scientific reports

Check for updates

OPEN

Associations of cardiometabolic disease and depression with changes in instrumental activities of daily living disability among middle-aged and older adults

Yaling Wang[1] & Yong Soon Shin[2]✉

This study examined the independent and joint associations of cardiometabolic disease (CMD) and depression with changes in instrumental activities of daily living (IADL) disability among middle-aged and older adults. Longitudinal data were obtained from 16,780 individuals aged ≥ 45 years in the China Family Panel Studies from 2012 to 2020. Changes in IADL disability were assessed using transitions and trajectories. Mixed-effects models, Cox proportional hazards models, and multinomial logistic regression were applied, and joint associations were evaluated using multiplicative and additive interactions. CMD and depression were associated with higher IADL disability scores. Single CMD, cardiometabolic multimorbidity (CMM), and depression were associated with increased risks of new-onset and persistent disability, a higher likelihood of severe disability trajectories, and a lower likelihood of recovery. The combination of CMM and depression showed evidence of multiplicative and additive interaction for IADL disability scores, with a broadly consistent adverse additive interaction pattern across new-onset disability, persistent disability, and severe disability trajectories. These findings suggest that CMD and depression are independently associated with adverse changes in IADL disability, with CMM and depression showing an additional adverse joint association. Integrated management of physical and mental health may help reduce disability in ageing populations.

Keywords Cardiometabolic disease, Depression, Instrumental activities of daily living, Disability, Multimorbidity, Interaction

Disability refers to impairments in body function or daily living activities that affect quality of life, caregiving burden, and disease prognosis[1]. With population ageing in China, the disability burden among middle-aged and older adults continues to increase[2], and the number of disabled people was estimated to exceed 108 million in 2020[3]. Disability is a complex and dynamic process, with individuals frequently transitioning between different states[4–7]. However, most studies have focused on disability onset and progression, with limited attention to dynamic transitions such as recovery[5]. Understanding these dynamic processes is important for preventing disability, promoting recovery, and maintaining independence.

Disability is typically assessed using basic activities of daily living (BADL) and instrumental activities of daily living (IADL)[1]. BADL includes basic self-care tasks[8], whereas IADL includes activities required for independent community living[6]. IADL disability often occurs earlier than BADL disability and is more sensitive to early functional decline[2,9–12]. However, many studies still focus on ADL outcomes, and evidence specific to IADL disability remains limited[11].

Chronic physical and mental illnesses are key determinants of disability and recovery[13–16], and comorbidity rates are high among middle-aged and older adults[17–19]. Compared to single disease, comorbidity is associated with a higher risk of disability[15,20–22], and different patterns may have varying effects[5,15,17]. In China, cardiometabolic diseases (CMDs), including coronary heart disease, stroke, hypertension, and diabetes, represent the main physical multimorbidity pattern[23]. CMD has been consistently associated with disability and may also affect recovery[14,20,24–26]. Depression is the most common mental illness in China and globally[27], and is a major contributor to disability and recovery[16,28–33]. Evidence suggests that the coexistence of physical and

[1]Graduate School of Nursing, Hanyang University, Seoul, South Korea. [2]College of Nursing, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, South Korea. ✉email: ysshin2k@hanyang.ac.kr

mental disorders can lead to worse health outcomes[17,19]. However, it remains unclear how CMD and depression, independently and jointly, are associated with dynamic IADL disability transitions and trajectories, and whether their joint association exceeds the sum of their individual associations on the additive scale[13,19,34,35].

Using data from a nationwide cohort, we investigated the independent and joint associations of CMD and depression with changes in IADL disability over eight years. We assessed IADL scores, disability transitions, and trajectories, and evaluated both multiplicative and additive interactions between CMD and depression. The aim of this study was to inform clinical and nursing care to prevent disability and promote recovery in individuals with comorbid physical and mental diseases.

Methods

Study design

This study utilized data from the China Family Panel Studies (CFPS), conducted by the Institute of Social Science Survey at Peking University. CFPS completed its first survey in 2010, covering 25 provinces, municipalities, and autonomous regions, representing 95% of China's population. Follow-up surveys are conducted every two years, collecting data at individual, family, and community levels to reflect changes in China's society, economy, population, education, and health[36].

We used data from 2012, 2016, 2018, and 2020, which included CMD, depression (CES-D) and IADL indicators. We included individuals aged ≥ 45 years who participated in at least two surveys. Baseline was defined as each participant's first eligible survey wave of study entry. Individuals with baseline IADL scores greater than zero (indicative of disability) or with missing IADL data were excluded. Additional exclusions were made for participants with missing data on CMD status, CES-D scores, or key covariates (age, gender). The detailed process of participant selection was presented in Figure S1 and Table S1. The study was approved by the Biomedical Ethics Committee of Peking University (approval number: IRB00001052-14010).

Cardiometabolic disease and depression

CMD was defined using self-reported diagnoses of ischaemic heart disease, stroke, diabetes and hypertension[23]. The number of CMDs per individual ranged from 0 to 4. CMD status was categorised as no CMD (NCMD), single-CMD (SCMD), and cardiometabolic multimorbidity (CMM). CMD status was time varying, and each reported diagnosis was carried forward to subsequent waves.

Depression was assessed using the 8-item Centre for Epidemiologic Studies Depression Scale (CES-D8). The scale comprises six negative and two positive items, such as "I felt depressed," "I felt everything I did was an effort," "My sleep was restless," "I felt happy," "I felt lonely," "I enjoyed life," "I felt sad," and "I felt like I could not go on." Responses were scored on a 4-point Likert scale: "0 = none or less than 1 day," "1 = some days (1–2 days)," "2 = often (3–4 days)," and "3 = most days (5–7 days)" (positive items were reverse-scored). Total scores ranged from 0 to 24, with higher scores indicating more severe depression. A score > 9 indicated depressive symptoms (DS), while ≤ 9 indicated no depressive symptoms (NDS)[37]. Depression status was reassessed at each wave using the CES-D8 score and was allowed to change over time.

CMD and depression status were cross-classified into six mutually exclusive groups based on the three CMD categories and two depression categories. The NCMD and NDS group was used as the reference.

Instrumental activities of daily living

IADL was assessed using seven items covering outdoor activities, meal preparation, cooking, public transport use, shopping, personal hygiene, and laundry. Each item was scored 0 for independent performance and 1 for inability to perform independently, giving a total score of 0–7. Higher scores indicated worse IADL disability, and a score greater than 0 was classified as IADL disability. Changes in IADL disability were assessed using transitions and trajectories.

