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Frailty–depressive symptom transitions in relation to subsequent change in function-weighted multimorbidity burden: a longitudinal CHARLS study, 2011–2018

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Abstract

Background

Frailty and depressive symptoms often coexist in middle-aged and older adults and may precede increasing multimorbidity burden. However, it remains unclear whether different frailty–depressive symptom transition patterns are associated with subsequent changes in function-weighted multimorbidity burden and whether high-risk patterns are disproportionately concentrated among socioeconomically disadvantaged groups.

Methods

We used four waves (2011–2018) of the China Health and Retirement Longitudinal Study. Joint frailty and depressive-symptom states in 2011 and 2013 were grouped into seven two-wave transition patterns. Outcomes during 2013–2018 were annualized change in the Chinese multimorbidity-weighted index (CMWI) and upper-quartile CMWI growth. Associations were estimated using multivariable linear regression and modified Poisson regression with community-clustered robust standard errors. Repeated CMWI measurements were examined with linear mixed-effects models. Concentration indices assessed socioeconomic inequalities in persistent dual vulnerability and upper-quartile CMWI growth.

Results

Among 8,133 participants, 2,016 (24.8%) had upper-quartile CMWI growth. In primary Model A, persistent dual vulnerability showed the largest mean difference in annualized CMWI change compared with stable low risk (0.203 points/year, 95% CI 0.155–0.252) and the highest risk ratio for upper-quartile growth (RR 2.15, 95% CI 1.88–2.46). In secondary baseline-conditional Model B, the corresponding estimates were 0.271 points/year (95% CI 0.222–0.321) and RR 2.19 (95% CI 1.91–2.51). Model A marginal standardization gave an adjusted absolute risk difference of 20.5 percentage points (95% CI 16.4–24.6). Associations remained positive after excluding the mental-health-related component of the CMWI. Persistent dual vulnerability was concentrated among participants with lower household consumption (Erreygers index − 0.0586, 95% CI − 0.0799 to − 0.0387). Upper-quartile CMWI growth showed no clear socioeconomic concentration, and there was no clear evidence of multiplicative interaction on the risk-ratio scale (joint Wald P = 0.706).

Conclusions

Persistent co-occurrence of frailty and depressive symptoms was associated with the largest estimated subsequent increase in function-weighted multimorbidity burden. This pattern was disproportionately concentrated among participants with lower socioeconomic status. Joint assessment of frailty and depressive symptoms may help identify individuals at higher risk of increasing multimorbidity burden, although intervention studies are needed to determine whether targeted management can improve subsequent outcomes.

Background

Frailty and depressive symptoms commonly coexist in middle-aged and older adults [1–2]. Both may influence subsequent chronic disease burden [2–3]. Frailty reflects reduced physiological reserve, limited mobility, and impaired recovery after stress [4]. Depressive symptoms may affect disease control and healthcare use through lower physical activity, sleep and nutritional disturbances, poorer treatment adherence, and impaired chronic disease self-management [3, 5–6]. Persistent co-occurrence may combine physiological vulnerability with behavioral management difficulties. This may create a state of dual physical–psychological vulnerability and may be associated with increasing multimorbidity burden over time [2, 7–8]. Direct longitudinal evidence remains limited. From a health-equity perspective, limited socioeconomic resources may increase

psychosocial stress and restrict access to preventive care and chronic disease management. Dual vulnerability and its subsequent health consequences may therefore be unequally distributed across socioeconomic groups.

Recent longitudinal studies have further characterized the dynamic relationship between frailty and depressive symptoms across CHARLS, HRS, and ELSA [9–10]. Other longitudinal work has documented heterogeneity in multimorbidity trajectories and their associations with subsequent functional outcomes [11]. However, evidence remains limited on whether joint transitions in frailty and depressive symptoms are associated with subsequent changes in a function-weighted multimorbidity burden, and whether these transition patterns are socioeconomically patterned.

To address these gaps, we used CHARLS data from 2011 to 2018 [12]. We constructed seven two-wave transition patterns from the joint frailty and depressive-symptom status in 2011 and 2013. We examined their associations with annualized CMWI change and upper-quartile CMWI growth during 2013–2018. We also assessed the health-equity dimension. Specifically, we examined whether persistent dual vulnerability represented the highest-risk transition phenotype, whether this antecedent vulnerability was concentrated among socioeconomically disadvantaged groups, and whether socioeconomic status modified the association between frailty–depressive symptom transition patterns and upper-quartile CMWI growth. These analyses may support earlier identification of middle-aged and older adults at risk of increasing multimorbidity burden.

Methods

Study design and data source

This secondary longitudinal cohort analysis used data from CHARLS waves 1–4 (2011–2018). CHARLS is a nationally sampled longitudinal study of Chinese adults aged 45 years and older and uses multistage stratified probability-proportional-to-size sampling [12]. We treated 2013 as the analytic baseline. The exposure window was 2011–2013, during which joint frailty and depressive-symptom states were defined at both waves and combined into two-wave transition patterns. The outcome follow-up window was 2013–2018. We ended follow-up in 2018 to keep the exposure and outcome measurements within the pre-COVID-19 survey period, because the pandemic could affect depressive symptoms, physical function, healthcare use, and chronic disease ascertainment. Reporting followed the STROBE recommendations for cohort studies.

The source dataset contained 25,586 participants. Among them, 12,504 had sufficient frailty and depressive-symptom data in both 2011 and 2013 to define the two-wave exposure. The threshold for the secondary outcome was derived before complete-case restriction among 14,701 participants with CMWI data in both 2013 and 2018. The 75th percentile of annualized CMWI change defined upper-quartile CMWI growth, with ties at the threshold retained. Participants with complete exposure, 2013–2018 outcome, and covariate data were included in the primary regression analyses, yielding 8,133 participants (Fig. 1). No a priori sample-size calculation was performed because this was a secondary analysis of an existing cohort and all eligible participants were included.

Exposure: 2011–2013 two-wave frailty–depressive symptom transition categories

Frailty was assessed with a deficit-accumulation frailty index (FI) based on 29 health deficits. These included 6 activities of daily living (ADL) items, 6 instrumental activities of daily living (IADL) items, 7 cognitive-function items, 9 physical-function items, and 1 self-rated health item. Frailty and affective disorders have bidirectional associations [13]. To reduce overlap in the joint exposure, the FI excluded chronic disease diagnoses, depressive-symptom items, and other mental-health variables [14–15]. The FI was calculated when at least 80% of items had valid data. It was computed as the sum of observed deficit scores divided by the number of available items. Frailty was defined as FI ≥ 0.25 [16–17]. Robustness analyses used FI thresholds of 0.20 and 0.30. We also constructed a 17-item non-disability FI that excluded ADL and IADL items. The main analyses used 0.25 as the threshold (Additional file 1: Supplementary Table S1; Additional file 2: Supplementary Fig. S1).

Depressive symptoms were measured with the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10). Scores range from 0 to 30, with higher scores indicating more severe depressive symptoms. Depressive symptoms were defined as CES-D-10 ≥ 10 [18–19]. A threshold of CES-D-10 ≥ 12, proposed for a Chinese older clinical referral sample, was used in a robustness analysis [20] (Supplementary Table S1).

At each survey wave in 2011 and 2013, participants were classified into four joint states: neither frail nor having depressive symptoms, frailty only, depressive symptoms only, and both frailty and depressive symptoms. The two-wave combinations were grouped into seven transition patterns: stable low risk, incident single vulnerability, incident dual vulnerability, persistent single vulnerability, persistent dual vulnerability, improved, and other transitions. Stable low risk was the reference group. Persistent single vulnerability required the same single-vulnerability state at both waves. Transitions between frailty only and depressive symptoms only were classified as other transitions and treated as an exploratory category (Supplementary Table S1). In a five-category robustness analysis, incident and persistent states were combined within single and dual vulnerability. These categories describe changes between the two observed waves and do not imply that states were constant between survey assessments.

