 years among those without depression to 5.12 years among those with mild depression and 7.88 years among those with moderate-to-severe depression. These findings suggest that baseline depressive status had a limited impact on total remaining survival, but substantially altered the distribution of future years across mental health states. More severe baseline depression was associated with longer time expected to be lived with depression.

Table 2
Total life expectancy and state-specific life expectancy at age 60 by baseline depression status in the CHARLS population.

Health State	LE (year)	DFLE (year)	MDLE (year)	SDLE (year)	DFLE/LE	MDLE/LE	SDLE/LE
No depression	20.40	12.40	3.77	4.27	0.61	0.19	0.21
Mild depression	20.80	9.46	6.20	5.12	0.46	0.30	0.25
Moderate-to-severe depression	20.40	8.26	4.21	7.88	0.41	0.21	0.39
LE, life expectancy, DFLE, depression-free life expectancy, MDLE, mild depression life expectancy, SDLE, moderate-to-severe depression life expectancy.							

In the overall estimates, individuals with arthritis at age 60 had a total LE of 20.17 years, including 10.53 years of DFLE, accounting for 52.2% of total LE. MDLE was 4.37 years, accounting for 21.7%, and SDLE was 5.27 years, accounting for 26.1%. These results indicate that, during later life, individuals with arthritis were expected to spend only about half of their remaining lifetime free of depression, whereas approximately 47.8% of remaining life would be lived with mild or moderate-to-severe depression.

The age-specific life table (Table 3) showed that total LE and all state-specific life expectancies declined steadily with increasing starting age. Total LE decreased from 20.17 years at age 60 to 11.68 years at age 70 and further to 5.26 years at age 80. Between ages 60 and 80, DFLE consistently accounted for the largest proportion of total LE, remaining approximately 52%–56%. The proportions of MDLE and SDLE remained relatively stable, at approximately 21%–23% and 23%–27%, respectively. These findings suggest that although the absolute amount of remaining life decreased with age, the distribution of remaining years across depressive states was broadly stable.

Table 3
Life expectancy and state-specific life expectancy by age in the CHARLS analysis.

Age	LE (year)	DFLE (year)	MDLE (year)	SDLE (year)	DFLE/LE	MDLE/LE	SDLE/LE
60	20.17 (19.39–21.17)	10.53 (9.91–11.30)	4.37 (4.06–4.75)	5.27 (4.82–5.75)	0.52	0.22	0.26
61	19.30 (18.54–20.25)	10.08 (9.47–10.81)	4.18 (3.89–4.54)	5.05 (4.61–5.51)	0.52	0.22	0.26
62	18.41 (17.66–19.33)	9.63 (9.05–10.35)	3.97 (3.69–4.31)	4.81 (4.39–5.29)	0.52	0.22	0.26
63	17.48 (16.74–18.35)	9.13 (8.58–9.76)	3.78 (3.51–4.10)	4.58 (4.19–5.08)	0.52	0.22	0.26
64	16.61 (15.89–17.53)	8.65 (8.10–9.33)	3.61 (3.34–3.95)	4.36 (3.99–4.84)	0.52	0.22	0.26
65	15.75 (15.00–16.65)	8.11 (7.55–8.77)	3.46 (3.18–3.82)	4.18 (3.78–4.66)	0.52	0.22	0.27
66	14.97 (14.24–15.92)	7.66 (7.12–8.34)	3.31 (3.02–3.68)	4.00 (3.60–4.48)	0.51	0.22	0.27
67	14.07 (13.31–15.00)	7.14 (6.58–7.86)	3.13 (2.82–3.50)	3.80 (3.41–4.24)	0.51	0.22	0.27
68	13.24 (12.47–14.15)	6.74 (6.21–7.48)	2.92 (2.64–3.30)	3.57 (3.18–4.03)	0.51	0.22	0.27
69	12.44 (11.68–13.36)	6.33 (5.80–7.04)	2.74 (2.43–3.11)	3.37 (3.01–3.82)	0.51	0.22	0.27
70	11.68 (10.99–12.60)	5.97 (5.46–6.67)	2.56 (2.27–2.91)	3.14 (2.77–3.59)	0.51	0.22	0.27
71	10.88 (10.21–11.84)	5.59 (5.05–6.26)	2.41 (2.09–2.77)	2.89 (2.52–3.35)	0.51	0.22	0.27
72	10.18 (9.44–11.12)	5.28 (4.71–5.98)	2.25 (1.94–2.61)	2.65 (2.29–3.12)	0.52	0.22	0.26
73	9.44 (8.73–10.40)	4.93 (4.32–5.63)	2.11 (1.78–2.47)	2.41 (2.07–2.88)	0.52	0.22	0.26
74	8.89 (8.15–9.86)	4.68 (4.03–5.46)	1.95 (1.63–2.34)	2.26 (1.94–2.72)	0.53	0.22	0.25
75	8.10 (7.37–9.11)	4.22 (3.61–4.94)	1.77 (1.44–2.14)	2.11 (1.78–2.57)	0.52	0.22	0.26
76	7.51 (6.73–8.54)	3.93 (3.28–4.72)	1.69 (1.35–2.05)	1.89 (1.56–2.33)	0.52	0.23	0.25
77	6.94 (6.12–7.99)	3.58 (2.93–4.29)	1.59 (1.23–1.96)	1.77 (1.41–2.19)	0.52	0.23	0.26
78	6.38 (5.55–7.42)	3.40 (2.64–4.17)	1.44 (1.08–1.84)	1.53 (1.21–1.94)	0.53	0.23	0.24
79	5.92 (5.03–6.98)	3.30 (2.51–4.14)	1.22 (0.88–1.62)	1.40 (1.08–1.81)	0.56	0.21	0.24
80	5.26 (4.42–6.56)	2.95 (2.14–3.89)	1.10 (0.73–1.52)	1.21 (0.93–1.68)	0.56	0.21	0.23
81	4.95 (4.05–6.27)	2.83 (1.96–3.78)	1.09 (0.72–1.53)	1.03 (0.75–1.47)	0.57	0.22	0.21
82	4.65 (3.68–6.09)	2.62 (1.75–3.70)	1.05 (0.67–1.50)	0.98 (0.67–1.42)	0.56	0.23	0.21
83	4.35 (3.29–5.68)	2.61 (1.65–3.72)	0.95 (0.59–1.46)	0.79 (0.48–1.19)	0.6	0.22	0.18
84	3.73 (2.66–5.16)	2.22 (1.31–3.33)	0.74 (0.43–1.22)	0.77 (0.46–1.21)	0.6	0.2	0.21
85	3.21 (2.11–4.66)	1.90 (1.00–3.23)	0.61 (0.33–1.06)	0.70 (0.41–1.11)	0.59	0.19	0.22
LE, life expectancy, DFLE, depression-free life expectancy, MDLE, mild depression life expectancy, SDLE, moderate-to-severe depression life expectancy.							

