Exploring Multidimensional Frailty in Older Adults in Italy: An Intersectional Perspective

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Abstract

Frailty is a multidimensional phenomenon shaped by biological, psychological, and social domains, and represents a key public health concern in the context of ageing populations. This study investigates patterns of bio-psycho-social frailty among older adults in Italy, with the dual aim of (i) identifying discrete classes of frailty, rather than relying on continuous measures, and (ii) examining the demographic and socio-economic determinants of frailty classes through an intersectional lens. Data were drawn from the 2019 wave of the European Health Interview Survey (EHIS). Latent class analysis was applied to items of frailty corresponding to the domains of the Tilburg Frailty Indicator (TFI), and multinomial logistic regression was used to assess the intersectional influence of sex, age, education, and marital status on class membership. A four-class model provided the best fit for both men and women, capturing distinct frailty profiles across biological, psychological, and social dimensions. Results highlight that older women with lower educational attainment are disproportionately exposed to multiple forms of frailty, while younger elderly men were more likely to belong to the non-frail class, underscoring the compounding effects of gender and socio-economic disadvantage. While the TFI could not be perfectly replicated within the available data, the study provides robust evidence of the heterogeneity of frailty experiences and the need for policy and intervention strategies sensitive to intersecting vulnerabilities in later life.

Introduction

Frailty has been defined as *"a dynamic state affecting an individual who experiences losses in one or more domains of human functioning (physical, psychological and social), which is caused by the influence of a range of variables and increases the risk of adverse outcomes"* (Gobbens et al., 2010). Its prevalence is higher among older adults, largely due to age-related physiological and functional decline.

Its prevalence is higher among older adults, largely due to age-related physiological and functional decline. The first and most commonly applied interpretation of frailty is the phenotype model, a unidimensional model which defines frailty through five components of physical functioning: unintentional weight loss, exhaustion, low physical activity, slowness, and weakness (Fried et al., 2001). More recently, there has been a shift towards a multidimensional interpretation of frailty, and novel definitions based on the interaction between multiple domains including genetic, biological, functional, cognitive, psychological and socio-economic have been developed (Pilotto et al., 2020). This perspective is embodied in major frameworks, such as the deficit accumulation model, operationalized through the frailty index, with the breadth of comorbidities, disabilities, and age-related decline (Rockwood and Mitnitski, 2007; Rockwood 2016). Another influential multidimensional framework is the bio-psycho-social model of frailty developed by Gobbens (2010), which explicitly integrates physical, psychological, and social dimensions.

As in many other health-related and behavioral domains, frailty is unequally distributed across the population, reflecting underlying socioeconomic and demographic inequalities. Multiple social identities—such as gender, sex, age, educational level, religion, and socioeconomic position (SEP)—have been found to be associated both with overall frailty and with specific dimensions of frailty. For example, a Dutch study by Hoogendijk *et al.* (2018) reported that lower SEP was associated with a higher risk of frailty, even after adjusting for age, sex, and partner status.

Addressing frailty through the lens of social justice is essential, given the profound social and sociological relevance of inequalities among older adults. Mapping how frailty is distributed across social groups not only reveals the structural disadvantages that accumulate over the life course, but also underscores the ethical imperative to act upon these disparities. Principles of social justice demand that health systems and policies recognize frailty not as an inevitable outcome of ageing, but as a condition shaped by unequal access to resources, opportunities, and care. By integrating social justice considerations into frailty research, it becomes possible to design more equitable interventions, to promote social inclusion, and ultimately to reduce the disproportionate burden of frailty experienced by marginalized groups of older adults. To capture social inequalities in frailty in a way which is more realistic, nuanced, and in line with principles of social justice, the intersectional framework provides a powerful theoretical lens. Intersectionality highlights how multiple social identities interact to generate unique patterns of social oppression, stigma and discrimination. Coined by American scholar and lawyer Kimberlee Crenshaw (1989), who drew inspiration from Black feminist movements in the US, the term highlights how ethnicity, gender, sex, SEP, migratory background and other socially relevant identities of a person are interconnected to shape unique patterns and lived experiences. Rather than exerting additive effects, these identities are interdependent, amplifying social disadvantages in ways that differ across groups. For example, belonging to an ethnic minority may entail different consequences for men and women, just as the implications of lower SEP vary across gender and age groups.

Despite its relevance, the intersectional framework has rarely been applied in frailty research, although it can be a powerful theoretical approach in understanding inequalities in its onset and development. One exception in gerontology research is the study by Gustafsson *et al.* (2022), which applies the intersectional framework to examine inequalities in loneliness —a key dimension of social frailty—in Sweden. The authors found the highest risks among the most disadvantaged group, that is older, lower income, immigrant women in nursing homes. Inequalities of similar magnitude were however also seen for several other strata comprising immigrant nursing home residents with medium or low income but also including medium- and low-income women living in their own residence.

Frailty and social identities

Social determinants of frailty in older populations have been well documented across both unidimensional and multidimensional conceptualizations. Gobbens et al. (2010b) found that medium income, unhealthy lifestyle, and multimorbidity were predictors of multidimensional frailty, and that specific domains of frailty seem to be differently/particularly affected by specific risk factors (e.g., age for physical frailty, life events for psychological frailty, being a woman for social frailty). Subsequent studies (Mello et al. 2014; Di Tommaso et al., 2018) identified similar factors associated with physical frailty in the older population. Overall, age and SEP gradients have been confirmed across studies.

Frailty is closely linked to the ageing process, and **age** as a social identity plays a significant role in shaping the risk of becoming physically, socially, and/or psychologically frail. As a socially relevant marker, age can carry discriminatory consequences, as it categorizes individuals into groups perceived as more or less vulnerable (e.g., young children and older adults versus individuals in early or middle adulthood). This dynamic underpins the sociological concept of *ageism*, which encompasses stereotypes (how we think), prejudice (how we feel), and discrimination (how we act) directed at others—or oneself—on the basis of age. Importantly, ageism does not operate in isolation: it intersects with other socially relevant dimensions such as gender and ethnicity, compounding disadvantages and shaping unique social realities. Recognizing these intersections highlights the need to move beyond viewing age as a purely biological fact and instead to understand it as a social construct with material consequences. Giving voice to these experiences within research is crucial for developing more inclusive frameworks, informing social policy, and ultimately reducing inequities across the life course.

Gender differences in the prevalence of frailty in the elderly population have also been the object of several research studies. Indeed, a study from Mielke et al. (2022) demonstrated that there are gender differences in frailty transition rates, patterns and prediction. These gender differences in elderly frailty have been found and confirmed by other studies (Zhang et al., 2018). Beyond biological distinctions, however, gender operates as a social identity that shapes health trajectories through socially constructed roles, expectations, and inequalities. For instance, women often experience cumulative disadvantages over the life course, including lower SEP, caregiver burdens, and reduced access to resources, which can exacerbate their vulnerability to frailty in later life. Conversely, men may face different risks linked to occupational histories, health behaviors, or cultural norms surrounding masculinity. These dynamics illustrate how sex (as a biological category) and gender (as a social construct) interact to influence distinct pathways into frailty. Moreover, gender intersects with other social identities—such as age, ethnicity, and class—producing layered inequalities and unique outcomes. Recognizing these intersections is crucial for developing a more nuanced understanding of frailty and for informing interventions and policies that address the diverse needs of older adults.

Socio-economic status also plays an important role in worsening the frail condition of the elderly population. A study from Sirven *et al.* (2020) found that individuals with worsening economic conditions over time simultaneously experience a rapid increase in the frailty symptoms. A similar effect of lower SEP on frailty was confirmed by other studies (Hanlon et al., 2024). SEP represents a crucial social identity to assess within intersectional studies, as it strongly shapes health trajectories and later-life outcomes. In the context of elderly frailty, SEP has generally been found to be inversely associated with the risk of becoming frail, although the strength and direction of this association can vary depending on the outcome measures and indicators employed (Wang and Hulme, 2021). Despite the recognized importance of SEP, to our knowledge no study has specifically examined its role in relation to frailty among the Italian elderly population. This literature gap makes it particularly relevant to investigate how socioeconomic inequalities intersect with other social dimensions to influence frailty in later life.

