

Divergent fall burden across multidimensional health, functional, and social profiles among adults aged 60 years and older: a cross-sectional latent class analysis of BRFSS

Onchira Vadtanapong

Chulabhorn Royal Academy

Prasert Kham-ai

Chulabhorn Royal Academy

Kancharee Pattana

kancharee.pat@cra.ac.th

Chulabhorn Royal Academy

Peng Li

University of Alabama at Birmingham

Research Article

Keywords: Falls, older adults, latent class analysis, multimorbidity, functional limitation, social determinants of health, BRFSS

Posted Date: October 12th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10859026/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Falls arise from interacting clinical, functional, and social factors, but it remains unclear whether older adults with substantial morbidity or cardiometabolic treatment-status indicators experience similar fall burden when their functional, cognitive, mobility, and social characteristics differ. This study aimed to identify multidimensional population profiles and examine differences in self-reported falls across these configurations.

Methods

We conducted a cross-sectional analysis of the 2023 Behavioral Risk Factor Surveillance System. Latent class analysis included 189,639 U.S. adults aged 60 years or older and 21 indicators spanning chronic morbidity, cardiometabolic treatment status, functional and sensory limitations, and social-disadvantage indicators. Associations with falls were estimated using survey-weighted regression adjusted for age group, sex, and race/ethnicity. Sensitivity analyses used posterior-probability weighting, prevalence ratios, restriction to adults aged 65 years or older, and injurious falls.

Results

Six profiles were identified. Among 187,435 respondents with fall data, survey-weighted fall prevalence ranged from 17.11% in the Low-Burden Independent Profile to 57.08% in the Complex Multidomain Dependency Profile. Adjusted odds ratios for Classes 2–6 versus the Low-Burden Independent Profile were 6.97, 3.93, 2.31, 1.29, and 1.90, respectively. Notably, the Cardiovascular-Functional Compromise and Cardiometabolic-Functional Preservation Profiles showed contrasting fall burden despite prominent cardiometabolic treatment-status indicators: adjusted odds ratios were 2.31 and 1.29, respectively. Associations were stronger for injurious falls and remained consistent across sensitivity analyses.

Conclusions

Fall burden did not simply parallel morbidity or cardiometabolic treatment status but differed substantially according to the broader functional, cognitive, mobility, and social configuration in which these conditions occurred. These population-level profiles may inform multidomain fall surveillance and prevention research but should not be interpreted as clinical diagnoses or prospective risk categories.

Background

As a leading cause of morbidity, mortality, and loss of independence in aging populations worldwide, falls are a major public health concern [1]. In the United States, an estimated 14 million adults aged 65

years or older reported at least one fall in 2020; thus, falls are the leading cause of fatal and nonfatal injuries in this age group [2]. In addition to acute injury, falls are associated with functional decline, loss of independence, increased use of healthcare services, and increased expenditure [3].

Falls in later life are multifactorial rather than attributable to a single isolated exposure, as their risk emerges from interactions among age-related physiological changes and multiple intrinsic and extrinsic factors, including chronic disease, functional and sensory impairment, medication-related effects, and environmental hazards [2]. Consistent with this view, a recent systematic review and meta-analysis found that older age, female sex, previous falls, fear of falling, depression, visual impairment, dementia, and balance disorder were significantly associated with falls among community-dwelling older adults [4].

Multimorbidity is especially relevant to fall vulnerability because many older adults live with multiple potentially interacting chronic conditions that may reduce physiological reserve and increase functional burden. In a 3-year, multicountry prospective study, each additional chronic disease was associated with higher rates of all falls and injurious falls, and multimorbidity was associated with greater fall incidence even among generally healthy and active community-dwelling older adults [5]. Similarly, a community-based study in China found higher odds of falling and recurrent falling among older adults with multimorbidity, highlighting the importance of disease clustering rather than isolated conditions alone [6]. Treatment-related factors are also relevant because multimorbidity and polypharmacy frequently co-occur in later life [7], and polypharmacy has been associated with frailty, cognitive and functional impairment, falls, hospitalization, and mortality [8].

Social circumstances may also contribute to fall vulnerability. Social vulnerability, conceptualized as limitations in social connections, support, or participation, has been linked to frailty, physical decline, and cognitive impairment among older adults [9]. Longitudinal evidence has also shown that poor social support is associated with incident frailty among community-dwelling older adults [10]. Because these conditions may interact with morbidity and disability to influence independence, access to assistance, and exposure to hazards, social circumstances should be considered alongside clinical and functional factors when characterizing fall-associated profiles in later life [9, 10].

Falls in later life rarely result from a single risk factor. Rather, they reflect combinations of chronic conditions, treatment status, functional and cognitive limitations, mobility problems, and social circumstances that occur together within the same individual [11]. Examining these factors separately may therefore overlook important patterns of vulnerability that are not readily apparent from any single observed characteristic. Person-centered approaches such as latent class analysis can identify such underlying profiles by grouping individuals who share similar combinations of characteristics [12]. Previous studies have used latent class analysis to describe multimorbidity profiles among older adults [13] and to support fall-risk classification [14]. However, it remains unclear whether integrating clinical, functional, cognitive, mobility, treatment-related, and social characteristics reveals distinct profiles with substantially different levels of fall occurrence.

Understanding these latent profiles may be important for fall prevention because older adults with apparently similar disease or treatment status may have very different functional, cognitive, mobility, or social needs. Identifying these multidimensional configurations can therefore provide a more complete basis for person-centered assessment and help indicate which domains may require greater attention in fall-prevention planning. Rather than relying only on readily observable characteristics or disease counts, recognizing how vulnerabilities cluster within individuals may support more appropriately tailored prevention strategies. In particular, it is important to determine whether older adults with substantial cardiometabolic morbidity or treatment-status indicators experience different fall burden depending on whether functional capacity is preserved or compromised.

Therefore, using data from the 2023 Behavioral Risk Factor Surveillance System (BRFSS), we identified multidimensional profiles among adults aged 60 years or older based on chronic morbidity, cardiometabolic treatment status, functional and sensory limitations, and social-disadvantage indicators [15]. Our objective extended beyond identifying latent classes: we examined whether fall occurrence differed across cross-domain configurations and whether functional preservation versus limitation distinguished the fall burden of profiles with substantial morbidity or treatment-status indicators. We hypothesized that profiles combining morbidity with functional, cognitive, or mobility limitation would show substantially greater fall occurrence than profiles in which chronic or cardiometabolic conditions occurred with relative functional preservation. We additionally examined whether the observed ordering persisted for injurious falls and across analyses addressing classification uncertainty.

Methods

Study design and data source

This cross-sectional study used data from the 2023 Behavioral Risk Factor Surveillance System (BRFSS), a state-based survey of noninstitutionalized adults in the United States. The BRFSS uses a complex sampling design incorporating stratification, clustering, and sampling weights to support population-level inference. The present analysis focused on U.S. adults aged 60 years or older.