3.4 Differences in Life Expectancy by Sex and Educational Attainment in CHARLS

Subgroup analyses in the CHARLS primary analysis showed clear differences in life expectancy and its state-specific composition by sex and educational attainment among individuals with arthritis (Table 4). At age 60, women had a longer total LE than men (21.45 years vs. 18.51 years). However, the proportion of DFLE was lower in women than in men (45.8% vs. 61.9%), whereas the proportion of SDLE was higher (30.8% vs. 19.0%). These findings suggest that although women were expected to live longer, they also spent more of their remaining lifetime with depression. Analyses stratified by education further showed that higher educational attainment was associated with longer total LE and a higher proportion of DFLE. Age-specific results by sex and education are presented in Supplementary Tables S1 and S2.

Table 4
Life expectancy and state-specific life expectancy at age 60 by baseline depression status in the CHARLS population, stratified by sex and education

Health State	Female				Male				Lower education				Higher education	
	LE	DFLE	MDLE	SDLE	LE	DFLE	MDLE	SDLE	LE	DFLE	MDLE	SDLE	LE	DFLE
	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)
No depression	22.07	11.92	4.47	5.68	18.9	12.82	3.12	2.97	19.88	11.84	3.8	4.24	25.34	17.26
Mild depression	21.76	8.93	6.69	6.14	19.07	10.37	5.35	3.35	20.34	8.98	6.24	5.13	25.2	14.3
Moderate-to-severe depression	21.15	7.89	4.58	8.69	18.56	9.08	3.4	6.09	20.06	7.9	4.24	7.92	24.54	13.44
LE, life expectancy, DFLE, depression-free life expectancy, MDLE, mild depression life expectancy, SDLE, moderate-to-severe depression life expectancy.														

Joint stratified analyses by sex and education showed similar patterns (Fig. 3 and Supplementary Table S3). At age 60, total LE was 21.03 years among women with lower education and 17.86 years among men with lower education, compared with 27.05 years and 23.65 years among women and men with higher education, respectively. Women with lower education had the greatest burden of life expectancy lived with depression, with SDLE accounting for 31.4% of total LE. In contrast, men with higher education showed the most favorable life expectancy profile, with the highest proportion of DFLE (68.5%). Overall, women and individuals with lower educational attainment, particularly women with lower education, experienced a greater burden of life expectancy lived with depression, although women tended to have longer total LE than men within the same educational group.

3.5 Comparative Validation cohort

3.5.1 Transition Probabilities Between Depressive States Among Older Adults With Arthritis in HRS

Figure S1 presents the age-specific transition probabilities between depressive states in the overall HRS sample. The transition patterns were broadly consistent with those observed in CHARLS. Among individuals without depression at age 60, remaining non-depressed was the most likely subsequent outcome, although this probability declined with age, while transitions to depression or death increased. Among individuals with mild depression, subsequent transitions were mainly characterized by either persistence of mild depression or recovery to no depression, supporting the interpretation of mild depression as an unstable and potentially reversible intermediate state. In contrast, individuals with moderate-to-severe depression were more likely to remain in the same state and had a lower probability of recovery to no depression. The probability of transitioning to death increased with age across all baseline depressive states and was generally higher among those with more severe baseline depression. Overall, these findings support the consistency of the HRS results with the main CHARLS analysis.