Outcomes: CMWI change and upper-quartile growth

The CMWI includes 14 common chronic conditions. Each condition is weighted according to its effect on physical function, and the weights are summed. Higher scores indicate greater function-weighted multimorbidity burden [21]. The primary outcome was annualized CMWI change from 2013 to 2018. The secondary outcome was upper-quartile CMWI growth. This binary outcome was defined as annualized CMWI change at or above the highest quartile in 14,701 participants with CMWI follow-up data. Ties at the threshold were included. Upper-quartile CMWI growth is a relative high-growth outcome defined from the sample distribution. Repeated CMWI measurements from 2013, 2015, and 2018 were analyzed as a supplementary outcome. The original CMWI contains an item for “emotional, nervous, or psychiatric problems.” Depressive symptoms were also part of the frailty–depressive symptom exposure. To address possible double counting of depression-related information, we removed this item from the original CMWI. We retained the original weights of the other 13 conditions and recalculated the index using the same method. This measure was termed CMWI-13. Construction of the CMWI and CMWI-13 is shown in Supplementary Table S2. Core exposure and outcome definitions are shown in Table 1.

Table 1
Definitions of core exposures and outcomes

Category	Variable	Definition/construction	Basis/source
Core exposure	Frailty–depressive symptom transition pattern	FI and depressive symptoms were derived from health and functional items and the CES-D-10. Wave-specific frailty–depressive symptom states were then combined into 2011–2013 transition patterns.	[16,19]
Frailty index	FI	Deficit-accumulation frailty index based on 29 health deficits: 6 ADL items, 6 IADL items, 7 cognitive items, 9 physical-function items, and 1 self-rated health item. When at least 80% of items were nonmissing, FI was calculated as the sum of available deficit scores divided by the number of available items.	[16–17]
Frailty	Frailty	Defined as FI ≥ 0.25.	[16–17]
Depressive-symptom score	CES-D-10 total score	Measured using the 10-item Center for Epidemiologic Studies Depression Scale in CHARLS. Scores range from 0 to 30. Positively worded items are reverse coded. Higher scores indicate more depressive symptoms.	[18–19]
Depressive symptoms	Depressive symptoms	Defined as CES-D-10 ≥ 10 in the primary regression models; CES-D-10 ≥ 12 in the robustness analysis.	[19–20]
2011–2013 transition pattern	Frailty–depressive symptom transition pattern	Categories were stable low risk, incident single vulnerability, incident dual vulnerability, persistent single vulnerability, persistent dual vulnerability, improved, and other transitions. Persistent single vulnerability required the same single-vulnerability state at both waves. Transitions between frailty only and depressive symptoms only were classified as other transitions.	Constructed in this study
Outcome	Primary outcome: annualized CMWI change, defined as (2018 CMWI − 2013 CMWI)/5. Secondary outcome: upper-quartile CMWI growth, defined as the highest quartile of annualized CMWI change, threshold ≥ 0.46 points/year.	Annualized increase was calculated as 2018 CMWI minus 2013 CMWI divided by 5 years. The highest quartile of annualized CMWI increase during 2013–2018 had a threshold of ≥ 0.46 CMWI points/year.	Constructed in this study
CMWI score	Chinese multimorbidity-weighted index	Weighted sum of 14 CHARLS chronic-condition indicators using Chinese disease weights.	[21,26]
Multimorbidity	Multimorbidity	Descriptively defined as the presence of two or more of the 14 chronic conditions in 2013.	[11]

Note: CMWI = Chinese multimorbidity-weighted index; CES-D-10 = 10-item Center for Epidemiologic Studies Depression Scale; FI = frailty index.

Health-equity analysis

Household consumption per capita reflects household material living standards and is less affected than current income by irregular income after retirement. We therefore used 2013 household consumption per capita as the socioeconomic ranking variable [22]. Participants were ranked from low to high using the continuous consumption measure. Concentration curves and concentration indices were used to assess the consumption-related distribution of persistent dual vulnerability and upper-quartile CMWI growth. Because both indicators were binary and bounded between 0 and 1, the Erreygers-corrected

concentration index was the primary equity measure; the conventional concentration index and age- and sex-standardized concentration indices were supplementary measures [23]. To assess the effect of missing household-consumption data, we modeled the probability that consumption was observed among the 8,133 participants in the main analysis. Inverse probability weights for observed consumption were then used to re-estimate concentration indices among the 5,625 participants with observed consumption (Supplementary Table S3) [24]. Consumption was also divided into quintiles from Q1 (lowest) to Q5 (highest). Socioeconomic heterogeneity was first assessed using modified Poisson regression with transition-pattern-by-consumption-quintile interaction terms and community-clustered robust standard errors. A joint Wald test assessed the overall multiplicative interaction on the risk-ratio scale. As a secondary analysis, household consumption was dichotomized into lower (Q1–Q2) and higher (Q3–Q5) groups, and stratum-specific risk ratios, adjusted probabilities, and absolute risk differences were estimated. For all three concentration indices, 95% CIs were calculated from 2,000 cluster bootstrap resamples using community as the resampling unit. Age- and sex-standardization models were refitted in each resample. In inverse-probability-weighted resampling, the consumption-observation model and weights were re-estimated within each bootstrap sample.

Covariates

We identified some factors in the CHARLS data that may be associated with frailty, depression and the cumulative burden of multimorbidity. In line with previous research, The primary adjustment set included age, sex, education, marital status, residence, health insurance, smoking, and alcohol use. All covariates were measured in 2013, at the end of the exposure window.

Statistical analysis

For baseline descriptive statistics, continuous variables are presented as mean (SD) or median (interquartile range), according to their distributions, and categorical variables as counts and percentages. Annualized CMWI change was analyzed using multivariable linear regression. A 6-degree-of-freedom global Wald test first assessed the overall association between the seven-category transition pattern and the outcome. We then estimated mean differences (β coefficients) and 95% CIs for each category relative to stable low risk. Model A was the primary association model and adjusted for age, sex, education, marital status, urban/rural residence, health insurance, smoking, and alcohol use. Model B additionally adjusted for 2013 CMWI and therefore addressed a different, baseline-conditional estimand rather than a more fully adjusted version of Model A. Upper-quartile CMWI growth was analyzed using modified Poisson regression to estimate risk ratios (RRs) [25]. Both linear and modified Poisson models used cluster-robust standard errors, with the CHARLS community sampling unit as the clustering level (443 clusters in the primary analytic sample). Adjusted probabilities and absolute risk differences were calculated by marginal standardization from primary Model A over the observed covariate distribution; their 95% CIs used the delta method with the community-clustered covariance matrix. For the linear models, we examined residual-versus-fitted plots, normal Q-Q plots, and the Breusch-Pagan test. HC3 heteroskedasticity-robust standard errors were retained as a sensitivity analysis (Supplementary Table S4, Panel B).

Repeated CMWI measurements in 2013, 2015, and 2018 were analyzed using linear mixed-effects models with participant-specific random intercepts and random slopes. Time was coded as years since 2013 (0, 2, and 5), and transition-category-by-time interactions estimated annual slope differences relative to stable low risk. Random-effects structures were compared using restricted likelihood ratio tests, and model parameters were estimated by restricted maximum likelihood. Robustness analyses included adjustment for 2011 CMWI or the number of chronic conditions in 2011; stratification by baseline multimorbidity; exclusion of participants in the highest quartile of baseline CMWI; restriction to participants with no chronic conditions at baseline; exclusion of early upper-quartile CMWI growth during 2013–2015; alternative FI and CES-D-10 thresholds; use of the non-disability FI; exclusion of other transitions; use of a five-category exposure; and inverse probability of inclusion weighting. The association models were not weighted by the CHARLS survey weights because the primary estimand was the longitudinal association within the analytic cohort rather than a nationally weighted prevalence

estimate. Accordingly, descriptive proportions should not be interpreted as nationally weighted prevalence estimates. All analyses were performed in R version 4.6.1. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

Statistical model specification and concentration-index calculation

The following equations describe the main statistical models and equity measures. D denotes transition-category indicator variables, and X denotes covariates. Stable low risk was the reference transition category and therefore was not included in the sum over transition categories.

