Research Square

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Physical, psychological and cognitive multimorbidity and fall risk in older adults: a four-country longitudinal cohort analysis

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Abstract

Background

. Multimorbidity is associated with falls, but whether physical, psychological and cognitive multimorbidity is consistently associated with falls across countries remains unclear.

Methods

. Data were drawn from the China Health and Retirement Longitudinal Study (CHARLS), Health and Retirement Study (HRS), English Longitudinal Study of Ageing (ELSA) and Mexican Health and Aging Study (MHAS). Participants aged ≥ 65 years were classified into eight mutually exclusive categories according to physical, psychological and cognitive multimorbidity status. Falls were defined as at least one fall since the previous interview. Modified Poisson regression with participant-clustered robust standard errors estimated relative risks (RRs) and 95% confidence intervals (CIs), adjusting for demographic, socioeconomic and behavioural factors. Sensitivity analyses used logit-linked generalised estimating equations, excluded baseline fallers and applied one-wave lagged exposures.

Results.

The study included 7,686 participants from CHARLS, 14,392 from HRS, 5,547 from ELSA and 9,894 from MHAS. Compared with participants with no morbidity in any domain, physical–psychological multimorbidity was associated with falls, with adjusted RRs of 1.87 (95% CI 1.58–2.20), 1.99 (1.81–2.19), 1.75 (1.53–2.00) and 1.65 (1.54–1.76), respectively. Corresponding RRs for physical–psychological–cognitive multimorbidity were 1.88 (1.59–2.23), 2.18 (1.97–2.41), 2.21 (1.84–2.65) and 1.70 (1.57–1.83). Physical–cognitive and psychological–cognitive multimorbidity were also associated with falls, whereas psychological morbidity alone and cognitive impairment alone showed weaker and less consistent associations. Sensitivity analyses broadly supported the primary findings, although some estimates were attenuated after excluding baseline fallers.

Conclusions.

Physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity were consistently associated with falls across four countries. Integrated assessment of physical, psychological and cognitive health may improve the identification of older adults requiring fall-risk assessment.

1. Introduction

Falls are common and serious adverse health events among older adults. They can lead to injuries, disability, increased healthcare utilisation and mortality, while also compromising older adults' ability to live independently. The World Health Organization (WHO) estimates that approximately 684,000 fatal falls occur worldwide each year, making falls the second leading cause of unintentional injury-related death after road traffic injuries[1]. Approximately one-third of adults aged 65 years and older experience at least one fall each year, with this proportion increasing to approximately 50% among those aged 80 years and older [2]. Recent evidence indicates that an estimated 45,657,816 incident falls occurred among adults aged 65 years and older worldwide in 2021, representing an increase of 182.09% from 16,185,684 cases in 1990. The disability and mortality burdens attributable to falls also varied substantially across regions at different levels of sociodemographic development[3, 4]. Collectively, this evidence demonstrates that falls are not merely adverse health events affecting individual older adults, but a major public health concern requiring urgent attention in the context of global population ageing.

Given the substantial health losses and societal burden associated with falls, identifying factors related to the risk of falls among older adults is of considerable importance. Falls are not isolated or random events; rather, they result from the combined effects of multiple health-related and environmental factors. Numerous factors have been shown to increase the risk of falls among older adults[5–7], among which multimorbidity warrants particular attention. Multimorbidity is generally defined as the coexistence of two or more chronic conditions in the same individual. Importantly, it is not confined to the accumulation of physical conditions, but may also involve psychological morbidity and cognitive impairment, thereby complicating disease management and increasing the burden on healthcare systems [8–10]. With population ageing and the growing burden of chronic conditions, the prevention and management of multimorbidity have become important priorities in primary health care[11]. Previous studies have examined the association between multimorbidity and the risk of falls, but several gaps in the existing evidence remain. Most studies have been conducted within a single country and have reported that a greater number of chronic conditions, specific multimorbidity patterns and functional limitations are associated with a higher risk of falls[9, 12, 13]. These studies provide an important basis for understanding the relationship between multimorbidity and falls; however, whether their findings are consistent across different social, healthcare and ageing contexts remains uncertain. Moreover, previous research has focused primarily on physical chronic conditions or patterns of physical multimorbidity, whereas the integrated assessment of physical, psychological and cognitive multimorbidity remains relatively limited[14].

Drawing on data from longitudinal ageing cohorts in China, the United States, England and Mexico, this study examined the associations between different patterns of physical, psychological and cognitive multimorbidity and self-reported falls among older adults. The findings provide cross-national evidence to support the identification of older adults who may benefit from fall-risk assessment and the development of comprehensive fall-prevention strategies.

2. Methods

Study design and participants

This study used data from four nationally representative longitudinal ageing studies conducted in the United States, China, England and Mexico: the Health and Retirement Study (HRS), the China Health and Retirement Longitudinal Study (CHARLS), the English Longitudinal Study of Ageing (ELSA) and the Mexican Health and Aging Study (MHAS), respectively[15–18]. The analysis included data from HRS collected between 2010 and 2018, CHARLS between 2011 and 2018, ELSA between 2014 and 2018, and MHAS between 2012 and 2018. Participants aged 65 years and older were included to enhance comparability across the four cohorts.