Another relevant social feature related to the frail condition of the elderly is **marital status** and the composition of the family household. A recent review found that unmarried individuals had an almost twice higher frailty risk than married individuals (Kojima et al., 2020). The same was confirmed in the Italian setting in a study from Trevisan *et al (2016).,* and by other studies (Fohn et al., 2018; Wong et al., 2021). Marital status represents a key social feature to be considered in intersectional studies on elderly frailty, as it reflects both structural and relational dimensions of social life that strongly influence health trajectories in later years. Being married or cohabiting is often associated with greater social support, economic stability, and access to care, all of which may reduce the risk of frailty. Conversely, widowhood, divorce, or lifelong singlehood can increase vulnerability through mechanisms such as social isolation, reduced financial resources, and diminished emotional support. Importantly, the impact of marital status does not operate in isolation but intersects with other social identities—such as gender, socioeconomic position, and age—to produce differentiated risks and outcomes. For example, widowed women may experience compounding disadvantages related to lower pensions, caregiving histories, and weaker economic security compared to widowed men. Addressing marital status within an intersectional framework is therefore crucial to fully capture the heterogeneity of frailty experiences among older adults and to inform policies that promote more inclusive forms of social support.

Applying an intersectional framework to research on frailty in older adults can deepen our understanding of how social dimensions interact within the older population. This approach helps to identify groups are at heightened risk of frailty, while also accounting for how membership in specific social categories intersects with different dimensions of frailty. Identifying these high-risk groups is essential not only for monitoring population health, but also for designing targeted policies that promote social inclusion and improve care for frail older adults. Importantly, intersectionality highlights that social identities may not be equally associated with all dimensions of frailty; rather, some groups may experience a disproportionate burden in particular domains, underscoring the need for more nuanced analyses and tailored interventions.

To our knowledge, no intersectional study on multidimensional frailty in the Italian elderly population has yet been conducted, despite the fact that the Italian population is among the oldest globally. Some evidence exists on social inequalities in frailty among the Italian elderly, however these studies have not employed an explicitly intersectional approach. For example, Galluzzo *et al*. (2022) found that frail individuals were more likely to be older, female, less educated, and less frequently married compared to their non-frail counterparts. Similarly, Poli, Pandolfini *et al*. (2020) demonstrated that frailty is strongly associated with social exclusion, economic hardship, and weak social networks, and that older adults with lower educational attainment, financial difficulties, and greater exposure to social discrimination face a significantly higher risk of frailty and mortality. At present, it is not well understood how different social groups are distributed across the various dimensions of multidimensional frailty.

The purpose of this research is twofold. First, it aims to identify and measure the bio-psycho-social dimensions of frailty among community-dwelling older adults in Italy, applying a specific theoretical framework to identify classes of frailty, rather than assessing severity along a continuum. Second, it seeks to identify distinct profiles of frail older adults associated with each frailty class, using an intersectional perspective to examine how individual characteristics combine and to identify the key factors contributing to vulnerability across different dimensions of frailty.

Our research aims are intended to address the following questions:

- How do the different domains of bio-psycho-social frailty coexist within an older individual?
- Which socio-demographic characteristics best define the profiles of frailty among older adults?
- Do these characteristics intersect in ways that amplify disadvantage?

Methods

Data source and sample

Data comes from the European Health Interview Survey (EHIS). The survey has been established by the European Commission and is among those included in the Italian National Statistics Programme, which collects the set of needed statistical surveys in Italy, with the objective of monitoring the main aspects of the population's health conditions and use of health services.

The survey was conducted for a sample of approximately 30,000 households, resident in 835 Italian municipalities very heterogeneous in terms of population size. The survey was performed during the period September – December 2019. From the 2019 EHIS sample, we selected respondents aged 65 and older (N=13,719), and the final analytic sample included only those with complete information on the frailty indicator items.

Measures

Frailty indicator

Frailty was conceived following the bio-psycho-social model developed by Gobbens et al. (2010) and operationalized using the Tilburg Frailty Indicator (TFI), which was developed in line with this theoretical framework. The TFI comprises three domains and consists of 15 items, eight covering the bio/physical dimension of frailty, four the psychological dimension and three the social dimension. The TFI has been translated and validated in Italian (Mulasso et al., 2026), and previous research has examined its replicability in large-scale survey data, such as SHARE (Theou at al., 2013). Building on these works, we reproduced the indicator using EHIS. The resulting indicator consisted of the following 11 items across three domains: six for the physical domain (self-rated health, difficulties in walking 500 meters, climbing one flight of stairs, hearing and seeing and tiredness or lack of energy); three for the psychological domain (problems with memory or concentration, feeling down or depressed and low self-esteem); and two for social domain (living alone and receiving inadequate/insufficient help for own needs). Table A1 of the appendix describes in full detail the construction of each item highlighting similarities and discrepancies compared to TFI original version and with the adaptation proposed by Theou et al. (2013).

We then tested the psychometric properties of the TFI obtained from the EHIS data, as described in the analysis section below. Furthermore, as sensitivity analysis we replicated our analysis using the Survey of Health, Ageing and Retirement in Europe (SHARE) and computed the TFI version proposed and validated by Theou and colleagues (2013) for the Italian sample, in order to compare the results. SHARE is a multidisciplinary and cross-national panel database of micro data on health, socioeconomic status, and social and family networks of individuals aged 50 or older (Borsch, 2022). We used the ninth wave, carried out in 2022, and selected respondents aged 65 and above and resident in Italy.

Strata

The strata considered in this work are known to be correlated with various forms of frailty—physical, psychological, or social—and at the same time contribute to defining individual identity. We considered two assigned characteristics and two socially constructed dimensions:

Sex First we considered sex (female, and male) as a fundamental individual characteristic that defines people's identity.

Age distinguishing younger elderly (aged 65 to 69), this group is interesting as the majority of them is going through a life transition such as retirement, which changes their societal role and their routine. Then the intermediate elderly aged 70 to 74, and finally the older elderly aged 75 and above. We could not further distinguish this group due to data availability.

Education While education is not an intrinsic characteristic which is given at birth and not changeable, it is a very important predictor of health and many outcomes over the life course of individuals. At the same time, it very much characterizes individuals' attitudes, views and social position. Education consisted of three categories, elementary or less than elementary school; lower secondary education; upper secondary education or above. The choice of grouping upper secondary and higher level of education together was dependent on the population subgroup analyzed, that is older Italian people.

Income This is an alternative measure of socio-economic position to education. Unlike education, it is not time-invariant once the highest level is reached, it rather changes across the life course, and it is meaningful in terms of material resources that individuals have. We considered income quintiles.

Marital status As education, this is not an intrinsic characteristic given at birth and not changeable, but represents an important predictor of health, whose effect is known in literature to differ depending on gender and other individual characteristics. We distinguished partnered individuals, widowed, and single and separated and divorced as third group.

Covariates

Covariates included determinants of frailty identified by Gobbens et al. (2010) that were not part of the intersectional strata. These comprised **healthy lifestyle factors**, operationalized as smoking behavior (current smoker, former smoker, or never/rarely smoked), weekly vegetable intake (measured on a continuous scale: one or more times a day, 4–6 times a week, 1–3 times a week, less than once a week, never), and BMI categorized as underweight, normal weight, overweight, or obese. **Number of chronic diseases** was also included, covering asthma, chronic bronchitis, myocardial infarction, angina, hypertension, other heart diseases, stroke, osteoarthritis or arthritis, lower back disorder or other chronic back conditions, cervical disorder or other chronic neck conditions, diabetes, allergy, liver cirrhosis, urinary incontinence, kidney problems, chronic renal failure, hyperlipidemia, tumor, Parkinson's disease, and other chronic conditions. **Life events** were captured with a question asking whether respondents had experienced adverse events in the past three years. **Satisfaction with the home living environment** was measured on a continuum as the number of housing problems, ranging from 0 to 6, including: housing expenses too high, dwelling too small, dwelling far from relatives, irregular water supply, damp patches or mold/fungi, and poor overall condition. Finally, when the **socioeconomic position (SEP) component** of the intersectional strata was measured via education, we controlled for income; conversely, when the strata were defined by income tertiles, we controlled for education.

Analysis Plan

Psychometric properties

Psychometric properties were assessed measuring the reliability and validity of the TFI.