For the primary outcome, annualized CMWI change was calculated as:

$\Delta CMWI_i = (CMWI_i,2018 - CMWI_i,2013) / 5.$

Here, $\Delta CMWI_i$ is the annualized CMWI change for participant i from 2013 to 2018. The denominator 5 is the number of years between the two measurements.

The linear regression model for continuous annualized CMWI change was:

$\Delta CMWI_i = \alpha + \Sigma_g \beta_g D_{ig} + \Sigma_k \gamma_k X_{ik} + \varepsilon_i.$

Here, D_ig indicates whether participant i belongs to non-reference transition category g. X_ik denotes the kth covariate for participant i. G is the total number of frailty–depressive symptom transition categories. Because stable low risk is the reference category, G − 1 non-reference transition indicators are included. K is the number of covariate terms in the corresponding model. α is the intercept. βg is the adjusted mean difference in annualized CMWI change for transition category g relative to stable low risk, in points/year. γk is the coefficient for the kth covariate. The first summation is over g = 1, …, G − 1; the second is over k = 1, …, K.

The modified Poisson model for upper-quartile CMWI growth was:

$\log\{E(Y_i \mid D_i, X_i)\} = \alpha + \Sigma_g \beta_g D_{ig} + \Sigma_k \gamma_k X_{ik}.$

Here, Y_i indicates whether participant i met the definition of upper-quartile CMWI growth. exp(βg) is interpreted as a risk ratio.

As a robustness analysis of the effect scale, the logistic regression model was:

$\text{logit}\{P(Y_i = 1 \mid D_i, X_i)\} = \alpha + \Sigma_g \beta_g D_{ig} + \Sigma_k \gamma_k X_{ik}.$

The conventional concentration index was calculated as:

$C = 2\text{cov}(y_i, r_i) / \mu.$

C is the conventional concentration index. y_i is the binary indicator. μ is the mean of y_i. r_i is the fractional rank of participant i in the distribution of household consumption per capita. $C < 0$ indicates concentration among participants with lower consumption. $C > 0$ indicates concentration among participants with higher consumption. Values near 0 indicate no clear consumption-related concentration.

For binary outcomes bounded between 0 and 1, the Erreygers-corrected concentration index was calculated as $E = 4\mu C$. Negative values indicate concentration among participants with lower household consumption, whereas positive values indicate concentration among participants with higher consumption.

Missing data

The primary regression models used complete cases for the exposure, 2013–2018 outcomes, and covariates. The two-wave exposure and CMWI outcomes were not imputed. We used two types of inverse probability weights for different purposes. First, inverse probability of inclusion weights were used to assess selection into the main complete-case sample of 8,133 from the 12,504 participants with definable exposure. Second, weights for observed consumption were used to assess the effect of missing household consumption among the 8,133 participants in the main analysis on concentration-index estimates. The two sets of weights were modeled separately and used independently. Inverse probability weighting can reduce selection differences related to measured variables. It cannot correct bias from unmeasured factors, missing not at random, death, or loss to follow-up (Supplementary Table S3).

Results

Study population and baseline characteristics

Table 2 summarizes demographic characteristics and baseline health status for the 8,133 participants. Of these, 2,016 (24.8%) had upper-quartile CMWI growth. The 2011–2013 frailty–depressive symptom transition patterns were distributed as follows: stable low risk, 2,848 (35.0%); incident single vulnerability, 859 (10.6%); incident dual vulnerability, 778 (9.6%); persistent single vulnerability, 774 (9.5%); persistent dual vulnerability, 841 (10.3%); improved, 1,803 (22.2%); and other transitions, 230 (2.8%). Compared with the stable low-risk group, participants with persistent dual vulnerability were older. Higher proportions were women, rural residents, and had lower education. They also had higher CMWI scores and more chronic conditions in 2013. Baseline multimorbidity was present in 69.3% of the persistent dual-vulnerability group and 29.1% of the stable low-risk group.

Table 2
Baseline characteristics by transition pattern

Variable	Overall (N = 8133)	Stable low risk (N = 2848)	Incident single vulnerability (N = 859)	Incident dual vulnerability (N = 778)	Persistent single vulnerability (N = 774)	Persistent dual vulnerability (N = 841)	Improved (N = 1803)	Other (N = 230)
Age, years	59.15 (9.02)	57.31 (8.45)	58.66 (9.14)	59.95 (8.83)	60.33 (9.75)	61.95 (8.55)	60.08 (9.22)	59.71 (8.83)
Sex								
Male	2610 (32.1)	1265 (44.4)	294 (34.2)	170 (21.9)	199 (25.7)	139 (16.5)	499 (27.7)	44 (19.1)
Female	5523 (67.9)	1583 (55.6)	565 (65.8)	608 (78.1)	575 (74.3)	702 (83.5)	1304 (72.3)	186 (80.9)
Education								
No formal education	3922 (48.2)	847 (29.7)	378 (44.0)	494 (63.5)	432 (55.8)	624 (74.2)	1011 (56.1)	136 (59.1)
Traditional private school/ primary school	1738 (21.4)	682 (23.9)	184 (21.4)	150 (19.3)	164 (21.2)	135 (16.1)	385 (21.4)	38 (16.5)
Middle school	1624 (20.0)	816 (28.7)	196 (22.8)	97 (12.5)	112 (14.5)	68 (8.1)	292 (16.2)	43 (18.7)
High school/ vocational school	751 (9.2)	434 (15.2)	94 (10.9)	34 (4.4)	62 (8.0)	14 (1.7)	102 (5.7)	11 (4.8)
College or above	98 (1.2)	69 (2.4)	7 (0.8)	3 (0.4)	4 (0.5)	0 (0.0)	13 (0.7)	2 (0.9)
Marital status								
Married or cohabiting	6795 (83.5)	2530 (88.8)	739 (86.0)	621 (79.8)	616 (79.6)	630 (74.9)	1472 (81.6)	187 (81.3)
Other	1338 (16.5)	318 (11.2)	120 (14.0)	157 (20.2)	158 (20.4)	211 (25.1)	331 (18.4)	43 (18.7)
Residence								
Urban	2920 (35.9)	1315 (46.2)	329 (38.3)	222 (28.5)	251 (32.4)	167 (19.9)	571 (31.7)	65 (28.3)
Rural	5213 (64.1)	1533 (53.8)	530 (61.7)	556 (71.5)	523 (67.6)	674 (80.1)	1232 (68.3)	165 (71.7)
Health insurance								
No	248 (3.0)	71 (2.5)	27 (3.1)	28 (3.6)	37 (4.8)	24 (2.9)	54 (3.0)	7 (3.0)

Note: Continuous variables are presented as mean (SD), except for 2013 CMWI, which is presented as median (IQR). Categorical variables are presented as n (%).