3.5.2 Life Expectancy Differences and Subgroup Analyses in HRS

In the HRS analysis, total life expectancy (LE) at age 60 differed only slightly across baseline depressive states, with estimates of approximately 35 years. However, the composition of state-specific life expectancy varied substantially. Compared with individuals without depression at baseline, those with mild or moderate-to-severe depression had progressively fewer depression-free years and more years lived with depression, particularly moderate-to-severe depression (Supplementary Table S4). Age-specific estimates showed that LE, depression-free life expectancy (DFLE), mild depression life expectancy (MDLE), and moderate-to-severe depression life expectancy (SDLE) all declined with increasing starting age. Nevertheless, DFLE consistently accounted for the largest share of remaining life, while the proportion of SDLE generally decreased at older ages (Supplementary Table S5). Subgroup analyses showed patterns broadly consistent with those observed in CHARLS. Women had longer total LE than men, but they spent more years with depression and had a lower proportion of DFLE. In contrast, men had shorter total LE but relatively longer depression-free survival (Supplementary Table S6). Similarly, individuals with higher education had longer total LE and DFLE, whereas those with lower education had longer MDLE and SDLE across baseline depressive states (Supplementary Table S7). Joint stratified analyses further supported the consistency of these subgroup patterns with the CHARLS findings (Supplementary Figure S2).

3.5.3 Sensitivity Analysis in HRS

In the HRS sensitivity analysis using data from 2008 to 2020 (waves 9–15), total life expectancy at age 60 differed only slightly across baseline depressive states, with estimates of approximately 36 years. However, the composition of state-specific life expectancy varied substantially (Supplementary Table S8). Compared with individuals without depression at baseline, those with mild or moderate-to-severe depression had progressively shorter depression-free life expectancy and longer moderate-to-severe depression life expectancy. The age-specific life table further showed that all state-specific life expectancies declined with increasing starting age, while depression-free life expectancy consistently accounted for the largest share of remaining life (Supplementary Table S9). Overall, the sensitivity analysis yielded findings consistent with the main analysis, supporting the robustness of the observed pattern in HRS.

4 Discussion

Using a multi-state modelling framework, this study systematically characterized the dynamic transitions among no depression, mild depression, moderate-to-severe depression, and death in individuals with arthritis. We further estimated total life expectancy and state-specific life expectancy according to depressive status. The results showed that, although total life expectancy at age 60 differed only modestly across baseline depressive states, the composition of remaining life varied substantially. Compared with individuals without depression, those with mild or moderate-to-severe depression at baseline had markedly shorter depression-free life expectancy and a greater proportion of remaining life lived with mild or moderate-to-severe depression.

Transition probability analyses further indicated that different depressive states were associated with distinct health trajectories. The non-depressed state was relatively stable, whereas greater depressive severity was associated with a higher probability of remaining in an adverse mental health state and transitioning to death. These unfavorable patterns were not evenly distributed across sex and educational subgroups. Overall, our findings highlight the importance of mental health management among individuals with arthritis, particularly among those with a greater depression burden and in vulnerable subgroups, to improve long-term health outcomes.

In the overall estimates, LE and DFLE at age 60 were 20.17 and 10.53 years, respectively, in CHARLS, compared with 35.16 and 23.23 years in HRS. These estimates differ from those reported in previous studies. A prior study on depression-free life expectancy among older Chinese adults reported that LE and DFLE at age 65 were 25.39 and 15.61 years, respectively [22]. Another study estimated DFLE at age 60 in the Chinese population to be 23.10 years [16]. In a study examining widowhood and depression-free life expectancy in the United States, DFLE at age 60 was estimated to range from 18.2 to 18.9 years [15]. Under the modelling strategy and sample framework of the present study, the estimates from the two cohorts differed from previous findings and also varied considerably between cohorts. These differences should not be interpreted simply as true cross-national differences in survival among individuals with arthritis. They are more likely to reflect differences in cohort inclusion criteria, sample age structure, follow-up design, depression scales and cut-off values, ascertainment of mortality, and model specifications. Nevertheless, in both the Chinese and US cohorts, baseline depressive status and its severity at age 60 had a relatively limited impact on total LE. Compared with differences in the length of survival, the effect of depression among individuals with arthritis was more clearly reflected in the composition of remaining life. As baseline depressive severity increased, the expected number of future years lived without depression decreased, whereas the expected number of years lived with depression increased. These findings suggest that depression is not merely a coexisting condition in individuals with arthritis, but may continue to affect healthy ageing over a substantial part of later life.

The transition probability results provide a dynamic explanation for the observed differences in the composition of life expectancy. Overall, the non-depressed state showed a certain degree of stability, whereas mild depression and moderate-to-severe depression were associated with less favorable transition patterns. Mild depression is particularly important because individuals in this state may either recover to a non-depressed state or progress to moderate-to-severe depression, suggesting that it may represent a clinically modifiable transitional stage. In contrast, moderate-to-severe depression was more likely to persist or to transition to death. These findings indicate that early identification and intervention at the stage of mild depression may be important for improving subsequent health trajectories among individuals with arthritis. Therefore, in the long-term management of arthritis, earlier depression screening, together with integrated interventions such as pain control and functional rehabilitation, may be more effective than treatment initiated only after marked psychological deterioration has occurred.

Greater depressive severity was associated with a higher probability of transition to death, which is consistent with previous evidence showing that severe depression significantly increases mortality risk [23, 24]. In addition, we found that the ratio of DFLE to LE increased with age in both the Chinese and US cohorts. This pattern may partly reflect the higher mortality risk among individuals with moderate-to-severe depression, who may therefore be underrepresented at older ages. However, this finding may also suggest that mental health among older adults with arthritis does not necessarily deteriorate in a linear manner with advancing age. Some researchers have proposed that long-term survivors may have stronger coping capacity, more mature emotion regulation, and more stable social relationships, which may help reduce the persistence or recurrence of moderate-to-severe depression [22]. Evidence on age-related changes in the DFLE/LE ratio remains limited, and further research is needed to clarify this pattern.