Measures

Multimorbidity

Multimorbidity was defined as the presence of morbidity in at least two of the three health domains—physical, psychological and cognitive[19]. Physical morbidity was ascertained from participants' self-reported history of chronic conditions. Participants were classified as having physical morbidity if they reported at least one of the following conditions: hypertension, diabetes, cancer, chronic lung disease, heart disease, stroke or arthritis. Psychological morbidity and cognitive impairment were identified using cohort-specific scales and cognitive assessments, respectively, according to predefined thresholds (Supplementary Table S1). Within each domain, participants were classified as having morbidity if at least one relevant condition or impairment was present. The complexity of multimorbidity was further conceptualised according to the number of affected morbidity domains—physical, psychological and cognitive—in which at least one condition or impairment was present[20].

Fall

Falls were defined as a binary outcome based on participants' self-reported experience of at least one fall since the previous interview (1 = yes, 0 = no)[12].

Covariates

Based on previous studies [9, 21], the covariates included demographic characteristics, socioeconomic factors, health status and health behaviours. Specifically, these covariates comprised age, sex (male or female), education level (low, middle or high), current employment status (not working or working), marital status (not married or married), self-rated health (excellent, very good, good, fair or poor), household wealth quartile (Q1–Q4), limitations in activities of daily living (ADL), drinking and smoking status. The definitions and measurement methods for drinking and smoking status are presented in Supplementary Table S2. Education level was coded as 0, 1 and 2 for low, middle and high education, respectively. Household wealth was categorised into quartiles according to the wealth distribution within each cohort and coded from 0 to 3, corresponding to the lowest through highest quartiles.

Statistical analysis

First, descriptive statistics were used to summarise the baseline characteristics of the participants included in the analyses, including demographic characteristics, socioeconomic factors, health behaviours, health status, physical, psychological and cognitive morbidity status, and fall status. Continuous variables were presented as means and standard deviations (SDs), whereas categorical variables were presented as frequencies and percentages.

Analyses were conducted separately in the CHARLS, HRS, ELSA and MHAS cohorts. The primary exposure was physical, psychological and cognitive morbidity status assessed at each survey wave. Participants were classified into eight mutually exclusive categories based on the combinations of the three health domains: (1) physical disorder (Phy); (2) psychological disorder (Psy); (3) cognitive disorder (Cog); (4) physical–psychological multimorbidity (Phy + Psy); (5) physical–cognitive multimorbidity (Phy + Cog); (6) psychological–cognitive multimorbidity (Psy + Cog); (7) physical–psychological–cognitive multimorbidity (Phy + Psy + Cog); and (8) no morbidity in any of the three disorders (None; reference group). The outcome was whether participants reported at the same survey wave that they had experienced at least one fall since the previous interview. As the primary exposure, covariates and information on falls were all obtained from the same survey wave, the findings were primarily interpreted as population-averaged associations derived from longitudinal repeated-measures data.

Modified Poisson regression models were used in the primary analyses to estimate relative risks (RRs) and 95% confidence intervals (CIs) for the associations between the eight morbidity categories and self-reported falls. A Poisson distribution with a log link was specified, and participant-clustered robust standard errors were used to account for within-participant correlation arising from repeated observations. The same sequential adjustment strategy was applied across all four cohorts. Model 1 was unadjusted. Model 2 adjusted for age, sex and survey year. Model 3 further adjusted for education level and household wealth. Model 4 additionally adjusted for marital status, current employment status, smoking status and drinking status, and was designated as the primary model. Model 5 further adjusted for self-rated health and ADL limitation status[19]. In all models, no morbidity in any of the three domains (None) was used as the reference group.

Subgroup analyses were subsequently conducted to assess the consistency of the associations between the eight morbidity categories and self-reported falls across different population subgroups. The analyses were stratified by age group, sex, education level, household wealth, marital status, current employment status, smoking status, drinking status and ADL limitation status. The same modelling framework as that used in the primary analysis was applied, with no morbidity in any of the three domains (None) as the reference group. In each subgroup-specific model, the corresponding stratification variable was omitted from the covariate adjustment. The results were reported as adjusted RRs with 95% CIs.

Several sensitivity analyses were conducted to assess the robustness of the findings. First, generalised estimating equation (GEE) models with a logit link were used to re-estimate the associations between the eight morbidity categories and self-reported falls. Odds ratios (ORs) and 95% CIs were reported to

assess the sensitivity of the findings to model specification. Second, the primary analyses were repeated after excluding participants who had reported a fall at baseline to evaluate the potential influence of previous falls. Third, lagged-exposure models were constructed in which the morbidity category measured at the preceding survey wave was treated as the exposure and falls reported at the subsequent survey wave were treated as the outcome. These analyses assessed the robustness of the findings under an alternative temporal ordering of the exposure and outcome. The analyses were restricted to observations with complete data for all variables included in the corresponding model. The baseline characteristics of participants included in the analyses were compared with those of participants excluded because of missing information to assess the potential for selection bias.

This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement[22]. All statistical tests were two-sided, and a P value of < 0.05 was considered statistically significant.