Variable	Overall (N = 8133)	Stable low risk (N = 2848)	Incident single vulnerability (N = 859)	Incident dual vulnerability (N = 778)	Persistent single vulnerability (N = 774)	Persistent dual vulnerability (N = 841)	Improved (N = 1803)	Other (N = 230)
Yes	7885 (97.0)	2777 (97.5)	832 (96.9)	750 (96.4)	737 (95.2)	817 (97.1)	1749 (97.0)	223 (97.0)
Household consumption per capita quintile								
Q1 (lowest)	1164 (14.3)	311 (10.9)	114 (13.3)	119 (15.3)	130 (16.8)	183 (21.8)	275 (15.3)	32 (13.9)
Q2	1262 (15.5)	438 (15.4)	143 (16.6)	120 (15.4)	106 (13.7)	124 (14.7)	298 (16.5)	33 (14.3)
Q3	1134 (13.9)	423 (14.9)	118 (13.7)	108 (13.9)	105 (13.6)	101 (12.0)	256 (14.2)	23 (10.0)
Q4	1084 (13.3)	468 (16.4)	98 (11.4)	103 (13.2)	91 (11.8)	83 (9.9)	208 (11.5)	33 (14.3)
Q5 (highest)	981 (12.1)	403 (14.2)	125 (14.6)	70 (9.0)	94 (12.1)	78 (9.3)	177 (9.8)	34 (14.8)
Missing	2508 (30.8)	805 (28.3)	261 (30.4)	258 (33.2)	248 (32.0)	272 (32.3)	589 (32.7)	75 (32.6)
Smoking								
No	6864 (84.4)	2318 (81.4)	717 (83.5)	662 (85.1)	673 (87.0)	755 (89.8)	1534 (85.1)	205 (89.1)
Yes	1269 (15.6)	530 (18.6)	142 (16.5)	116 (14.9)	101 (13.0)	86 (10.2)	269 (14.9)	25 (10.9)
Alcohol use								
No	5880 (72.3)	1826 (64.1)	612 (71.2)	603 (77.5)	603 (77.9)	692 (82.3)	1357 (75.3)	187 (81.3)
Yes	2253 (27.7)	1022 (35.9)	247 (28.8)	175 (22.5)	171 (22.1)	149 (17.7)	446 (24.7)	43 (18.7)
2013 CMWI	2.20 (0.00, 3.50)	1.00 (0.00, 2.20)	1.60 (0.00, 2.90)	2.90 (1.30, 4.20)	2.20 (0.70, 4.00)	3.40 (2.20, 5.20)	2.20 (0.20, 3.50)	2.20 (0.75, 3.50)
Number of chronic conditions in 2013	1.56 (1.46)	1.07 (1.15)	1.35 (1.29)	2.07 (1.55)	1.82 (1.53)	2.50 (1.66)	1.65 (1.46)	1.80 (1.54)
Multimorbidity								
No	4581 (56.3)	2018 (70.9)	538 (62.6)	310 (39.8)	384 (49.6)	258 (30.7)	962 (53.4)	111 (48.3)

Note: Continuous variables are presented as mean (SD), except for 2013 CMWI, which is presented as median (IQR). Categorical variables are presented as n (%).

Variable	Overall (N = 8133)	Stable low risk (N = 2848)	Incident single vulnerability (N = 859)	Incident dual vulnerability (N = 778)	Persistent single vulnerability (N = 774)	Persistent dual vulnerability (N = 841)	Improved (N = 1803)	Other (N = 230)
Yes	3552 (43.7)	830 (29.1)	321 (37.4)	468 (60.2)	390 (50.4)	583 (69.3)	841 (46.6)	119 (51.7)

Note: Continuous variables are presented as mean (SD), except for 2013 CMWI, which is presented as median (IQR). Categorical variables are presented as n (%).

Annualized CMWI change

The seven frailty–depressive symptom transition patterns were associated overall with annualized CMWI change in both Model A and Model B. Community-clustered global Wald tests were $\chi^2(6) = 94.67$ and $\chi^2(6) = 158.73$, respectively, with $P < 0.001$ for both. Compared with stable low risk, persistent dual vulnerability was associated with a mean difference in annualized CMWI change of 0.203 points/year (95% CI 0.155–0.252) in primary Model A. In baseline-conditional Model B, the estimate was 0.271 points/year (95% CI 0.222–0.321). Estimates for the other transition categories are shown in Table 3. The repeated-measures analysis included 24,081 observations from 8,133 participants. The difference in annual CMWI slope between persistent dual vulnerability and stable low risk was 0.201 points/year (95% CI 0.161–0.240) (Supplementary Table S4; Supplementary Fig. S2).

Table 3
Two-wave frailty–depressive symptom transition categories and annualized CMWI change (primary outcome)

Transition category	Model A β (95% CI)	Model B β (95% CI)
Stable low risk	Reference	Reference
Incident single vulnerability	0.055 (0.018–0.092)	0.069 (0.033–0.106)
Incident dual vulnerability	0.145 (0.098–0.191)	0.193 (0.145–0.240)
Persistent single vulnerability	0.109 (0.067–0.150)	0.146 (0.104–0.187)
Persistent dual vulnerability	0.203 (0.155–0.252)	0.271 (0.222–0.321)
Improved	0.064 (0.034–0.095)	0.093 (0.062–0.124)
Other transitions	0.083 (0.013–0.152)	0.115 (0.046–0.184)

Note: β is the mean difference in annualized CMWI change for each transition category relative to stable low risk, in points/year. Model A adjusted for age, sex, education, marital status, urban/rural residence, health insurance, smoking, and alcohol use. Model B additionally adjusted for 2013 CMWI. Inference used community-clustered robust standard errors (443 communities). Community-clustered global Wald tests for the seven-category exposure were: Model A, $\chi^2(6) = 94.67$, $P < 0.001$; Model B, $\chi^2(6) = 158.73$, $P < 0.001$. Model A was the primary association model. After 2013 CMWI was added, Model B estimated the association conditional on disease burden at the start of outcome follow-up. HC3 robust standard errors are shown as a sensitivity analysis in Supplementary Table S4, Panel B.

Upper-quartile CMWI growth

The highest quartile of annualized CMWI change was 0.46 points/year, equivalent to an increase of about 2.30 points over 5 years. After ties at the threshold were retained, 3,718 participants (25.29%) met the definition of upper-quartile CMWI growth. In the primary regression sample of 8,133 participants, 2,016 (24.8%) met this definition. The seven transition categories were associated overall with upper-quartile CMWI growth (Table 4; Fig. 2). Compared with stable low risk, the RR for upper-quartile CMWI growth in the persistent dual-vulnerability group was 2.15 (95% CI 1.88–2.46) in primary Model A. Baseline-conditional Model B additionally included 2013 CMWI; the corresponding RR was 2.19 (95% CI 1.91–2.51). Marginal standardization from Model A gave adjusted probabilities of 38.4% (95% CI 34.6%–42.1%) for persistent dual vulnerability and 17.9% (95% CI 16.2%–19.5%) for stable low risk. The risk difference was 20.5 percentage points (95% CI

16.4–24.6). Modified Poisson estimates, Model A adjusted probabilities, and risk differences for the other transition categories are shown in Table 4 and Fig. 2. Logistic and log-binomial estimates on alternative effect scales are reported with the other robustness analyses.

Table 4
Two-wave frailty–depressive symptom transition categories and upper-quartile CMWI growth

Transition category	Model A RR (95% CI)	Model B RR (95% CI)	Model A adjusted probability (95% CI)	Model A risk difference, percentage points (95% CI)
Stable low risk	Reference	Reference	17.9 (16.2–19.5)	Reference
Incident single vulnerability	1.30 (1.11–1.52)	1.31 (1.12–1.53)	23.3 (20.3–26.2)	5.4 (2.0–8.8)
Incident dual vulnerability	1.81 (1.58–2.07)	1.83 (1.60–2.10)	32.3 (29.0–35.5)	14.4 (10.8–18.0)
Persistent single vulnerability	1.64 (1.42–1.89)	1.65 (1.43–1.92)	29.2 (25.9–32.5)	11.4 (7.7–15.0)
Persistent dual vulnerability	2.15 (1.88–2.46)	2.19 (1.91–2.51)	38.4 (34.6–42.1)	20.5 (16.4–24.6)
Improved	1.39 (1.23–1.58)	1.41 (1.24–1.59)	24.9 (22.7–27.1)	7.0 (4.4–9.7)
Other transitions	1.52 (1.22–1.90)	1.53 (1.23–1.92)	27.2 (21.6–32.7)	9.3 (3.5–15.1)

Note: RRs were estimated using modified Poisson regression with community-clustered robust standard errors (443 communities). Covariates in Models A and B were defined as in Table 3. Model A was the primary association model. Model B additionally adjusted for 2013 CMWI and estimated the association conditional on disease burden at the start of outcome follow-up. Adjusted probabilities and risk differences were obtained by marginal standardization from Model A; their 95% CIs used the delta method with the community-clustered covariance matrix. Upper-quartile growth was defined as the highest quartile of annualized CMWI change. Logistic ORs were used only as an effect-scale robustness analysis and are not presented as the main effect measure in this table.