Stratified analyses further suggested substantial heterogeneity in the burden of depression and its impact on the composition of life expectancy across subgroups. In this study, stratification by sex and educational attainment was not conducted merely for descriptive purposes. Rather, these two variables represent two important dimensions of mental health trajectories among individuals with arthritis: biological and social role differences, and differences in social resources and health management capacity. Sex-stratified analysis has clear clinical relevance. The observed sex differences in this study may be partly explained by known sex disparities in both depression and arthritis. Previous studies have shown that women generally have a higher prevalence and burden of depression than men [25, 26], and that the burden of arthritis and chronic pain is also greater among women [27]. Women with arthritis may therefore face both a greater musculoskeletal disease burden and greater mental health vulnerability. This may make them more likely to experience depressive states during long-term follow-up and to accumulate more years lived with depression. These findings suggest that emotional screening and integrated interventions should be given greater attention in the clinical management of female patients with arthritis.

Stratification by educational attainment is also important. Compared with indicators such as income, which may fluctuate substantially over time, educational attainment is generally more stable in older populations. In this study, individuals with arthritis and lower educational attainment showed a less favorable depression-related composition of life expectancy. Educational attainment is associated not only with the risk of depression, but also with health literacy and the ability to use healthcare resources [28, 29]. Individuals with lower education may occupy a lower socioeconomic position and may have greater difficulty understanding disease-related information and implementing long-term management strategies. As a result, they may be more likely to accumulate adverse health states and more years lived with depression [30]. Therefore, stratification by education does not merely compare differences in depression across educational groups. Rather, it helps assess how long-term mental health trajectories among individuals with arthritis may vary across different social resource contexts. These findings also suggest that mental health interventions in arthritis management should not adopt a completely uniform approach. Greater attention should be given to vulnerable groups with relatively limited health literacy and weaker social support.

Further joint stratification by sex and educational attainment suggests that the burden of depression and its long-term impact among individuals with arthritis are not evenly distributed across the population. Instead, they are more likely to be concentrated in socio-demographically vulnerable subgroups. More proactive screening, follow-up, and support for these groups may be more effective than general management strategies in improving long-term health outcomes.

Given the increasing prevalence of arthritis in older populations and the substantial impact of depression on overall functioning, the potential link between depressive symptoms and arthritis in adults should be carefully recognized. For individuals with arthritis, disease management should not aim solely to prolong survival, but also to maximize the years lived in better mental health. Therefore, DFLE is not merely a statistical measure; it is an important outcome for assessing the quality of healthy ageing and the effectiveness of comprehensive management in this population. From clinical and public health perspectives, incorporating depression screening into routine arthritis care, together with early identification and intervention for individuals with mild depression, may help delay the development of adverse psychological trajectories and improve quality of life, functional independence, and long-term health outcomes.

This study has several strengths. First, we used a multi-state model to simultaneously characterize dynamic transitions among no depression, mild depression, moderate-to-severe depression, and death in individuals with arthritis. This approach provides a more comprehensive representation of long-term health trajectories than conventional single-endpoint analyses. Second, we distinguished mild depression from moderate-to-severe depression and estimated both total life expectancy and life expectancy lived in different depressive states, allowing a more detailed assessment of how depression affects the composition of remaining life.

Several limitations should also be acknowledged. First, because of data limitations, arthritis was mainly defined using self-reported information. We were unable to further distinguish arthritis subtypes, disease duration, or disease severity. Therefore, potential heterogeneity in the relationship between different types of arthritis and depression could not be fully assessed. Second, depressive status was defined using scale-based symptom scores rather than clinical diagnoses. Accordingly, the depression severity categories in the two cohorts should be regarded as approximately harmonized classifications, rather than fully equivalent clinical categories. Third, the multi-state model was based on the Markov assumption, under which future transitions depend primarily on the current state. This approach may not fully capture historical information such as cumulative depression burden, duration of depressive episodes, or recurrent symptoms. Fourth, this study identified dynamic associations between depressive states and transition to death, rather than causal effects. Therefore, mechanistic interpretations should be made with caution. Finally, our findings were based on specific study populations and measurement frameworks. Generalization to other populations should be validated in settings with different cultural backgrounds, disease profiles, and healthcare systems. Similarly, the findings should not be directly extrapolated to specific arthritis subtypes.

Future studies should incorporate more detailed information on arthritis subtype, pain severity, functional impairment, inflammatory markers, and treatment patterns to better clarify the potential mechanisms linking arthritis and depression. In addition, future work may consider time-varying covariates or more flexible transition modelling strategies to capture dynamic changes between health states more accurately.

5 Conclusion

This study showed that baseline depressive status had a relatively limited impact on total life expectancy, but substantially influenced the composition of remaining life. As depressive severity increased, individuals with arthritis experienced shorter depression-free life expectancy and longer survival with depression. Greater depressive severity was further associated with less favorable health trajectories and a higher probability of transition to death. These mental health losses also varied substantially across sex and educational subgroups. These findings suggest that depression screening and early intervention should be incorporated into routine long-term management of individuals with arthritis. Particular attention should be given to high-risk and vulnerable groups to improve long-term health outcomes and promote healthy ageing.