Reliability was evaluated in terms of internal consistency. Internal consistency refers to the extent to which all items in a test measure the same concept or construct. Internal consistency of the score was assessed using the Cronbach's alpha (α). The Cronbach's alpha score ranges from 0 to 1, where 1 represents the highest amount of internal consistency, and 0 the minimum. α values greater than 0.70 are considered acceptable. Additionally, corrected total item correlation was calculated to assess if the single items behaved consistently with the rest of the test. Higher item correlations indicate better internal consistency. *Validity* was assessed through criterion validity and known-group validity. Criterion validity examines the relationship between a measurement score and an external criterion. We evaluated this using correlation coefficients and receiver operating characteristic (ROC) curve analyses, calculating the Area Under the Curve (AUC). AUC values were interpreted as follows: <0.7 = poor (no discrimination), 0.7–0.8 = acceptable, 0.8–0.9 = excellent, ≥0.9 = outstanding. External criteria included self-rated health, hospitalizations, presence of chronic conditions, limitation in daily activities, visits to practitioner. Known-group validity evaluates an instrument's ability to discriminate between groups known to differ on the variable of interest (Davidson 2014). Group differences were assessed using the non-parametric Kruskal-Wallis test. Groups considered included gender, age (5-year interval classes) and socioeconomic status (operationalized as highest educational attainment achieved and categorized as none, primary, lower secondary, upper secondary, tertiary or more).

Latent Class Analysis of Frailty and Intersectional Effects

To derive categorical indicators of frailty, we applied latent class analysis (LCA) to 11 binary variables corresponding to the items of the TFI.

Our analytic strategy followed the systematic framework outlined by Masyn (2012), which has been widely employed in empirical research, including applications of the intersectionality framework (e.g., Garnett et al., 2014). The sequential steps were: (1) to determine the optimal number of latent classes, and (2) to relate latent class membership to external descriptors. In this study, the second step allows for formal testing of intersectional effects.

We estimated models with 2 to 7 latent classes (the algebraic specification is provided in the Appendix). Selection of the best-fitting model—that is, the most appropriate representation of categorical frailty—was guided by a combination of statistical fit indices, classification diagnostics, substantive interpretability, and parsimony. Fit statistics included the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample-size adjusted BIC (SABIC), Consistent AIC (CAIC), and Approximate Weight of Evidence Criterion (AWE), with lower values indicating better fit. In addition, we employed the Vuong–Lo–Mendell–Rubin adjusted likelihood ratio test (VLMR-LRT) to compare whether a model with *k* classes provided a significantly better fit than a model with *k–1* classes.

Classification quality was assessed using several diagnostics. The entropy statistic provides an overall index of classification accuracy, ranging from 0 to 1, with values ≥ 0.80 generally considered indicative of good separation between classes. The odds of correct classification (OCC_k) provide a class-specific measure of certainty in assignment, with values above 5 considered adequate (Masyn, 2012). The average posterior class probability ($AvePP_k$) indicates the precision of classification for each class, with values ≥ 0.70 reflecting well-separated classes (Masyn, 2012). These quantitative criteria were evaluated alongside qualitative inspection of the conditional response probabilities for each item across classes, to assess whether the resulting profiles captured substantively meaningful and interpretable distinctions in frailty.

Modelling gender

Examining gender differences implies investigating variation along one axis of the intersectional strata. To address this, we adopted two approaches. First, we stratified the sample by gender and re-estimated the model described above separately for males and females, which allows for descriptive comparison but does not provide a formal statistical test of gender invariance. Therefore, we additionally conducted a multigroup LCA, which involved determining if the latent class model fits the data equally well for men and women.

Based on the optimal number of latent classes selected considering the whole sample, in the second approach gender was added as a “known class” to determine the best-fitting multigroup model. Equality constraints across groups were imposed and tested in a stepwise fashion to evaluate whether latent frailty categories differ significantly by gender. The best-fitting model was derived within a K-class solution after comparing the following nested and full models – a) a fully constrained model in which measurement invariance was assumed and the response probabilities and class sizes were constrained (this is equal to the LCA model run on the full sample without account for gender); b) a semi-constrained model in which response probabilities were fixed and class sizes free to vary; and c) a fully unconstrained model, in which both response probabilities and class sizes were free to vary. Selection of the optimal model was based on comparing the constrained (nested) models’ fit against the corresponding unconstrained (fuller) models (Seet et al., 2024).

This step helped us determine if the latent class model developed for the total sample fits the data equally well regardless of gender or if we needed to allow model parameters such as class membership or conditional probabilities within class to vary by gender to better fit the data.

If the fully unconstrained model fits the data significantly better than the constrained model, this would suggest separate latent class models, one for each gender, might be necessary. This represents a first step toward identifying intersectional effects, as gender is considered not only as a characteristic but also as a potential factor shaping the outcome structure itself, thereby influencing the analysis of correlation between frailty categories and the other intersectional elements.

Finally, once the optimal number of classes was identified and gender invariance assessed, we examined predictors of latent class membership using multinomial logistic regression (Muthén, 2002). To capture intersectional processes, the regression model included interaction terms reflecting the joint effects of social stratification variables. Moreover, the stratified analyses as well as multigroup LCA followed by multivariable multinomial regression (not including gender among the independent variables) represent another approach to identify intersectional effects[1]. (Guan et al., 2021).

Results

Descriptive results

Of the 13,719 EHIS respondents aged 65 and above, 13,376 had complete records for all frailty items. They represented the sample for this study. Table 1 presents descriptive statistics for i) frailty items; ii) elements of social strata. Descriptive results for SHARE data are available in Table A2 of the appendix.

Table 1. Descriptive statistics

	Males (N=5,908)	Females (N=7,468)	Total (N=13,376)
Frailty domains			
Physical frailty			
Self-rated health	55.0	64.6	60.3
Problem with walking	12.4	22.3	17.9
Problem with balance	12.2	22.4	17.9
Hearing problems	24.6	26.2	25.5
Eyesight problems	30.0	35.6	33.1
Lack of energy	12.5	21.5	17.5

[1] Analyses (eg regressions) stratified by groups are alternative approach to reduce n-way interaction term, which is difficult to interpret, this method assesses the association between a (n-1)-way interaction term between two or more axes of interest by strata of a nth axis of social position. Effectively, this is an evaluation of effect modification.

Psychological dimension			
Problems with memory	31.6	41.5	37.1
Feeling down or depressed	21.3	35.8	29.4
Feeling a failure	11.1	18.1	15.0
Social dimension			
Living alone	18.5	37.5	29.1
No help from other people	10.2	19.6	15.5
Strata elements			
Age			
65-69	27.6	24.3	25.7
70-74	25.7	22.7	24.0
75+	46.8	53.0	50.3
Education			
Primary education or less	38.3	54.1	47.1
Lower secondary education	28.3	21.8	24.7
Upper secondary education or above	33.3	24.1	28.2
Marital status			
Partnered	78.0	47.9	61.2
Widowed	10.5	42.1	28.2
Single or divorced/separated	11.4	10.0	10.6
Income quintile			
1st	12.0	13.0	12.6
2nd	19.6	22.2	21.1
3rd	20.8	22.3	21.6
4th	22.6	21.8	22.2
5th	24.9	20.7	22.6

Frailty indicator and classes of frailty

The TFI ranged from 0 to 11, mean 3.5 (sd 2.9) and median 3. The distribution is illustrated in figure A1 of the appendix. 15% of the sample had no problem with any frailty items, 19% in one item and 14% in two items, the remainder 50% had problems with three or more items. The Cronbach's alpha of 0.81 for the total TFI was considered acceptable. The values of internal consistency were 0.76, 0.64 and 0.20 for physical, psychological, and social domain, respectively. The appendix (Table A3) also presents internal consistency for single items, through the raw alpha estimated eliminating the item and corrected item-total correlations.

The criterion validity of the total TFI was excellent for GALI 0.87 (0.86-0.88) and good for chronic conditions 0.72 (0.71-0.74) (see table A4 of the appendix for full results). Finally, known groups comparison supports the construct validity of the TFI (see Appendix Table A5).

The psychometric properties indicate that the TFI measured in EHIS is a valid and reliable instrument. However, the continuous score reported above provides limited insight into the *types* of frailty, as they do not reveal which specific items—or combinations of items—underlie different frailty profiles. To address this limitation, we applied LCA and identified a four-class model as the best-fitting solution. Tables 2 and 3 reports latent class models goodness of fit indicators and model classification diagnostics of the 4-class and 5-class solutions.