Study population

The analytic sample was restricted to respondents aged 60 years or older using the BRFSS age variable (`_AGE80`). A total of 207,121 respondents met the age criterion. After applying the final indicator coding scheme and retaining respondents with complete data on all latent class indicators, 189,639 respondents were included in the primary LCA, representing 91.6% of the age-eligible sample.

Outcome measures

Considering the highly skewed and zero-inflated distribution of fall counts in the BRFSS, falls were modeled as a binary outcome to improve the robustness and interpretability of the results. The primary outcome was any fall in the past 12 months, derived from the BRFSS falls question (*FALL12MN*). Respondents reporting one or more falls were coded as 1, whereas respondents reporting no falls were coded as 0. Responses indicating refusal or "don't know/not sure" were treated as missing for the outcome. A secondary outcome used in sensitivity analysis was at least one injurious fall in the past 12 months, derived from *FALLINJ5*. This outcome was coded as 1 for respondents reporting one or more fall-related injuries and 0 for those reporting none.

Latent class indicators

Latent class indicators were selected a priori to reflect four multidimensional domains potentially relevant to falls: chronic morbidity, cardiometabolic treatment status, functional and sensory limitations, and social disadvantage.

Comorbidity indicators

The following self-reported chronic conditions were included as morbidity indicators: myocardial infarction (*CVDINFR4*), coronary heart disease or angina (*CVDCRHD4*), stroke (*CVDSTRK3*), chronic obstructive pulmonary disease (*CHCCOPD3*), depressive disorder (*ADDEPEV3*), chronic kidney disease (*CHCKDNY2*), and arthritis (*HAVARTH4*).

For these indicators, responses were coded as 1 = yes, 0 = no, and 2 = unknown/refused. Uncertainty responses were retained as a separate category to reduce exclusions from the LCA.

Cardiometabolic treatment-status indicators

Because medication-related questions in the 2023 BRFSS followed skip patterns, direct inclusion of medication items would have produced substantial missingness. To address this issue, we created composite categorical indicators representing hypertension and diabetes status together with the corresponding treatment information.

For hypertension, *BPHIGH6* and *BPMEDS1* were combined into a six-level variable (*htn_tx*): 0 = no hypertension, 1 = borderline hypertension, 2 = hypertension without medication, 3 = hypertension with medication, 4 = hypertension with medication status unknown/not asked, and 5 = hypertension status unknown.

For diabetes, *DIABETE4* and *INSULIN1* were combined into a six-level variable (*dm_ins*): 0 = no diabetes, 1 = prediabetes/borderline diabetes, 2 = diabetes without insulin, 3 = diabetes with insulin use, 4 = diabetes with insulin status unknown/not asked, and 5 = diabetes status unknown.

Use of cholesterol-lowering medication (*CHOLMED3*) was coded as 1 = yes, 0 = no, and 2 = unknown/refused. These coding decisions accommodated BRFSS skip patterns while preserving clinically relevant distinctions in disease and treatment status. The variables represent cardiometabolic treatment status rather than medication burden, polypharmacy, treatment complexity, or treatment-related adverse effects.

Biophysical and functional indicators

Functional and sensory limitation was represented by hearing difficulty (*DEAF*), vision difficulty (*BLIND*), cognitive difficulty (*DECIDE*), difficulty walking or climbing stairs (*DIFFWALK*), difficulty dressing or bathing (*DIFFDRES*), and difficulty doing errands alone (*DIFFALON*). Each indicator was coded as 1 = yes, 0 = no, and 2 = unknown/refused.

Social-disadvantage indicators

Social-disadvantage indicators included education (*EDUCA*), household income (*INCOME3*), housing tenure (*RENTHOM1*), marital status (*MARITAL*), and employment status (*EMPLOY1*).

Low education represented less than high school graduation (*EDUCA* categories 1–3), and low income represented annual household income below \$25,000 (*INCOME3* categories 1–4). Renting was coded from *RENTHOM1* = 2. Not currently married included *MARITAL* categories 2–6, whereas *MARITAL* = 1 represented married respondents. Not working included homemakers, students, retirees, and respondents unable to work (*EMPLOY1* categories 5–8); respondents employed for wages or self-employed were coded as working. Other or uncertain responses were retained as a separate category.

These indicators were treated as proxies of social disadvantage; they do not directly measure social isolation, social support, housing safety, or financial hardship.

Rationale for handling unknown and skip-pattern responses

Direct use of medication items initially resulted in substantial sample loss because only eligible subgroups received questions about insulin and blood pressure medication. To reduce exclusions associated with these skip patterns, disease and treatment responses were combined into structured categorical indicators, and uncertainty responses were retained as separate categories. This approach retained 91.6% of age-eligible respondents for the LCA.

Latent class analysis

In this study, LCA was used to identify unobserved subgroups with distinct constellations of morbidity, cardiometabolic treatment status, functional and sensory limitations, and social-disadvantage

indicators. Candidate solutions containing one to eight classes were first estimated in a random subsample of 30,000 respondents using 20 random starts and a maximum of 5,000 iterations. Model selection considered the Bayesian information criterion, sample-size-adjusted Bayesian information criterion, entropy, minimum class size, replication of the best log-likelihood, substantive interpretability, and stability. The final six-class solution was then re-estimated in the full analytic sample using 50 random starts, a maximum of 5,000 iterations, a convergence tolerance of 1×10^{-5} , and random seed 4321. The best log-likelihood was replicated in 34 of 50 starts.

Each respondent was assigned to the class with the highest posterior probability for the primary analysis. Classification quality was assessed using class-specific average posterior probabilities (APPs) and relative entropy. Higher APPs indicate clearer class assignment, whereas entropy summarizes overall separation across classes.

Survey-weighted regression analysis

Latent classes were estimated without survey weights because poLCA does not directly incorporate complex survey design variables. Associations between class membership and falls were subsequently examined using survey-weighted analyses incorporating the BRFSS primary sampling unit (*_PSU*), stratum (*_STSTR*), and final sampling weight (*_LLCPWT*). The survey option for strata containing a single primary sampling unit was set to "adjust." Survey-weighted prevalence estimates with 95% confidence intervals were calculated overall and by modal class.

The primary association analysis used survey-weighted logistic regression with modal class assignment. Model 1 adjusted for age group, whereas the primary fully adjusted model included age group, sex, and race/ethnicity. Age was categorized as 60–64, 65–69, 70–74, 75–79, and 80 years or older because *_AGE80* top-codes respondents aged 80 years or older.

Class 1 was used as the reference category. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated from the survey-weighted model coefficients. Respondents with missing outcome or covariate data were excluded from the corresponding outcome model.

Sensitivity analyses

Four sensitivity analyses evaluated the robustness of the outcome associations.