3. Results

3.1 Baseline characteristics of participants

According to the inclusion and exclusion criteria, a total of 37,519 adults aged 65 years and older were included in the study, comprising 7,686 participants from CHARLS, 14,392 from HRS, 5,547 from ELSA and 9,894 from MHAS (Figure 1). Baseline characteristics are presented in Table 1. The four cohorts differed significantly in demographic characteristics, health behaviours, health status, ADL limitations and the distribution of physical, psychological and cognitive morbidity status. The mean age of CHARLS participants was 70.3 years (SD = 5.1), 44.0% were women and 19.7% reported at least one fall. The corresponding figures were 72.6 years (SD = 7.4), 58.1% and 34.9% in HRS; 72.1 years (SD = 6.6), 52.0% and 26.3% in ELSA; and 71.3 years (SD = 6.6), 54.5% and 44.7% in MHAS, respectively. The distributions of the four multimorbidity categories also varied considerably across cohorts. In CHARLS, the proportions of participants with physical–psychological multimorbidity, physical–cognitive multimorbidity, psychological–cognitive multimorbidity and physical–psychological–cognitive multimorbidity were 15.0%, 13.5%, 3.3% and 12.9%, respectively. The corresponding proportions were 8.2%, 14.5%, 0.2% and 4.3% in HRS; 8.1%, 6.5%, 0.2% and 1.4% in ELSA; and 24.0%, 5.7%, 0.8% and 5.5% in MHAS.

3.2 Associations between physical–psychological–cognitive morbidity patterns and falls

After adjustment for age, sex, education level, household wealth, marital status, current employment status, smoking status, drinking status and survey year, multimorbidity involving two or three health domains was associated with a higher risk of falls across all four cohorts. Compared with participants with no morbidity in any of the three domains, those with physical–psychological multimorbidity had a

significantly higher risk of falls, with RRs of 1.87 (95% CI 1.58–2.20), 1.99 (95% CI 1.81–2.19), 1.75 (95% CI 1.53–2.00) and 1.65 (95% CI 1.54–1.76) in CHARLS, HRS, ELSA and MHAS, respectively. Physical–cognitive multimorbidity was also associated with a higher risk of falls, with corresponding RRs of 1.31 (95% CI 1.09–1.57), 1.45 (95% CI 1.32–1.60), 1.42 (95% CI 1.22–1.64) and 1.33 (95% CI 1.22–1.45). Similarly, psychological–cognitive multimorbidity was associated with a higher risk of falls, with RRs of 1.69 (95% CI 1.32–2.15), 1.58 (95% CI 1.16–2.14), 1.93 (95% CI 1.05–3.54) and 1.44 (95% CI 1.23–1.70) in the four cohorts, respectively. Participants with physical–psychological–cognitive multimorbidity also had a higher risk of falls across all four cohorts, with RRs of 1.88 (95% CI 1.59–2.23), 2.18 (95% CI 1.97–2.41), 2.21 (95% CI 1.84–2.65) and 1.70 (95% CI 1.57–1.83), respectively (Table 2). After further adjustment for self-rated health and ADL limitations, these associations were generally attenuated, although most multimorbidity categories remained associated with a higher risk of falls. The associations for physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity were the most consistent across the four cohorts. In addition, compared with participants with no morbidity in any of the three domains, the estimated risk of falls increased progressively as the number of affected morbidity domains increased from one to two and three in all four cohorts (Supplementary Table S7).

3.3 Subgroup analyses of the association between physical–psychological–cognitive multimorbidity and falls

Subgroup analyses showed that the associations between multimorbidity involving two or three health domains and a higher risk of falls were generally consistent across most participant characteristics. The association between physical–psychological multimorbidity and falls remained relatively stable across age groups. Among participants aged 65–69 years, physical–psychological multimorbidity was associated with a higher risk of falls, with RRs of 1.80, 1.99, 1.85 and 1.73 in CHARLS, HRS, ELSA and MHAS, respectively. Among those aged 70–74 years, the corresponding RRs were 2.06, 2.30, 2.11 and 1.66. In analyses stratified by sex, physical–psychological multimorbidity was associated with a higher risk of falls among both men and women, with consistent directions of association across the four cohorts. Similar findings were observed among participants who were not currently working, for whom the RRs associated with physical–psychological multimorbidity were 2.02, 2.07, 1.71 and 1.69 in CHARLS, HRS, ELSA and MHAS, respectively. Physical–cognitive multimorbidity was also positively associated with self-reported falls in most subgroups, with particularly consistent findings in HRS and MHAS. For example, the direction of association between physical–cognitive multimorbidity and falls was broadly consistent across the four cohorts among both men and women. Among participants who were not currently working, most estimates indicated a higher risk of falls, although the confidence intervals were wide in some cohorts. Estimates for psychological–cognitive multimorbidity were generally greater than 1; however, the confidence intervals were wide in several subgroups, particularly in cohorts and subgroups with small sample sizes, indicating limited precision and stability. Overall, physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity showed

broadly consistent positive associations with self-reported falls across subgroups defined by age, sex, employment status, smoking status and ADL limitation status, supporting the robustness of the primary findings (Figure 2 and Supplementary Figures S4–S6).

3.4 Sensitivity analyses

The sensitivity analyses broadly supported the primary findings. First, after the associations were re-estimated using GEE models with a logit link, the directions of the associations between multimorbidity involving two or three health domains and self-reported falls were generally consistent with those obtained from the modified Poisson regression models. In particular, physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity were associated with a higher risk of self-reported falls across all four cohorts. Second, after participants who had reported a fall at baseline were excluded, the overall patterns of association remained broadly consistent, although several estimates became less precise and had wider confidence intervals because of the reduced sample sizes (Supplementary Tables S4–S5). Third, the lagged-exposure models showed that multimorbidity status measured at the preceding survey wave remained associated with a higher risk of falls reported at the subsequent wave. The associations for physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity were the most consistent across the four cohorts (Supplementary Table S6).