IADL disability transitions were examined among participants with data from at least two waves. Stable disability-free status was defined as a score of 0 at participant-specific study entry and at all subsequent assessments. New-onset disability was defined as the first score greater than 0 after study entry. Persistent disability was defined as disability at two consecutive follow-up assessments. Recovery was defined as a subsequent return to a score of 0 after the first occurrence of disability.

IADL disability trajectories were assessed among participants with data from at least three waves, using time since participant-specific study entry as the time scale. Participants with scores of 0 at all observed waves were classified a priori into the stable disability-free group. Zero-inflated Poisson group-based trajectory modelling was applied to the remaining participants. Three model-derived trajectories were combined with the predefined stable disability-free group to form four analytic groups: stable disability-free, mild disability, severe disability with recovery, and severe disability without recovery. Model-selection and classification diagnostics are reported in the Supplementary Methods and Table S2.

Covariates

Sociodemographic characteristics included region (rural or urban), gender (male or female), age (continuous variable), marital status (with a partner [married or cohabiting] or without a partner [unmarried, divorced, or widowed]), education level (low [junior high school or below], medium [senior high school or vocational school], or high [college or above]), and family per capita income (low [below the 25th percentile of the surveyed population], medium [25th–75th percentile], or high [above the 75th percentile]). Lifestyle factors included smoking (never smoked or smoker), alcohol consumption (never drank or drinker), physical activity frequency (< 2 or ≥ 2 times/week), sleep status (unhealthy [< 7 or > 9 h per day] or healthy [7–9 h per day])[38], and weight status (non-obese [BMI < 28 kg/m^2] or obese [BMI ≥ 28 kg/m^2]).

Statistical analysis

Baseline characteristics were described across the six CMD–depression groups defined at baseline for descriptive purposes only. Categorical data were presented as frequency (percentage), and continuous data as mean (standard deviation). The χ^2 test was used to compare categorical variables, and the Kruskal-Wallis test was used to compare continuous variables. To describe changes in IADL disability status over time, transition matrices were constructed based on consecutive survey waves and visualised using Sankey diagrams.

Associations between CMD, depression, and IADL outcomes were evaluated using three analytical approaches. Mixed-effects Poisson regression models with repeated observations nested within individuals were used to assess associations with IADL disability scores. Time-varying Cox proportional hazards models were used to assess IADL disability transitions, with follow-up time as the timescale. For new-onset and persistent disability, time at risk began at participant-specific study entry; for recovery, it began at the first occurrence of disability. In the mixed-effects Poisson and Cox models, CMD status, depression status, and covariates were treated as time-varying variables. Multinomial logistic regression models were used to assess associations with IADL trajectory membership. In the trajectory models, CMD status, depression status, and covariates were assessed at the first follow-up because the corresponding baseline exposure–outcome cells at baseline were too sparse to support stable estimates.

Main associations were estimated using models that included CMD status and depression status as separate variables without interaction terms. Joint associations were evaluated in separate models using the six mutually exclusive CMD–depression groups, with NCMD and NDS as the reference. Multiplicative interactions (INTM) were assessed in models containing CMD–depression product terms. Additive interactions (INTA) were evaluated using the relative excess risk due to interaction (RERI), attributable proportion (AP), and synergy index (S), derived from the joint exposure estimates. RERI, AP, and S and their 95% confidence intervals (CIs) were calculated from the model coefficients and variance–covariance matrices using the delta method. CIs including 1 for INTM or S, or 0 for RERI and AP, were considered to indicate no statistically significant interaction. The interaction analyses were exploratory. No adjustment for multiple testing was applied, and interpretation focused on patterns across outcomes rather than individual estimates or *P* values.

Sensitivity analyses included subgroup analyses stratified by sex and urban–rural residence, analyses restricted to participants with ≥3 survey waves, and alternative model specifications. Firth penalised logistic regression, mixed-effects negative-binomial regression, and stabilised inverse-probability-of-selection weighting were used to assess the robustness of the trajectory, Poisson, and longitudinal regression models, respectively. Fine–Gray competing-risk models were additionally used to assess the robustness of IADL disability transition analyses, with death before the occurrence of each IADL disability transition treated as the competing event. Additional analyses examined alternative CMD classifications, continuous CES-D8 scores, alternative IADL disability definitions, and a broader definition of functional improvement.

Results

Baseline characteristics

Of 53,236 CFPS participants surveyed between 2012 and 2020, 26,761 were excluded because of ineligible age or missing age or gender data, 4,459 because of missing key variables or baseline IADL disability, and 5,236 because they contributed data from only one wave. The longitudinal analyses included 16,780 participants with data from at least two waves. Of these, 11,420 contributed data from at least three waves and were included in the trajectory analysis (Figure S1). Baseline characteristics across CMD-depression status groups are shown in Table 1. The mean age was 58.65 ± 9.10 years, 49.63% were female, 88.35% had no CMD, 85.82% had no depression, 76.54% had neither CMD nor depression, and only 0.35% had both CMM and depression. Significant differences were observed across groups in sociodemographic and lifestyle factors.

Changes in IADL disability

Across consecutive survey waves, most participants remained disability-free (80.75%–86.54%), whereas smaller proportions experienced new-onset (8.49%–13.46%), persistent disability (3.34%–4.23%), or recovery (4.88%–5.30%) (Figure S2 and Table S3). Among initially disability-free participants, 20.70% developed new-onset IADL disability, 3.90% experienced persistent IADL disability, and 6.07% recovered independence.

Associations of CMD and depression with IADL disability scores

Mixed-effects Poisson regression models (Figure S4) showed that CMD and depression were associated with higher IADL disability scores (DS: IRR = 1.86, 95% CI 1.73–2.00; SCMD: IRR = 1.42, 95% CI 1.30–1.57; CMM: IRR = 2.08, 95% CI 1.81–2.39). Interaction results are presented in Table 2 and Table S4. There was little evidence of multiplicative or additive interaction between SCMD and DS. For CMM and DS, the multiplicative interaction estimate was 1.45 (95% CI 1.16–1.80), and the additive interaction estimates were RERI = 2.19 (95% CI 1.34–3.04), AP = 0.45 (95% CI 0.35–0.55), and S = 2.32 (95% CI 1.79–2.99). The joint CMM–DS group had the largest estimate for IADL disability scores (IRR = 4.85, 95% CI 4.02–5.85; Figure S5).