1. Posterior-probability-weighted regression

To account for classification uncertainty, each respondent contributed one record to each of the six classes. The BRFSS sampling weight was multiplied by the respondent's posterior probability for that class, and individual observations were clustered within primary sampling units. These models were treated as sensitivity analyses rather than formal bias-adjusted three-step corrections.

2. Prevalence-ratio model

Because falls were common, survey-weighted Poisson regression with a log link and robust variance was used to estimate adjusted prevalence ratios.

3. Restriction to adults aged 65 years or older

The fully adjusted logistic regression model was repeated after excluding respondents aged 60–64 years.

4. Alternative outcome definition

The fully adjusted analysis was repeated using injurious fall in the past 12 months as the outcome. Respondents reporting no falls or no fall-related injuries were coded as 0, whereas respondents reporting one or more fall-related injuries were coded as 1.

Domain score visualization

For descriptive visualization only, individual-level scores were calculated for chronic morbidity, cardiometabolic treatment status, functional and sensory limitation, and social disadvantage. Scores were standardized from 0 to 100, with higher values indicating a greater proportion of endorsed characteristics among indicators with known responses. Unknown or refused responses were excluded from each respondent-specific denominator. These scores were not used to estimate the latent classes or outcome models.

Class labeling and interpretation

Class labels were assigned to summarize the dominant cross-domain configuration rather than any single indicator. Naming emphasized combinations of morbidity, functional and cognitive limitation, mobility, cardiometabolic treatment status, and social-context indicators that distinguished one class from another. Where informative, labels were constructed as paired contrasts, particularly to distinguish cardiometabolic burden accompanied by functional compromise from cardiometabolic burden occurring with relative functional preservation. The labels were interpretive summaries of empirically derived response patterns and were not intended to represent clinical diagnoses, validated phenotypes, prospective risk categories, or treatment-allocation rules.

Statistical software

All analyses were performed in R version 4.5.3. Data were imported using haven, latent class models were estimated using poLCA, and complex-sample prevalence and regression analyses were conducted using survey. Data management and reshaping were performed using dplyr and tidyr [16].

Results

Study sample and participant characteristics

The 2023 BRFSS included 433,323 respondents. After excluding respondents younger than 60 years, 207,121 were eligible, and 189,639 (91.6%) had complete data for all LCA indicators and comprised the latent class analytic sample. The analytic sample had a survey-weighted mean age of 70.13 years; 54.4% were women and 70.7% were White, non-Hispanic. Overall sociodemographic characteristics of the analytic sample are presented in Table 1.

Table 1

Survey-weighted sociodemographic characteristics of the latent class analytic sample (N = 189,639)

Characteristic	Unweighted n	Survey-weighted estimate
Age, mean years	189,639	70.13
Age group, years		
60–64	38,597	26.8%
65–69	43,019	22.2%
70–74	41,572	21.0%
75–79	32,093	14.3%
≥ 80	34,358	15.7%
Sex		
Male	84,331	45.6%
Female	105,308	54.4%
Race/ethnicity		
White, non-Hispanic	158,823	70.7%
Black, non-Hispanic	12,320	10.6%
Asian, non-Hispanic	2,575	3.5%
American Indian/Alaska Native, non-Hispanic	2,288	0.8%
Hispanic	8,616	11.2%
Other race, non-Hispanic	5,017	3.1%
Education		
High school graduate or higher	179,649	88.6%
Less than high school	9,346	11.0%
Unknown	644	0.4%
Annual household income		
Note. Estimates are survey-weighted using the 2023 BRFSS final sampling weights, strata, and primary sampling units. Unweighted n represents the number of respondents in the latent class analytic sample. Education, household income, housing tenure, marital status, and employment status were included as indicators in the latent class analysis and are presented here to describe the overall analytic sample rather than to compare latent classes. Age was based on the BRFSS _AGE80 variable and therefore was top-coded at 80 years. “Not working” corresponds to the prespecified LCA coding and includes homemakers, students, retirees, and respondents unable to work.		

Characteristic	Unweighted n	Survey-weighted estimate
≥\$25,000/year	127,582	64.3%
<\$25,000/year	23,506	13.8%
Unknown	38,551	22.0%
Housing tenure		
Own home	159,479	86.6%
Rent home	24,333	10.6%
Other/unknown	5,827	2.8%
Marital status		
Married	104,053	58.4%
Not currently married	84,391	41.0%
Unknown	1,195	0.7%
Employment status		
Working	44,767	25.4%
Not working	140,607	71.7%
Other/unknown	4,265	2.8%
Note. Estimates are survey-weighted using the 2023 BRFSS final sampling weights, strata, and primary sampling units. Unweighted n represents the number of respondents in the latent class analytic sample. Education, household income, housing tenure, marital status, and employment status were included as indicators in the latent class analysis and are presented here to describe the overall analytic sample rather than to compare latent classes. Age was based on the BRFSS _AGE80 variable and therefore was top-coded at 80 years. “Not working” corresponds to the prespecified LCA coding and includes homemakers, students, retirees, and respondents unable to work.		

Latent class identification

Candidate solutions showed progressively lower information criteria as the number of classes increased. However, the seven- and eight-class solutions contained modal classes representing only 1.25% and 1.16% of the screening sample, respectively, whereas the six-class solution had a minimum modal class size of 6.63%. The six-class solution was therefore retained because it provided the most defensible balance of model fit, class-size adequacy, stability, and substantive interpretability (Table 2).

Table 2

Fit and classification indices for one- to eight-class solutions in the screening sample (n = 30,000)

Classes	Log-likelihood	BIC	Adjusted BIC	Entropy	Minimum class, %	Best log-likelihood replications
1	-316,320	633,134	632,981	NA	100.00	NA
2	-300,816	602,632	602,324	0.758	28.45	20
3	-297,593	596,691	596,227	0.660	21.38	17
4	-295,650	593,310	592,690	0.656	13.80	20
5	-294,693	591,902	591,126	0.674	9.17	1
6	-293,817	590,654	589,723	0.655	6.63	8
7	-293,154	589,833	588,747	0.676	1.25	8
8	-292,570	589,171	587,929	0.671	1.16	2
<i>Note. BIC = Bayesian information criterion. Adjusted BIC = sample-size-adjusted Bayesian information criterion. Entropy ranges from 0 to 1, with higher values indicating clearer overall class separation. Minimum class percentage is based on modal assignment. Candidate models used 20 random starts.</i>						

In the final full-sample model, the best log-likelihood was replicated in 34 of 50 random starts, the model converged after 278 iterations, and relative entropy was 0.661. Class-specific average posterior probabilities ranged from 0.703 to 0.828, indicating acceptable classification quality. The final solution comprised six profiles: Class 1, Low-Burden Independent Profile (31.17%); Class 2, Complex Multidomain Dependency Profile (7.26%); Class 3, Mobility-Constrained Musculoskeletal Profile (11.78%); Class 4, Cardiovascular-Functional Compromise Profile (7.10%); Class 5, Cardiometabolic-Functional Preservation Profile (27.73%); and Class 6, Social-Context Mixed-Burden Profile (14.96%).

