Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Recovered but Not Reset: Longitudinal Health History and Future Vulnerability Across Three National Cohorts

Di Zeng
West China Hospital of Sichuan University
Zhimeng Cheng
West China Hospital of Sichuan University
Jiong Lu
1017346985@qq.com

West China Hospital of Sichuan University

Research Article

Keywords: resilience, disability, cognition, depressive symptoms, geriatric assessment

Posted Date: November 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10922222/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

A favorable current geriatric assessment may conceal whether an older adult has been durably preserved or has only recently recovered from multidomain vulnerability. We tested whether longitudinal health history remains prognostically informative after current health is held constant.

Methods

We analyzed adults aged 60 years or older in HRS, ELSA, and CHARLS using repeated mobility, instrumental activities of daily living (IADL), episodic memory, and depressive symptoms. Among observations currently multidomain-preserved, modified Poisson models compared durable preservation with recent recovery after adjustment for current raw domain values, age, sex, education, and wave. Secondary analyses examined recurrent and remote vulnerability, persistence after isolated episodes, same-domain recurrence, incident basic-ADL limitation, and history-aware prediction.

Results

Recent recovery was associated with higher standardized next-wave deterioration risk in HRS (54.5% vs 34.9%; RR 1.56, 95% CI 1.47–1.66), ELSA (43.6% vs 29.7%; RR 1.47, 1.36–1.59), and CHARLS (56.4% vs 40.2%; RR 1.40, 1.28–1.54). Recurrent vulnerability carried the highest risk in all cohorts (RR 1.86–2.03). In HRS and ELSA, one isolated vulnerable episode remained informative after three subsequent preserved assessments. Prior cognitive, mobility, and affective vulnerability preferentially recurred in the same domain. Earlier health also improved participant-separated out-of-sample prediction beyond current health.

Conclusions

Apparent recovery and durable preservation were not prognostically equivalent. Longitudinal functional, cognitive, and affective history may improve near-term geriatric risk assessment when interpreted alongside current health.

INTRODUCTION

Comprehensive geriatric assessment is necessarily anchored in the present. Clinicians assess mobility, independence, cognition, mood, and other domains as they appear at the current encounter. Yet identical current profiles can be reached through very different paths: one older adult may have remained stable for years, whereas another may only recently have recovered from functional, cognitive, or affective

difficulty. If those histories carry different future risks, a favorable current snapshot may be falsely reassuring. (1, 2)

Late-life health is dynamic. Disability can remit and recur, frailty states change over time, and resilience frameworks emphasize recovery after stressors rather than static deficit alone. Prior disability history has also been shown to influence subsequent functional transitions, suggesting that current status may not fully summarize the process that preceded it. (3–14) Recent longitudinal work has extended this perspective to multidomain health-state transitions across national aging cohorts. (15, 16)

Most trajectory and transition studies, however, describe longitudinal patterns or rates of change rather than directly asking whether earlier health remains informative after a detailed current multidomain phenotype has already been measured. This distinction matters clinically. If current health is prognostically sufficient, two people who look the same today should have similar near-term risk regardless of how they arrived there. If it is not, the path into the current state deserves explicit consideration.

We examined this question in three national aging cohorts from the United States, England, and China. We first evaluated whether a common multidomain state architecture was reproducible across cohorts. We then fixed the current state as multidomain-preserved and compared durable preservation with recent, remote, and recurrent vulnerability. Finally, we tested whether historical information persisted after repeated apparent recovery, predicted the domain of future deterioration and incident basic-ADL limitation, and improved prediction beyond detailed current measurements. Our objective was prognostic rather than causal: to determine whether longitudinal history contains information not captured by the measured current snapshot.

METHODS

Study populations and design

We conducted secondary longitudinal analyses of adults aged 60 years or older in the Health and Retirement Study (HRS), English Longitudinal Study of Ageing (ELSA), and China Health and Retirement Longitudinal Study (CHARLS). The principal comparable period was 2010–2018 for HRS and ELSA and 2011–2018 for CHARLS. HRS contributed 54,545 complete person-waves from 17,893 participants to state discovery, ELSA 34,054 person-waves from 10,004 participants, and CHARLS 26,637 person-waves from 12,135 participants. Analyses used scheduled observations and did not bridge missing waves. The cohort profiles and parent-study methods have been described previously. (20–22) Cohort structure, harmonized measures, and principal analysis samples are summarized in Table 1.

Table 1
Cohort structure, harmonized measures, and principal analysis samples

Characteristic	HRS (US)	ELSA (England)	CHARLS (China)
Principal observation period	2010–2018	2010–2018	2011–2018
Minimum age	≥ 60 years	≥ 60 years	≥ 60 years
Harmonized waves	Waves 10–14	Waves 5–9	2011, 2013, 2015, 2018
State-discovery sample	54,545 person-waves 17,893 participants	34,054 person-waves 10,004 participants	26,637 person-waves 12,135 participants
Primary preserved-state analysis	6,215 triplets 3,902 participants	6,090 triplets 3,439 participants	1,969 triplets 1,595 participants
Mobility	Walking several blocks; stairs; stooping/kneeling; lifting 10 lb	Walking 100 yards; stairs; stooping/kneeling; lifting 10 lb	Conceptually matched walking; stairs; stooping; lifting
IADL	Meals; shopping; money; medications	Same 4-item core	Same 4-item core
Episodic memory	Immediate + delayed recall	Immediate + delayed recall	Immediate + delayed recall
Depressive symptoms	Cohort-standard repeated score	Cohort-standard repeated score	Cohort-standard repeated score
Independently derived states	Preserved; cognitive; mobility; affective; multidomain	Same five interpretable states	Same five interpretable states

Abbreviations: HRS, Health and Retirement Study; ELSA, English Longitudinal Study of Ageing; CHARLS, China Health and Retirement Longitudinal Study; IADL, instrumental activities of daily living. State-discovery samples include complete person-waves used for independent within-cohort state estimation. Primary triplets required an observed previous, current, and next scheduled state, with the current state fixed as multidomain-preserved.

The historical window was selected to create directly comparable repeated multidomain sequences and, in HRS and ELSA, a five-assessment span long enough to test whether information remained two and three assessments earlier. State discovery treated person-waves as time-independent observations; participant chronology was restored only after state definitions were fixed.

Multidomain health phenotype and state discovery

Four repeated domains were selected because conceptually comparable measures were available across all three cohorts: mobility limitation, instrumental activities of daily living (IADL), episodic memory, and depressive symptoms. Mobility summarized difficulty with walking, climbing stairs, stooping or kneeling, and lifting or carrying. IADL covered preparing meals, shopping, managing money, and taking medications. Episodic memory combined immediate and delayed word recall. Depressive symptoms used the cohort-standard repeated symptom measure. Measures were oriented so that higher values represented worse health and standardized within cohort.

