Frailty Trajectories and Transitions in Older Adults: A Population-Based Approach Using Linked Administrative Data

Abstract

Frailty is a multidimensional geriatric syndrome reflecting vulnerability from accumulated health deficits (Clegg et al., 2013). It is a major determinant of functional ability, service use, and quality of life, and its growing prevalence challenges the sustainability and equity of health and long-term care systems (Hoogendijk et al., 2019). Longitudinal evidence shows that frailty evolves through heterogeneous, non-linear trajectories, with transitions between robustness, vulnerability, and severe frailty (Gill et al., 2006; Bolano et al., 2019). Social disadvantage related to education, income, gender, and migration further amplifies these risks (Welstead et al., 2021). The Lancet Commission on Frailty (Dent et al., 2025) calls for improved measurement, early detection, and policy integration of frailty prevention.

This study, part of the DIFF project, uses Lombardy's integrated administrative data (>10 million residents) to model frailty trajectories and transitions among adults aged 65+. Individual records are linked across hospital, emergency, outpatient, pharmacy, exemption, homecare, and social-care databases through encrypted identifiers. A validated Frailty Index (FI) based on 40 indicators of morbidity, disability, and social vulnerability is computed annually following the cumulative-deficit model (Mitnitski et al., 2001; Rebora et al., 2025).

We apply Group-Based Trajectory Modelling to identify subpopulations with distinct FI patterns and Multistate Modelling to estimate transition probabilities and durations between frailty states and death. Preliminary results on 92,000 older adults reveal substantial heterogeneity: most experience gradual FI increases, while ~13% show sharp worsening or temporary recovery. Linked administrative data enable dynamic surveillance and actionable evidence for equitable, preventive, and integrated care.

Background

Frailty is a geriatric syndrome—a state of increased vulnerability due to the accumulation of health deficits and declining physiological reserves (Clegg et al., 2013). It is a major determinant of functional ability, health service use, and quality of life (Rodríguez-Mañas et al., 2013; Morley et al., 2013), and it elevates risks of hospitalization, institutionalization, dependency, and premature mortality (Rudnicka et al., 2020). Its rising prevalence challenges the sustainability and equity of health and long-term care, underscoring the need for preventive and integrated models (Hoogendijk et al., 2019; Dent et al., 2025).

Frailty is now recognized as multidimensional and dynamic—shaped by physical, psychological, and social domains and by life-course exposures (Rockwood & Mitnitski, 2007; Fried et al., 2001). Longitudinal studies show that trajectories are heterogeneous and non-linear, with transitions between robustness, vulnerability, and severe frailty, including phases of stability, sudden deterioration, and partial recovery (Gill et al., 2006; Bolano et al., 2019). Viewing frailty as an evolving process is crucial to identify windows of intervention and to build transition-based surveillance with early-warning indicators (van Kan et al., 2018).

Frailty also reflects social inequalities: it disproportionately affects socio-economically disadvantaged individuals, migrants, and women, mirroring cumulative disadvantage in education, income, and access to care.
The Lancet Commission on Frailty (Dent et al., 2025) called for renewed attention to:
(1) causal and life-course pathways linking biological and social determinants;
(2) improved measurement and early detection through validated indicators;
(3) evaluation of care models for adults living with frailty; and
(4) policy reform embedding frailty prevention within ageing and equity strategies.

Linked administrative data can advance these goals thanks to longitudinal coverage, completeness, and cross-sector linkages enabling population-level monitoring of frailty trajectories and determinants (Clegg et al., 2016; Reeves et al., 2023), yet remain under-used in Europe. Within this framework, the DIFF project develops social-statistical approaches to health vulnerability by linking individual trajectories with structural inequalities. This extended abstract focuses on its regional component, leveraging integrated administrative data from Lombardy to model frailty trajectories and transitions and to examine how healthcare access and service use shape their evolution.

Objectives

We advance the understanding of frailty as a multidimensional, dynamic social-health process observable in longitudinal administrative data:

1- Operationalize a validated Frailty Index (FI) using integrated healthcare and social-care databases (Rebora et al., 2025).

2- Characterize heterogeneous frailty trajectories among adults aged 65+, identifying pathways of stability, worsening, variability, and recovery

3- Model transitions between frailty states—including improvement, deterioration, and mortality—through multistate frameworks accounting for right-censoring and competing risks.

4- Estimate transition probabilities, expected durations, and short-term FI fluctuations as early-warning indicators.

5- Assess how healthcare and social-care access influence resilience or decline, and inform equitable service planning.

Sub-analyses adopt an intersectional perspective (gender × migrant status × socio-economic position).

Data Integration and Study Population

We use Lombardy's integrated data warehouse, linking individual-level records for >10 million residents across hospital discharges (ICD-9-CM diagnoses/procedures), emergency visits, outpatient/diagnostic services, pharmacy dispensing (ATC), exemptions (chronic disease, disability, income), residential/intermediate-care admissions, home-care assessments with ADL data, prosthetics/orthotics (EN ISO 9999), and psychiatric/disability registries. Encrypted

identifiers enable longitudinal tracking of morbidity, service use, and dependency. The cohort includes all residents aged 65+ continuously registered between 2015 and 2023.