4. Discussion

Using longitudinal ageing cohort data from four countries, this study systematically examined the associations between physical, psychological and cognitive multimorbidity and falls. Physical, psychological and cognitive multimorbidity was consistently associated with a higher risk of falls among older adults. Compared with participants with no physical, psychological or cognitive morbidity, those with two-domain or three-domain physical, psychological and cognitive multimorbidity had a higher risk of falls. The associations of physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity with falls were the most consistent across the four cohorts, while physical–cognitive multimorbidity also showed positive associations in most cohorts and subgroups. These findings suggest that the risk of falls is not attributable solely to a single chronic condition or a single health domain, but may be influenced by the combined effects of physical, psychological and cognitive multimorbidity.

The findings of this study are consistent with previous research showing that multimorbidity is an important marker for identifying older adults at high risk of falls [9, 12, 14]. Among the different patterns of physical, psychological and cognitive multimorbidity, physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity showed relatively consistent associations with falls across the cohorts. Several potential mechanisms may explain how physical morbidity, psychological morbidity and cognitive impairment jointly increase the risk of falls. Physical morbidity may adversely

affect mobility and postural control through pain, reduced muscle strength, gait abnormalities, impaired balance, diminished cardiorespiratory reserve and disease-related complications[23–25]. Previous studies have also demonstrated a cumulative effect of physical chronic conditions, whereby a greater number or complexity of physical conditions is associated with a higher risk of falls among older adults [26, 27]. In the presence of impaired physical function, psychological morbidity and cognitive impairment may further increase the risk of falls. Psychological morbidity, particularly depressive symptoms, may lead to reduced physical activity, greater fatigue, impaired attention, slower reaction time and increased fear of falling, thereby affecting older adults' daily activities and mobility outside the home[28]. Cognitive impairment may compromise executive function, spatial judgement, recognition of environmental hazards and dual-task walking ability, making it more difficult for older adults to adjust their gait and posture promptly in complex environments [5, 29]. When physical, psychological and cognitive multimorbidity is present, functional limitations and medication-related risks may become more pronounced[30, 31].

Cross-cohort analyses showed that, despite differences across the four countries in the distribution of physical, psychological and cognitive multimorbidity, the prevalence of falls and the measurement of health status, the directions of the associations between physical, psychological and cognitive multimorbidity and a higher risk of falls were broadly consistent. These findings suggest that the association between physical, psychological and cognitive multimorbidity and falls was not confined to a single cohort, but showed a degree of consistency across different social and healthcare contexts. However, the magnitudes of the associations varied across cohorts. These variations may first reflect differences in measurement. Falls were assessed primarily using self-reported information and may therefore have been influenced by the recall period, fall severity, cognitive status and culturally shaped reporting practices[32]. Physical morbidity was also largely based on self-reported diagnoses and may have been affected by differences in healthcare utilisation and opportunities for diagnosis. In addition, the scales, thresholds and assessment instruments used to identify psychological morbidity and cognitive impairment differed across cohorts, which may have affected the comparability of the findings[33]. Contextual differences in chronic disease management, rehabilitation services, family care and living environments may also have contributed to variation in the strength of the associations across cohorts.

This study has important public health and clinical implications. The findings suggest that physical, psychological and cognitive multimorbidity may serve as an important marker for identifying older adults at high risk of falls. In particular, older adults with physical–psychological multimorbidity or physical–psychological–cognitive multimorbidity should be prioritised in fall-prevention efforts. Older adults frequently experience a combination of chronic disease burden, functional limitations, reduced mobility and increasing care needs. Limited access to safe living environments, health information, rehabilitation services, assistive devices and healthcare services may further increase the likelihood of falls[21, 34]. For older adults with physical, psychological and cognitive multimorbidity, fall prevention should not be confined to the management of individual diseases. Instead, comprehensive risk assessment and multifactorial interventions should be implemented, including medical history assessment, medication

review, exercise training, nutritional support, health education, environmental assessment and modification, rehabilitation, occupational therapy and referral to specialist services[11]. Existing evidence indicates that exercise interventions are among the most consistently effective approaches for preventing falls in community-dwelling older adults, whereas multifactorial interventions may be particularly appropriate for those with complex health conditions or multiple risk factors[35]. Primary care services and healthy ageing programmes should therefore incorporate physical, psychological and cognitive multimorbidity status, ADL limitations, previous falls and functional status into routine fall-risk screening to improve the targeting and effectiveness of fall-prevention programmes [11, 36]. Falls can result not only in injuries, disability and mortality, but also in substantial costs related to emergency care, hospitalisation, rehabilitation, long-term care and informal care[37]. Early identification and intervention among older adults with physical, psychological and cognitive multimorbidity may therefore also have important implications for healthcare resource allocation [11, 38].