Latent class profiles

Class 1 (Low-Burden Independent Profile) had the lowest probabilities of most chronic conditions, cardiometabolic treatment-status indicators, functional limitations, and social-disadvantage indicators; therefore, it served as the reference profile. The label reflects relative preservation across the measured domains rather than absence of morbidity.

Class 2 (Complex Multidomain Dependency Profile) showed the broadest concentration of adverse indicators across domains. Defining features included arthritis (0.778), depression (0.476), difficulty walking or climbing stairs (0.908), cognitive difficulty (0.439), difficulty dressing or bathing (0.410), difficulty doing errands alone (0.581), low income (0.475), and not-currently-married status (0.784). The label emphasizes the simultaneous presence of morbidity and multiple mobility, cognitive, and activity limitations rather than a single dominant disease.

Class 3 (Mobility-Constrained Musculoskeletal Profile) was characterized by high probabilities of arthritis (0.783) and difficulty walking or climbing stairs (0.701), with more moderate cognitive and activity limitations than Class 2. Its identity therefore reflects a predominantly musculoskeletal-mobility pattern rather than generalized multidomain dependency.

Class 4 (Cardiovascular-Functional Compromise Profile) had the highest probabilities of myocardial infarction (0.648), coronary heart disease or angina (0.676), treated hypertension (0.771), and cholesterol-lowering medication use (0.833), together with moderate mobility limitation. The label highlights cardiovascular burden occurring in the context of measurable functional compromise.

Class 5 (Cardiometabolic-Functional Preservation Profile) showed high probabilities of treated hypertension (0.726) and cholesterol-lowering medication use (0.761) but low probabilities of cognitive and functional limitations. This identity was intentionally framed as a contrast to Class 4: prominent cardiometabolic treatment-status indicators occurred with relative functional preservation.

Class 6 (Social-Context Mixed-Burden Profile) combined moderate morbidity and functional limitation with high probabilities of low income (0.435), renting a home (0.380), and not-currently-married status (0.855). The label emphasizes the co-occurrence of mixed health burden with social-context indicators; these proxies should not be interpreted as direct measures of social isolation, financial hardship, or housing safety.

Table 3 summarizes the interpretive identity, defining configuration, distinguishing feature, and observed fall prevalence of each profile. Figure 1 presents the underlying class-specific conditional probabilities across the four indicator domains.

Table 3
Interpretive identities and distinguishing configurations of the six multidimensional profiles

Profile	Estimated class, %	Defining configuration	Distinguishing identity	Any fall, %
Class 1. Low-Burden Independent Profile	31.17	Low probabilities across most measured indicators	Broad relative preservation; reference configuration	17.11
Class 2. Complex Multidomain Dependency Profile	7.26	Multimorbidity plus marked walking, cognitive, dressing/bathing, and errands limitations	Broadest cross-domain morbidity and activity limitation	57.08
Class 3. Mobility-Constrained Musculoskeletal Profile	11.78	Arthritis plus pronounced walking/climbing-stairs limitation	Musculoskeletal-mobility dominant; less generalized dependency than Class 2	44.98
Class 4. Cardiovascular-Functional Compromise Profile	7.10	Cardiovascular multimorbidity, treated cardiometabolic indicators, and mobility limitation	Cardiovascular burden with functional compromise	32.07
Class 5. Cardiometabolic-Functional Preservation Profile	27.73	Treated hypertension/cholesterol medication with low cognitive and functional limitation	Cardiometabolic treatment-status burden with functional preservation	20.82
Class 6. Social-Context Mixed-Burden Profile	14.96	Mixed morbidity and moderate functional limitation plus low income, renting, and not-currently-married status	Social-context indicators with moderate clinical and functional burden	26.60
<i>Note. Profile labels summarize dominant cross-domain response patterns and are interpretive rather than diagnostic. Estimated class percentages are model-based proportions from the final LCA. Any-fall percentages are survey-weighted prevalence estimates. Social-context indicators are proxies and do not directly measure social isolation, financial hardship, or housing safety.</i>				

In Fig. 1, columns are identified as Classes 1–6; the corresponding profile identities are summarized in Table 3. Figure 2 presents standardized individual-level domain-score distributions as a descriptive visualization. Higher scores indicate greater morbidity, cardiometabolic treatment status, functional and sensory limitation, or social disadvantage; these scores were not used to define the classes.

Association between multidimensional profiles and falls

Among the 187,435 respondents included in the any-fall analysis, the overall survey-weighted prevalence of any fall was 26.78% (95% CI 26.32–27.26). Prevalence ranged from 17.11% in the Low-Burden Independent Profile (Class 1) to 57.08% in the Complex Multidomain Dependency Profile (Class 2);

corresponding estimates were 44.98% for the Mobility-Constrained Musculoskeletal Profile (Class 3), 32.07% for the Cardiovascular-Functional Compromise Profile (Class 4), 20.82% for the Cardiometabolic-Functional Preservation Profile (Class 5), and 26.60% for the Social-Context Mixed-Burden Profile (Class 6) (Table 4).

Table 4
Survey-weighted prevalence and association of multidimensional profiles with any fall in the past 12 months

Latent profile	Estimated class, %	Outcome n	Any fall, % (95% CI)	Adjusted OR (95% CI)	Posterior-weighted OR (95% CI)
Class 1. Low-Burden Independent Profile	31.17	63,970	17.11 (16.44–17.80)	Reference	Reference
Class 2. Complex Multidomain Dependency Profile	7.26	12,709	57.08 (55.00–59.14)	6.97 (6.31–7.69)	6.35 (5.84–6.91)
Class 3. Mobility-Constrained Musculoskeletal Profile	11.78	20,952	44.98 (43.40–46.57)	3.93 (3.63–4.27)	3.45 (3.24–3.67)
Class 4. Cardiovascular-Functional Compromise Profile	7.10	12,459	32.07 (30.29–33.90)	2.31 (2.09–2.54)	2.18 (2.02–2.36)
Class 5. Cardiometabolic-Functional Preservation Profile	27.73	50,631	20.82 (20.02–21.65)	1.29 (1.20–1.38)	1.23 (1.17–1.29)
Class 6. Social-Context Mixed-Burden Profile	14.96	26,714	26.60 (25.33–27.92)	1.90 (1.75–2.06)	1.77 (1.66–1.88)
<i>Note. Estimated class percentages are model-based proportions from the final LCA. Outcome n values are unweighted modal-class counts among respondents included in the any-fall analysis (n = 187,435). Prevalence estimates are survey weighted. Adjusted ORs control for age group, sex, and race/ethnicity. Posterior-weighted models multiply the BRFSS sampling weight by class-membership probability. Class 1 is the reference. OR = odds ratio; CI = confidence interval.</i>					

In the fully adjusted model, Classes 2–6 had significantly higher odds of reporting any fall in the past 12 months than the Low-Burden Independent Profile. Adjusted ORs were 6.97 (95% CI 6.31–7.69) for the Complex Multidomain Dependency Profile, 3.93 (3.63–4.27) for the Mobility-Constrained Musculoskeletal Profile, 2.31 (2.09–2.54) for the Cardiovascular-Functional Compromise Profile, 1.29 (1.20–1.38) for the Cardiometabolic-Functional Preservation Profile, and 1.90 (1.75–2.06) for the Social-

Context Mixed-Burden Profile (all $p < .001$). Posterior-probability-weighted estimates were slightly attenuated but preserved the same ordering: 6.35, 3.45, 2.18, 1.23, and 1.77, respectively (all $p < .001$).