Complete person-waves were clustered independently within each cohort using k-means with five clusters and 100 random initializations. (23) States were labeled multidomain-preserved, cognitive-predominant, mobility-predominant, affective-predominant, and multidomain disability from the standardized centroid profiles. Pairwise correlations of matched centroids and adjacent-wave transition matrices quantified cross-cohort similarity. Applying HRS centroids without re-estimation to ELSA and CHARLS provided an additional transportability check.

Principal preserved-state and history-pattern analyses

The principal clinically interpretable analysis required observed states at the immediately previous, current, and next scheduled waves, with the current state fixed as multidomain-preserved. Durable preservation was defined as preserved at both the previous and current waves; recent recovery was defined as non-preserved at the previous wave and preserved at the current wave. Modified Poisson regression with participant-clustered robust standard errors adjusted current raw mobility, IADL, episodic-memory, and depressive-symptom values, age, sex, education, and landmark wave. Marginal predictions yielded standardized next-wave deterioration risks and risk differences.

A fixed two-assessment history window further classified current-preserved observations as durable preservation, remote vulnerability, recent vulnerability, or recurrent vulnerability. The purpose was to distinguish whether history carried more information than a simple ever-vulnerable flag. Because the exact remote-versus-recent ordering was not expected to be identical across countries, recurrence was prespecified as the clinically strongest history pattern rather than assuming a universal monotonic recency gradient.

Persistence after an isolated vulnerable episode

We next asked whether risk returned to the durable-preservation level after repeated favorable reassessments. HRS and ELSA provided complete five-wave 2010–2018 sequences. Histories were restricted to either continuous preservation through a common 2016 landmark or exactly one non-preserved episode in 2010, 2012, or 2014 followed only by preserved observations through 2016; deterioration was assessed in 2018. Modified Poisson models adjusted the current four-domain phenotype, age, sex, and education. Among single-episode histories, a linear depth term tested whether

risk attenuated as the number of subsequent preserved assessments increased, additionally accounting for the type of the prior vulnerable state.

Domain recurrence and external functional outcome

Domain recurrence and external functional outcome
Domain-recurrence analyses tested whether prior vulnerability predicted the type as well as the occurrence of future deterioration. Among currently preserved observations, a previous cognitive-, mobility-, or affective-predominant state was compared with previous preservation, and the corresponding same-domain state at the next wave was the outcome. Incident basic-ADL limitation served as an external functional outcome not used to construct the multidomain states. Basic ADL included dressing, bathing, eating, bed transfer, and toileting.

Historical-information and prediction analyses

To establish that the finding did not depend on state discretization, a cluster-free analysis calculated a multidomain burden as the mean of standardized mobility, IADL, memory-impairment, and depressive-symptom scores. Fixed three-wave models predicted next-wave burden from the complete current four-domain phenotype, age, sex, and education before adding previous burden. Participant-separated five-fold cross-validation compared out-of-fold R^2 with and without history.

HRS and ELSA also permitted a measurement stress test using non-overlapping historical and future item sets. Mobility, IADL, memory, and depressive-symptom items were divided into disjoint forms; history was constructed from one form and the future outcome from the other, then the forms were swapped. The strongest specification retained all 18 current-wave item indicators separately. Five-wave HRS and ELSA sequences then sequentially added $t - 1$, $t - 2$, and $t - 3$ historical burden to estimate the cumulative information recovered by deeper history.

For the discrete states, first-order models estimated P(next state | current state) and second-order models estimated P(next state | previous state, current state). Participant-grouped five-fold cross-validation compared multiclass log loss, with participant bootstrap resampling for confidence intervals. Robustness analyses included overlap weighting of the current phenotype, restriction to the central preserved cluster, one-landmark-per-participant analyses, alternative state numbers, inverse-probability attrition weighting in HRS, fully nested validation, frozen cross-cohort state definitions, and history-label permutation.

Use of AI-assisted technology

N/A

Ethics, reporting, data, and code availability

This secondary analysis used deidentified research data and was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional and national research ethics requirements. HRS core data collection is overseen by the University of Michigan Health Sciences/Behavioral Sciences Institutional Review Board (HUM00061128 and HUM00246459). CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015). ELSA Waves 5–9 received approval from NHS Research Ethics Committees. Participants provided informed consent under the respective parent-study protocols. ELSA data were accessed under the UK Data Service End User Licence. Reporting was guided by STROBE recommendations for observational studies. Individual-participant data remain governed by parent-cohort access conditions and are not redistributed; analysis code and aggregate derived results can be shared as Supplementary Information.

RESULTS

Cross-national multidomain health architecture was reproducible

All three cohorts independently yielded the same five interpretable states: multidomain-preserved, cognitive-predominant, mobility-predominant, affective-predominant, and multidomain disability (Fig. 1A–B). Matched-centroid correlations were 0.993 for HRS–ELSA, 0.986 for HRS–CHARLS, and 0.981 for ELSA–CHARLS. Adjacent-wave transition-matrix correlations were 0.983, 0.951, and 0.973, respectively (Fig. 1C; eTable 2 in the Supplement).

Historical state improved next-state prediction despite the current state already being known. Relative out-of-fold log-loss reduction after adding previous state was 7.0% (95% CI 6.5–7.5) in HRS, 6.1% (5.5–6.7) in ELSA, and 3.1% (2.4–3.7) in CHARLS (Fig. 1D; eTable 5 in the Supplement). Thus, the state architecture was similar across cohorts and was not first-order Markov in the narrow predictive sense tested here.

Same current preserved health, different future risk

The equal-history analysis included 6,215 HRS triplets from 3,902 participants, 6,090 ELSA triplets from 3,439 participants, and 1,969 CHARLS triplets from 1,595 participants. At the first eligible landmark, the mean ages of participants were 73.4 years in HRS, 70.8 years in ELSA, and 71.4 years in CHARLS, respectively. Despite fixing the current state as preserved and directly adjusting the current raw mobility, IADL, memory, and depressive-symptom values, recent recovery was associated with substantially higher next-wave deterioration in every cohort (Fig. 2A,C).

Standardized risk after durable preservation versus recent recovery was 34.9% versus 54.5% in HRS (RR 1.56, 95% CI 1.47–1.66; risk difference + 19.6 percentage points), 29.7% versus 43.6% in ELSA (RR 1.47, 1.36–1.59; +13.9 points), and 40.2% versus 56.4% in CHARLS (RR 1.40, 1.28–1.54; +16.2 points).