Abbreviations

CHARLS, China Health and Retirement Longitudinal Study;

HRS, Health and Retirement Study;

OA, osteoarthritis;

RA, rheumatoid arthritis;

MSM, multi-state Markov model;

LE, life expectancy;

DFLE, depression-free life expectancy;

MDLE, mild depression life expectancy;

SDLE, moderate-to-severe depression life expectancy;

CES-D, Center for Epidemiologic Studies Depression Scale;

Declarations

Ethics approval and consent to participate

The CHARLS surveys were approved by the Institutional Review Board of Peking University, and all participants provided written informed consent. The HRS was approved by the Health Sciences and Behavioral Sciences Institutional Review Board at the University of Michigan, and informed consent was obtained from all participants. The present study was based on secondary analyses of publicly available, de-identified data from these two cohorts.

Consent for publication

Not applicable.

Competing interests

No competing interests.

Clinical trial number

Not applicable.

Human Ethics and Consent to Participate declarations

Not applicable

Funding

This study was supported by funding from the Key Project of the National Natural Science Foundation of China (U21A20390), Jilin Scientific and Technological Development Program (20230204075YY, 20240305034YY). And project of "Medical + X" Interdisciplinary Innovation Team of Norman Bethune Health Science Center of Jilin University (2024JBGS04).

Author Contribution

SZ and ZY: Conceptualization, data curation, methodology, formal analysis and writing-original draft preparation. SZ, YS and XT: Writing-reviewing and editing. SZ and ZL: Validation and visualization. XT and YQ: Supervision, project administration and Resources. All authors read and approved the final manuscript.

Acknowledgement

We would like to thank the CHARLS and HRS research teams, investigators, staff, and participants for their contributions to data collection and for making the data and documentation publicly available. These resources made this study possible.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to concerns of privacy and confidentiality, but some material can be available from the corresponding author on reasonable request.

References

1. Gao Y, Yu H, Han W, Wang N, Zheng B, Yang A, Wang Y. Osteoarthritis in older adults: A global health challenge and the role of high BMI in shaping disease trends. *PLoS ONE*. 2026;21(3):e0344284.
2. Verbrugge LM, Juarez L. Arthritis disability and heart disease disability. *Arthritis Rheum*. 2008;59(10):1445–57.
3. Tang S, Zhang C, Oo WM, Fu K, Risberg MA, Bierma-Zeinstra SM, Neogi T, Atukorala I, Malfait AM, Ding C et al. Osteoarthritis. *Nature reviews Disease primers* 2025, 11(1):10.
4. Konzett V, Aletaha D. Management strategies in rheumatoid arthritis. *Nat Rev Rheumatol*. 2024;20(12):760–9.
5. Murphy LB, Cisternas MG, Pasta DJ, Helmick CG, Yelin EH. Medical Expenditures and Earnings Losses Among US Adults With Arthritis in 2013. *Arthritis Care Res*. 2018;70(6):869–76.
6. Mental Health of Older Adults. <http://www.who.int/mediacentre/factsheets/fs381/en/>
7. Aaron RV, Ravyts SG, Carnahan ND, Bhattiprolu K, Harte N, McCaulley CC, Vitalicia L, Rogers AB, Wegener ST, Dudeney J. Prevalence of Depression and Anxiety Among Adults With Chronic Pain: A Systematic Review and Meta-Analysis. *JAMA Netw open*. 2025;8(3):e250268.