Associations of CMD and depression with IADL disability transitions

Main effects from the Cox models are shown in Figure S6, with interaction results presented in Table S5 and Fig. 1. CMD and depression were associated with increased risks of new-onset and persistent disability. For new-onset disability, the estimates were HR = 1.79 (95% CI 1.67–1.93) for DS, HR = 1.16 (95% CI 1.07–1.25) for SCMD, and HR = 1.52 (95% CI 1.36–1.70) for CMM. There was little evidence of multiplicative interaction between CMD and DS. For CMM and DS, the additive interaction estimates were RERI = 0.59 (95% CI 0.12–1.06), AP = 0.20 (95% CI 0.06–0.34), and S = 1.45 (95% CI 1.09–1.92). Compared to participants without CMD or

	NDS & NCMD	NDS & SCMD	NDS & CMM	DS & NCMD	DS & SCMD	DS & CMM		
	N = 12,843	*N* = 1355	*N* = 202	*N* = 1982	*N* = 339	*N* = 59	Statistic	*P* value
Age, years, mean (SD)	54.79 (8.71)	59.18 (9.04)	60.81 (8.97)	54.95 (8.46)	59.04 (9.06)	60.73 (8.46)	96.16	< 0.001
Gender, n (%)							193.92	< 0.001
Female	6031 (46.96)	706 (52.10)	111 (54.95)	1,221 (61.60)	221 (65.19)	38 (64.41)		
Male	6812 (53.04)	649 (47.90)	91 (45.05)	761 (38.40)	118 (34.81)	21 (35.59)		
Education, n (%)							117.21	< 0.001
Low	10,231 (83.00)	1,045 (79.71)	162 (82.23)	1,734 (91.12)	296 (90.24)	47 (82.46)		
Medium	1633 (13.25)	193 (14.72)	25 (12.69)	143 (7.51)	27 (8.23)	7 (12.28)		
High	462 (3.75)	73 (5.57)	10 (5.08)	26 (1.37)	5 (1.52)	3 (5.26)		
Marital status, n (%)							210.11	< 0.001
Unpartnered	968 (7.54)	132 (9.74)	15 (7.43)	324 (16.35)	57 (16.81)	15 (25.42)		
Partnered	11,870 (92.46)	1,223 (90.26)	187 (92.57)	1,658 (83.65)	282 (83.19)	44 (74.58)		
Household income, n (%)							162.51	< 0.001
Low	3024 (24.11)	291 (21.77)	52 (26.53)	625 (32.50)	104 (30.86)	19 (32.20)		
Medium	6192 (49.37)	636 (47.57)	80 (40.82)	987 (51.33)	175 (51.93)	25 (42.37)		
High	3326 (26.52)	410 (30.67)	64 (32.65)	311 (16.17)	58 (17.21)	15 (25.42)		
Region, n (%)							179.40	< 0.001
Rural	6916 (54.07)	638 (47.29)	76 (37.62)	1,318 (66.84)	208 (61.36)	29 (49.15)		
Urban	5875 (45.93)	711 (52.71)	126 (62.38)	654 (33.16)	131 (38.64)	30 (50.85)		
Physical activity, n (%)							175.27	< 0.001
<2 times/week	7650 (59.57)	639 (47.16)	89 (44.06)	1,361 (68.70)	202 (59.59)	36 (61.02)		
≥2 times/week	5192 (40.43)	716 (52.84)	113 (55.94)	620 (31.30)	137 (40.41)	23 (38.98)		
Sleeping status, n (%)							72.74	< 0.001
<7 or > 9 h per day	4618 (36.61)	550 (41.11)	88 (44.00)	835 (42.97)	177 (52.68)	29 (49.15)		
7–9 h per day	7996 (63.39)	788 (58.89)	112 (56.00)	1,108 (57.03)	159 (47.32)	30 (50.85)		
Ever smoking, n (%)							79.86	< 0.001
No	7077 (55.10)	805 (59.41)	130 (64.36)	1,265 (63.82)	228 (67.26)	38 (64.41)		
Yes	5766 (44.90)	550 (40.59)	72 (35.64)	717 (36.18)	111 (32.74)	21 (35.59)		
Ever drinking, n (%)							98.00	< 0.001
No	8805 (68.56)	967 (71.37)	154 (76.24)	1,537 (77.55)	280 (82.60)	45 (76.27)		
Yes	4037 (31.44)	388 (28.63)	48 (23.76)	445 (22.45)	59 (17.40)	14 (23.73)		
Obesity, n (%)							127.45	< 0.001
No	11,897 (93.39)	1,170 (87.31)	157 (79.29)	1,828 (94.23)	308 (93.05)	53 (91.38)		
Yes	842 (6.61)	170 (12.69)	41 (20.71)	112 (5.77)	23 (6.95)	5 (8.62)		

Table 1. Baseline characteristics of participants according to CMD and depression status. Data are presented as mean (SD) or n (%), as appropriate. In CFPS, *P* values were calculated using the Kruskal-Wallis and χ^2 tests for continuous and categorical variables, respectively. CFPS, China Family Panel Studies; CMD, cardiometabolic disease; NCMD, no CMD; SCMD, single-CMD; CMM, cardiometabolic multimorbidity; DS, depressive symptoms; NDS, no depressive symptoms.

DS, the other five groups had a 20%–190% higher risk of new-onset disability, with the largest estimate observed in the joint CMM–DS group (HR = 2.90, 95% CI 2.49–3.38).

For persistent disability, the estimates were HR = 1.82 (95% CI 1.54–2.15) for DS, HR = 1.30 (95% CI 1.09–1.55) for SCMD, and HR = 2.19 (95% CI 1.77–2.70) for CMM. There was little evidence of multiplicative interaction between CMD and DS. For CMM and DS, the additive interaction estimates were RERI = 1.49 (95% CI 0.26–2.73), AP = 0.35 (95% CI 0.13–0.56), and S = 1.82 (95% CI 1.14–2.93). Compared to participants without CMD or DS, the other five groups had a 32%–331% higher risk of persistent disability, with the largest estimate observed in the joint CMM–DS group (HR = 4.31, 95% CI 3.23–5.74).

CMM and depression were associated with a lower likelihood of recovery from disability (DS: HR = 0.84, 95% CI 0.76–0.93; CMM: HR = 0.80, 95% CI 0.69–0.93). There was little evidence of multiplicative or additive interaction for recovery.