This study has several limitations. First, falls were primarily ascertained from participants' self-reports and may therefore have been subject to recall bias and reporting bias. Second, the four cohorts differed in survey questions, follow-up intervals and variable measurement methods. Although variables were harmonised across cohorts, measurement error may have remained. Third, the criteria used to identify physical morbidity, psychological morbidity and cognitive impairment were not fully consistent across cohorts, which may have affected the comparability of the cross-cohort findings. Fourth, as an observational study, residual confounding and reverse causation could not be completely excluded. In the primary analyses, physical, psychological and cognitive multimorbidity status, some covariates and falls were measured at the same survey wave, precluding the establishment of a clear temporal sequence. Although sensitivity analyses excluding participants with falls at baseline and using lagged-exposure models broadly supported the primary findings, the possibility of time-varying confounding and reverse causation remained. In addition, this study did not distinguish between the number of falls, injury severity or injurious falls, which limited the interpretation of falls of differing clinical severity.

5. Conclusions

In conclusion, using longitudinal ageing cohort data from China, the United States, England and Mexico, this study found that physical, psychological and cognitive multimorbidity status was consistently associated with a higher risk of falls among older adults. The associations of physical–psychological multimorbidity and physical–psychological–cognitive multimorbidity with falls were the most consistent across cohorts, whereas psychological morbidity alone and cognitive impairment alone showed weaker and less consistent associations. These findings suggest that fall prevention in older adults should move beyond single-disease management, incorporate multidimensional assessments of physical, psychological and cognitive health, and adopt more comprehensive and equity-oriented strategies for risk identification and intervention.

Abbreviations

CHARLS
China Health and Retirement Longitudinal Study
HRS
Health and Retirement Study
ELSA
English Longitudinal Study of Ageing
MHAS
Mexican Health and Aging Study
WHO
World Health Organization
ADL
Activities of daily living
SD
Standard deviation
RR
Relative risk
CI
Confidence interval
GEE
Generalised estimating equation
OR
Odds ratio
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology

Declarations

Availability of data and materials

The original data for this study are available on their respective websites: the China Health and Retirement Longitudinal Study-CHARLS (http://charls.pku.edu.cn/index/en.html), the Health and Retirement Study-HRS (https://hrs.isr.umich.edu/), the English Longitudinal Study of Ageing-ELSA (https://www.elsa-project.ac.uk) and the Mexican Health and Ageing Study-MHAS (http://www.mhasweb.org/).

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Contributions

Xu Jin: Conceptualization, study design, methodology, data curation, formal analysis, interpretation of results, writing-original draft preparation. Yiyang Sun: Study design, data curation, formal analysis, interpretation of results, writing-original draft preparation, writing-review and editing. Xin Li: Study design, data curation, formal analysis, interpretation of results, writing-original draft preparation, writing-review and editing. Ruiyang Zhang, Yuxin Kuang and Youzhi Wang: Data curation, validation, writing-review and editing. Yanping Wang and Weidong Huang: Conceptualization, study design, methodology, supervision, interpretation of results, writing-review and editing. Hongjuan Yu: Conceptualization, study design, methodology, supervision, project administration, interpretation of results, writing-review and editing. Hongjuan Yu is the leading corresponding author.

Ethics approval and consent to participate

Each cohort received ethical approval from the relevant institutional review boards, and all participants provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Tables

Table 1. Baseline characteristics of participants by cohort

Variables	CHARLS (n= 7,686)	HRS (n=14,392)	ELSA (n= 5,547)	MHAS (n= 9,894)
Age, mean (SD)	70.3 (5.1)	72.6 (7.4)	72.1 (6.6)	71.3 (6.6)
Age group, n (%)				
65-69	4,263 (55.5%)	6,370 (44.3%)	2,580 (46.5%)	5,242 (53.0%)
70-74	1,888 (24.6%)	3,051 (21.2%)	1,155 (20.8%)	1,964 (19.9%)
75+	1,535 (20.0%)	4,971 (34.5%)	1,812 (32.7%)	2,688 (27.2%)
Fall, n (%)				
No	6,175 (80.3%)	9,365 (65.1%)	4,086 (73.7%)	5,468 (55.3%)
Yes	1,511 (19.7%)	5,027 (34.9%)	1,461 (26.3%)	4,426 (44.7%)
Sex, n (%)				
Male	4,303 (56.0%)	6,025 (41.9%)	2,661 (48.0%)	4,497 (45.5%)
Female	3,383 (44.0%)	8,367 (58.1%)	2,886 (52.0%)	5,397 (54.5%)
Marital status, n (%)				
Married or partnered	5,934 (77.2%)	8,253 (57.3%)	3,843 (69.3%)	6,220 (62.9%)
Other marital status	1,752 (22.8%)	6,139 (42.7%)	1,704 (30.7%)	3,674 (37.1%)
Education, n (%)				
Low	7,016 (91.3%)	2,931 (20.4%)	1,603 (28.9%)	8,878 (89.7%)
Middle	482 (6.3%)	7,682 (53.4%)	2,864 (51.6%)	229 (2.3%)
High	188 (2.4%)	3,779 (26.3%)	1,080 (19.5%)	787 (8.0%)
Currently working, n (%)				
No	4,148 (54.0%)	10,993 (76.4%)	4,728 (85.2%)	7,177 (72.5%)
Yes	3,538 (46.0%)	3,399 (23.6%)	819 (14.8%)	2,717 (27.5%)
Wealth quartile, n (%)				
Q1 lowest	1,297 (16.9%)	2,721 (18.9%)	1,168 (21.1%)	2,439 (24.7%)
Q2	2,381 (31.0%)	3,467 (24.1%)	1,324 (23.9%)	2,386 (24.1%)
Q3	2,014 (26.2%)	3,969 (27.6%)	1,482 (26.7%)	2,449 (24.8%)
Q4 highest	1,994 (25.9%)	4,235 (29.4%)	1,573 (28.4%)	2,620 (26.5%)
Smoking, n (%)				