8. Parmelee PA, Tighe CA, Dautovich ND. Sleep disturbance in osteoarthritis: linkages with pain, disability, and depressive symptoms. *Arthritis Care Res.* 2015;67(3):358–65.
9. Machado GP, Gignac MA, Badley EM. Participation restrictions among older adults with osteoarthritis: a mediated model of physical symptoms, activity limitations, and depression. *Arthritis Rheum.* 2008;59(1):129–35.
10. Goubran M, van Allen ZM, Bilodeau M, Boisgontier MP. Depressive Symptoms and Physical Activity Mediate the Adverse Effect of Pain on Functional Dependence in Patients With Arthritis: Evidence From the Canadian Longitudinal Study on Aging. *Phys Ther* 2025, 105(11).
11. Alwhaibi M. Depression, Anxiety, and Health-Related Quality of Life in Adults with Rheumatoid Arthritis: Findings from a National Survey. *Journal of clinical medicine* 2025, 14(22).
12. Sweeney M, Carpenter L, de Souza S, Caton E, Galloway J, Cope A, Yates M, Nikiphorou E, Norton S. Self-management behaviors do not affect remission but mediate between mental health and disease outcomes in a longitudinal study of rheumatoid arthritis. *Rheumatol Int.* 2025;45(2):31.
13. Liu R, Xin Y, Shao Y, Wu B, Liu Y. Association of improvement and worsening of depressive symptoms with arthritis. *BMC Geriatr.* 2024;24(1):909.
14. Ausserwinkler M, Hueber AJ, Gensluckner S, Paulweber B, Trinkla E, Langthaler P, Iglseider B, Flamm M, Aigner E, Wernly B. Association between rheumatoid arthritis and depressive symptoms: A population-based analysis from the Paracelsus 10,000 study. *Psychiatry Res.* 2026;361:117122.
15. Feraldi A, Giudici C, Brouard N. Estimating the Sex Gap in Depression-Free Life Expectancy Among Widowed Americans Aged 50 and Older: An Application Using the Interpolated Markov Chain Approach. *J Aging Health.* 2025;37(1–2):117–30.
16. Hu Z, Liu X, Jiang F, Ma L, Yang J, Chen Y, Zhu L, Mao Z, Hou J, Wang C. Multidimensional evaluation of healthy life expectancy indicators based on mental health among the rural older population: A large-scale cross-sectional study. *J Affect Disord.* 2022;319:318–24.
17. Wang Y, Tao L, Lu G, Chen H, Jing W, Jin C, Liu J. Social and digital engagement associated with reduced depressive symptoms in adults aged 50 and older: a multi-country cohort study. *BMC Med* 2026.
18. Wang Y, Liu M, Yang F, Chen H, Wang Y, Liu J. The associations of socioeconomic status, social activities, and loneliness with depressive symptoms in adults aged 50 years and older across 24 countries: findings from five prospective cohort studies. *lancet Healthy Longev.* 2024;5(9):100618.
19. Kalbfleisch JD, Lawless JFJJ. The analysis of panel data under a Markov assumption. 1985, 80(392):863–71.
20. Putter H, Fiocco M, Geskus, RBJSim. Tutorial in biostatistics: competing risks and multi-state models. 2007, 26(11):2389–430.
21. Cai L, Hayward MD, Saito Y, Lubitz J, Hagedorn A, Crimmins EJD. Estimation of multi-state life table functions and their variability from complex survey data using the SPACE Program. 2010, 22(6):129.
22. Xie R, Wu H, Zhao F, Dong H. Study on depression-free life expectancy in the elderly population in China. *BMC Public Health.* 2025;25(1):3507.
23. Penninx BW, Geerlings SW, Deeg DJ, van Eijk JT, van Tilburg W, Beekman AT. Minor and major depression and the risk of death in older persons. *Arch Gen Psychiatry.* 1999;56(10):889–95.
24. Wu S, Zhong X, Gong Y, Yao Y, Shirai K, Kondo K, Wang X, Guan L, Chen Q, Liu K et al. Depression and the Risk of Dementia and All-Cause Mortality Among Japanese Older Adults: A 9-Year Longitudinal Study From JAGES. *The journals of gerontology Series B, Psychological sciences and social sciences* 2024, 79(7).
25. Global regional. and national burden of 12 mental disorders in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The lancet Psychiatry* 2022, 9(2):137–150.
26. Kuehner C. Why is depression more common among women than among men? *lancet Psychiatry.* 2017;4(2):146–58.
27. Global regional, national burden of osteoarthritis. 1990–2020 and projections to 2050: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Rheumatol.* 2023;5(9):e508–22.
28. Berkman ND, Sheridan SL, Donahue KE, Halpern DJ, Crotty K. Low health literacy and health outcomes: an updated systematic review. *Ann Intern Med.* 2011;155(2):97–107.
29. Cohen AK, Nussbaum J, Weintraub MLR, Nichols CR, Yen IH. Association of Adult Depression With Educational Attainment, Aspirations, and Expectations. *Prev Chronic Dis.* 2020;17:E94.
30. Domènech-Abella J, Mundó J, Leonardi M, Chatterji S, Tobiasz-Adamczyk B, Koskinen S, Ayuso-Mateos JL, Haro JM. The association between socioeconomic status and depression among older adults in Finland, Poland and Spain: A comparative cross-sectional study of distinct measures and pathways. *J Affect Disord.* 2018;241:311–8.