Figure 1 presents the probability of each frailty item estimated by the 4-class model. The four classes were labeled as “non frailty” (50.4%), “psychological frail” (13.0%) presenting highest conditional item-probability for items related to the psychological frailty domain, “physical frailty” (20.4%), with highest item probabilities for items pertaining to physical domain, particularly related to mobility; and “multiple frailty” (16.3). Remarkably, the item self-rated health presents high and very high probabilities across all groups, due to the high prevalence of poor/fair SRH in the sample. Figure A2 of the appendix illustrates the profile plot of the 5-class solution, the second-best solution, which differs from the 4-class model mostly by splitting the physical frailty group in two groups that we named “physical mobility frailty” and “physical and cognitive frailty”.

Figure 1. Probability of each frailty item estimated by the 4-class model

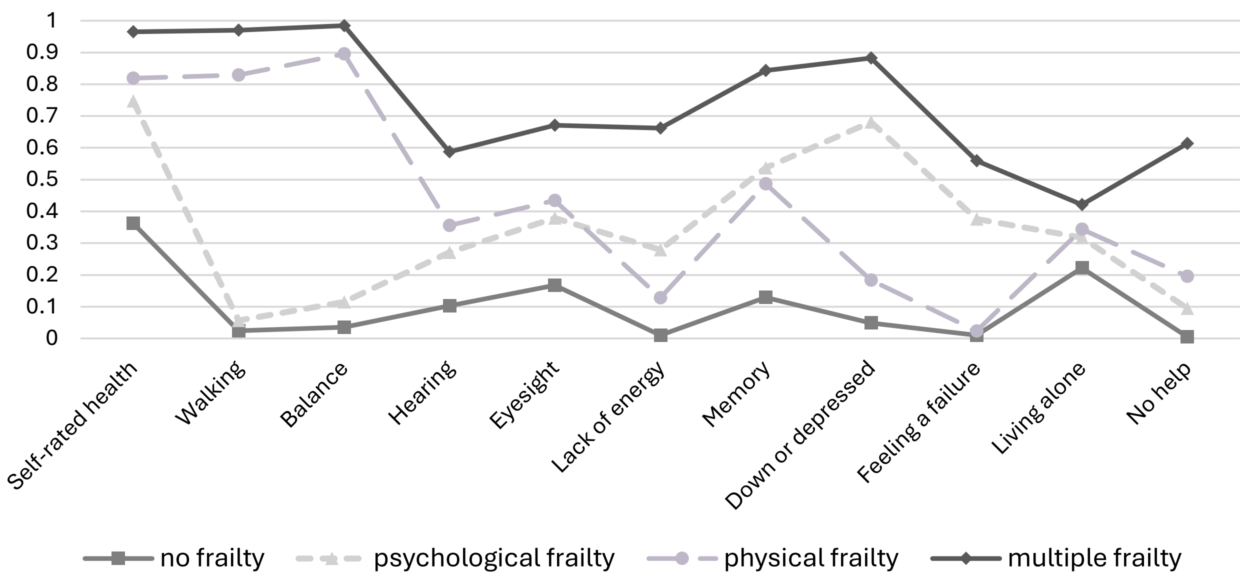


Table 2. Fit Statistics and Classification Coefficients - Latent Class Analysis Models on Frailty Components

Class	AIC	BIC	SABIC	CAIC	AWE	VLMR LRT (p-value)
2	144002.2	144174.8	144101.7	144074.1	144215.1	<0.001
3	140971.7	141234.3	141123.0	141081.1	141295.6	<0.001
4	138391.3	138743.9	138594.5	138538.3	138826.2	<0.001
5	137929.8	138372.4	138184.9	138114.2	138475.7	<0.001
6	137497.0	138029.6	137803.9	137719.0	138153.9	<0.001
7	137271.9	137894.5	137630.7	137531.4	138039.9	0.004

Note AIC= Akaike Information Criterion; BIC = Bayesian Information Criterion; SABIC = Sample-size adjusted BIC; CAIC = Consistent Akaike Information Criterion; AWE = Approximate Weight of Evidence Criterion; VLMR-LRT_p = Vuong-Lo-Mendell-Rubin adjusted likelihood ratio test

Table 3. Model classification diagnostics of the 4-class and 5-class solutions

4-class	**Entropy**=0.815			
	Model estimated proportion for class *k*	**Modal class assignment proportion for class k**	**Average posterior probability for class k**	**Odds of corrected classification**
class 1	0.163	0.161	0.913	53.9
class 2	0.504	0.522	0.929	12.9
class 3	0.130	0.115	0.829	32.6
class 4	0.204	0.203	0.862	24.4
5-class	**Entropy**=0.789			
	Model estimated proportion for class *k*	**Modal class assignment proportion for class k**	**Average posterior probability for class k**	**Odds of corrected classification**
class 1	0.128	0.130	0.755	21.1
class 2	0.125	0.113	0.82	31.8
class 3	0.093	0.086	0.756	30.3
class 4	0.154	0.157	0.894	46.4
class 5	0.501	0.514	0.932	13.7

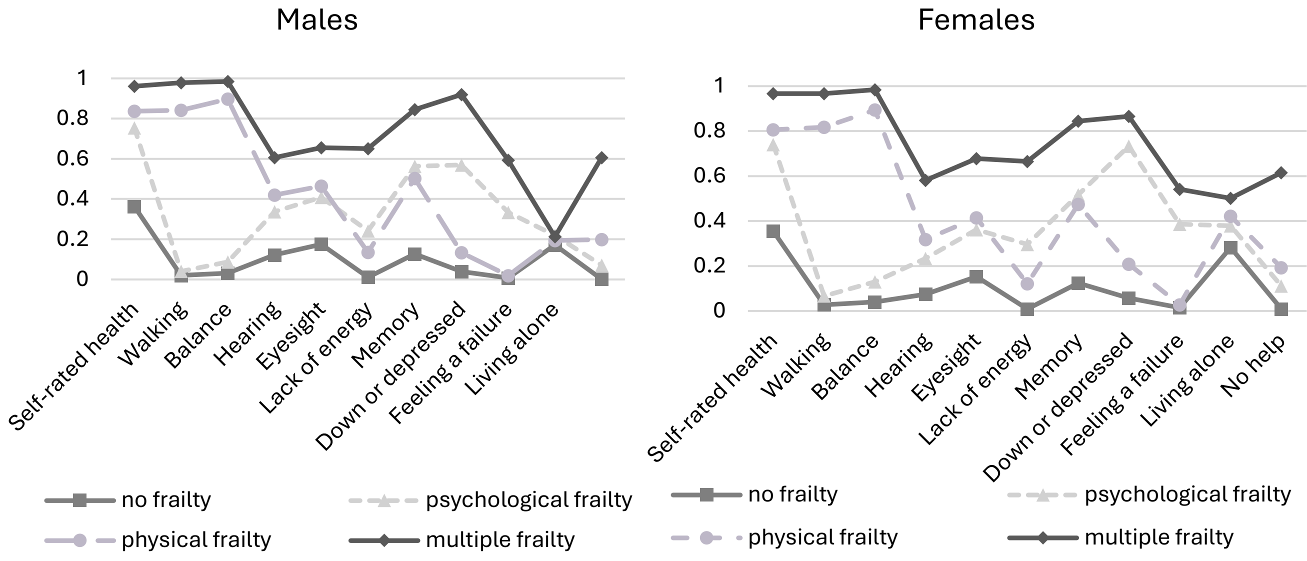
Sex

Stratified model

Figure 2 shows the conditional item probabilities for males and females in the 4-class model of the stratified analysis. Tables A6 and A7 in the appendix report the statistical fit indices and classification quality measures. For both sexes, the 4-class solution was ultimately selected. Among males, the 4-class model emerged as the clearly preferable choice, whereas among females the 5-class model provided a more closely comparably good choice. For both genders, the 4-class solution corresponded to classes with similar frailty item probabilities and hence interpretable in a similar way with each other and to the 4-class model obtained for the total sample.

Females belonging to “No frailty” class were 41.2%, males were 60.8%; multiple frailty were 10% of males and 21.4% of females; psychological frailty 13.2% of males and 13.5% of females and physical frailty 16% of males and 23.8% of females.

Figure 2. Probability of each frailty item estimated by the 4-class model, by sex



Multiple-group LCA model

After determining the four-class latent class model as best solution, model invariance was then examined using multiple-group LCA. Table 4 presents the fit statistics and parameters of the fully constrained, partially constrained and fully unconstrained 4-class models. The fully unconstrained model had the lowest AIC, BIC and SABIC values, while the partially constrained model had the highest entropy. The partially constrained model was selected as the most appropriate model. Hence, the results indicate that it is reasonable to assume measurement invariance of the classes across the diagnostic groups, while class membership differs across the groups.