Associations of CMD and depression with IADL disability trajectories

Multinomial logistic regression models (Figure S7) showed that, compared to the stable disability-free group, SCMD participants had a higher likelihood of belonging to the mild disability and severe disability without recovery groups (OR = 1.22, 95% CI 1.07–1.39; OR = 1.79, 95% CI 1.32–2.41). Participants with CMM or DS had a higher likelihood of belonging to the mild disability, severe disability with recovery, and severe disability without recovery groups, with ORs ranging from 1.35 (95% CI 1.06–1.71) to 5.09 (95% CI 3.52–7.38). Compared

NDS & NCMD	IRR (95% CI)	INTM (95% CI)	RERI (95% CI)	AP (95% CI)	S (95% CI)
	1(ref)				
NDS & SCMD	1.49 *** (1.34, 1.65)				
NDS & CMM	1.82 *** (1.55, 2.13)				
DS & NCMD	1.85 *** (1.69, 2.02)				
DS & SCMD	2.38 *** (2.08, 2.73)	0.86 (0.74, 1.02)	0.05 (-0.28, 0.37)	0.02 (-0.11, 0.15)	1.04 (0.82, 1.31)
DS & CMM	4.85 *** (4.02, 5.85)	1.45 # (1.16, 1.80)	2.19 # (1.34, 3.04)	0.45 # (0.35, 0.55)	2.32 # (1.79, 2.99)

Table 2. Interaction between CMD and depression in relation to IADL disability scores. Effect estimates from mixed-effects Poisson regression are presented as IRR (95% CI). Abbreviations: IRR, incidence rate ratio; 95% CI, 95% confidence interval; CFPS, China Family Panel Studies; CMD, cardiometabolic disease; NCMD, no CMD; SCMD, single-CMD; CMM, cardiometabolic multimorbidity; DS, depressive symptoms; NDS, no depressive symptoms; INTM, multiplicative interaction. Additive interaction was assessed using RERI, AP, and S. RERI, relative excess risk due to interaction; AP, attributable proportion due to interaction; S, synergy index. The fully adjusted model was adjusted for sociodemographic characteristics (age, gender, marital status, education level, household income level, and region) and lifestyle factors (physical activity, sleep status, smoking status, alcohol consumption, and weight status), in addition to the primary independent variables. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. #: Measures of interaction are statistically significant.

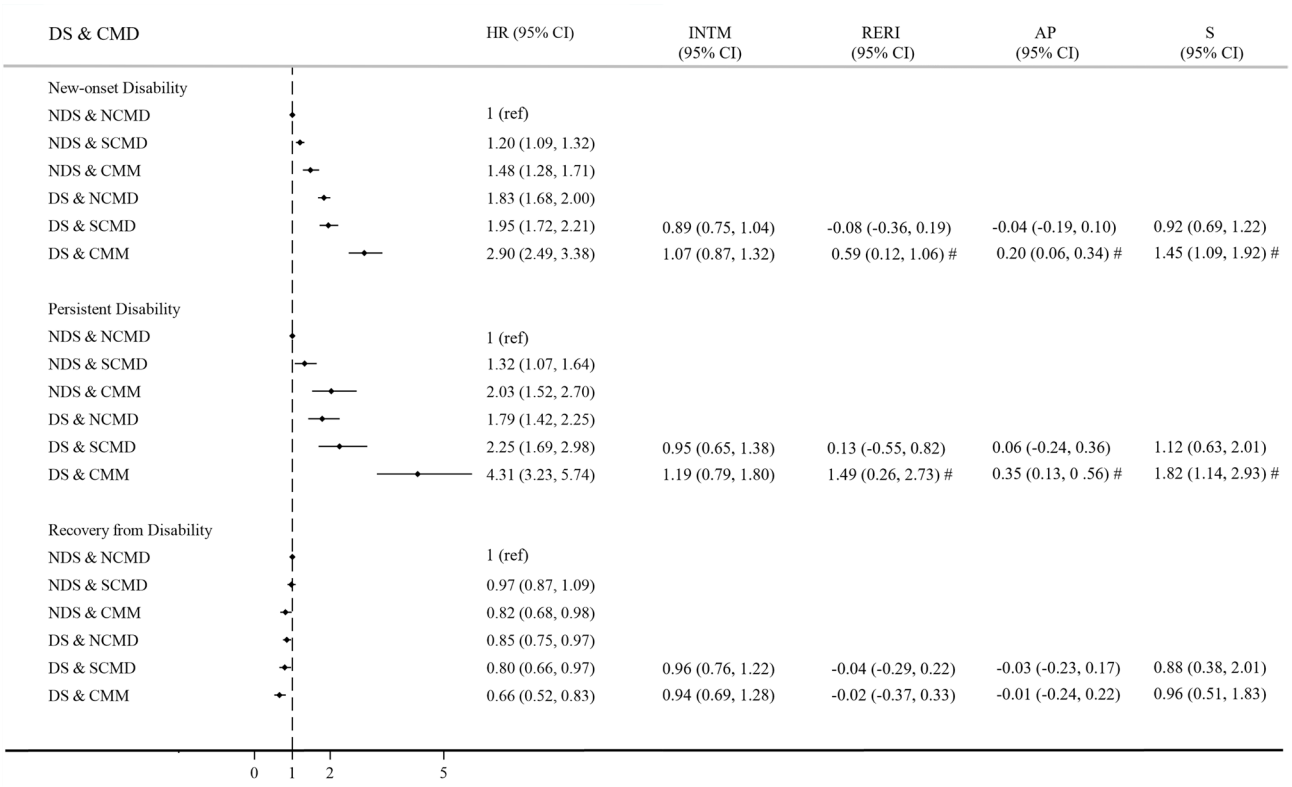
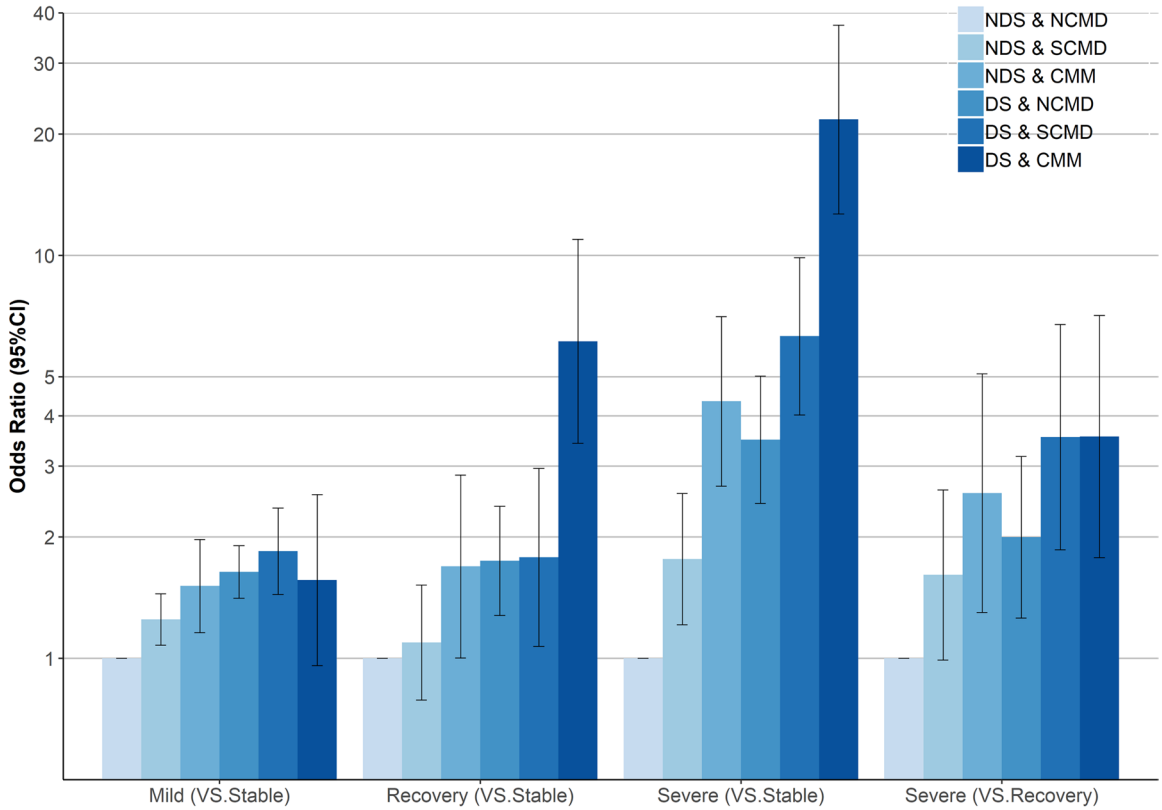