The fixed history window showed an additional gradient (Fig. 2B; eTable 6 in the Supplement). Recurrent vulnerability was the highest-risk pattern in all three cohorts: standardized risks were 59.3% in HRS, 51.3% in ELSA, and 61.7% in CHARLS, corresponding to RRs of 1.86 (1.68–2.06), 1.91 (1.67–2.19), and 2.03 (1.60–2.58) versus durable preservation. HRS and CHARLS showed higher risk after recent than remote vulnerability, whereas ELSA showed similar risks after remote and recent vulnerability. The cross-cohort invariant was therefore persistence of historical information and amplification by recurrence, not a universal recency ordering.

Risk did not reset after repeated apparent recovery

In the isolated-episode analysis, favorable reassessments did not restore the risk profile of continuous preservation during the observed interval (Fig. 3). In HRS, standardized 2018 deterioration risk was 26.6% after durable preservation and 40.0%, 37.2%, and 38.7% after one, two, and three subsequent preserved assessments following a single earlier vulnerable episode. The RR remained 1.46 (95% CI 1.12–1.90) after three preserved assessments.

ELSA independently showed corresponding risks of 26.7%, 34.3%, 38.8%, and 37.6%; the RR after three preserved assessments was 1.41 (1.12–1.77). There was no evidence of monotonic attenuation among exposed histories in HRS (P = 0.75) or ELSA (P = 0.63). These data support persistence of prognostic information after apparent recovery, while not establishing an irreversible biological mechanism.

History predicted where deterioration recurred and extended to basic ADL

Prior vulnerability contained domain-specific information (Fig. 4A–B). After return to the preserved state, a prior cognitive-predominant state predicted cognitive recurrence in HRS, ELSA, and CHARLS (RR 1.79, 1.53, and 1.39, respectively). Corresponding RRs were 1.91, 2.14, and 1.96 for mobility recurrence and 4.47, 2.89, and 2.88 for affective recurrence.

Recent recovery also predicted incident basic-ADL limitation, an outcome not used in state construction (Fig. 4C). RRs were 1.44 (95% CI 1.08–1.93) in HRS and 1.35 (1.03–1.76) in ELSA; the CHARLS estimate was directionally concordant but imprecise (1.26, 0.92–1.73). This external outcome reduces the likelihood that the history signal reflects only reclassification of the same four domains. The principal longitudinal health-history associations across the three cohorts are summarized in Table 2.

Table 2
Principal longitudinal health-history associations across the three cohorts

Analysis	HRS	ELSA	CHARLS
Primary preserved-state contrast: durable preservation	34.9% (33.3–36.4)	29.7% (28.3–31.2)	40.2% (37.3–43.0)
Primary preserved-state contrast: recent recovery	54.5% (52.6–56.4) RR 1.56 (1.47–1.66) RD + 19.6 pp	43.6% (41.5–45.6) RR 1.47 (1.36–1.59) RD + 13.9 pp	56.4% (53.2–59.6) RR 1.40 (1.28–1.54) RD + 16.2 pp
Remote vulnerability	43.3%; RR 1.36 (1.20–1.54)	42.5%; RR 1.58 (1.39–1.80)	44.3%; RR 1.46 (1.11–1.92)
Recent vulnerability	48.9%; RR 1.53 (1.38–1.71)	41.9%; RR 1.56 (1.36–1.79)	50.8%; RR 1.67 (1.27–2.19)
Recurrent vulnerability	59.3%; RR 1.86 (1.68–2.06)	51.3%; RR 1.91 (1.67–2.19)	61.7%; RR 2.03 (1.60–2.58)
One isolated vulnerable episode followed by 3 preserved assessments	38.7%; RR 1.46 (1.12–1.90)	37.6%; RR 1.41 (1.12–1.77)	Not estimable with available wave depth
Cognitive same-domain recurrence	RR 1.79 (1.64–1.97)	RR 1.53 (1.38–1.69)	RR 1.39 (1.18–1.62)
Mobility same-domain recurrence	RR 1.91 (1.64–2.23)	RR 2.14 (1.71–2.68)	RR 1.96 (1.40–2.76)
Affective same-domain recurrence	RR 4.47 (2.79–7.18)	RR 2.89 (2.03–4.10)	RR 2.88 (1.74–4.77)
Incident basic-ADL limitation	RR 1.44 (1.08–1.93)	RR 1.35 (1.03–1.76)	RR 1.26 (0.92–1.73)

Values are standardized risks (95% CIs) where shown, followed by adjusted risk ratios (RRs) and, for the principal contrast, standardized risk differences (RDs). Primary preserved-state models adjusted for current raw mobility, IADL, episodic memory, depressive symptoms, age, sex, education, and landmark wave. Fixed history-pattern RRs use durable preservation as the reference. The isolated-episode persistence analysis was available in HRS and ELSA only. Basic ADL was not used to define the multidomain states.

Earlier health added information beyond detailed current measurement

The cluster-free analysis independently supported the state-based findings (Fig. 5C). Adding previous multidomain burden to the complete current four-domain phenotype increased participant-separated out-of-fold R^2 from 0.597 to 0.637 in HRS (ΔR^2 +0.041), 0.507 to 0.581 in ELSA (+ 0.074), and 0.434 to

0.459 in CHARLS (+ 0.025). Previous burden coefficients were 0.349 (95% CI 0.317–0.381), 0.401 (0.331–0.471), and 0.332 (0.274–0.390), respectively.

The saturated-current, non-overlapping-item stress test preserved the signal (Fig. 5D; eTable 11 in the Supplement). With all 18 current-wave item indicators included separately, HRS history coefficients were 0.247 (0.213–0.280) and 0.239 (0.205–0.273) across reciprocal item rotations; ELSA coefficients were 0.222 (0.181–0.263) and 0.214 (0.169–0.259). Out-of-fold R^2 increments remained positive in every rotation.

Deeper history carried additional information in five-wave HRS and ELSA sequences (Fig. 5A–B). In HRS, out-of-fold R^2 increased from 0.590 with the current phenotype alone to 0.629 after t − 1, 0.637 after t − 2, and 0.641 after t − 3. ELSA increased from 0.481 to 0.562, 0.579, and 0.591. All three historical depths retained mutually adjusted coefficients in both cohorts, although the ELSA coefficients were not monotonic with lag. The data therefore indicate cumulative historical information rather than a universal decay function.