A particularly informative contrast emerged between the Cardiovascular-Functional Compromise and Cardiometabolic-Functional Preservation Profiles. Both showed prominent cardiometabolic treatment-status indicators, but their functional configurations and fall burden diverged. The Cardiovascular-Functional Compromise Profile had a fall prevalence of 32.07% and an adjusted OR of 2.31, whereas the Cardiometabolic-Functional Preservation Profile had a prevalence of 20.82% and an adjusted OR of 1.29. The greatest fall burden occurred in the Complex Multidomain Dependency and Mobility-Constrained Musculoskeletal Profiles, both characterized by marked functional, cognitive, or mobility limitation.

Sensitivity analyses

Sensitivity analyses consistently supported the primary ordering of associations (Table S1). Adjusted prevalence ratios were 3.46 for Class 2, 2.60 for Class 3, 1.88 for Class 4, 1.22 for Class 5, and 1.63 for Class 6. Restriction to adults aged 65 years or older produced a similar pattern. Associations were stronger for injurious falls: adjusted ORs were 9.02, 4.65, 3.17, 1.40, and 2.20 for Classes 2–6, respectively. Posterior-probability-weighted estimates for injurious falls remained significant and followed the same pattern.

Taken together, the modal-assignment, posterior-probability-weighted, prevalence-ratio, age-restricted, and injurious-fall analyses yielded substantively consistent findings.

Discussion

The principal finding of this study was not simply the identification of six latent profiles, but the divergence in fall burden across distinct multidomain configurations. The profile identities summarized in Table 3 make these contrasts explicit: fall occurrence was highest in the Complex Multidomain Dependency and Mobility-Constrained Musculoskeletal Profiles, whereas prominent cardiometabolic treatment-status indicators accompanied by relative functional preservation were associated with substantially lower fall burden. The most informative contrast was between the Cardiovascular-Functional Compromise and Cardiometabolic-Functional Preservation Profiles, which shared prominent cardiometabolic features but differed in functional status and in adjusted odds of falls (2.31 versus 1.29).

These findings suggest that chronic disease or treatment status alone does not adequately characterize fall-associated heterogeneity in older adults; the broader configuration in which morbidity occurs appears to distinguish markedly different levels of fall occurrence. This extends person-centered fall research [4, 14] by shifting the interpretive focus from the mere existence of latent classes to the contrasts between their cross-domain configurations. The same ordering persisted after accounting for classification uncertainty, using prevalence ratios, restricting the sample to adults aged 65 years or older, and examining injurious falls. Because the study was cross-sectional, these profiles should be

interpreted as empirical configurations associated with falls rather than causal pathways, clinical diagnoses, or prospectively validated risk strata.

Contrasting high-burden profiles: multidomain dependency versus mobility-constrained musculoskeletal pattern

The Complex Multidomain Dependency Profile had the highest prevalence and adjusted odds of falls and combined multimorbidity with marked mobility, cognitive, and activity limitations. Difficulty walking or climbing stairs (0.908), cognitive difficulty (0.439), and difficulty doing errands alone (0.581) were particularly prominent. This pattern is consistent with evidence that concurrent impairments across mobility and cognition are associated with elevated fall vulnerability [17]. The term dependency in the profile label refers to the clustering of activity limitations within the observed indicators and should not be interpreted as a validated dependency or frailty diagnosis.

The Mobility-Constrained Musculoskeletal Profile represented a different high-burden configuration. It was dominated by arthritis (0.783) and mobility limitation (0.701), yet showed less extensive cognitive and activity limitation than the Complex Multidomain Dependency Profile. Despite this narrower configuration, it had nearly fourfold higher adjusted odds of falls than the Low-Burden Independent Profile. This pattern is consistent with evidence linking musculoskeletal impairment and mobility limitation to recurrent falls among older adults with knee osteoarthritis [18] and supports assessment of gait, mobility, pain, and activity limitation when planning individualized fall-prevention interventions [19]. Together, Classes 2 and 3 show that high fall burden can arise from different configurations: broad multidomain dependency or a more concentrated musculoskeletal-mobility constraint.

Similar cardiometabolic burden, divergent functional context

The Cardiovascular-Functional Compromise and Cardiometabolic-Functional Preservation Profiles provide the clearest within-study contrast supporting the central interpretation. Both showed prominent cardiometabolic treatment-status indicators, but the former combined cardiovascular multimorbidity with moderate functional limitation and had more than twice the adjusted odds of falls, whereas the latter retained relative functional preservation and showed only a 29% increase in adjusted odds. This contrast suggests that the functional context accompanying cardiometabolic morbidity may be more informative for understanding fall-associated heterogeneity than treatment-status indicators considered in isolation.

The BRFSS variables used in this study captured hypertension treatment, insulin use, and cholesterol-lowering medication use but did not measure medication count, specific drug classes, doses, adherence, regimen complexity, or orthostatic hypotension. Accordingly, the observed class differences cannot be attributed directly to polypharmacy or adverse medication effects. Medication reconciliation and review

of drugs that increase fall risk remain clinically relevant, but these mechanisms require direct evaluation in future studies [2, 20].

A distinct social-context mixed-burden configuration

The Social-Context Mixed-Burden Profile combined moderate morbidity and functional limitation with low income, renting, and not-currently-married status and had 90% higher adjusted odds of falls than the Low-Burden Independent Profile. Its identity is distinct from the predominantly clinical and functional configurations of Classes 2–5 because social-context indicators are part of the defining pattern. These findings suggest that socioeconomic circumstances may add useful context to multidomain assessment. Importantly, marital status is not equivalent to living arrangement, lack of support, or social isolation, and renting does not directly measure housing safety. The profile therefore supports direct assessment of social support, financial barriers, and the home environment rather than assuming these conditions from the BRFSS indicators alone [21].