Table 4 Fit statistics of 4-class models (invariance testing)

	Number of parameters	AIC	BIC	SABIC	Entropy
Fully constrained [a]	48	156754.05	157114.11	156961.57	0.815
Partially constrained [b]	51	156121.86	156504.43	156342.35	0.820
Fully unconstrained [c]	95	155529.53	156242.14	155940.24	0.814

[a] Model fixing item thresholds and class probabilities across groups and classes
[b] Model fixing item thresholds, and allowing differences in class probabilities across groups
[c] Model allowing differences in class probabilities and item thresholds

Intersectional effects

Figure 3 shows the dimension of the 36 strata composed by sex, age, education and marital status. The largest stratum was females aged 75 and above, with primary education or less who were widowed (13%, N=1758), then males aged 75 and above, with primary education or less and partnered (8%, N=1047) and males aged 65-74, with upper secondary education or above and partnered (7.6%, N=1018). The smallest group consisted of males aged 75 and above with lower secondary education who were single or divorced (0.3%, N=43).

Figure 3. Dimension of intersectional strata

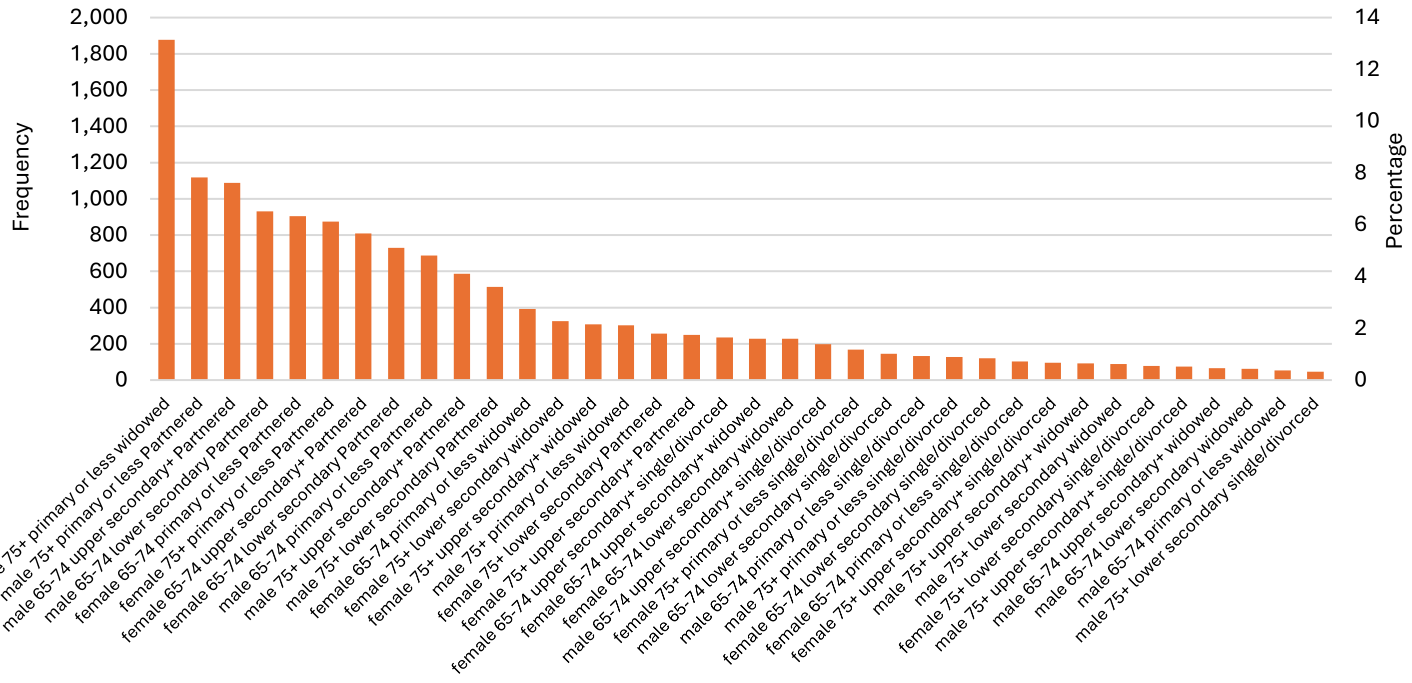


Table 5 presents the results, expressed in terms of average marginal effects (AMEs), from the multinomial logistic regression analysis of demographic and socioeconomic factors, that compose the intersectional strata, associated with different classes of frailty. Females were more likely than males to belong to class of frailty, especially multiple frailty, 6.3 percentage points more likely and 12.5 points less likely to belong to non-frailty class. The age effect was the largest, i.e., those aged 75 and above more likely to be in multiple and physical frailty classes (15.2 and 11.1 percentage points respectively) and less likely to be in non-frailty (25.6 pp), but no differences were observed for psychological frailty class. Those highly educated were less likely than those with lowest education to be in multiple and physical frailty classes, but no differences emerged for psychological frailty. Finally, compared to partnered respondents both widowed and single or divorced were more likely to be in multiple and psychological frailty classes, but no differences between partnered and single or divorced were observed for physical frailty. Overall, the largest AMEs were observed for age —except for psychological frailty—and for highest level of education compared with the lowest.

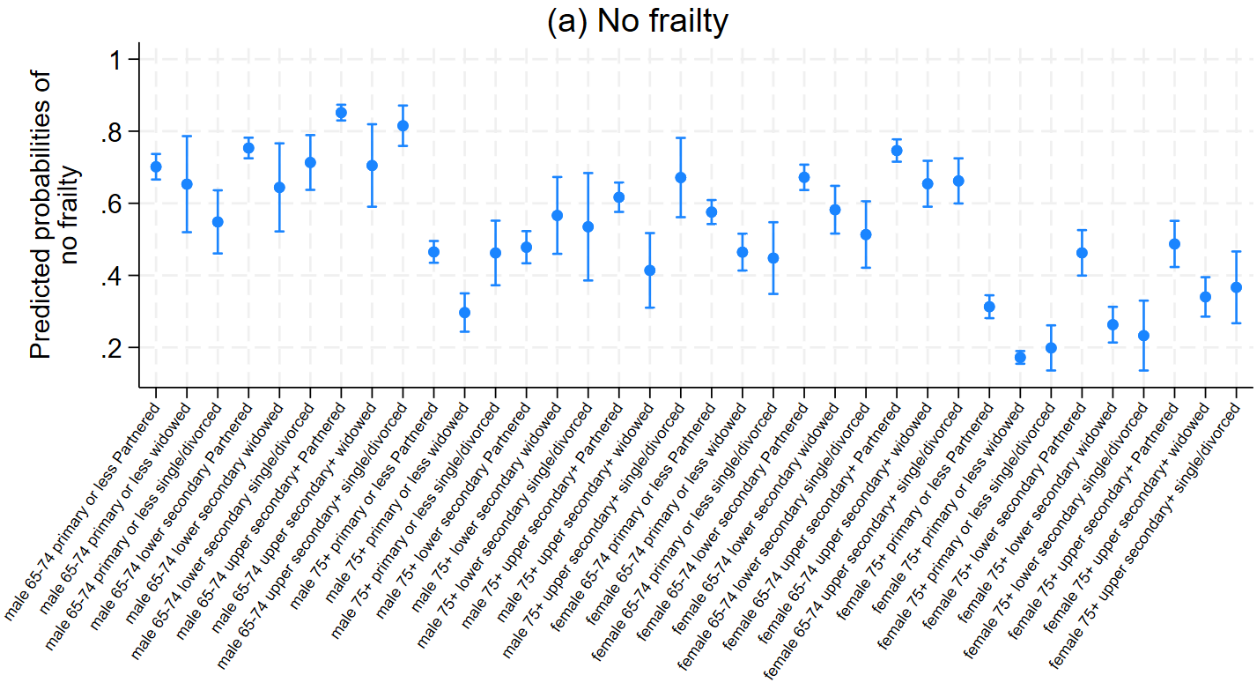
Table 5. Average marginal effects for a multinomial logistic regression model for frailty classes