No	5,392 (70.2%)	12,939 (89.9%)	5,100 (91.9%)	8,968 (90.6%)
Yes	2,294 (29.8%)	1,453 (10.1%)	447 (8.1%)	926 (9.4%)
Drinking, n (%)				
No	5,147 (67.0%)	7,093 (49.3%)	782 (14.1%)	7,820 (79.0%)
Yes	2,539 (33.0%)	7,299 (50.7%)	4,765 (85.9%)	2,074 (21.0%)
Self-rated health, n (%)				
Excellent	603 (7.8%)	1,213 (8.4%)	545 (9.8%)	199 (2.0%)
Very good	979 (12.7%)	4,348 (30.2%)	1,637 (29.5%)	355 (3.6%)
Good	3,992 (51.9%)	4,863 (33.8%)	1,907 (34.4%)	2,530 (25.6%)
Fair	1,688 (22.0%)	2,970 (20.6%)	1,098 (19.8%)	5,243 (53.0%)
Poor	424 (5.5%)	998 (6.9%)	360 (6.5%)	1,567 (15.8%)
ADL limitation, n (%)				
No	5,990 (77.9%)	11,829 (82.2%)	4,595 (82.8%)	7,944 (80.3%)
Yes	1,696 (22.1%)	2,563 (17.8%)	952 (17.2%)	1,950 (19.7%)
Multimorbidity, n (%)				
None	990 (12.9%)	1,052 (7.3%)	1,027 (18.5%)	1,502 (15.2%)
Phy	2,531 (32.9%)	9,209 (64.0%)	3,505 (63.2%)	4,348 (43.9%)
Psy	244 (3.2%)	54 (0.4%)	55 (1.0%)	301 (3.0%)
Cog	488 (6.3%)	153 (1.1%)	58 (1.0%)	182 (1.8%)
Phy + Psy	1,152 (15.0%)	1,187 (8.2%)	452 (8.1%)	2,379 (24.0%)
Phy + Cog	1,034 (13.5%)	2,090 (14.5%)	359 (6.5%)	560 (5.7%)
Psy + Cog	255 (3.3%)	30 (0.2%)	11 (0.2%)	76 (0.8%)
Phy + Psy + Cog	992 (12.9%)	617 (4.3%)	80 (1.4%)	546 (5.5%)

Table 2. Associations between physical, psychological and cognitive morbidity patterns and fall reports across four national ageing cohorts

	Multimorbidity status	Model 1 RR (95% CI)	Model 2 RR (95% CI)	Model 3 RR (95% CI)	Model 4 RR (95% CI)	Model 5 RR (95% CI)
CHARLS (n = 7,686)	None	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
	Phy	1.21 (1.03, 1.43)	1.17 (1.00, 1.38)	1.17 (1.00, 1.38)	1.19 (1.01, 1.40)	1.06 (0.91, 1.25)
	Psy	1.28 (0.96, 1.70)	1.24 (0.93, 1.64)	1.21 (0.91, 1.61)	1.20 (0.90, 1.60)	1.08 (0.82, 1.43)
	Cog	1.15 (0.90, 1.46)	1.08 (0.85, 1.38)	1.06 (0.83, 1.35)	1.05 (0.82, 1.34)	1.04 (0.81, 1.32)
	Phy + Psy	1.99 (1.68, 2.35)	1.86 (1.58, 2.20)	1.84 (1.56, 2.17)	1.87 (1.58, 2.20)	1.42 (1.19, 1.69)
	Phy + Cog	1.47 (1.23, 1.76)	1.32 (1.10, 1.58)	1.30 (1.08, 1.55)	1.31 (1.09, 1.57)	1.14 (0.95, 1.37)
	Psy + Cog	1.92 (1.51, 2.45)	1.74 (1.36, 2.22)	1.69 (1.32, 2.15)	1.69 (1.32, 2.15)	1.38 (1.08, 1.77)
	Phy + Psy + Cog	2.17 (1.84, 2.56)	1.92 (1.62, 2.27)	1.86 (1.57, 2.20)	1.88 (1.59, 2.23)	1.37 (1.14, 1.63)
HRS (n = 14,392)	None	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
	Phy	1.44 (1.31, 1.57)	1.36 (1.25, 1.49)	1.37 (1.25, 1.49)	1.34 (1.23, 1.46)	1.16 (1.06, 1.27)
	Psy	1.33 (1.01, 1.75)	1.29 (0.98, 1.70)	1.29 (0.98, 1.70)	1.27 (0.96, 1.67)	1.06 (0.82, 1.39)
	Cog	0.90 (0.71, 1.13)	0.80 (0.64, 1.00)	0.81 (0.65, 1.02)	0.80 (0.64, 1.00)	0.77 (0.62, 0.96)
	Phy + Psy	2.16 (1.96, 2.37)	2.03 (1.85, 2.24)	2.05 (1.86, 2.25)	1.99 (1.81, 2.19)	1.40 (1.27, 1.54)
	Phy + Cog	1.66 (1.51, 1.82)	1.46 (1.33, 1.60)	1.49 (1.35, 1.64)	1.45 (1.32, 1.60)	1.20 (1.09, 1.32)