DISCUSSION

Across three national aging cohorts, older adults who were currently in the same favorable multidomain state had markedly different near-term outcomes depending on how they arrived there. Recent recovery was associated with 13.9–19.6 percentage-point higher standardized risk of losing preservation, recurrent vulnerability approximately doubled risk, and one isolated episode remained informative after three subsequent preserved assessments in HRS and ELSA. History also predicted the domain of recurrence and incident basic-ADL limitation. These clinical contrasts converged with cluster-free and out-of-sample analyses showing that earlier health retained information after detailed current measurement.

This finding extends rather than replaces conventional trajectory, frailty-transition, and pace-of-aging approaches. Those methods describe patterns of change, transition probabilities, or longitudinal rates. Our question was conditional: once current mobility, IADL, memory, and depressive symptoms are measured, is the latest snapshot a sufficient summary for near-term prognosis? The answer was consistently no within the observed domains. Measurements two and three assessments earlier still improved prediction in HRS and ELSA, and previous state improved next-state prediction in all three cohorts. The result therefore cannot be reduced to the immediately preceding observation alone.

The distinction between durable preservation and recent recovery may be clinically useful because both groups can appear reassuring at a current assessment. A patient who has recently recovered from mobility difficulty may still merit closer attention to gait, falls, strength, and physical function; analogous reasoning may apply after cognitive or affective vulnerability. Same-domain recurrence across countries supports this targeted interpretation. We do not propose a new clinical score, and the data do not establish that intensified monitoring prevents deterioration. Rather, they suggest that longitudinal

functional, cognitive, and affective context may help determine how reassuring a favorable current examination should be.

Several mechanisms could generate the observed history signal. Earlier vulnerability may reflect incomplete recovery, reduced physiological reserve, recurrent exposures, treatment effects, stable latent susceptibility, or residual measurement error. The non-overlapping-item stress test addresses two narrow alternatives—reuse of identical questionnaire items and overly coarse current-domain summaries—because historical and future phenotypes were built from disjoint items while all 18 current-wave items entered separately. Nevertheless, no observational analysis can exclude all unmeasured vulnerability or measurement error. Accordingly, the results should not be interpreted as evidence of biological memory, hysteresis, or causal path dependence.

The persistence analysis adds an important boundary to the recovery concept. In both HRS and ELSA, the excess risk after one isolated vulnerable episode remained detectable after three favorable reassessments, with no monotonic decline across the exposed histories. This should not be interpreted as permanent damage; the approximately two-year spacing between waves cannot resolve shorter cycles, and risk may change beyond the observed window. The supported conclusion is narrower: repeated favorable snapshots did not immediately erase the prognostic information carried by a prior episode.

Strengths include three large national cohorts, independent state discovery, direct adjustment for the current raw phenotype, participant-separated prediction, a cluster-free primary information test, non-overlapping-indicator validation, multiple historical depths, an isolated-episode design, same-domain recurrence, and an external basic-ADL outcome. The consistency of state geometry and transition dynamics across countries strengthens the interpretation that the phenomenon is not specific to one questionnaire or health system.

Limitations should temper interpretation. Harmonized domains were conceptually comparable but not identical across cohorts; for example, walking items differed in distance, and depressive-symptom instruments differed across cohort families. Assessments were spaced approximately two years apart. Complete-case selection, attrition, and informative missingness remain possible despite sensitivity analyses. Primary models estimate conditional associations and prediction rather than nationally representative prevalence. The state labels are relative phenotype summaries rather than diagnoses. Finally, later-life history may correlate with unmeasured disease severity, treatment, social context, or physiological reserve, so causal mechanisms require other data.

CONCLUSIONS

For geriatric assessment, “recovered” should not automatically mean “risk reset.” A favorable current profile is more informative when interpreted together with the recent path that preceded it. Prospective studies should test whether simple history flags or structured longitudinal summaries improve clinical triage, follow-up, and prevention of functional decline beyond current multidomain assessment alone.

Abbreviations

ADL, activities of daily living; CHARLS, China Health and Retirement Longitudinal Study; CI, confidence interval; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; IADL, instrumental activities of daily living; IRB, Institutional Review Board; NHS, National Health Service; RR, risk ratio; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

This secondary analysis used deidentified research data and was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional and national research ethics requirements. HRS core data collection is overseen by the University of Michigan Health Sciences/Behavioral Sciences Institutional Review Board (HUM00061128 and HUM00246459). CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015). ELSA Waves 5–9 received approval from NHS Research Ethics Committees. All participants provided informed consent under the respective parent-study protocols. The present secondary analysis involved no new participant recruitment or collection of new identifiable information. Clinical trial number: not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The individual-participant data used in this study are available from the respective parent cohorts (HRS, ELSA, and CHARLS) subject to their access and data-use procedures. ELSA data were accessed under the UK Data Service End User Licence. The authors are not permitted to redistribute the individual-level data. Analysis code and non-identifying aggregate derived results may be provided in the Supplementary Information or made available from the corresponding author on reasonable request, subject to applicable data-use conditions.

Competing Interests

The authors declare that they have no competing interests.

Funding

This research received no specific funding.

Authors' contributions

Di Zeng: Conceptualization (lead); data curation (lead); formal analysis (lead); investigation (lead); methodology (lead); visualization (lead); writing – original draft (lead); writing – review and editing (equal).

Jiong Lu: Conceptualization (supporting); investigation (supporting); methodology (equal); supervision (supporting); writing – review and editing (equal).

Zhimeng Cheng: Conceptualization (lead); methodology (equal); interpretation (lead); supervision (lead); writing – review and editing (equal).

All authors reviewed and approved the final manuscript and agreed to be accountable for the integrity and accuracy of the work. Jiong Lu is the guarantor and accepts full responsibility for the work and the conduct of the study.

Acknowledgements

Not applicable.

References

1. Garrard JW, Cox NJ, Dodds RM, et al. Comprehensive geriatric assessment in primary care: a systematic review. Aging Clin Exp Res. 2020;32:197–205.
2. Ellis G, Gardner M, Tsiachristas A, et al. Comprehensive geriatric assessment for older adults admitted to hospital. Cochrane Database Syst Rev. 2017;9:CD006211.
3. Quiñones AR, Nagel CL, Botoseneanu A, et al. Multidimensional trajectories of multimorbidity, functional status, cognitive performance, and depressive symptoms among diverse groups of older adults. J Multimorb Comorb. 2022;12:26335565221143012.
4. Zhou J, Wei MY, Zhang J, et al. Association of multimorbidity patterns with incident disability and recovery of independence among middle-aged and older adults. Age Ageing. 2022;51:afac177.
5. Whitson HE, Duan-Porter W, Schmader KE, et al. Physical resilience in older adults: systematic review and development of an emerging construct. J Gerontol Biol Sci Med Sci. 2016;71:489–95.
6. Olde Rikkert MGM, Melis RJF. Rerouting geriatric medicine by complementing static frailty measures with dynamic resilience indicators of recovery potential. Front Physiol. 2019;10:723.
7. Hardy SE, Gill TM. Recovery from disability among community-dwelling older persons. JAMA. 2004;291:1596–602.