Robustness and classification uncertainty

The ordering of associations was stable across multiple sensitivity analyses. Posterior-probability weighting produced modestly smaller estimates than modal assignment, as expected when classification uncertainty was incorporated, but all associations remained statistically significant. Prevalence-ratio models and restriction to adults aged 65 years or older yielded the same substantive pattern. Associations were stronger for injurious falls, particularly for Classes 2 and 3, indicating that profiles marked by functional, cognitive, and mobility limitation were also strongly associated with more consequential falls.

Methodological strengths

This study combines a large population-based sample with a person-centered analytic framework and multiple checks on model and outcome robustness. Candidate solutions from one to eight classes were systematically compared, the best log-likelihood for the final model was replicated across multiple starts, and classification quality was quantified using entropy and class-specific average posterior probabilities. Outcome analyses incorporated the BRFSS complex survey design and demographic adjustment, while sensitivity analyses addressed classification uncertainty, the commonness of the outcome, the age definition, and injurious falls. Structured handling of skip-pattern variables also retained 91.6% of age-eligible respondents for the latent class analysis.

Limitations

Several limitations should be considered. First, the cross-sectional design precludes temporal or causal inference, and class membership should not be interpreted as predicting future falls. Second, falls and all class indicators were self-reported and may have been affected by recall, reporting, or misclassification error. Third, the LCA was estimated without complex-survey weights, although survey design was incorporated into the prevalence and regression analyses. Fourth, posterior-probability

weighting reduced reliance on modal assignment but is not a formal bias-adjusted three-step correction. Fifth, retaining unknown and skip-pattern responses as explicit categories preserved the sample size but may have influenced class formation. Sixth, *_AGE80* top-codes respondents aged 80 years or older, limiting evaluation of age gradients within the oldest group. Seventh, the BRFSS is a telephone survey of noninstitutionalized adults and may underrepresent nursing-home residents and people with severe cognitive or functional impairment. Finally, the BRFSS lacked objective gait and balance assessments, a validated frailty measure, detailed medication data, and direct measures of social isolation, social support, home hazards, or treatment burden.

Interpretation and implications

The six profile identities should be viewed as empirical summaries of multidomain heterogeneity rather than clinical categories. Their value lies in making contrasts visible: similar or overlapping disease and treatment-status patterns can coexist with markedly different functional and social configurations and different prevalence of falls. For population surveillance and hypothesis generation, this profile-based framing may help identify combinations of mobility, cognition, activity limitation, treatment status, and social disadvantage that warrant joint consideration. At the individual level, however, assessment and intervention should be based on directly measured needs rather than latent-profile membership.

From a prevention perspective, the findings support assessment across domains rather than reliance on disease counts alone. The Complex Multidomain Dependency and Mobility-Constrained Musculoskeletal Profiles indicate different high-burden pathways for assessment, whereas the contrast between Cardiovascular-Functional Compromise and Cardiometabolic-Functional Preservation underscores the importance of functional status when interpreting cardiometabolic morbidity. The Social-Context Mixed-Burden Profile further indicates that health and functional assessment may need to be complemented by direct assessment of social support, financial barriers, housing conditions, transportation, and other contextual factors because the BRFSS social indicators are proxies rather than direct measures.

Conclusions

Fall burden among older adults did not simply parallel the presence of chronic morbidity or cardiometabolic treatment status but differed markedly across identifiable multidomain configurations. The Complex Multidomain Dependency and Mobility-Constrained Musculoskeletal Profiles showed the highest fall occurrence, whereas the Cardiometabolic-Functional Preservation Profile showed only a modest elevation despite prominent cardiometabolic treatment-status indicators. The contrast with the Cardiovascular-Functional Compromise Profile highlights the importance of the functional context in which morbidity occurs, while the Social-Context Mixed-Burden Profile illustrates an additional configuration in which social-disadvantage indicators co-occurred with mixed health burden. These contrasts became stronger for injurious falls and remained consistent across analyses addressing classification uncertainty, outcome prevalence, and age restriction. For public health surveillance and prevention research, the findings support multidomain characterization of fall-associated heterogeneity

rather than reliance on disease counts alone. The identified profiles are population-level empirical patterns and should not be interpreted as clinical diagnoses or prospective risk categories.

List of abbreviations

APP, average posterior probability; BIC, Bayesian information criterion; BRFSS, Behavioral Risk Factor Surveillance System; CI, confidence interval; LCA, latent class analysis; OR, odds ratio; PR, prevalence ratio; PSU, primary sampling unit.

Declarations

Human Ethics approval and consent to participate

The study protocol was reviewed by the Chulabhorn Royal Academy Institutional Review Board and was approved as exempt (Project Code: IRB 147/2569). This study involved secondary analysis of publicly available, de-identified data from the 2023 Behavioral Risk Factor Surveillance System (BRFSS). The investigators had no direct contact with participants and had no access to personally identifiable information. Accordingly, no additional informed consent was obtained for the present secondary analysis. The study was conducted in accordance with applicable ethical principles and international guidelines for research involving human participants.

Consent for publication

Not applicable.

Clinical trial number

Not applicable

Competing interests

The authors declare that they have no competing interests.

Use of generative artificial intelligence

During preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing. All AI-generated textual suggestions were critically reviewed, verified, and revised by the authors. No personally identifiable, confidential, or sensitive participant information was provided to the generative AI tool. The authors take full responsibility for the accuracy, integrity, and final content of the manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors and was conducted without external funding.

Author Contribution

O.V. conceived the research problem and research question, contributed to refinement of the research question and study design, and participated in data analysis. P.K. contributed to development of the research question, designed the study methodology, selected the data source, and conducted the data analysis. K.P. contributed to the study design and prepared the initial draft of the manuscript. P.L. provided overall scientific oversight, evaluated the feasibility of the study, independently reviewed the statistical analyses and presentation of the results, and critically reviewed the manuscript. All authors reviewed and approved the final manuscript.

Acknowledgement

We thank Peter Fogarty from Scribendi (www.scribendi.com) for language editing of an earlier draft of this manuscript.