	Psy + Cog	1.75 (1.29, 2.37)	1.57 (1.16, 2.12)	1.61 (1.19, 2.18)	1.58 (1.16, 2.14)	1.24 (0.90, 1.70)
	Phy + Psy + Cog	2.46 (2.23, 2.71)	2.19 (1.98, 2.41)	2.25 (2.04, 2.49)	2.18 (1.97, 2.41)	1.47 (1.33, 1.62)
ELSA (n = 5,547)	None	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
	Phy	1.36 (1.22, 1.52)	1.27 (1.14, 1.41)	1.26 (1.13, 1.40)	1.26 (1.13, 1.41)	1.13 (1.01, 1.26)
	Psy	1.50 (1.05, 2.14)	1.45 (1.01, 2.08)	1.46 (1.02, 2.08)	1.44 (1.01, 2.06)	1.27 (0.90, 1.80)
	Cog	1.09 (0.74, 1.59)	0.95 (0.65, 1.37)	0.94 (0.65, 1.37)	0.95 (0.65, 1.39)	0.94 (0.65, 1.37)
	Phy + Psy	2.07 (1.82, 2.35)	1.81 (1.59, 2.07)	1.78 (1.56, 2.03)	1.75 (1.53, 2.00)	1.28 (1.11, 1.47)
	Phy + Cog	1.76 (1.52, 2.02)	1.43 (1.24, 1.66)	1.42 (1.23, 1.65)	1.42 (1.22, 1.64)	1.21 (1.04, 1.41)
	Psy + Cog	2.24 (1.26, 3.97)	2.00 (1.09, 3.65)	1.93 (1.05, 3.55)	1.93 (1.05, 3.54)	1.55 (0.91, 2.64)
	Phy + Psy + Cog	2.89 (2.43, 3.44)	2.29 (1.91, 2.75)	2.25 (1.88, 2.69)	2.21 (1.84, 2.65)	1.61 (1.34, 1.95)
MHAS (n = 9,894)	None	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
	Phy	1.33 (1.25, 1.42)	1.26 (1.18, 1.34)	1.25 (1.17, 1.34)	1.25 (1.17, 1.34)	1.19 (1.12, 1.28)
	Psy	1.39 (1.24, 1.57)	1.34 (1.19, 1.50)	1.33 (1.18, 1.49)	1.33 (1.19, 1.50)	1.26 (1.12, 1.41)
	Cog	1.23 (1.06, 1.42)	1.16 (1.00, 1.34)	1.14 (0.99, 1.32)	1.14 (0.99, 1.32)	1.14 (0.98, 1.31)
	Phy + Psy	1.84 (1.72, 1.97)	1.66 (1.55, 1.77)	1.65 (1.54, 1.76)	1.65 (1.54, 1.76)	1.45 (1.35, 1.55)

	Phy + Cog	1.51 (1.39, 1.64)	1.34 (1.23, 1.46)	1.33 (1.22, 1.45)	1.33 (1.22, 1.45)	1.25 (1.15, 1.36)
	Psy + Cog	1.58 (1.34, 1.87)	1.46 (1.24, 1.72)	1.44 (1.22, 1.70)	1.44 (1.23, 1.70)	1.34 (1.14, 1.58)
	Phy + Psy + Cog	1.99 (1.85, 2.15)	1.71 (1.58, 1.85)	1.69 (1.56, 1.83)	1.70 (1.57, 1.83)	1.48 (1.36, 1.60)

Abbreviations: CHARLS, China Health and Retirement Longitudinal Study; HRS, Health and Retirement Study; ELSA, English Longitudinal Study of Ageing; MHAS, Mexican Health and Aging Study; RR, relative risk; CI, confidence interval. Model 1 was unadjusted; Model 2 adjusted for age, sex, and survey year; Model 3 further adjusted for education and wealth; Model 4 further adjusted for marital status, current working status, current smoking, and current drinking; Model 5 further adjusted for self-rated health and ADL limitation. The reference category was no physical, psychological, or cognitive morbidity.