The study population includes all residents aged 65+ continuously registered in the regional health service between 2015 and 2023.

Construction of the Frailty Index

Annually, FI is computed as the proportion of 40 accumulated deficits spanning morbidity, disability, and social vulnerability. Deficits integrate multiple flows to enhance sensitivity and temporal consistency:

- Chronic conditions (e.g., cardiovascular disease, diabetes, renal insufficiency) combine diagnostic codes from hospital and emergency data, exemptions, and medication records (ICD-9-CM, ATC).
- Functional limitations and dependency are derived from homecare and nursing-home assessments.
- Sensory impairments and assistive-device use come from prosthetics and orthotics flows.
- Socio-economic vulnerability is proxied by income-based exemptions and living-alone status.

Indicators are harmonized across domains and recall periods (1–10 years depending on source), following the cumulative-deficit model (Mitnitski et al., 2001; Rebora et al., 2025). The resulting FI allows reproducible, population-wide measurement of frailty trajectories.

Methods

We analyze frailty both as a continuous FI (capturing subtle but meaningful changes often missed by categorical scales; Welstead et al., 2021) and as a state-based dynamic process with annual classification into non-frail, pre-frail, frail, and severely frail using validated cut-offs. Two complementary strategies are employed:

1. Group-Based Trajectory Modelling (GBTM) to identify clusters with non-linear, non-monotone FI patterns, labelled as stability/slight deterioration, worsening, variability, or recovery, and profiled by demographic/clinical features.
2. Multistate Modelling to estimate transition intensities between frailty states (death absorbing), evaluate transitions over 5-year intervals (2015–2020), stratify by 5-year age groups up to 90+, and compute transition probabilities, expected sojourn times, and n-step matrices over 5–10 years.

Preliminary Results

In a pilot sample of 92,000 older adults, trajectories are markedly heterogeneous. Most exhibit gradual FI increases, ~13% show sharper worsening or temporary recovery following acute events. Transition patterns differ by sex and age: 5-year state persistence is common at 65–70, while worsening becomes prevalent from 75+.

Discussion and Expected Contributions

Linked administrative data can operationalize frailty longitudinally and model transitions at population scale. Combining trajectory and multistate approaches shifts monitoring from static prevalence to process-oriented surveillance of vulnerability. From a social-statistical perspective, the framework integrates clinical, behavioural, and contextual determinants, enabling evaluation of inequality mechanisms and system responsiveness. Results will support early identification of rapid decline for preventive targeting, quantify benefits of community/home-based care, and distinguish protective (preventive) from risk-related (avoidable) service contacts. Overall, we advance frailty as a dynamic, socially embedded process and provide actionable evidence for health equity and integrated care design.

References

van Kan, G.A., Rolland, Y., Morley, J. E., & Vellas, B. (2008). Frailty: Toward a clinical definition. Journal of the American Medical Directors Association, 9(2), 71-72

Bolano, D., Berchtold, A., & Von Gunten, A. (2019). The heterogeneity of disability trajectories in later life: Dynamics of activities of daily living performance among nursing home residents. Journal of Aging and Health, 31(7), 1316–1332.

Clegg, A., et al. (2013). Frailty in elderly people. The Lancet, 381(9868), 752–762.

Clegg, A., Bates, C., et al. (2016). Development and validation of an electronic frailty index using routine primary care electronic health record data. Age and Ageing, 45(3), 353–360.

Dent, E., et al. (2025). Reorienting frailty in clinical practice, public health, and policy: The Lancet Commission on Frailty. The Lancet.

Fried, L. P., et al. (2001). Frailty in older adults: Evidence for a phenotype. The Journals of Gerontology Series A: Biological Sciences 56(3), M146–M156.

Gill, T. M., et al. (2006). Transitions between frailty states among community-living older persons. Archives of Internal Medicine, 166(4), 418–423.

Hoogendijk, E. O., et al. (2019). Frailty: Implications for clinical practice and public health. The Lancet, 394(10206), 1365–1375.

Mitnitski, A. B., et al. (2001). Accumulation of deficits as a proxy measure of aging. The Scientific World Journal, 33298.

Rebora, P., et al. (2025). Population-based validation of a frailty index using regional healthcare records for public health use. Scientific Reports, 15(1), 33298.

Rodríguez-Mañas, L., et al. (2013). Searching for an operational definition of frailty: a Delphi method based consensus statement. The frailty operative definition-consensus conference project. Journals of gerontology series a: biomedical sciences, 12(1), 76–87.

Rudnicka, E., et al. (2020). The World Health Organization (WHO) approach to healthy ageing. Maturitas, 139, 6–11.

Hoogendijk, E. O., & Dent, E. (2022). Trajectories, transitions, and trends in frailty among older adults: a review. Annals of Geriatric Medicine and Research, 26(4), 289–299.

Welstead, M., Jenkins, N. D., Russ, T. C., Luciano, M., & Muniz-Terrera, G. (2021). A systematic review of frailty trajectories: their shape and influencing factors. The Gerontologist, 61(8), e463–e475.