Robustness analyses

Among 14,699 participants with complete CMWI-13 data in 2013 and 2018, the 75th percentile of annualized change was 0.44 points/year. After ties at the threshold were retained, 4,273 participants met the definition of upper-quartile CMWI-13 growth. Among the 8,133 participants in the main analysis, 2,323 (28.6%) had upper-quartile CMWI-13 growth. Compared with stable low risk, the mean difference in annualized CMWI-13 change for persistent dual vulnerability was 0.180 points/year (95% CI 0.141–0.220) in Model A and 0.249 points/year (95% CI 0.208–0.290) in Model B. The corresponding RRs for upper-quartile CMWI-13 growth were 1.70 (95% CI 1.51–1.91) and 1.90 (95% CI 1.69–2.15). The Model B risk difference was 19.3 percentage points (95% CI 15.4–23.1). The difference in annual slope in the repeated-measures analysis was 0.179 points/year (95% CI 0.140–0.217). Compared with the original 14-item CMWI, the mean difference in annualized change, the RR for upper-quartile growth, and the annual slope difference were all smaller (Table 5).

Table 5
Robustness analysis using CMWI-13 after excluding the mental-health-related component

Outcome	Model A estimate (95% CI)	Model B estimate (95% CI)	n (observations)
Annualized CMWI-13 change, β (points/year)	0.180 (0.141–0.220)	0.249 (0.208–0.290)	8133
Upper-quartile CMWI-13 growth, RR	1.70 (1.51–1.91)	1.90 (1.69–2.15)	8133 (2323)
Adjusted probability: persistent dual vulnerability, %	—	40.9 (37.5–44.6)	8133 (2323)
Adjusted probability: stable low risk, %	—	21.6 (20.1–23.3)	8133 (2323)
Adjusted risk difference, percentage points	—	19.3 (15.4–23.1)	8133 (2323)
Repeated-measures annual slope difference (points/year)	—	0.179 (0.140–0.217)	8133 (24081)

Note: Except for the two adjusted probabilities, all effect estimates compare persistent dual vulnerability with stable low risk. The threshold for upper-quartile CMWI-13 growth was annualized change ≥ 0.44 points/year. Model A adjusted for age, sex, education, marital status, urban/rural residence, health insurance, smoking, and alcohol use. Model B additionally included 2013 CMWI-13. Adjusted probabilities and the risk difference were obtained by logistic marginal standardization from Model B. Repeated-measures results came from a REML random-intercept and random-slope model using 2013, 2015, and 2018 data.

Other robustness analyses supported the same direction of association. After adjustment for 2011 CMWI, the RR for upper-quartile CMWI growth associated with persistent dual vulnerability was 2.15 (95% CI 1.89–2.46). After adjustment for the number of chronic conditions in 2011, the RR was 2.09 (95% CI 1.83–2.39). Results were consistent across baseline-burden restrictions, alternative FI and CES-D-10 thresholds, the non-disability FI, exclusion of early upper-quartile CMWI growth, the five-category exposure definition, and alternative effect scales (Supplementary Table S5). The inverse-probability-of-inclusion-weighted RR for selection from 12,504 participants with definable exposure to the 8,133-participant main sample was 2.15 (95% CI 1.88–2.47) (Supplementary Table S3).

Socioeconomic status and concentration

Persistent dual vulnerability was more common in lower quintiles of household consumption per capita. Its prevalence was 15.72% in Q1 and 7.95% in Q5. Upper-quartile CMWI growth varied less across quintiles, ranging from 22.31% to 26.91% (Fig. 3A). Among 5,625 participants with observed household consumption, the Erreygers-corrected concentration index for persistent dual vulnerability was − 0.0586 (community-cluster bootstrap 95% CI − 0.0799 to − 0.0387). The unstandardized concentration index was − 0.1448 (− 0.1933 to − 0.0973). The age- and sex-standardized concentration index was − 0.1128 (− 0.1626 to − 0.0647). These results indicate concentration among participants with lower socioeconomic status (Table 6; Fig. 3B). For upper-quartile CMWI growth, the Erreygers-corrected concentration index was − 0.0053 (95% CI − 0.0324 to 0.0218). The unstandardized and age- and sex-standardized indices were − 0.0053 (− 0.0325 to 0.0221) and 0.0052 (− 0.0210 to 0.0317), respectively. No clear socioeconomic concentration was observed (Table 6; Fig. 3B). Results using socioeconomic-status weighting were similar in direction (Supplementary Table S3). There was no evidence of a transition-pattern-by-consumption-quintile interaction on the risk-ratio scale (community-clustered joint Wald test P = 0.706; 439 communities). For persistent dual vulnerability versus stable low risk, the RR was 1.99 (95% CI 1.61–2.47) in Q1–Q2 and 2.54 (95% CI 2.08–3.10) in Q3–Q5. The ratio of RRs for lower versus higher consumption was 0.79 (95% CI 0.60–1.03; P = 0.085). The adjusted risk differences were 18.8 percentage points (95% CI 12.2–25.4) and 24.9 percentage points (95% CI 18.5–31.3), respectively (Supplementary Table S6).

Table 6
Consumption-related concentration indices for persistent dual vulnerability and upper-quartile CMWI growth

Indicator	n	Mean	Erreygers-corrected concentration index (95% CI)	Unstandardized concentration index (95% CI)	Age- and sex-standardized concentration index (95% CI)
Persistent dual vulnerability	5625	0.1012	−0.0586 (− 0.0799 to − 0.0387)	−0.1448 (− 0.1933 to − 0.0973)	−0.1128 (− 0.1626 to − 0.0647)
Upper-quartile CMWI growth	5625	0.2464	−0.0053 (− 0.0324 to 0.0218)	−0.0053 (− 0.0325 to 0.0221)	0.0052 (− 0.0210 to 0.0317)

Note: 95% CIs were based on 2,000 cluster bootstrap resamples using community as the resampling unit to account for within-community correlation. Age- and sex-standardization used indirect standardization, and the standardization model was refitted in each resample. The Erreygers-corrected index was the primary concentration measure for the binary outcomes.

Discussion

In this longitudinal analysis, two-wave joint frailty and depressive-symptom transition patterns during 2011–2013 were associated with subsequent change in function-weighted multimorbidity burden during 2013–2018. Persistent dual vulnerability had the largest point estimates. In the primary Model A, the mean difference in annualized CMWI change relative to stable low risk was 0.203 points/year (95% CI 0.155–0.252), and the RR for upper-quartile CMWI growth was 2.15 (95% CI 1.88–2.46). Repeated-measures and robustness analyses supported the same direction of association. Conditional Model B, which additionally included 2013 CMWI, yielded a mean difference of 0.271 points/year (95% CI 0.222–0.321) and an RR of 2.19 (95% CI 1.91–2.51). Because 2013 CMWI is part of the change score, Model B represents a different baseline-conditional estimand and should not be interpreted as a more fully adjusted causal estimate.

The transition patterns captured heterogeneity in the joint course of frailty and depressive symptoms. Stable low risk indicated absence of both conditions at the two observed waves, incident vulnerability indicated new single or dual vulnerability, persistent categories indicated continued vulnerability, and the improved category indicated partial resolution. The persistent dual-vulnerability group already had a higher CMWI level in 2013 and showed faster subsequent growth. This pattern suggests that persistent co-occurrence may identify individuals on a less favorable multimorbidity trajectory. Previous studies have usually examined frailty, depressive symptoms, or multimorbidity separately [2–3, 11]. By separating incident, persistent, and improved joint states, the present study adds temporal information to this literature. The use of CMWI also extends disease-count approaches because conditions are weighted by their functional impact [21, 26]. Several biological and behavioral processes could contribute to the observed associations. Frailty and later-life depressive symptoms are both associated with chronic inflammation, neuroendocrine dysregulation, metabolic abnormalities, sleep disturbance, and nutritional vulnerability [4–5, 27]. Depressive symptoms may also affect physical activity, treatment adherence, and chronic disease self-management [3, 5–6]. In a cross-sectional study of older adults with heart failure, frailty was negatively correlated with self-care maintenance, while social support and depression each independently mediated this relationship and also showed a significant sequential mediation effect [32]. These processes may lie on the pathway between the exposure and subsequent disease burden and were therefore not included in the primary adjustment set. The study does not establish mechanism-specific causal effects. The original CMWI also includes an item for emotional, nervous, or psychiatric problems, which could partly overlap with the depressive-symptom exposure. After this component was removed, associations with annualized CMWI-13 change, upper-quartile CMWI-13 growth, and repeated-measures slopes were attenuated but remained positive. CMWI-13 has not been independently validated and should be interpreted only as a targeted robustness analysis.