8. Hardy SE, Dubin JA, Holford TR, et al. Transitions between states of disability and independence among older persons. Am J Epidemiol. 2005;161:575–84.
9. Hardy SE, Allore HG, Guo Z, et al. The effect of prior disability history on subsequent functional transitions. J Gerontol Biol Sci Med Sci. 2006;61:272–7.
10. Gill TM, Allore HG, Hardy SE, et al. The dynamic nature of mobility disability in older persons. J Am Geriatr Soc. 2006;54:248–54.
11. Gill TM, Allore HG, Gahbauer EA, et al. Change in disability after hospitalization or restricted activity in older persons. JAMA. 2010;304:1919–28.
12. Gijzel SMW, Whitson HE, van de Leemput IA, et al. Resilience in clinical care: getting a grip on the recovery potential of older adults. J Am Geriatr Soc. 2019;67:2650–7.
13. Colon-Emeric C, Schmader K, Cohen HJ, et al. Ageing and physical resilience after health stressors. Stress Health. 2023;39(S1):48–54.
14. O'Caoimh R, Galluzzo L, Rodríguez-Laso Á, et al. Transitions and trajectories in frailty states over time: a systematic review of the European Joint Action ADVANTAGE. Ann Ist Super Sanita. 2018;54:246–52.
15. Wang S, Wang L, Wang Y, et al. Bidirectional transitions of frailty states in middle-aged and older adults: findings from two longitudinal cohort studies. Arch Gerontol Geriatr. 2026;141:106085.
16. Du S, Zhang N, Yu H. Population burden and individual risk in transitions to somatic-cognitive involvement among middle-aged and older adults: a multinational longitudinal health-state transition study. Arch Gerontol Geriatr. 2026;150:106360.
17. Stolz E, Mayerl H, Hoogendijk EO. Frailty in the oldest old: is the current level or the rate of change more predictive of mortality? Age Ageing. 2022;51:afac020.
18. Li X, Schöttker B, Holleczek B, Brenner H. Association of longitudinal repeated measurements of frailty index with mortality: cohort study among community-dwelling older adults. eClinicalMedicine. 2022;53:101630.
19. Balachandran A, Pei H, Shi Y, et al. Pace of Aging analysis of healthspan and lifespan in older adults in the US and UK. Nat Aging. 2025;5:1132–42.
20. Sonnega A, Faul JD, Ofstedal MB, et al. Cohort Profile: the Health and Retirement Study (HRS). Int J Epidemiol. 2014;43:576–85.
21. Steptoe A, Breeze E, Banks J, Nazroo J. Cohort Profile: the English Longitudinal Study of Ageing. Int J Epidemiol. 2013;42:1640–8.
22. Zhao Y, Hu Y, Smith JP, Strauss J, Yang G. Cohort Profile: the China Health and Retirement Longitudinal Study (CHARLS). Int J Epidemiol. 2014;43:61–8.
23. Hartigan JA, Wong MA, Algorithm. AS 136: a k-means clustering algorithm. J R Stat Soc Ser C Appl Stat. 1979;28:100–8.
24. De Giovanni D, Menzietti M, Pirra M, et al. Functional disability in the Health and Retirement Study: a semi-Markov multi-state analysis. Ann Oper Res Published online. 2025. 10.1007/s10479-025-

06526-7.