	Multiple frailty	No frailty	Psychological frailty	Physical frailty
Female	0.063***	-0.125***	0.012**	0.050***
	[0.050, 0.076]	[-0.142, -0.108]	[0.001, 0.024]	[0.036, 0.065]
Age 75+ (ref. 65-74)	0.152***	-0.256***	-0.007	0.111***
	[0.139, 0.164]	[-0.273, -0.238]	[-0.019, 0.005]	[0.096, 0.126]

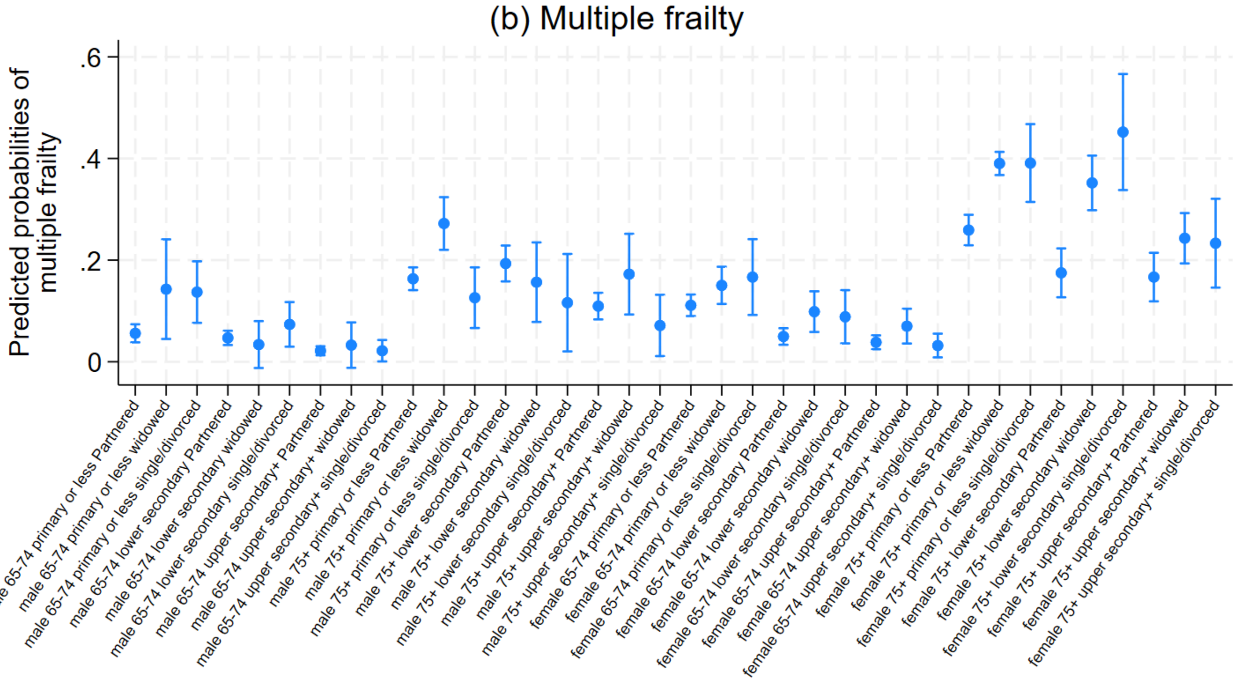
Lower secondary (ref. Primary or lower education)	-0.031***	0.077***	0.002	-0.048***
	[-0.047, -0.015]	[0.057,0.098]	[-0.012, 0.017]	[-0.066, -0.030]
Upper secondary+	-0.084***	0.170***	0.000	-0.086***
	[-0.098, -0.069]	[0.150,0.190]	[-0.014, 0.013]	[-0.102, -0.069]
Widowed (ref. Partnered)	0.071***	-0.122***	0.025***	0.027***
	[0.056,0.086]	[-0.143, -0.102]	[0.010, 0.040]	[0.010, 0.044]
Single/divorced	0.045***	-0.083***	0.019**	0.019
	[0.023,0.067]	[-0.109, -0.056]	[0.000, 0.037]	[-0.005, 0.043]

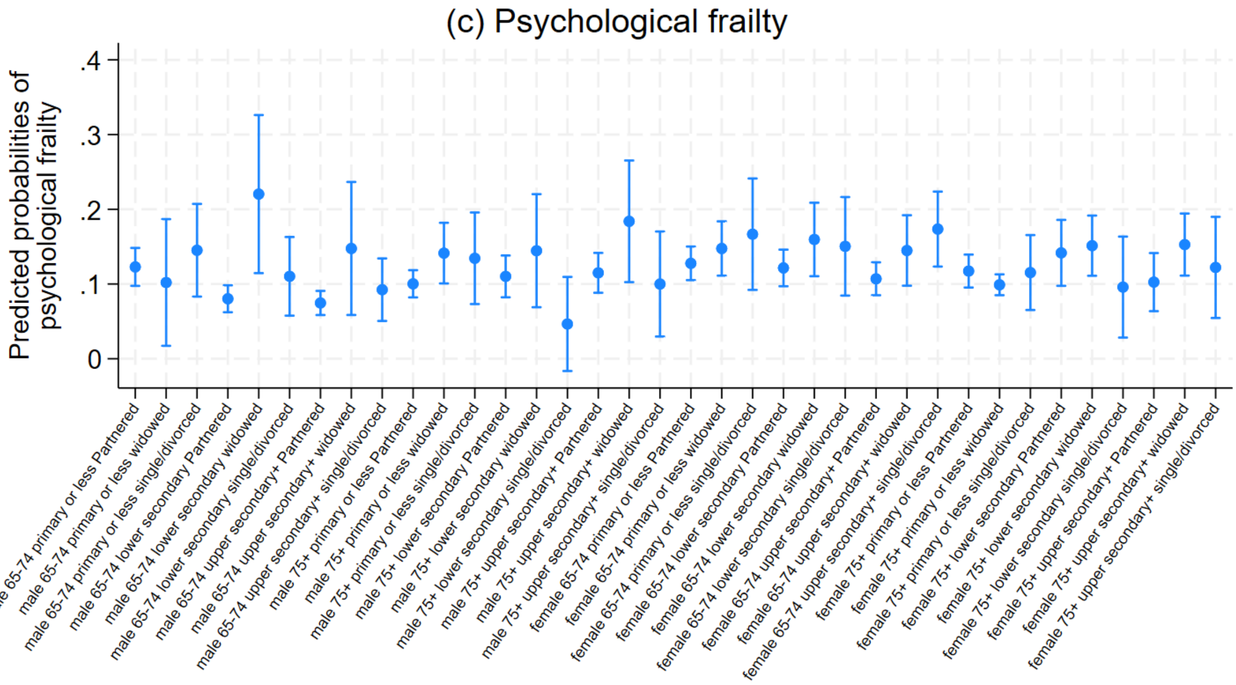
Figure 4 presents the predicted probabilities for each frailty class by intersectional strata, derived from the multinomial logistic regression analysis. The probability of belonging to the non-frail group was highest for males aged 65-74 with upper secondary education or above and partnered (85.2%, 95% CI 83.0-87.4) and males aged 65-74 with upper secondary education or above, single or divorced (81.5%, 75.9-87.1). The lowest predicted probability was observed for females aged 75+, with lowest educational level and widowed (17.2%, 15.5-19.0). In contrast, the highest probability of belonging to multiple frailty class was observed for females aged 75+, with lower secondary education and single or divorced (45.2%, 33.8-56.5) and females aged 75+ with primary education or less and widowed (39.0, 36.7-41.3) and single or divorced (39.1, 31.4-46.7). The psychological frailty class showed the smallest differences across intersectional strata, with only a few strata exhibiting significantly different predicted probabilities. For the physical frailty class, intersectional effects were similar in direction to those observed for multidimensional frailty, but generally smaller in magnitude and statistical significance.