Fig. 1. Interaction between CMD and depression in relation to IADL disability transitions: new-onset, persistence, and recovery Effect estimates from the Cox regression are presented as HR (95% CI). The fully adjusted model accounted for sociodemographic characteristics (age, gender, marital status, education level, household income level, and region) and lifestyle factors (physical activity, sleep status, smoking status, alcohol consumption, and weight status), in addition to the primary independent variables. Abbreviations: HR, hazard ratio; 95% CI, 95% confidence interval; CFPS, China Family Panel Studies; CMD, cardiometabolic disease; NCMD, no CMD; SCMD, single-CMD; CMM, cardiometabolic multimorbidity; DS, depressive symptoms; NDS, no depressive symptoms; INTM, multiplicative interaction. Additive interaction was assessed using RERI, AP, and S. RERI, relative excess risk due to interaction; AP, attributable proportion due to interaction; S, synergy index. #: Measures of interaction are statistically significant.



DS & SCMD				
INTM (95%CI)	0.90 (0.66,1.23)	0.93 (0.49,1.77)	1.02 (0.55, 1.89)	1.10 (0.47, 2.57)
RERI (95%CI)	-0.04 (-0.56, 0.47)	-0.06 (-1.10, 0.98)	2.05 (-0.71, 4.81)	0.93 (-1.39, 3.25)
AP (95%CI)	-0.02 (-0.31, 0.26)	-0.03 (-0.63, 0.57)	0.33 (0.00, 0.65)	0.26 (-0.26, 0.79)
S (95%CI)	0.95 (0.52, 1.74)	0.93 (0.25, 3.43)	1.63 (0.90, 2.95)	1.58 (0.55, 4.52)
DS & CMM				
INTM (95%CI)	0.63 (0.36, 1.11)	2.07 (0.92, 4.65)	1.43 (0.68, 3.02)	0.69 (0.25, 1.88)
RERI (95%CI)	-0.59 (-1.47, 0.29)	3.68 (0.09, 7.27)#	14.91 (3.54, 26.28)#	-0.02 (-2.91, 2.88)
AP (95%CI)	-0.38 (-1.10, 0.35)	0.60 (0.33, 0.88)#	0.69 (0.50, 0.87)#	0.00 (-0.82, 0.81)
S (95%CI)	0.49 (0.12, 1.98)	3.56 (1.36, 9.33)#	3.56 (1.89, 6.71)#	0.99 (0.32, 3.08)

Fig. 2. Interaction between CMD and depression in relation to IADL disability trajectories. Effect estimates from the multinomial logistic regression are presented as OR (95% CI). The OR axis is displayed on a logarithmic scale. Estimates for the CMM and depressive symptoms subgroup should be interpreted cautiously because of the small subgroup size. Full estimates and events/denominators are reported in the corresponding tables.

The fully adjusted model accounted for sociodemographic characteristics (age, gender, marital status, education level, household income level, and region) and lifestyle factors (physical activity, sleep status, smoking status, alcohol consumption, and weight status), in addition to the primary independent variables. Abbreviations: OR, odds ratio; 95% CI, 95% confidence interval; CFPS, China Family Panel Studies; CMD, cardiometabolic disease; NCMD, no CMD; SCMD, single-CMD; CMM, cardiometabolic multimorbidity; DS, depressive symptoms; NDS, no depressive symptoms; INTM, multiplicative interaction. Additive interaction was assessed using RERI, AP, and S. RERI, relative excess risk due to interaction; AP, attributable proportion due to interaction; S, synergy index. Stable, stable disability-free status; Mild, mild disability; Recovery, severe disability with recovery; Severe, severe disability without recovery. #: Measures of interaction are statistically significant.

to the severe disability without recovery group, participants with SCMD, CMM, or DS had a lower likelihood of belonging to the severe disability with recovery group, with ORs ranging from 0.44 (95% CI 0.27–0.73) to 0.60 (95% CI 0.40–0.90).

Interaction results are presented in Table S7 and Fig. 2. There was little evidence of multiplicative interaction between CMD and DS. Additive interaction estimates for CMM and DS showed a similar adverse pattern across both severe disability trajectories, whereas the corresponding estimates for SCMD and DS were less consistent.

Compared with the stable disability-free group, the largest estimate for severe disability without recovery was observed in the joint CMM–DS group (OR = 21.74, 95% CI 12.67–37.30).

Sensitivity analyses

Sensitivity analyses generally supported the robustness of the main findings. Sex- and urban–rural-stratified analyses showed similar directions, although some estimates were less precise because of smaller subgroup sizes and fewer events (Tables S8–S13). Alternative model specifications, weighting approaches, competing-risk analyses, and analyses using alternative exposure or outcome definitions showed similar overall patterns, although some estimates were attenuated or less precise (Tables S14–S30).

Discussion

In this study, CMD (including single CMD and CMM) and depression were independently and adversely associated with changes in IADL disability among middle-aged and older Chinese adults. We also observed a significant additive interaction between CMM and depression, which indicates that individuals with both conditions were more likely to experience worse disability outcomes. Sensitivity analyses supported the robustness of the findings.