The health-equity analyses showed a clearer socioeconomic gradient in persistent dual vulnerability than in subsequent upper-quartile CMWI growth. Persistent dual vulnerability was concentrated among participants with lower household

consumption per capita, and inverse-probability-weighted estimates were similar. By contrast, upper-quartile CMWI growth showed little consumption-related concentration, and there was no clear evidence of multiplicative interaction between transition pattern and household consumption on the risk-ratio scale. A nonsignificant interaction does not establish equivalence across socioeconomic groups, particularly because some cross-classified groups were small. The pattern may also reflect differences in disease detection. CMWI is based on self-reported physician-diagnosed conditions, and people with greater socioeconomic resources may have more opportunities for examination and diagnosis [28–31]. Underdiagnosis among people with fewer resources could therefore attenuate the observed socioeconomic gradient in recorded multimorbidity growth.

This study has several limitations. First, complete-case analysis and differential mortality may have introduced selection bias. Second, the use of survey-based measures and self-reported diagnoses may have resulted in measurement error, while two-wave assessments could not capture changes between or after survey waves. Finally, household consumption was measured at the end of the exposure window and survey weights were not applied, limiting causal interpretation and national representativeness.

As multimorbidity and mental health problems become increasingly common in ageing societies, our findings have implications for chronic disease management and health equity. In clinical and community settings, primary care resources and proactive health services may warrant greater prioritization for older adults who are socioeconomically disadvantaged, live in underserved areas, or reside in rural communities. Routine health assessments and chronic disease follow-up could provide opportunities for proactive screening and risk stratification, helping to identify high-risk individuals before multimorbidity burden accumulates rapidly. Integrated physical and mental health management should also be strengthened for older adults at high risk of chronic disease progression. Persistent co-occurrence of frailty and depressive symptoms could be considered a potential risk indicator in primary care risk assessment. For individuals identified as high risk, integrated management could combine multimorbidity monitoring, maintenance of physical function, mental health follow-up, and medication safety review, rather than relying on fragmented single-disease care. At the health-system level, performance assessment in primary care for older adults could place greater emphasis on early risk prevention. Indicators such as coverage of physical–psychological vulnerability screening, standardized follow-up of high-risk groups, and maintenance of functional status may be considered. Such changes could help shift the focus of care upstream from disease treatment to risk prevention and support earlier, more equitable, and more continuous health management for older adults.

Conclusions

Persistent dual vulnerability had the largest point estimates for subsequent increases in function-weighted multimorbidity burden among the two-wave transition patterns. After excluding the mental-health-related component of the CMWI, the estimates were attenuated but remained positive. Persistent dual vulnerability was more concentrated among participants with lower household consumption, while there was no clear evidence of multiplicative effect modification on the risk-ratio scale. Joint assessment of frailty and depressive symptoms may help identify high-risk groups, although further causal and intervention studies are needed before targeted management strategies can be recommended.

Abbreviations

Abbreviations used in this article.

Abbreviation	Full term
ADL	Activities of daily living
CES-D-10	10-item Center for Epidemiologic Studies Depression Scale
CHARLS	China Health and Retirement Longitudinal Study
CI	Confidence interval
CMWI	Chinese multimorbidity-weighted index
CMWI-13	13-item Chinese multimorbidity-weighted index excluding the emotional, nervous, or psychiatric problems component
FI	Frailty index
IADL	Instrumental activities of daily living
IQR	Interquartile range
OR	Odds ratio
Q1–Q5	Quintiles of household consumption per capita
REML	Restricted maximum likelihood
RR	Risk ratio
SD	Standard deviation

Declarations

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Authors' contributions

Mingyun Huang contributed to the conceptualization, methodology, data analysis, and manuscript writing. Cheng Chen contributed to the literature review and data interpretation. Hongxia Gao provided critical revisions to the manuscript. Yuanyuan Zou, Yanjing Zhang, Yiran Chen were involved in the literature review and provided feedback on the manuscript draft. All authors read and approved the final manuscript.

Ethics approval and consent to participate

This study report adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies. The CHARLS protocol was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants provided written informed consent. This study is a secondary analysis of CHARLS data and involved no new participant recruitment or intervention.

Clinical trial number

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Consent for publication

Not applicable.

Availability of data and materials

The datasets analyzed during the current study are available to registered users through the official CHARLS website [http://charls.pku.edu.cn].

Competing interests

The authors declare no competing interests.

References

1. Sang N, Liu RC, Zhang MH, Lu ZX, Wu ZG, Zhang MY, et al. Changes in frailty and depressive symptoms among middle-aged and older Chinese people: a nationwide cohort study. BMC Public Health. 2024;24(1):301. 10.1186/s12889-024-17824-3.
2. Fei Z, Qian Y, Tu Y, Wu C. Association between frailty and physical-psychological multimorbidity in middle-aged and elderly Chinese adults: a longitudinal study in Chinese middle-aged and older adults. BMC Psychiatry. 2024;24(1):935. 10.1186/s12888-024-06398-4.
3. Bobo WV, Grossardt BR, Virani S, St Sauver JL, Boyd CM, Rocca WA. Association of depression and anxiety with the accumulation of chronic conditions. JAMA Netw Open. 2022;5(5):e229817. 10.1001/jamanetworkopen.2022.9817.
4. Kim DH, Rockwood K. Frailty in older adults. N Engl J Med. 2024;391(6):538–48. 10.1056/NEJMra2301292.
5. Szymkowicz SM, Gerlach AR, Homiack D, Taylor WD. Biological factors influencing depression in later life: role of aging processes and treatment implications. Transl Psychiatry. 2023;13(1):160. 10.1038/s41398-023-02464-9.
6. Jones DL, Yue J, Nguyen TN, Ahmad F, Chow CK. Impact of depression on medication non-adherence in coronary artery disease: a systematic review and meta-analysis. Open Heart. 2025;12(2):e003680. 10.1136/openhrt-2025-003680.
7. Zhang Z, Xu H, Zhang R, Yan Y, Ling X, Meng Y, et al. Frailty and depressive symptoms in relation to cardiovascular disease risk in middle-aged and older adults. Nat Commun. 2025;16:6008. 10.1038/s41467-025-61089-2.
8. Deng MG, Liu F, Liang Y, Wang K, Nie JQ, Liu J. Association between frailty and depression: a bidirectional Mendelian randomization study. Sci Adv. 2023;9(38):eadi3902. 10.1126/sciadv.adi3902.
9. Zhong S, He L, Yi F, Li H, Hua X. Association between frailty status and depression among older adults: panel data analysis of three longitudinal cohort studies. BMC Public Health. 2026;26:1089. 10.1186/s12889-026-26783-w.
10. Liu Z, Liu H, Cheng Z, Deng F, Qin L. Dynamic interplay between depressive symptoms, healthy lifestyle, and frailty in middle-aged and older adults: a cross-cohort longitudinal study. BMC Public Health. 2026. 10.1186/s12889-026-29068-4.
11. Cezard G, McHale CT, Sullivan F, Bowles JKF, Keenan K. Studying trajectories of multimorbidity: a systematic scoping review of longitudinal approaches and evidence. BMJ Open. 2021;11(11):e048485. 10.1136/bmjopen-2020-048485.
12. Zhao Y, Hu Y, Smith JP, Strauss J, Yang G. Cohort Profile: The China Health and Retirement Longitudinal Study (CHARLS). Int J Epidemiol. 2014;43(1):61–8. 10.1093/ije/dys203.
13. Borges MK, Jeuring HW, Marijnissen RM, van Munster BC, Aprahamian I, van den Brink RHS, et al. Frailty and affective disorders throughout adult life: a 5-year follow-up of the Lifelines Cohort Study. J Am Geriatr Soc. 2022;70(12):3424–35. 10.1111/jgs.18021.
14. Theou O, Haviva C, Wallace L, Searle SD, Rockwood K. How to construct a frailty index from an existing dataset in 10 steps. Age Ageing. 2023;52(12):afad221. 10.1093/ageing/afad221.