Data Availability

The 2023 Behavioral Risk Factor Surveillance System data analyzed in this study are publicly available from the U.S. Centers for Disease Control and Prevention at (https://www.cdc.gov/brfss/annual_data/annual_2023.html)

References

1. World Health Organization. Step Safely: Strategies for preventing and managing falls across the life-course [Internet]. World Health Organization. 2021 [cited 2026 Mar 19]. Available from: <https://www.who.int/publications/i/item/978924002191-4>
2. Colón-Emeric CS, McDermott CL, Lee DS, Berry SD. Risk Assessment and Prevention of Falls in Older Community-Dwelling Adults: A Review. JAMA. 2024;331:1397–406.
3. Kakara R, Bergen G, Burns E, Stevens M. Nonfatal and Fatal Falls Among Adults Aged ≥ 65 Years - United States, 2020–2021. MMWR Morb Mortal Wkly Rep. 2023;72:938–43.
4. Li Y, Hou L, Zhao H, Xie R, Yi Y, Ding X. Risk factors for falls among community-dwelling older adults: A systematic review and meta-analysis. Front Med (Lausanne). 2022;9:1019094.
5. Huberty S, Freystätter G, Wiecezorek M, Dawson-Hughes B, Kanis JA, Rizzoli R, et al. Association Between Multimorbidity and Rate of Falls: A 3-Year 5-Country Prospective Study in Generally Healthy

- and Active Community-Dwelling Adults Aged ≥ 70 Years. *J Am Med Dir Assoc*. 2023;24:804–e8104.
6. Nie X-Y, Dong X-X, Lu H, Li D-L, Zhao C-H, Huang Y, et al. Multimorbidity patterns and the risk of falls among older adults: a community-based study in China. *BMC Geriatr*. 2024;24:660.
 7. Nicholson K, Liu W, Fitzpatrick D, Hardacre KA, Roberts S, Salerno J, et al. Prevalence of multimorbidity and polypharmacy among adults and older adults: a systematic review. *Lancet Healthy Longev*. 2024;5:e287–96.
 8. Hung A, Kim YH, Pavon JM. Deprescribing in older adults with polypharmacy. *BMJ*. 2024;385:e074892.
 9. Hanlon P, Wightman H, Politis M, Kirkpatrick S, Jones C, Andrew MK, et al. The relationship between frailty and social vulnerability: a systematic review. *Lancet Healthy Longev*. 2024;5:e214–26.
 10. Barghouth MH, Klein J, Bothe T, Ebert N, Schaeffner E, Mielke N. Social support and frailty progression in community-dwelling older adults. *Front Public Health*. 2024;12:1408641.
 11. Kohler-Voinov LC, Sayyid ZN, Cullen KE. Multifactorial predictors of falls in older adults: a decade of data from the National Health and Aging Trends Study. *BMC Geriatr*. 2025;25:950.
 12. Rachid T, Abarda A, Hasbaoui A. Latent class analysis: A review and recommendations for future applications in health sciences. *Procedia Comput Sci*. 2024;238:1062–7.
 13. Liu R, Nagel CL, Chen S, Newsom JT, Allore HG, Quiñones AR. Multimorbidity and associated informal care receiving characteristics for US older adults: a latent class analysis. *BMC Geriatr*. 2024;24:571.
 14. Bae S, Lee MJ, Pak D, Yoo E-Y, Kim J, Hong I. Development of Fall Risk Classification Models for Community-Dwelling Older Adults using Latent Class Analysis and Machine Learning. *Gerontology*. 2025;71:337–50.
 15. Centers for Disease Control and Prevention. 2023 BRFSS survey data and documentation [Internet]. Centers for Disease Control and Prevention. 2025 [cited 2026 Mar 19]. Available from: https://www.cdc.gov/brfss/annual_data/annual_2023.html
 16. R Core Team. R: The R Project for Statistical Computing [Internet]. R: A language and environment for statistical computing. 2025 [cited 2026 Jun 8]. Available from: <https://www.R-project.org/>
 17. Montero-Odasso M, van der Velde N, Martin FC, Petrovic M, Tan MP, Ryg J et al. World guidelines for falls prevention and management for older adults: a global initiative. *Age Ageing*. 2022;51.
 18. Iijima H, Aoyama T. Increased recurrent falls experience in older adults with coexisting of sarcopenia and knee osteoarthritis: a cross-sectional study. *BMC Geriatr*. 2021;21:698.
 19. Pua Y-H, Ong P-H, Clark RA, Matcher DB, Lim EC-W. Falls efficacy, postural balance, and risk for falls in older adults with falls-related emergency department visits: prospective cohort study. *BMC Geriatr*. 2017;17:291.
 20. Rasu RS, Xavier C, Rianon N. Dynamic changes in medication burden leading to fall and hospital readmissions in older adults: Toward a strategy for improving risk and managing costs. *J Manag Care Spec Pharm*. 2025;31:96–100.

21. Siefkas AC, McCarthy EP, Leff B, Dufour AB, Hannan MT. Social isolation and falls risk: lack of social contacts decreases the likelihood of bathroom modification among older adults with fear of falling. J Appl Gerontol. 2022;41:1293–300.