Figures

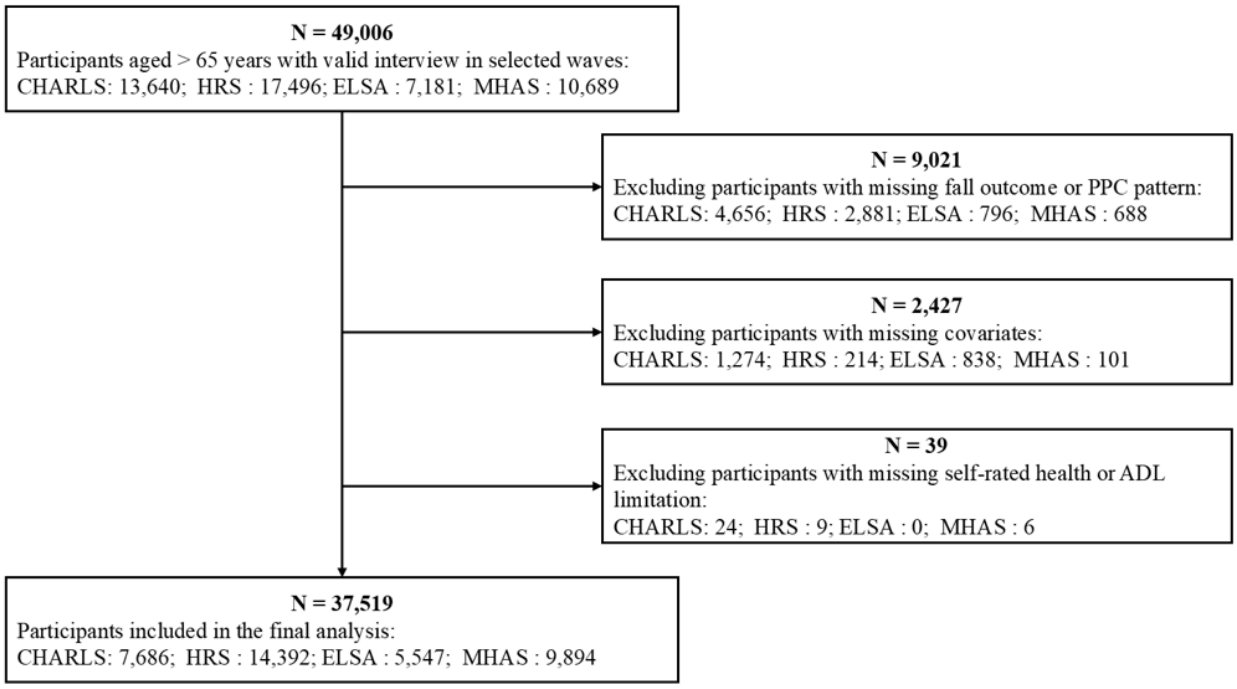


Figure 1

The flowchart of the study design

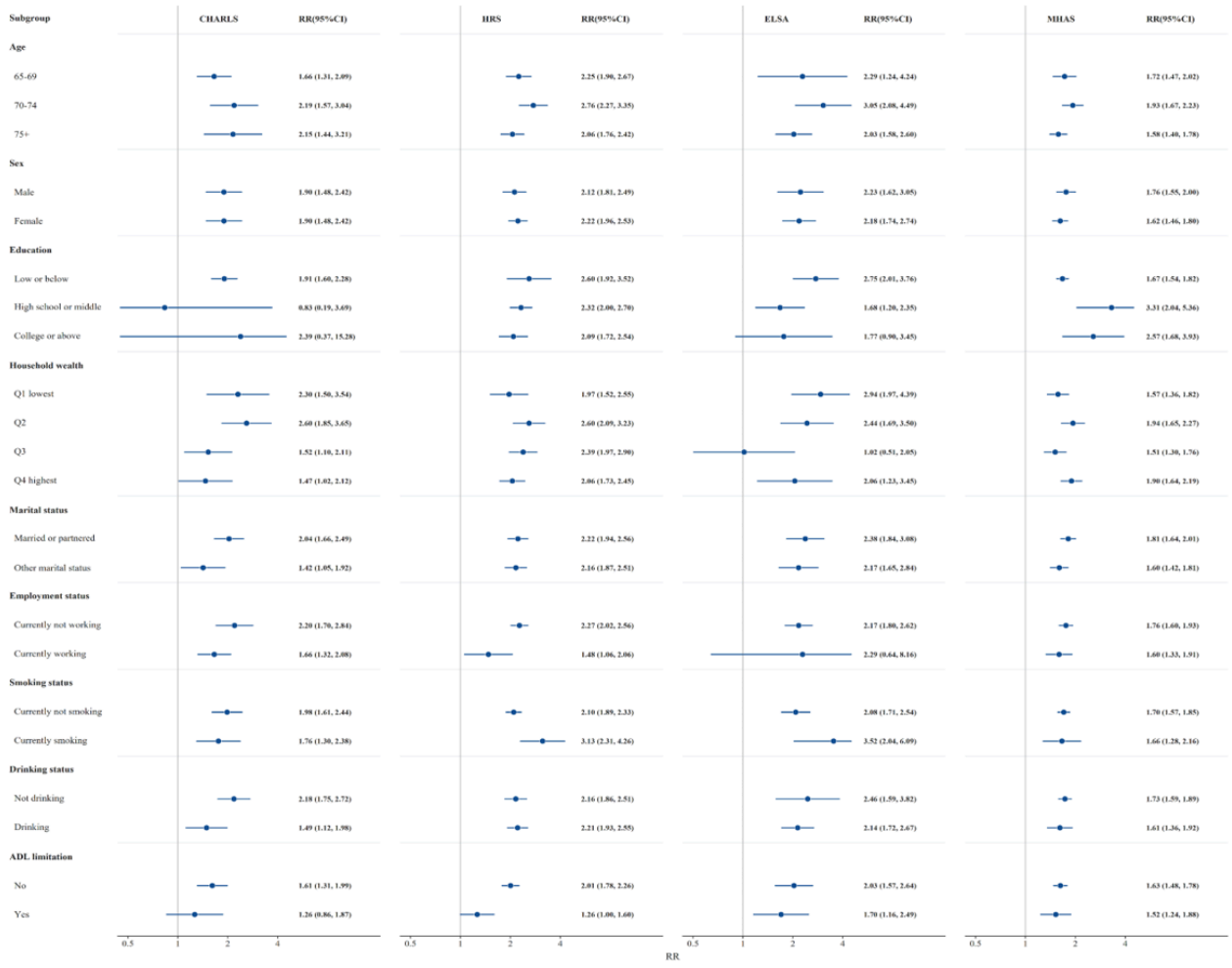


Figure 2

Association between physical, psychological and cognitive morbidity and falls stratified by different factors

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