Figures

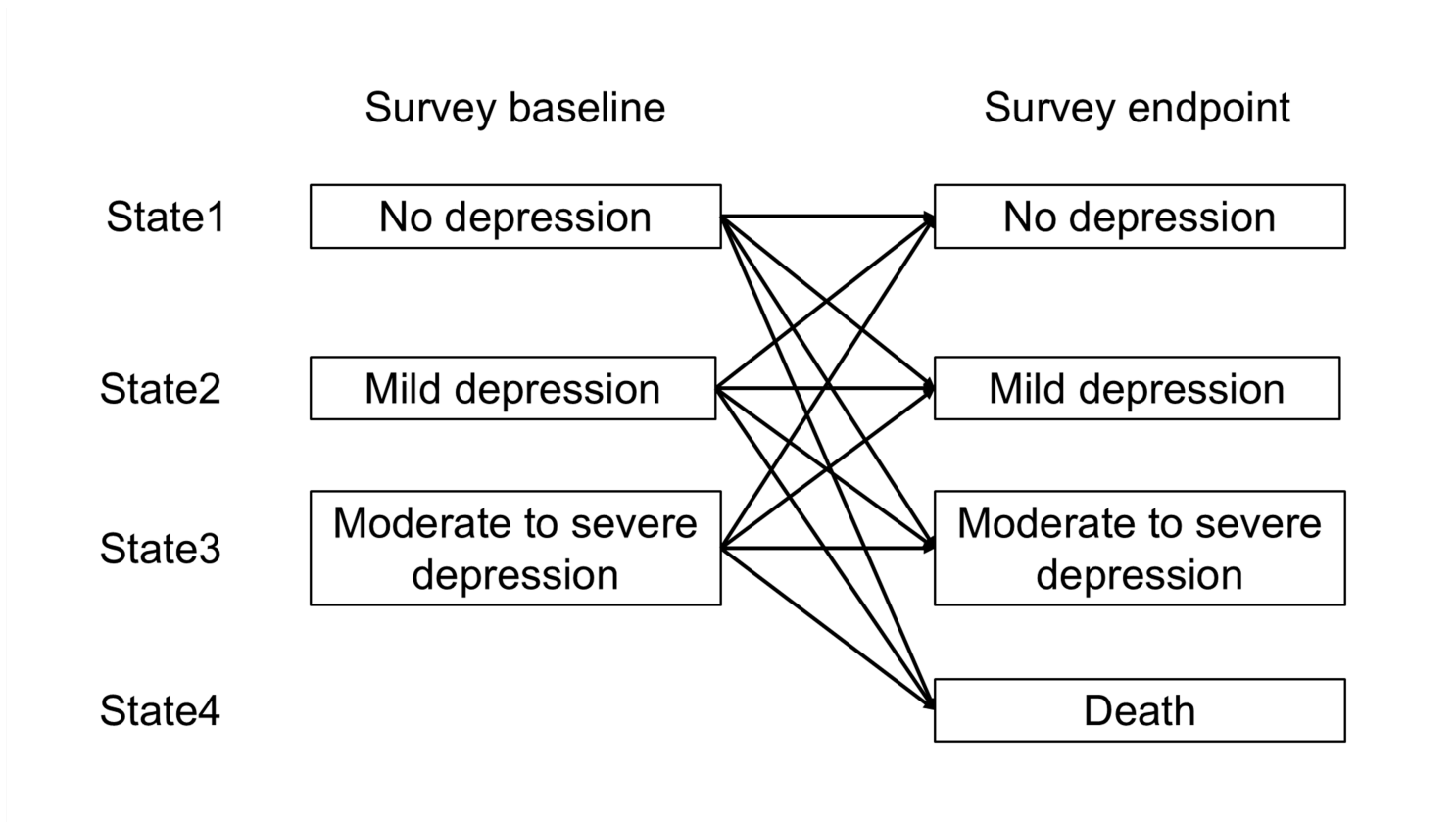


Figure 1

Multi-state schematic diagram of the health status transition.