During follow-up, 20.70% of initially disability-free participants developed new-onset IADL disability, with 18.82% progressing to persistent disability and 62.78% subsequently recovering independence. The four IADL disability trajectories were similar to those reported in the U.S. Health and Retirement Study (HRS)[39]. Over half of participants maintained independence in IADL, indicating that most middle-aged and older adults are ageing healthily[2,22]. However, more than 20% experienced IADL disability, highlighting a substantial medical and caregiving burden in China[2]. Notably, over half of those who developed disability later regained independence, underscoring the value of timely treatment and care in reducing the societal burden of disability.

Numerous studies have demonstrated an association between CMD and IADL disability, with CMM showing a stronger association. Multiple studies based on China's CHARLS survey have shown that, compared to a single disease, CMM is linked to a more rapid progression of IADL disability[5,24,40]. Similar findings have been reported in Canada, Sweden, Australia, and Belgium[25,26,41–43]. Our study supports these findings and extends them by evaluating IADL disability through transitions (new-onset and persistent disability) and trajectories (mild and severe disability), while considering duration and severity. The results show that both single CMD and CMM are positively associated with the risk of these IADL disability states, with CMM posing higher risks[9,12,44,45]. Studies focusing on single CMD also support our findings[4,7]. We also assessed recovery, defined as recovery from disability in transitions and recovery from severe disability in trajectories. Single CMD was only associated with a lower likelihood of recovery from severe disability, whereas CMM was linked to a reduced probability of both states. These findings partly align with previous studies. A UK study suggested that a higher chronic disease burden was associated with poorer recovery of IADL function[20]. Studies from India and Mexico reported no significant association between CMD and recovery[10,14]. Several mechanisms may underlie these associations. Stroke and ischaemic heart disease may directly cause functional impairment[5,9]. CMD may also accelerate physical ageing and muscle strength loss through chronic inflammation[5,42], thereby increasing the risk of disability. Compared to single CMD, CMM may exert greater cumulative effects[5,21,43]. There is also evidence that diseases within a multimorbidity pattern may interact, weakening compensatory mechanisms and leading to more severe functional limitations, which may explain the lower likelihood of recovery among individuals with CMM[21].

Depression has likewise been consistently associated with IADL disability. Over the past few decades, a growing number of studies have assessed the impact of depression on functional outcomes[28–30,46–50]. In China, studies from different regions have shown that depression is associated with an increased risk of IADL disability[30,46,47]. Similar associations have also been reported in India, Brazil, South Korea, France, and the United States[28,29,48–50]. Regarding recovery, multiple studies have suggested that depression is associated with a decreased likelihood of regaining function[16,31,32], and that improvement in depression may be associated with better functional recovery[33]. Our study adds to this evidence by showing that depression was associated with new-onset, persistent, mild, and severe disability, and with a lower likelihood of recovery. These results suggest that depression may influence the dynamic course of IADL disability. Several mechanisms may explain this association. Depression may reduce physical activity and limit social engagement, which may directly impair IADL function[30]. Depression may also act as a stressor that causes and aggravates inflammatory processes, thereby increasing the risk of IADL disability[30]. In addition, symptoms such as fatigue, poor sleep, and anorexia may reduce treatment adherence and hinder recovery[16,30,47].

We further identified an interaction between CMD and depression in relation to IADL disability. Several studies have reported similar findings[13,19,34,35]. The SLAS-Singapore cohort study reported additive and multiplicative effects of physical multimorbidity and depression on BADL-IADL disability[19]. The ELSI-Brazil cross-sectional study reported that individuals with multimorbidity and depression had the highest risk of IADL disability[35]. The NHATS–United States cohort study reported higher BADL-IADL scores in people with physical multimorbidity and depression than in those with physical multimorbidity alone[13]. While previous studies have explored interactions between physical and mental conditions, few have focused on specific combinations such as CMD and depression in relation to the dynamic course of IADL disability. Our findings add to this area. We found little evidence of additive or multiplicative interaction between single CMD and depression, whereas the additive interaction estimates for CMM and depression showed a broadly consistent adverse pattern across several IADL disability states, including new-onset, persistent, and severe disability. CMM and depression have been reported to be bidirectionally associated[17], with CMM increasing the risk of depression and depression potentially worsening physical disease progression. One possible explanation is that CMM imposes a greater cumulative disease burden and more complex self-management demands than a single CMD. Depression

may further compromise the capacity to manage multiple concurrent conditions. Shared inflammatory and neuroendocrine pathways may also reinforce this joint association. Together, these biological and behavioural mechanisms may contribute to greater functional impairment[17,19,21]. However, evidence remains limited, and further research is needed to clarify the mechanisms underlying this interplay.

This study has several strengths, including the use of nationally representative longitudinal data from China, a focus on middle-aged and older adults, and the assessment of IADL disability across multiple outcomes. We also examined the independent and joint associations of CMD and depression. Our findings highlight the adverse functional associations of the co-occurrence of CMM and depression.

Several limitations should be acknowledged. CMD diagnoses were self-reported, and depression was assessed using the CES-D8, which may have introduced measurement error and limited comparability with studies using other instruments[51]. Reverse causation cannot be excluded because functional decline may also contribute to depressive symptoms[30]. In the trajectory analyses, exposures and covariates were assessed at the first follow-up because the joint CMM–depression group was sparse at study entry; temporal ambiguity and sparse-data bias therefore remain possible. The small CMM–depression subgroup may also have reduced the precision of some estimates and may limit generalisability. Additive interaction measures derived from hazard ratios and odds ratios may be sensitive to the underlying effect scale and outcome frequency. The coarse assessment of physical activity and the omission of cognitive function and other disabling chronic conditions may have contributed to residual confounding, while limited information on medication use and treatment restricted the assessment of treatment-related effect modification. Complete-case analysis and loss to follow-up may have introduced selection bias, while death may have contributed to survivor bias, although the sensitivity analyses produced broadly similar findings. Future studies could use more objective assessments and consider a broader range of potential confounders.

Conclusion

This study provides epidemiological evidence that single CMD, CMM, and depression are independently associated with an increased risk of IADL disability and a decreased likelihood of recovery among middle-aged and older Chinese adults. An additive interaction between CMM and depression was observed in relation to IADL disability. The comorbidity of physical and mental diseases is associated with worse functional outcomes. These findings highlight the potential value of early screening for depression among middle-aged and older adults with CMDs, particularly those with CMM, together with timely management of both physical and mental health conditions to help reduce the risk of adverse functional outcomes.