Figures

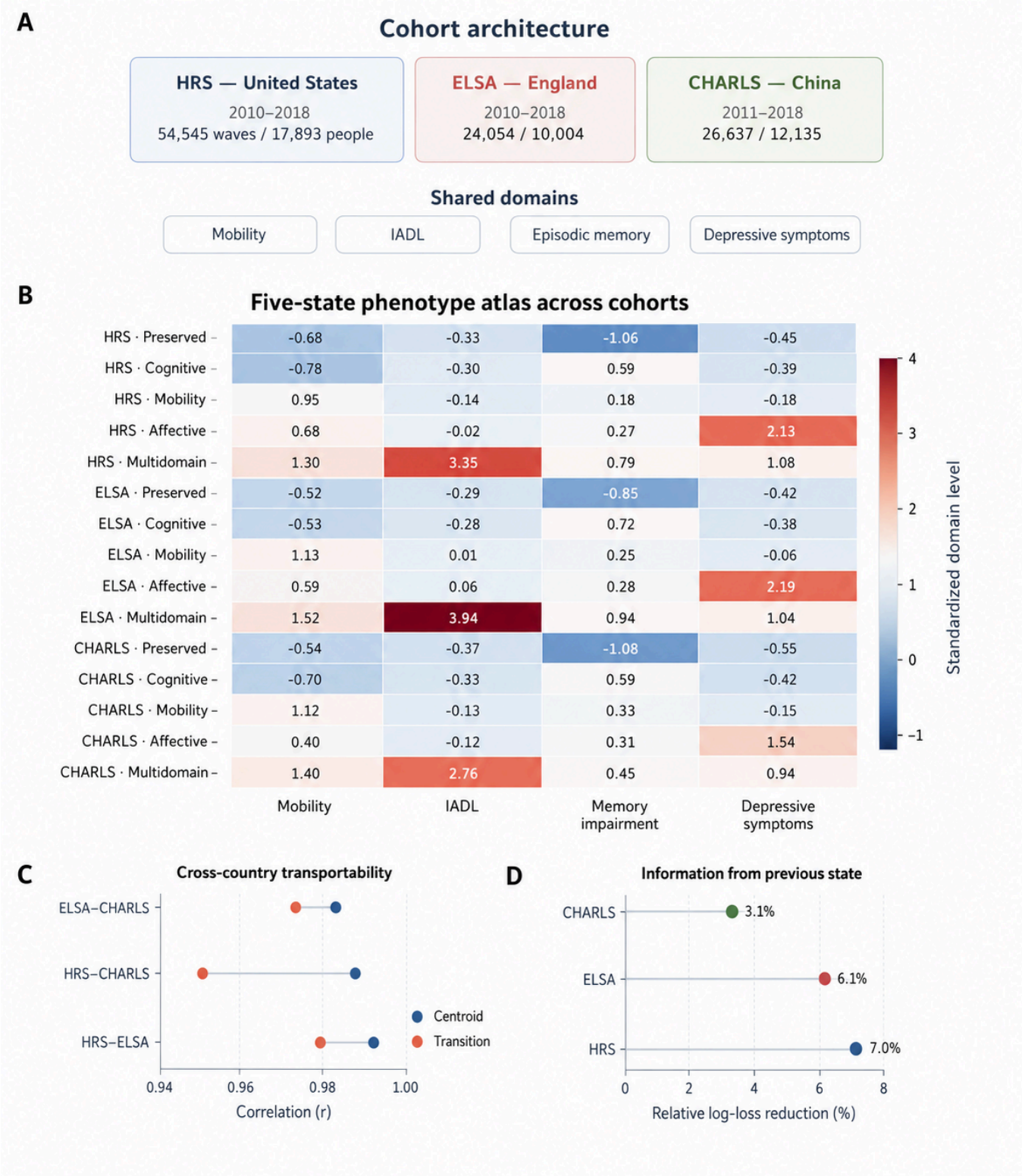


Figure 1

Cross-national architecture of multidomain health states. Panel A summarizes the three national aging cohorts and four shared domains. Panel B shows standardized centroid profiles for independently derived five-state systems. Panel C compares pairwise centroid and transition-matrix correlations. Panel D shows the relative reduction in participant-separated out-of-fold next-state log loss when previous state is added to current state. HRS, Health and Retirement Study; ELSA, English Longitudinal Study of Ageing; CHARLS, China Health and Retirement Longitudinal Study; IADL, instrumental activities of daily living.

Alt text: Four-panel figure summarizing HRS, ELSA, and CHARLS; a heatmap shows five corresponding multidomain health states across mobility, IADL, memory, and depressive symptoms; bar charts show high cross-cohort centroid and transition correlations and improved next-state prediction after adding previous state.

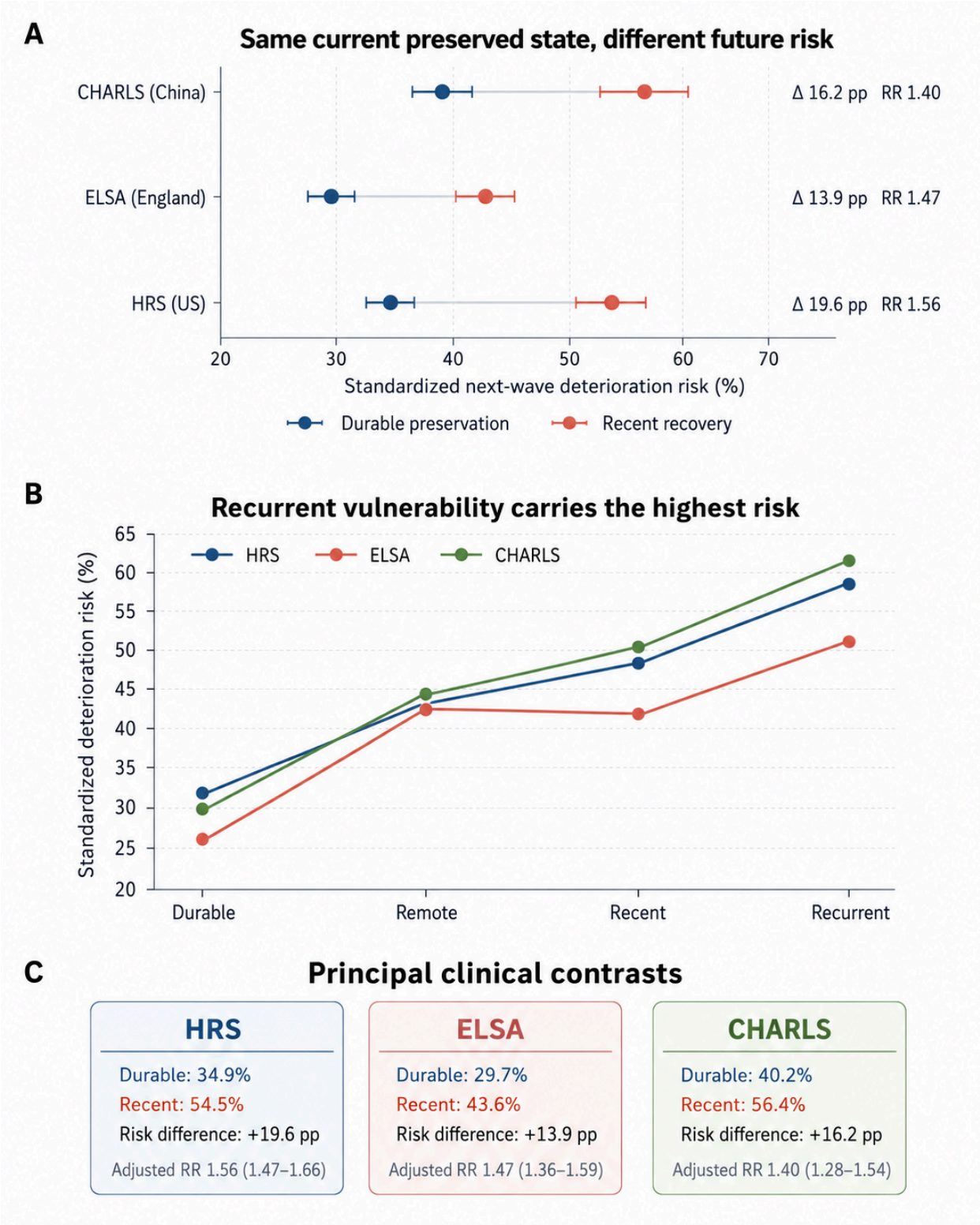


Figure 2

Current recovery does not equal prognostic reset. Panel A compares standardized next-wave deterioration risk after durable preservation versus recent recovery among observations currently in the multidomain-preserved state. Panel B shows standardized risk across durable, remote, recent, and recurrent vulnerability histories. Panel C summarizes the principal absolute and relative contrasts.

Models adjust current mobility, IADL, episodic memory, depressive symptoms, age, sex, education, and landmark wave. RR, risk ratio; pp, percentage points.

Alt text: Three-panel figure showing that older adults currently in the same preserved state have higher future deterioration risk after recent or recurrent vulnerability than after durable preservation in the United States, England, and China.