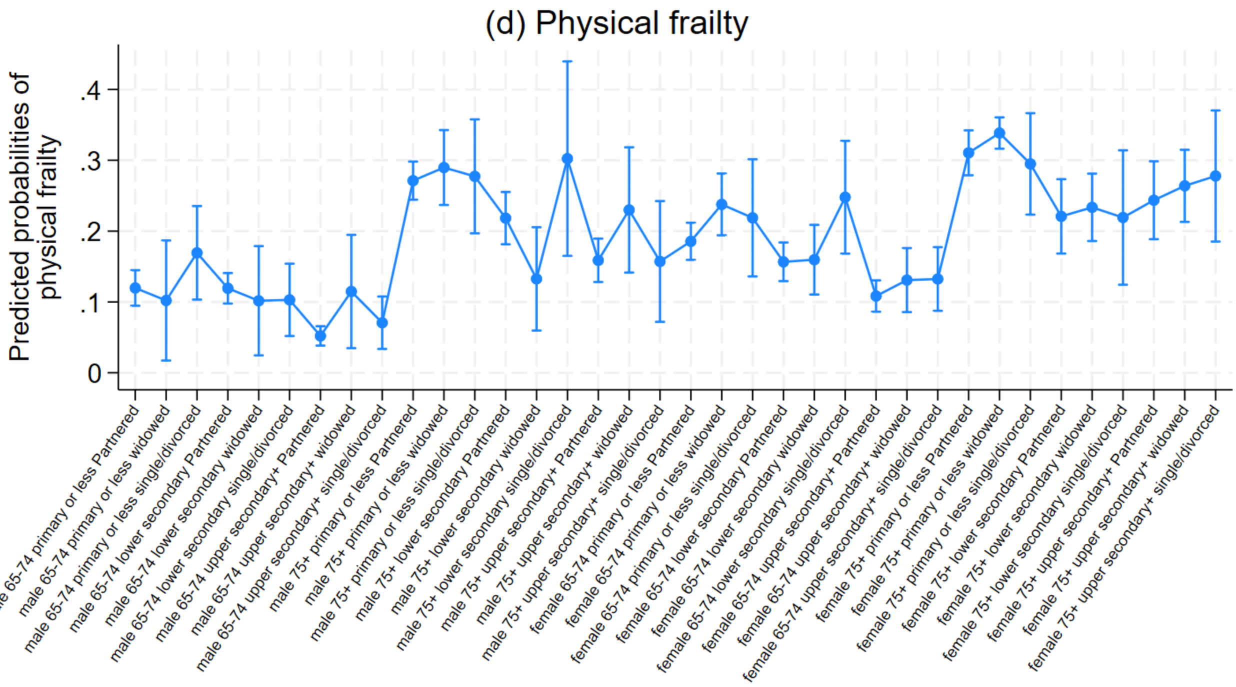
Figure 4. Adjusted predictions of strata with 95% Cis panels a, b, c, d



(a) No frailty
Predicted probabilities of no frailty
1
.8
.6
.4
.2
male 65-74 primary or less Partnered
male 65-74 primary or less widowed
male 65-74 primary or less single/divorced
male 65-74 lower secondary Partnered
male 65-74 lower secondary widowed
male 65-74 lower secondary single/divorced
male 65-74 upper secondary+ Partnered
male 65-74 upper secondary+ widowed
male 65-74 upper secondary+ single/divorced
male 75+ primary or less Partnered
male 75+ primary or less widowed
male 75+ primary or less single/divorced
male 75+ lower secondary Partnered
male 75+ lower secondary widowed
male 75+ lower secondary single/divorced
male 75+ upper secondary+ Partnered
male 75+ upper secondary+ widowed
male 75+ upper secondary+ single/divorced
female 65-74 primary or less Partnered
female 65-74 primary or less widowed
female 65-74 primary or less single/divorced
female 65-74 lower secondary Partnered
female 65-74 lower secondary widowed
female 65-74 lower secondary single/divorced
female 65-74 upper secondary+ Partnered
female 65-74 upper secondary+ widowed
female 65-74 upper secondary+ single/divorced
female 75+ primary or less Partnered
female 75+ primary or less widowed
female 75+ primary or less single/divorced
female 75+ lower secondary Partnered
female 75+ lower secondary widowed
female 75+ lower secondary single/divorced
female 75+ upper secondary+ Partnered
female 75+ upper secondary+ widowed
female 75+ upper secondary+ single/divorced


(b) Multiple frailty
Predicted probabilities of multiple frailty
0
.2
.4
.6
male 65-74 primary or less Partnered
male 65-74 primary or less widowed
male 65-74 primary or less single/divorced
male 65-74 lower secondary Partnered
male 65-74 lower secondary widowed
male 65-74 lower secondary single/divorced
male 65-74 upper secondary+ Partnered
male 65-74 upper secondary+ widowed
male 65-74 upper secondary+ single/divorced
male 75+ primary or less Partnered
male 75+ primary or less widowed
male 75+ primary or less single/divorced
male 75+ lower secondary Partnered
male 75+ lower secondary widowed
male 75+ lower secondary single/divorced
male 75+ upper secondary+ Partnered
male 75+ upper secondary+ widowed
male 75+ upper secondary+ single/divorced
female 65-74 primary or less Partnered
female 65-74 primary or less widowed
female 65-74 primary or less single/divorced
female 65-74 lower secondary Partnered
female 65-74 lower secondary widowed
female 65-74 lower secondary single/divorced
female 65-74 upper secondary+ Partnered
female 65-74 upper secondary+ widowed
female 65-74 upper secondary+ single/divorced
female 75+ primary or less Partnered
female 75+ primary or less widowed
female 75+ primary or less single/divorced
female 75+ lower secondary Partnered
female 75+ lower secondary widowed
female 75+ lower secondary single/divorced
female 75+ upper secondary+ Partnered
female 75+ upper secondary+ widowed
female 75+ upper secondary+ single/divorced


(c) Psychological frailty
Predicted probabilities of psychological frailty
0
.1
.2
.3
.4
male 65-74 primary or less Partnered
male 65-74 primary or less widowed
male 65-74 primary or less single/divorced
male 65-74 lower secondary Partnered
male 65-74 lower secondary widowed
male 65-74 lower secondary single/divorced
male 65-74 upper secondary+ Partnered
male 65-74 upper secondary+ widowed
male 65-74 upper secondary+ single/divorced
male 75+ primary or less Partnered
male 75+ primary or less widowed
male 75+ primary or less single/divorced
male 75+ lower secondary Partnered
male 75+ lower secondary widowed
male 75+ lower secondary single/divorced
male 75+ upper secondary+ Partnered
male 75+ upper secondary+ widowed
male 75+ upper secondary+ single/divorced
female 65-74 primary or less Partnered
female 65-74 primary or less widowed
female 65-74 primary or less single/divorced
female 65-74 lower secondary Partnered
female 65-74 lower secondary widowed
female 65-74 lower secondary single/divorced
female 65-74 upper secondary+ Partnered
female 65-74 upper secondary+ widowed
female 65-74 upper secondary+ single/divorced
female 75+ primary or less Partnered
female 75+ primary or less widowed
female 75+ primary or less single/divorced
female 75+ lower secondary Partnered
female 75+ lower secondary widowed
female 75+ lower secondary single/divorced
female 75+ upper secondary+ Partnered
female 75+ upper secondary+ widowed
female 75+ upper secondary+ single/divorced



(d) Physical frailty
Predicted probabilities of physical frailty
0
.1
.2
.3
.4
male 65-74 primary or less Partnered
male 65-74 primary or less widowed
male 65-74 primary or less single/divorced
male 65-74 lower secondary Partnered
male 65-74 lower secondary widowed
male 65-74 lower secondary single/divorced
male 65-74 upper secondary+ Partnered
male 65-74 upper secondary+ widowed
male 65-74 upper secondary+ single/divorced
male 75+ primary or less Partnered
male 75+ primary or less widowed
male 75+ primary or less single/divorced
male 75+ lower secondary Partnered
male 75+ lower secondary widowed
male 75+ lower secondary single/divorced
male 75+ upper secondary+ Partnered
male 75+ upper secondary+ widowed
male 75+ upper secondary+ single/divorced
female 65-74 primary or less Partnered
female 65-74 primary or less widowed
female 65-74 primary or less single/divorced
female 65-74 lower secondary Partnered
female 65-74 lower secondary widowed
female 65-74 lower secondary single/divorced
female 65-74 upper secondary+ Partnered
female 65-74 upper secondary+ widowed
female 65-74 upper secondary+ single/divorced
female 75+ primary or less Partnered
female 75+ primary or less widowed
female 75+ primary or less single/divorced
female 75+ lower secondary Partnered
female 75+ lower secondary widowed
female 75+ lower secondary single/divorced
female 75+ upper secondary+ Partnered
female 75+ upper secondary+ widowed
female 75+ upper secondary+ single/divorced