Data availability

The data supporting the findings of this study are publicly available from the China Family Panel Studies (CFPS) website at http://www.isss.pku.edu.cn/cfps.

Received: 11 June 2026; Accepted: 15 September 2026
Published online: 02 October 2026

References

1. Zhang, L., Hu, H. & Sun, C. Research progress on disability assessment tools for the elderly and risk factors. *Chin. J. Mod. Nurs.* **28** (36), 5007–5012 (2022).
2. Ding, H., Wang, K., Li, Y. & Zhao, X. Trends in disability in activities of daily living and instrumental activities of daily living among Chinese older adults from 2011 to 2018. *Aging Clin. Exp. Res.* **36** (1), 27 (2024).
3. Luo, Y., Su, B. & Zheng, X. Trends and Challenges for Population and Health During Population Aging - China, 2015–2050. *China CDC Wkly.* **3** (28), 593–598 (2021).
4. Gill, T. M., Allore, H. G., Gahbauer, E. A. & Murphy, T. E. Change in disability after hospitalization or restricted activity in older persons. *JAMA* **304** (17), 1919–1928 (2010).
5. Zhou, J., Wei, M. Y., Zhang, J., Liu, H. & Wu, C. Association of multimorbidity patterns with incident disability and recovery of independence among middle-aged and older adults. *Age Ageing* **51**(8). (2022).
6. Xu, W., Li, Y-X., Hu, Y. & Wu, C. Association of Frailty with recovery from disability among community-dwelling Chinese older adults: China health and retirement longitudinal study. *BMC Geriatr.* **20** (1), 119 (2020).
7. Hardy, S. E., Dubin, J. A., Holford, T. R. & Gill, T. M. Transitions between states of disability and independence among older persons. *Am. J. Epidemiol.* **161** (6), 575–584 (2005).
8. Katz, S. & Akpom, C. A. A measure of primary sociobiological functions. *Int. J. Health Serv.* **6** (3), 493–508 (1976).
9. Tsai, Y-H., Chuang, L-L., Lee, Y-J. & Chiu, C-J. How Does Diabetes Accelerate Normal Aging? An Examination of ADL, IADL, and Mobility Disability in Middle-aged and Older Adults With and Without Diabetes. *Diabetes Res. Clin. Pract.* **182**, 109114 (2021).
10. Díaz-Venegas, C. & Wong, R. Recovery from physical limitations among older Mexican adults. *Arch. Gerontol. Geriatr.* **91**, 104208 (2020).
11. Zhao, Y. et al. Trajectories of physical functioning and its predictors in older adults: A 12-year longitudinal study in China. *Front. Public. Health*. **10**, 923767 (2022).
12. Liao, W-L. & Chang, Y-H. Age trajectories of disability in instrumental activities of daily living and disability-free life expectancy among middle-aged and older adults in Taiwan: an 11-year longitudinal study. *BMC Geriatr.* **20** (1), 530 (2020).
13. Quiñones, A. R. et al. Prospective Disability in Different Combinations of Somatic and Mental Multimorbidity. *J. Gerontol. Biol. Sci. Med. Sci.* **73** (2), 204–210 (2018).
14. Paul, R., Srivastava, S., Muhammad, T. & Rashmi, R. Determinants of acquired disability and recovery from disability in Indian older adults: longitudinal influence of socio-economic and health-related factors. *BMC Geriatr.* **21** (1), 426 (2021).
15. Kriegsman, D. M. W., Deeg, D. J. H. & Stalman, W. A. B. Comorbidity of somatic chronic diseases and decline in physical functioning: the Longitudinal Aging Study Amsterdam. *J. Clin. Epidemiol.* **57** (1), 55–65 (2004).
16. Ostir, G. V. et al. Differential effects of premorbid physical and emotional health on recovery from acute events. *J. Am. Geriatr. Soc.* **50** (4), 713–718 (2002).
17. Triolo, F. et al. The complex interplay between depression and multimorbidity in late life: risks and pathways. *Mech. Ageing Dev.* **192**, 111383 (2020).