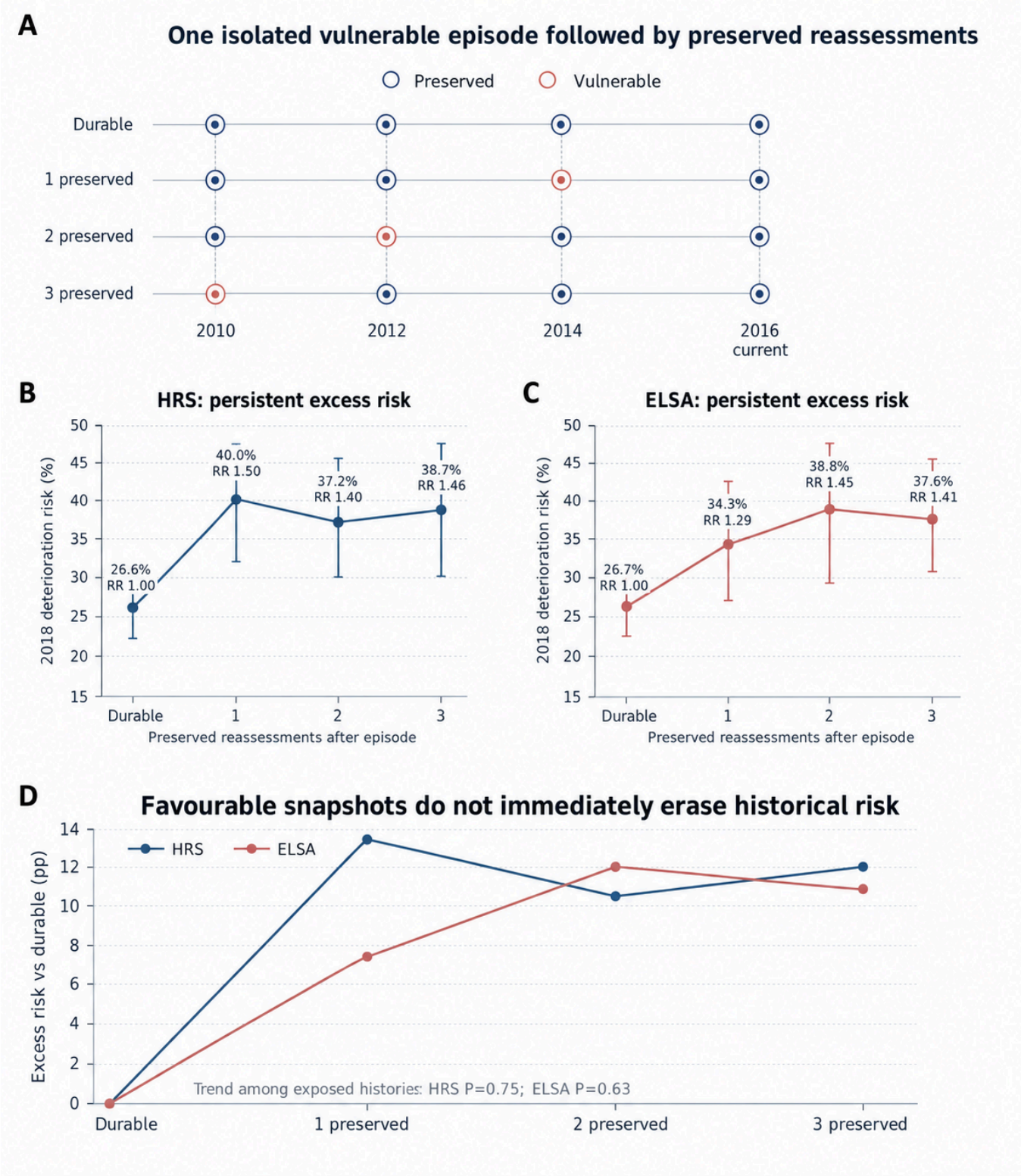


Figure 3

A single vulnerable episode remains prognostically informative after apparent recovery. Panel A illustrates the isolated-episode histories. Panels B and C show standardized 2018 deterioration risks in HRS and ELSA after continuous preservation or exactly one earlier vulnerable episode followed by one to three preserved assessments. Panel D shows excess risk versus durable preservation. There was no evidence of monotonic attenuation across one to three preserved assessments among exposed histories (HRS P=0.75; ELSA P=0.63).

Alt text: Four-panel figure showing HRS and ELSA histories with one isolated vulnerable episode followed by repeated preserved assessments; deterioration risk remains above the durable-preservation group after one, two, and three favorable reassessments.