Figures

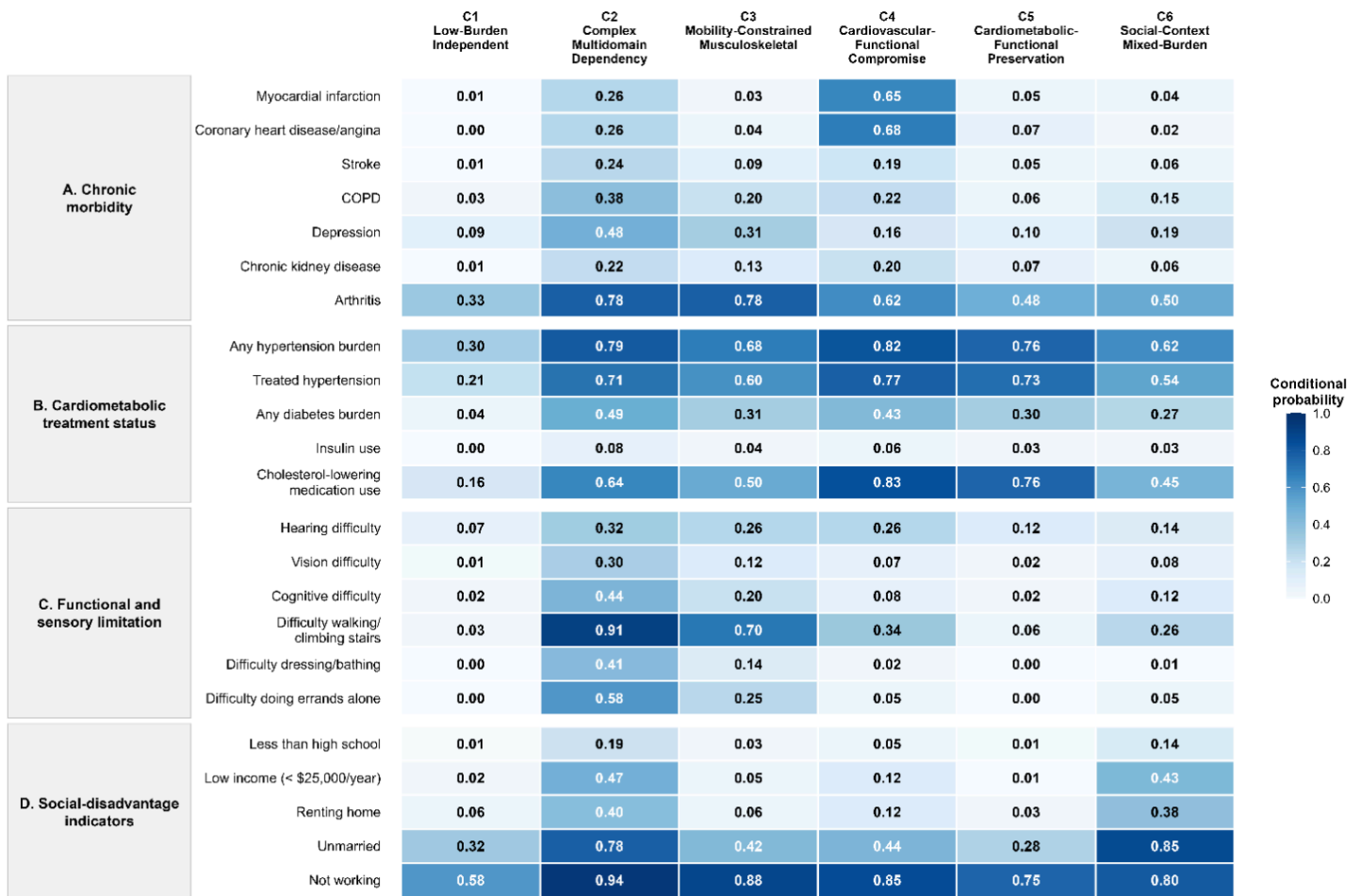


Figure 1

Conditional probabilities across the six multidimensional latent profiles.

Note: The heatmap displays class-specific conditional probabilities from the final six-class latent class model. Indicators are grouped into four domains: chronic morbidity, cardiometabolic treatment status, functional and sensory limitation, and social-disadvantage indicators. Higher values indicate a greater probability that members of a given latent class endorsed the corresponding characteristic. Darker shading represents higher conditional probabilities. Columns are labeled C1-C6; the corresponding interpretive profile identities are summarized in Table 3. The profile labels are descriptive summaries of empirically derived response patterns and should not be interpreted as clinical diagnoses. COPD, chronic obstructive pulmonary disease. Hypertension and diabetes were modeled as composite categorical indicators in the LCA. For interpretability, their conditional response probabilities are displayed as separate disease-status

and treatment-status components in the heatmap; therefore, the number of displayed rows exceeds the number of LCA indicators.

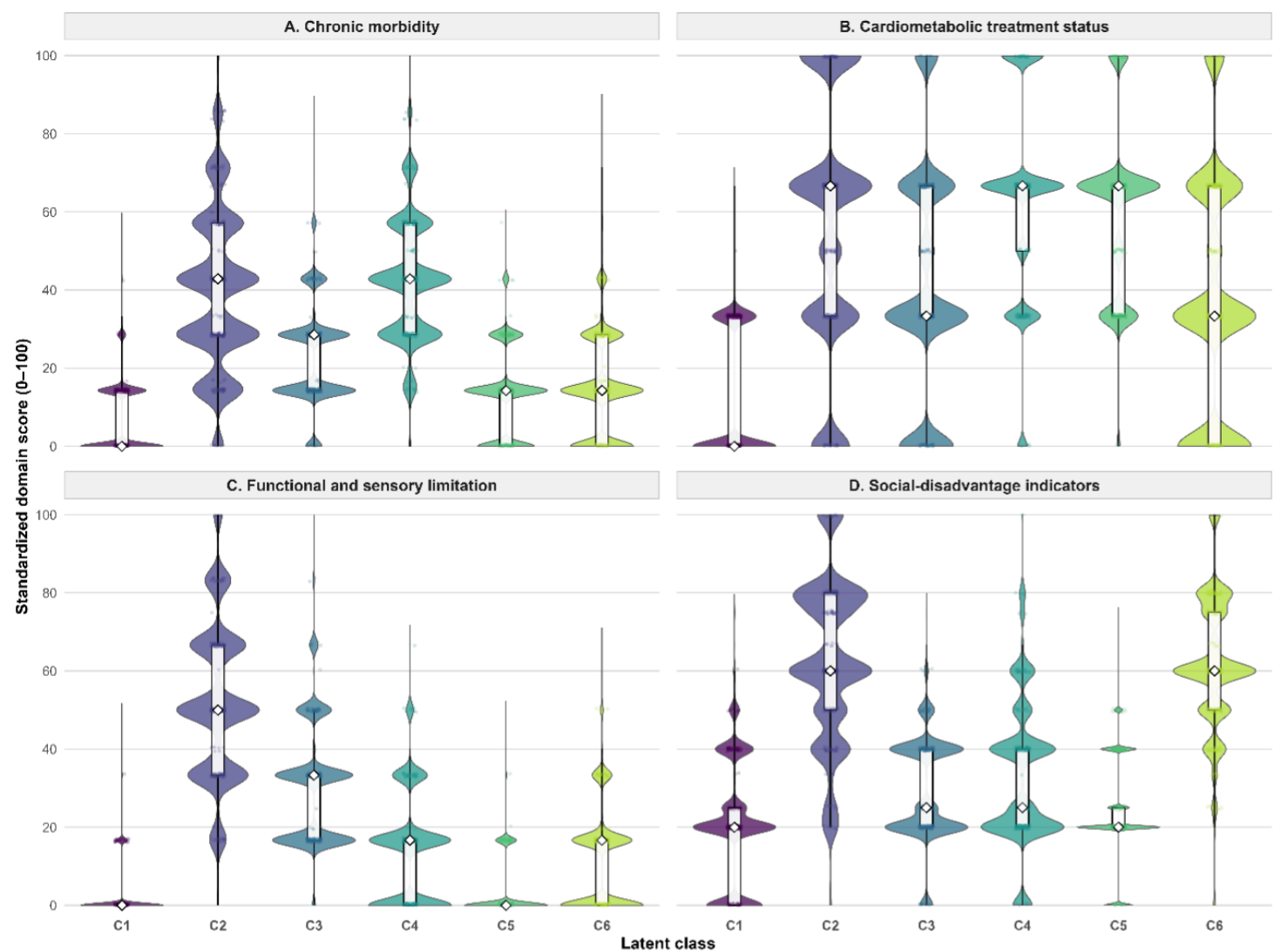


Figure 2

Distribution of standardized domain scores across the six multidimensional latent profiles.

Note: Violin plots show the distribution of standardized scores for chronic morbidity, cardiometabolic treatment status, functional and sensory limitation, and social-disadvantage indicators within each latent class. Scores were scaled from 0 to 100, with higher values indicating a greater number or proportion of characteristics within the corresponding domain. Violin densities and boxplots were calculated using the full analytic sample, while displayed points represent random subsamples of up to 250 respondents per latent class and domain to reduce overplotting. Unknown or refused responses were excluded from the individual-level denominator when calculating domain scores. These scores were used for descriptive visualization only and were not included in latent class estimation or outcome regression models.