15. Hanlon P, Welsh SA, Evans NR. Constructing a quality frailty index: you get out what you put in. Age Ageing. 2024;53(1):afad248. 10.1093/ageing/afad248.
16. Searle SD, Mitnitski A, Gahbauer EA, Gill TM, Rockwood K. A standard procedure for creating a frailty index. BMC Geriatr. 2008;8:24. 10.1186/1471-2318-8-24.
17. Rockwood K, Mitnitski A. Frailty in relation to the accumulation of deficits. J Gerontol Biol Sci Med Sci. 2007;62(7):722–7. 10.1093/gerona/62.7.722.
18. Radloff LS, The CES-D, Scale. A self-report depression scale for research in the general population. Appl Psychol Meas. 1977;1(3):385–401. 10.1177/014662167700100306.
19. Andresen EM, Malmgren JA, Carter WB, Patrick DL. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). Am J Prev Med. 1994;10(2):77–84. 10.1016/S0749-3797(18)30622-6.
20. Cheng ST, Chan ACM. The Center for Epidemiologic Studies Depression Scale in older Chinese: thresholds for long and short forms. Int J Geriatr Psychiatry. 2005;20(5):465–70. 10.1002/gps.1314.
21. Hu WH, Liu YY, Yang CH, Zhou T, Yang C, Lai YS, et al. Developing and validating a Chinese multimorbidity-weighted index for middle-aged and older community-dwelling individuals. Age Ageing. 2022;51(2):afab274. 10.1093/ageing/afab274.
22. Tang H, Li M, Liu LZ, Zhou Y, Liu X. Changing inequity in health service utilization and financial burden among patients with hypertension in China: evidence from China Health and Retirement Longitudinal Study (CHARLS), 2011–2018. Int J Equity Health. 2023;22:246. 10.1186/s12939-023-02062-7.
23. Erreygers G. Correcting the concentration index. J Health Econ. 2009;28(2):504–15. 10.1016/j.jhealeco.2008.02.003.
24. Lee KJ, Tilling KM, Cornish RP, Little RJA, Bell ML, Goetghebeur E, Hogan JW, Carpenter JR. Framework for the treatment and reporting of missing data in observational studies: the Treatment And Reporting of Missing data in Observational Studies framework. J Clin Epidemiol. 2021;134:79–88. 10.1016/j.jclinepi.2021.01.008.
25. Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol. 2004;159(7):702–6. 10.1093/aje/kwh090.
26. Lai YS, Gao XY, Hu WH, Liu YX, Zhang YJ, Liu JC, et al. Validity of the Chinese multimorbidity-weighted index in measuring disease burden using health check-ups data in primary care. BMC Public Health. 2024;24:1999. 10.1186/s12889-024-19479-6.
27. Jiang R, Noble S, Rosenblatt M, Dai W, Ye J, Liu S, et al. The brain structure, inflammatory, and genetic mechanisms mediate the association between physical frailty and depression. Nat Commun. 2024;15(1):4411. 10.1038/s41467-024-48827-8.
28. Chen X, Giles J, Yao Y, Yip W, Meng Q, Berkman L, et al. The path to healthy ageing in China: a Peking University-Lancet Commission. Lancet. 2022;400(10367):1967–2006. 10.1016/S0140-6736(22)01546-X.
29. Ni Y, Zhou Y, Kivimaki M, Cai Y, Carrillo-Larco RM, Xu X, et al. Socioeconomic inequalities in physical, psychological, and cognitive multimorbidity in middle-aged and older adults in 33 countries: a cross-sectional study. Lancet Healthy Longev. 2023;4(11):e618–28. 10.1016/S2666-7568(23)00195-2.
30. Zhang Y, Feng Z. Socioeconomic determinants for diagnosed non-communicable diseases among older people in China: individual- and regional-level effects. Health Soc Care Community. 2022;30(6):e5281–92. 10.1111/hsc.13947.
31. Su B, Li D, Xie J, Wang Y, Wu X, Li J, et al. Chronic Disease in China: Geographic and Socioeconomic Determinants Among Persons Aged 60 and Older. J Am Med Dir Assoc. 2023;24(2):206–e2125. 10.1016/j.jamda.2022.10.002.
32. Bu N, Leng M, Cao G, Dou C, Hou R, Lu X, et al. Frailty and Self-Care Maintenance Mediated by Social Support and Depression in Older Adults With Heart Failure. Nurs Res. 2025;74(2):115–22. 10.1097/NNR.0000000000000795.

Figures

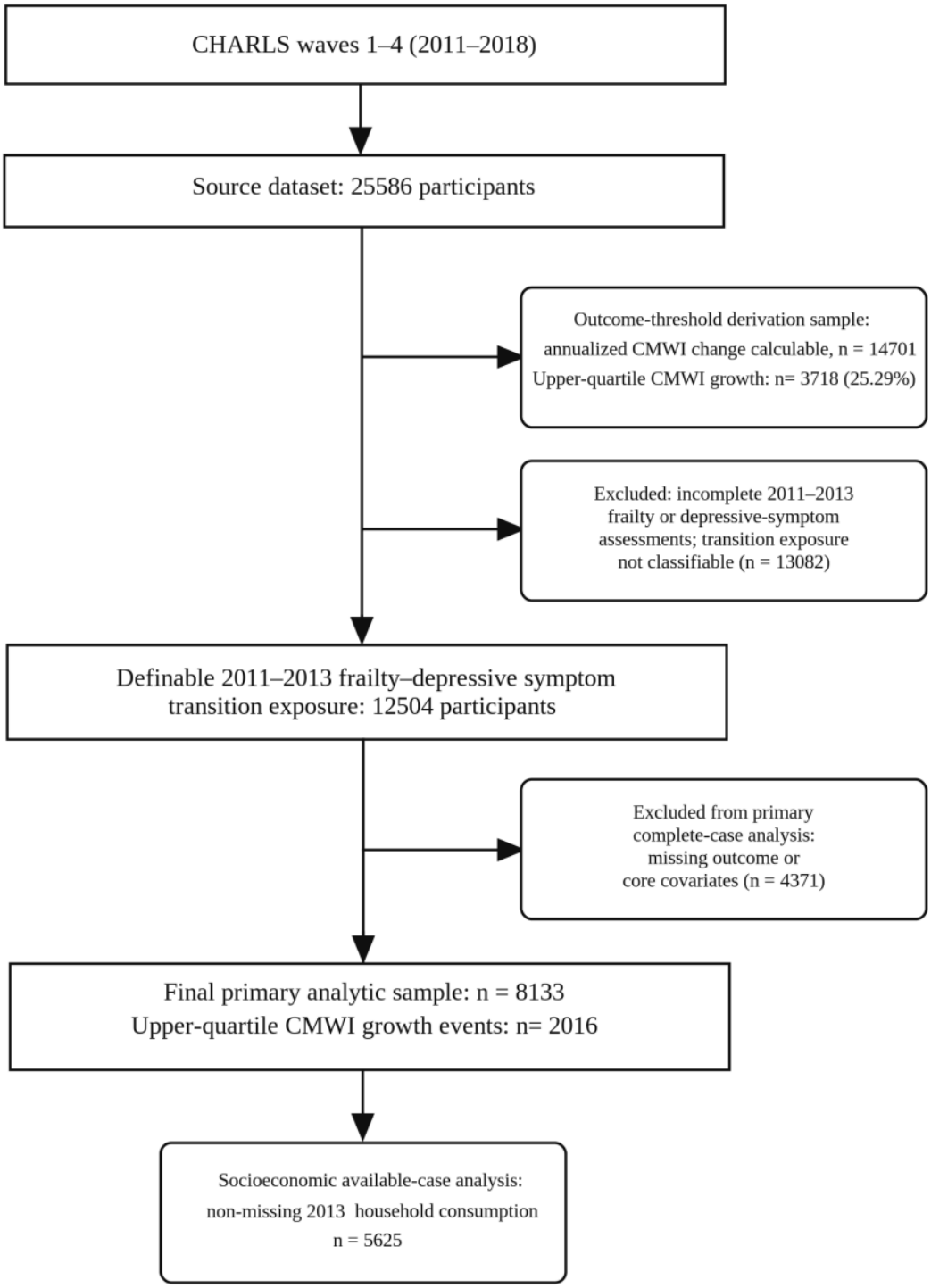


Figure 1

Participant selection flowchart

Flowchart. CHARLS, China Health and Retirement Longitudinal Study; CMWI, Chinese multimorbidity-weighted index.