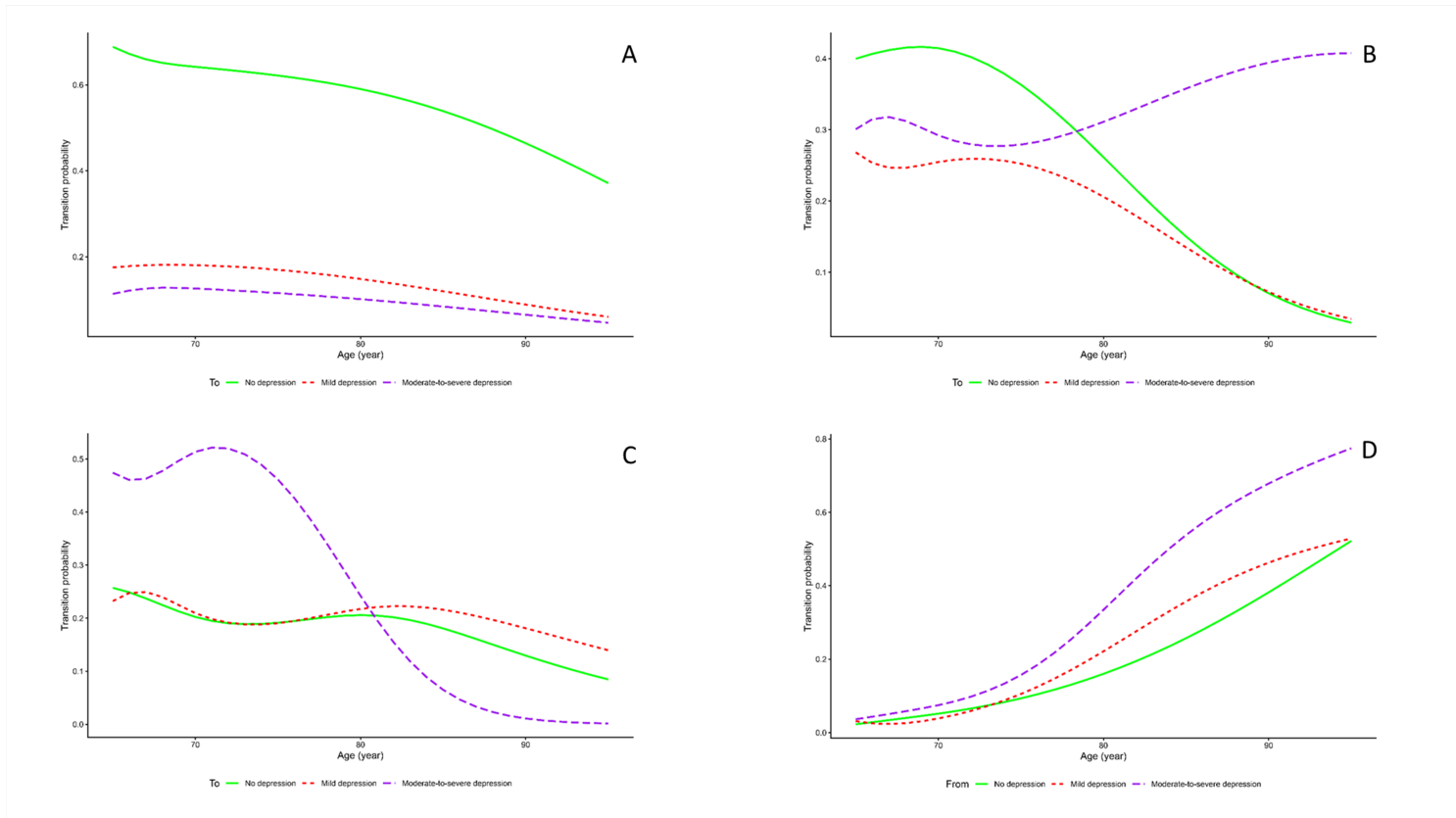


Figure 2

Transition probabilities between depression-related health states among older adults with arthritis in CHARLS. Panels A–C show the probabilities of transitioning from no depression, mild depression, and moderate-to-severe depression to each subsequent health state, respectively. Panel D shows the probabilities of transitioning from each depression-related health state to death.

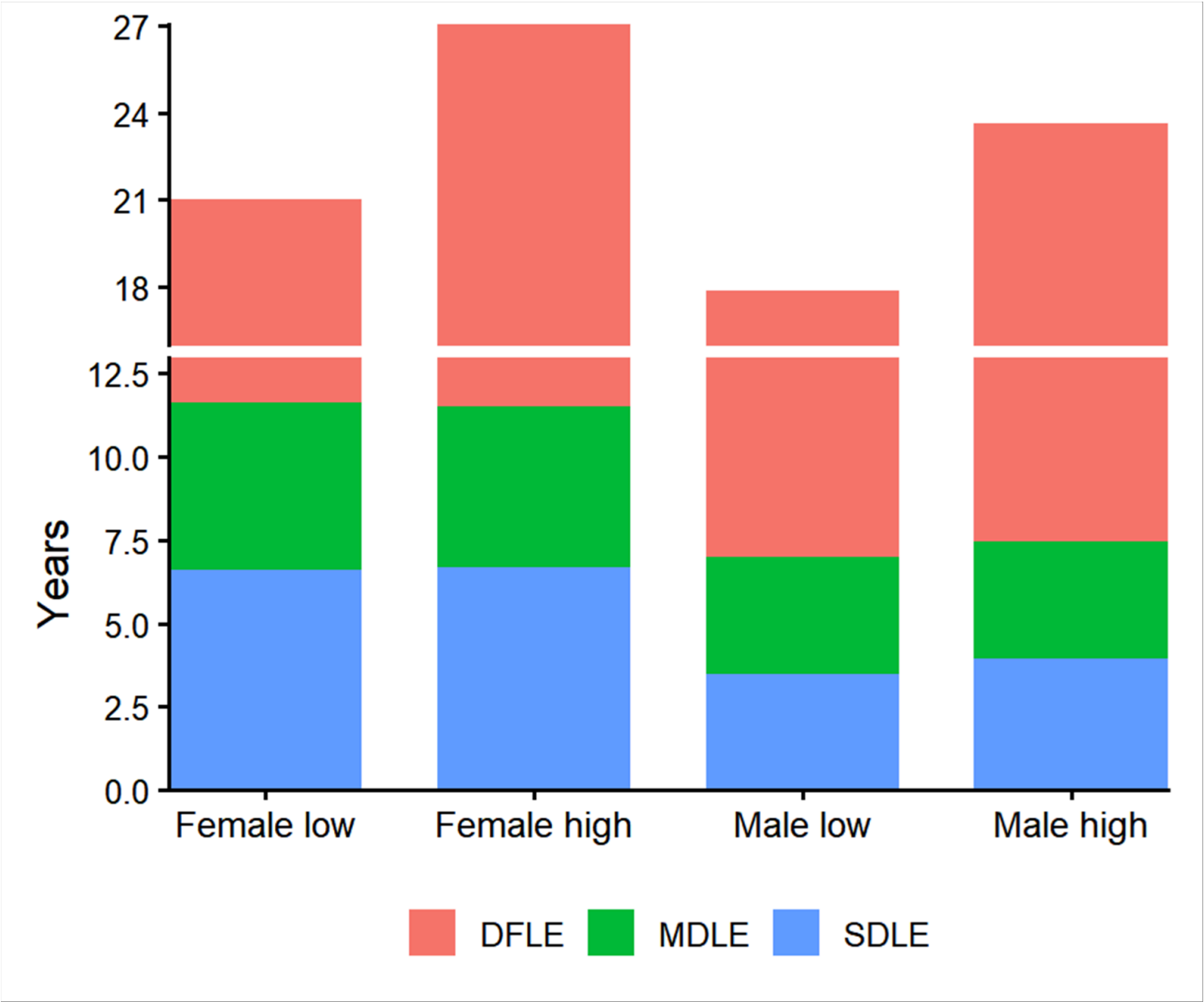


Figure 3

Composition of state-specific life expectancy among older adults with arthritis in the CHARLS population, stratified jointly by sex and educational level. LE, life expectancy, DFLE, depression-free life expectancy, MDLE, mild depression life expectancy, SDLE, moderate-to-severe depression life expectancy.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryDocument1.docx](#)
- [FigureS1.tiff](#)
- [FigureS2.tif](#)