18. Stubbs, B. et al. Depression and physical health multimorbidity: primary data and country-wide meta-analysis of population data from 190 593 people across 43 low- and middle-income countries. *Psychol. Med.* **47** (12), 2107–2117 (2017).
19. Ho, C. S. et al. Coexisting medical comorbidity and depression: multiplicative effects on health outcomes in older adults. *Int. Psychogeriatr.* **26** (7), 1221–1229 (2014).
20. Seidel, D., Jagger, C., Brayne, C., Matthews, F. E. & Cfas, M. Recovery in instrumental activities of daily living (IADLs): findings from the Medical Research Council Cognitive Function and Ageing Study (MRC CFAS). *Age Ageing*. **38** (6), 663–668 (2009).
21. Calderón-Larrañaga, A. et al. Multimorbidity and functional impairment-bidirectional interplay, synergistic effects and common pathways. *J. Intern. Med.* **285** (3), 255–271 (2019).
22. Zhang, Z. Y., Yuan, M. Q., Shi, Z. X. & Fang, Y. Multimorbidity developmental trajectory among middle-aged and older adults and its impact on new-onset disability in China. *Zhonghua Liu Xing Bing Xue Za Zhi*. **43** (12), 1893–1899 (2022).
23. Fan, J. et al. Multimorbidity patterns and association with mortality in 0.5 million Chinese adults. *Chin. Med. J. (Engl)*. **135** (6), 648–657 (2022).
24. Ruifen, W. et al. Associations between cardiometabolic multimorbidity and disability in middle-aged and older Chinese adults. *J. Jilin. Univ.* **47** (3), 761–769 (2021).
25. Marengoni, A. et al. Patterns of multimorbidity and risk of disability in community-dwelling older persons. *Aging Clin. Exp. Res.* **33** (2), 457–462 (2021).
26. Fishbook, B. N., Brinton, C. D., Siever, J., Klassen, T. D. & Sakakibara, B. M. Cardiometabolic multimorbidity and activity limitation: a cross-sectional study of adults using the Canadian Longitudinal Study on Aging data. *Fam. Pract.* **39** (3), 455–463 (2022).
27. Huang, Y. et al. Prevalence of mental disorders in China: a cross-sectional epidemiological study. *Lancet Psychiatry*. **6** (3), 211–224 (2019).
28. Han, S., Gao, Y. & Gan, D. The combined associations of depression and cognitive impairment with functional disability and mortality in older adults: a population-based study from the NHANES 2011–2014. *Front. Aging Neurosci.* **15**, 1121190 (2023).
29. Dos Santos, A. M. M., Corrêa, V. P., de Avelar, N. C. P., de Oliveira, C. & Schneider, I. J. C. Association between vitamin D insufficiency and depressive symptoms, and functional disability in community-dwelling Brazilian older adults: results from ELSI-Brazil study. *Sci. Rep.* **14** (1), 13909 (2024).
30. Wang, J. et al. Exploring the reciprocal relationship between activities of daily living disability and depressive symptoms among middle-aged and older Chinese people: a four-wave, cross-lagged model. *BMC Public. Health*. **23** (1), 1180 (2023).
31. Pérès, K., Verret, C., Alioum, A. & Barberger-Gateau, P. The disablement process: factors associated with progression of disability and recovery in French elderly people. *Disabil. Rehabil.* **27** (5), 263–276 (2005).
32. Al Snih, S., Markides, K. S., Ostir, G. V., Ray, L. & Goodwin, J. S. Predictors of recovery in activities of daily living among disabled older Mexican Americans. *Aging Clin. Exp. Res.* **15** (4), 315–320 (2003).
33. Nyunt, M. S. Z., Lim, M. L., Yap, K. B. & Ng, T. P. Changes in depressive symptoms and functional disability among community-dwelling depressive older adults. *Int. Psychogeriatr.* **24** (10), 1633–1641 (2012).
34. Hu, Y., Zhou, F., Kaminga, A. C., Yan, S. & Hu, Z. Associations of depressive symptoms and chronic diseases with activities of daily living among middle-aged and older population in China: A population-based cohort study. *Front. Psychiatry*. **13**, 848255 (2022).
35. da Rosa, P. P. S., Marques, L. P., Corrêa, V. P., De Oliveira, C. & Schneider, I. J. C. Is the combination of depression symptoms and multimorbidity associated with the increase of the prevalence of functional disabilities in Brazilian older adults? A cross-sectional study. *Front. Aging.* **4**, 1188552 (2023).
36. Xie, Y. & Hu, J. An Introduction to the China Family Panel Studies (CFPS). *Chin. Sociol. Rev.* **47** (1), 3–29 (2014).
37. Briggs, R., Carey, D., O'Halloran, A. M., Kenny, R. A. & Kennelly, S. P. Validation of the 8-item Centre for Epidemiological Studies Depression Scale in a cohort of community-dwelling older people: data from The Irish Longitudinal Study on Ageing (TILDA). *Eur. Geriatr. Med.* **9** (1), 121–126 (2018).
38. Hirshkowitz, M. et al. National Sleep Foundation's updated sleep duration recommendations: final report. *Sleep. Health*. **1** (4), 233–243 (2015).
39. Ren, Z. et al. Joint daily functional trajectory and risk of new-onset Alzheimer's disease and related dementias in older adults with normal and abnormal weight. *J. Affect. Disord.* **358**, 157–162 (2024).
40. He, H. et al. Longitudinal trajectories of disability among Chinese adults: the role of cardiometabolic multimorbidity. *Aging Clin. Exp. Res.* **36** (1), 79 (2024).
41. Jackson, C. A. et al. Multimorbidity patterns are differentially associated with functional ability and decline in a longitudinal cohort of older women. *Age Ageing*. **44** (5), 810–816 (2015).
42. Marengoni, A. et al. Patterns of Multimorbidity in a Population-Based Cohort of Older People: Sociodemographic, Lifestyle, Clinical, and Functional Differences. *Journals Gerontol. Ser. Biol. Sci. Med. Sci.* **75** (4), 798–805 (2020).
43. Yokota, R. T. C. et al. Impact of Chronic Conditions and Multimorbidity on the Disability Burden in the Older Population in Belgium. *Journals Gerontol. Ser. Biol. Sci. Med. Sci.* **71** (7), 903–909 (2016).
44. Chou, C-Y. et al. Disease-related disability burden: a comparison of seven chronic conditions in middle-aged and older adults. *BMC Geriatr.* **21** (1), 201 (2021).
45. Elayoubi, J., Haley, W. E., Nelson, M. E. & Hueluer, G. How Social Connection and Engagement Relate to Functional Limitations and Depressive Symptoms Outcomes After Stroke. *Stroke* **54** (7), 1830–1838 (2023).
46. Jiang, J., Tang, Z., Futatsuka, M. & Zhang, K. Exploring the influence of depressive symptoms on physical disability: a cohort study of elderly in Beijing, China. *Qual. Life Res.* **13** (7), 1337–1346 (2004).
47. Zhang, Y. et al. The activity of daily living (ADL) subgroups and health impairment among Chinese elderly: a latent profile analysis. *BMC Geriatr.* **21** (1), 30 (2021).
48. Sodhi, B., Malik, M., Agarwal, P. & Basu, S. The prevalence and predictors of depression and disability in older adults and elderly patients with Diabetes in India: Cross-sectional analysis from the Longitudinal Study on Ageing. *Diabetes Metab. Syndr.* **17** (4), 102765 (2023).
49. Nguyen, V. C. & Hong, G-R-S. Change in functional disability and its trends among older adults in Korea over 2008–2020: a 4-year follow-up cohort study. *BMC Geriatr.* **23** (1), 219 (2023).
50. Tchalla, A. et al. Risk factors of frailty and functional disability in community-dwelling older adults: a cross-sectional analysis of the FREEDOM-LNA cohort study. *BMC Geriatr.* **22** (1), 762 (2022).
51. Liu, S., Fang, Y., Su, Z., Cai, J. & Chen, Z. Factor structure and measurement invariance of the 8-item CES-D: a national longitudinal sample of Chinese adolescents. *BMC Psychiatry*. **23** (1), 868 (2023).

Acknowledgements

The authors thank the CFPS team for providing free and public data.

Author contributions

Yaling Wang: Writing – Conceptualization, Data curation, Formal analysis, Methodology, Resources, Software, Writing – original draft. Yong Soon Shin: Writing – Conceptualization, Methodology, Writing – review & editing.

Funding
Not applicable.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval and consent to participate
This study used publicly available and de-identified data from the China Family Panel Studies (CFPS), which was conducted by the Institute of Social Science Survey, Peking University. The CFPS was approved by the Biomedical Ethics Committee of Peking University (IRB00001052-14010), and all participants or their proxy respondents provided written informed consent before data collection. The authors of the present study were not involved in the original data collection. As this study was a secondary analysis of anonymized public data, additional ethical approval from the authors' institutions was not required. All methods were carried out in accordance with relevant guidelines and regulations.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-026-72238-y.

Correspondence and requests for materials should be addressed to Y.S.S.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

© The Author(s) 2026