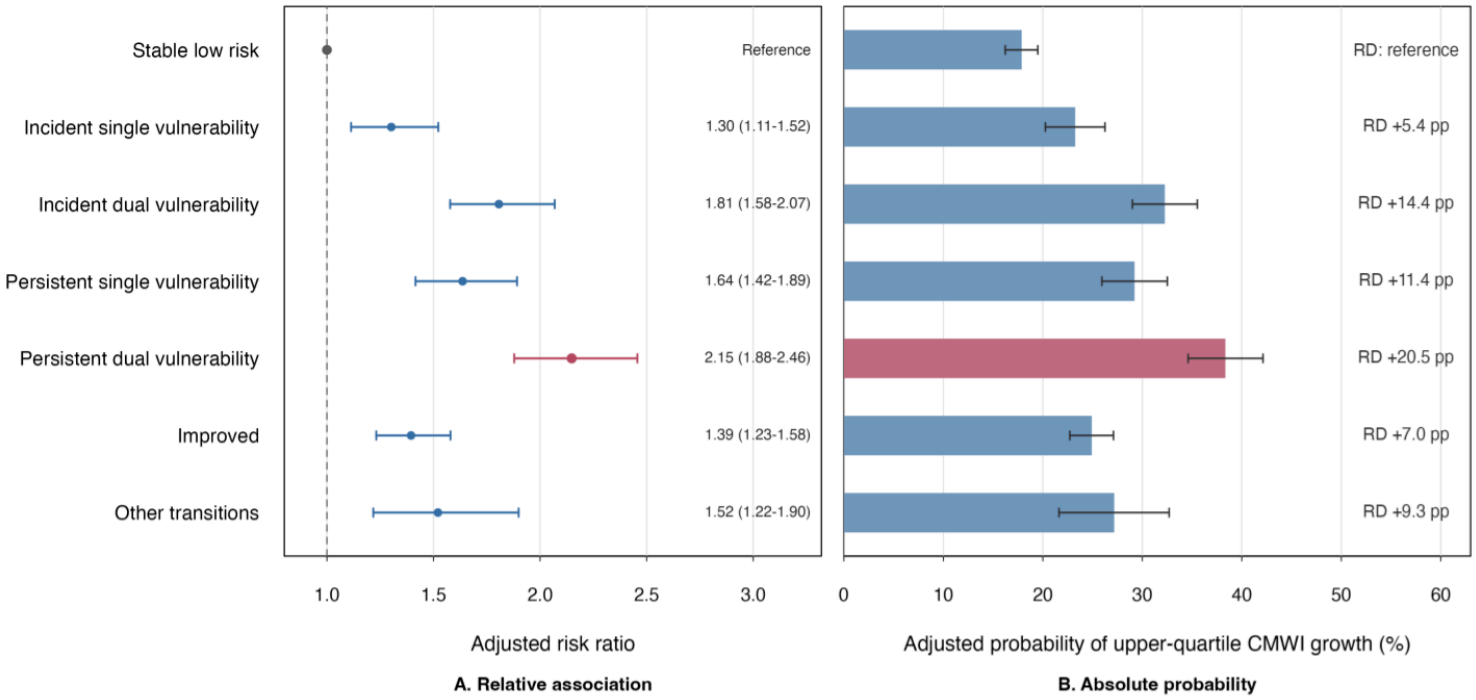


Figure 2

Relative associations and adjusted probabilities for upper-quartile CMWI growth

Panel A shows RRs and 95% CIs from primary modified Poisson regression Model A with community-clustered robust standard errors (443 communities) in the primary regression sample (n = 8,133; 2,016 upper-quartile growth events). Panel B shows Model A adjusted probabilities and absolute risk differences obtained by marginal standardization; 95% CIs used the delta method with the same community-clustered covariance matrix. Risk differences were calculated relative to the stable low-risk reference group. Other transitions were treated as an exploratory category.

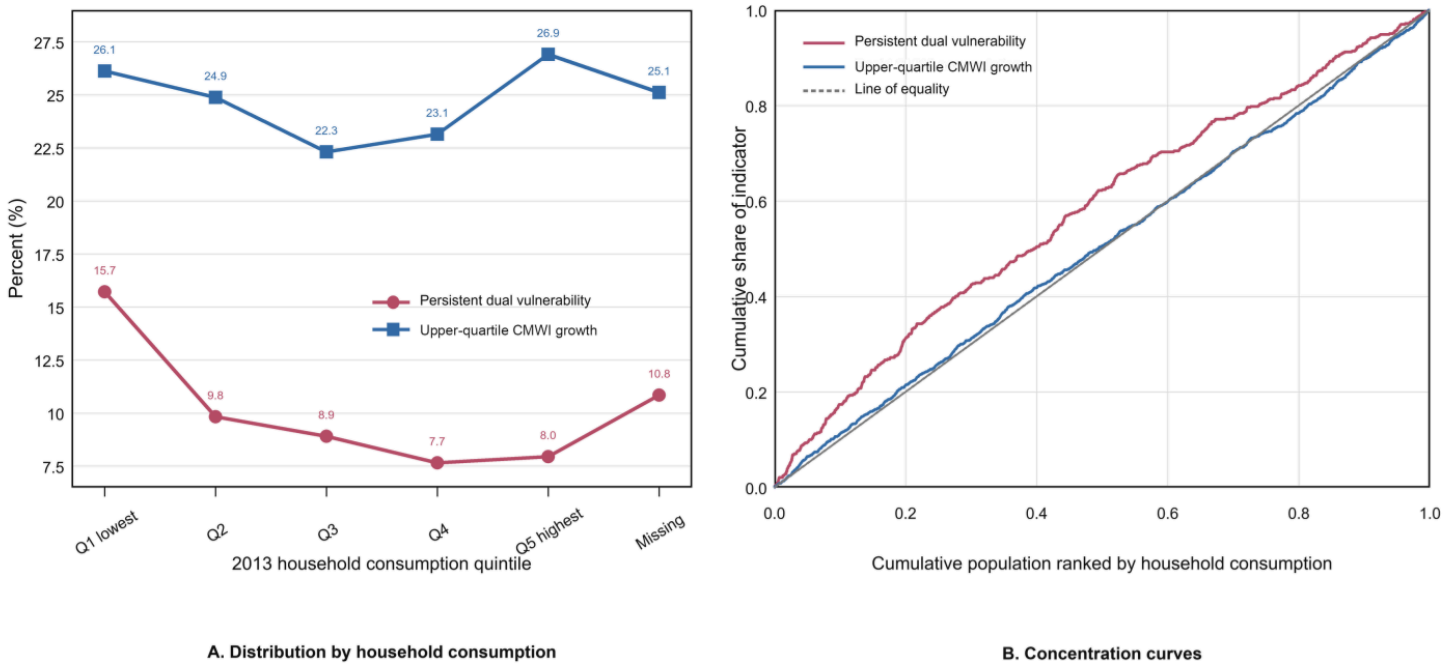


Figure 3

Household-consumption-related distribution of persistent dual vulnerability and upper-quartile CMWI growth

Panel A shows the distribution of persistent frailty–depressive symptom dual vulnerability and upper-quartile CMWI growth across 2013 quintiles of household consumption per capita among participants with household consumption data. Panel B shows concentration curves among participants with nonmissing household consumption data (n = 5,625). For the concentration curves, the 45° line indicates perfect equality. The curve farther from the line of equality represents persistent dual vulnerability. The curve closer to the line of equality represents upper-quartile CMWI growth.

Supplementary Files

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