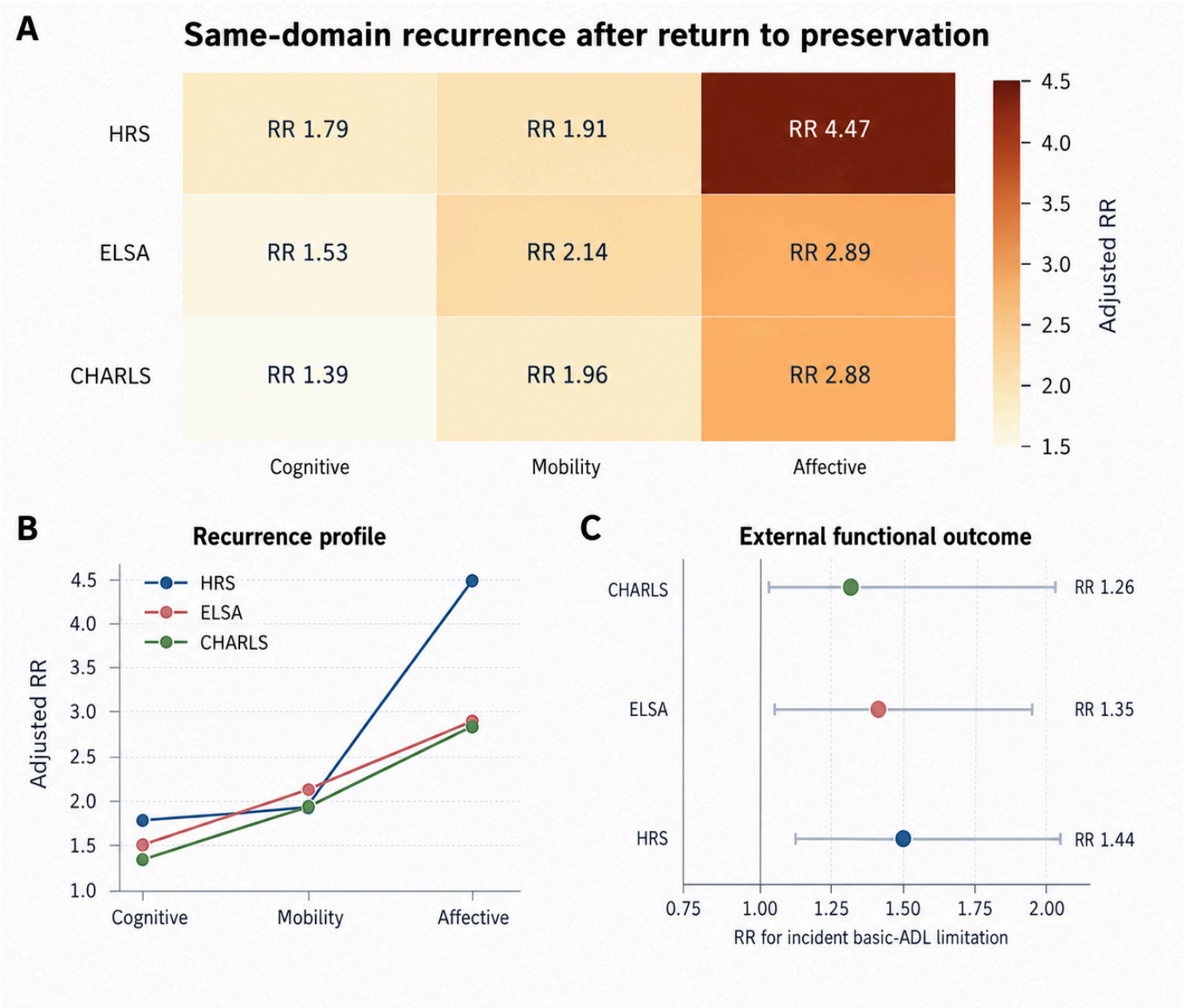


Figure 4

History is both general and domain-specific. Panels A and B summarize adjusted risk ratios for recurrence of the same cognitive-, mobility-, or affective-predominant state after return to preservation. Panel C shows adjusted risk ratios for incident basic-ADL limitation after recent recovery versus durable preservation among observations currently preserved and free of basic-ADL limitation. ADL, activities of daily living; RR, risk ratio.

Alt text: Three-panel figure showing higher same-domain recurrence after prior cognitive, mobility, or affective vulnerability across all three cohorts, plus higher incident basic-ADL limitation after recent recovery in HRS and ELSA with a directionally similar CHARLS estimate.

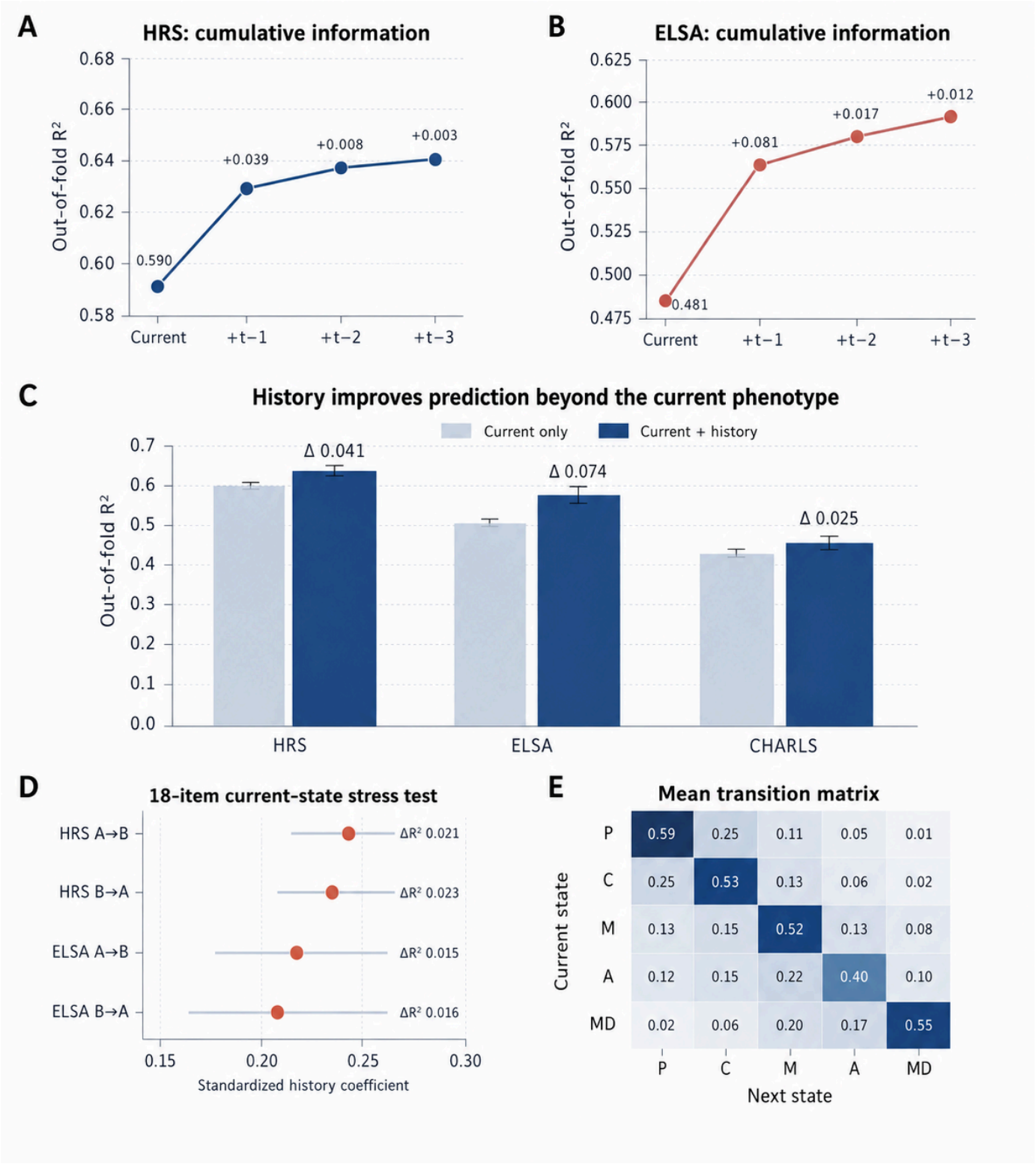


Figure 5

Longitudinal history carries information beyond a detailed current snapshot. Panels A and B show participant-separated out-of-fold R^2 as t−1, t−2, and t−3 multidomain history is sequentially added to the current phenotype in HRS and ELSA. Panel C compares current-only and current-plus-history prediction in all three cohorts. Panel D shows the saturated-current non-overlapping-item stress test in HRS and

ELSA. Panel E shows the mean adjacent-wave transition matrix. These analyses test prognostic information rather than a biological memory-decay process.

Alt text: Five-panel figure showing incremental prediction from deeper longitudinal history, current-only versus current-plus-history models, non-overlapping-item stress tests, and the pooled adjacent-wave transition matrix.

Supplementary Files

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

- SupplementaryInformation.docx