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Appendix of the paper

Sommario

Table A1 Operationalization of the Tilburg Frailty Indicator

TFI original questions	TFI Italian questionnaire	TFI by THEOU in SHARE	TFI in EHIS
Physical components			
Do you feel physically healthy? ☐yes☐ no	TIL1 Pensa di essere sufficientemente attivo dal punto di vista fisico?☐ SI ☐ NO	Would you say your health is (1) Excellent; (2) Very good; (3) Good; (4) Fair; (5) Poor Excellent, Very good, Good = 0; Fair, Poor = 1	How is your health in general? (1) Very good (2) Good (3) Neither good nor bad (4) Bad (5) Very bad) Very good, Good=0; Neither good nor bad, Bad, Very bad=1
Have you lost a lot of weight recently without wishing to do so? ('a lot' is: 6 kg or more during the last six months, or 3 kg or more during the last month) ☐yes☐ no	TIL2 Recentemente ha perso molto peso non intenzionalmente (per "molto" si intende: 6 kg o piú negli ultimi 6 mesi, o 3 kg o piú nell'ultimo mese)?☐ SI ☐ NO	What has your appetite been like? No diminution in desire for food = 0; diminution in desire for food = 1 If an uncodable response to the previous question, the following question: So have you been eating more or less than usual? More = 0; Neither more nor less = 0; Less = 1	
Do you experience problems in your daily life due to: difficulty in walking? ☐yes☐ no	TIL3 Nella sua vita quotidiana, riscontra problemi dovuti a: difficoltá nella deambulazione? ☐ SI ☐ NO	Please tell me if you have any difficulty with these because of a physical, mental, emotional or memory problem (exclude any difficulties you expect to last < 3 months): Walking 100 m No = 0; Yes = 1	Do you have difficulty walking 500 meters on a flat surface (equivalent to about five times the length of a soccer field) without any assistance? (1) No difficulty (2) Some difficulty (3) A lot of difficulty (4) Unable to do it No difficulty=0; Some difficult; A lot of difficulty, Unable to do it =1
Difficulty maintaining your balance? ☐yes☐ no	TIL4 Difficoltá nel mantenere l'equilibrio? ☐ SI ☐ NO	Please tell me if you have any difficulty with these because of a physical, mental, emotional or memory problem (exclude any difficulties you expect to last < 3 months): Climbing one flight of stairs without resting No = 0; Yes = 1	Do you have difficulty climbing up or down a flight of stairs (about 12 steps) without any assistance? (1) No difficulty (2) Some difficulty (3) A lot of difficulty (4) Unable to do it No difficulty=0; Some difficult; A lot of difficulty, Unable to do it =1
Poor hearing? ☐yes☐ no	TIL5 Scarso udito? ☐ SI ☐ NO	Is your hearing [using a hearing aid as usual] (1) Excellent, (2) Very good; (3) Good; (4) Fair; (5) Poor Excellent, Very good, Good = 0; Fair, Poor, or deaf = 1	Do you have difficulty hearing what is said in a conversation with another person in a QUIET room, even when using a hearing aid? (1) No difficulty (2) Some difficulty (3) A lot of difficulty (4) Unable to do it No difficulty=0; Some difficult; A lot of difficulty, Unable to do it =1
Poor vision? ☐yes☐ no	TIL6 Scarsa vista? ☐ SI ☐ NO	How good is your eyesight for seeing things at a distance, like recognizing a friend across the street [using glasses or contact lenses as usual]? Would you say it is (1)	Do you have difficulty seeing, even when using glasses or contact lenses? (1) No difficulty (2) Some difficulty (3) A lot of difficulty (4) Unable to do it

		Excellent; (2) Very good; (3) Good; (4) Fair (5) Poor Excellent, Very good, Good = 0; Fair, Poor, or blind = 1	No difficulty=0; Some difficult; A lot of difficulty, Unable to do it =1
Lack of strength in your hands? ☐yes☐ no	TIL7 Mancanza di forza nelle mani? ☐ SI ☐ NO	Handgrip strength measured by dynamometer Men BMI ≤ 24 and strength ≤ 29 = 1 BMI 24.1–26 and strength ≤30 = 1 BMI 26.1–28 and strength ≤30 = 1 BMI > 28 and strength ≤ 32 = 1 Women BMI ≤ 23 and strength ≤ 17 = 1 BMI 23.1–26 and strength ≤ 17.3 = 1 BMI 26.1–29 and strength ≤ 18 = 1 BMI > 29 and strength ≤ 21 = 1	
Physical tiredness? ☐yes☐ no	TIL8 Stanchezza fisica? ☐ SI ☐ NO	In the last month, have you had too little energy to do things you wanted to do? No = 0; Yes = 1	Feeling tired or having little energy (1) Never (2) Several days (3) More than half the days (4)Nearly every day Never, Several days=0; More than half the days; Nearly every day=1
Psychological components			
Do you have problems with your memory? ☐yes☐ sometimes ☐no	TIL9 Ha problemi di memoria? ☐ SI ☐ Qualche volta ☐ NO	Delayed recall test; recall 10 nouns after average of 5 minutes delay 3–10 score = 0; < 3 score = 1	Do you have difficulty remembering or concentrating? (1)No difficulty (2) Some difficulty (3) A lot of difficulty (4) Unable to do it No difficulty=0; Some difficulty; A lot of difficulty; Unable to do it=1
Have you felt down during the last month? ☐yes☐ sometimes ☐no	TIL10 Si é sentito giú di morale durante l'ultimo mese?☐ SI ☐ Qualche volta ☐ NO	In the last month, have you been sad or depressed? No = 0; Yes = 1	Feeling down, depressed, or hopeless (1) Never (2) Several days (3) More than half the days (4) Nearly every day Never=0; Several days, More than half the days, Nearly every day=1
Have you felt nervous or anxious during the last month? ☐yes☐ sometimes ☐no	TIL11 Si é sentito nervoso o ansioso durante l'ultimo mese?☐ SI ☐ Qualche volta ☐ NO	Have you been irritable recently? No = 0; Yes = 1	
Are you able to cope with problems well? ☐yes☐ no	TIL12 É in grado di far fronte ai problemi? ☐ SI ☐ NO	(1) In the last month, have you felt that you would rather be dead? (2) In the last month, have you cried at all? (3) Do you tend to blame yourself or feel guilty about anything? neither "rather be dead" nor both "cried" and "feel guilty" = 0; if "rather be dead" or if both "cried" and "feel guilty" = 1	Feeling bad about yourself, feeling like a failure, or feeling that you have let yourself or your family down (1) Never (2) Several days (3)More than half the days (4) Nearly every day Never=0; Several days, More than half the days, Nearly every day=1
Social components			

Do you live alone? ☐yes☐ no	TIL13 Vive da solo? ☐ SI ☐ NO	Number of people living in household >1 = 0; 1 = 1	Number of household members =1=1; >1=0
Do you sometimes miss having people around you? ☐yes☐ sometimes ☐no	TIL 14 A volte sente la mancanza di persone intorno a lei?☐ SI ☐ Qualche volta ☐ NO	Have you done any of these activities in the last month? Done voluntary or charity work; Cared for a sick or disabled adult; Provided help to family, friends or neighbors; Attended an educational or training course; Gone to a sport, social or other kind of club; Taken part in a religious organization (church, synagogue, mosque etc.); Taken part in a political or community-related organization ≥1 activity = 0; 0 activities = 1	
Do you receive enough support from other people? ☐yes ☐no	TIL15 Riceve sufficiente sostegno dalle altre persone?☐ SI ☐ NO	Thinking about the activities that you have problems with, does anyone ever help you with these activities? If yes, Would you say that the help you receive meets your needs (1) All the time; (2) Usually; (3) Sometimes; (4) Hardly ever Independent for IADLs (no help needed), or help meets needs “All the time” or “Usually” = 0; “Sometimes” “Hardly ever” or “no help received”= 1	Need to receive (more) help or additional help for at least one personal care activity (1) Yes, for at least one activity (2) No Need to receive (more) help or additional help for at least one domestic activity (1) Yes, for at least one activity (2) No If needs more help in Self Care or Activities of Daily Living ==1, else == 0

Latent class analysis

For binary items and a categorical latent variable C_k with K classes (C=k; K=2,...7), the marginal probability of observed item u_j (with j=1,2...,11) being equal to 1 is

$$Pr(u_j = 1) = \sum_{k=1}^{K} Pr(C_k = k) \prod_{j=1}^{J} Pr(u_j = 1|C_k = k)$$

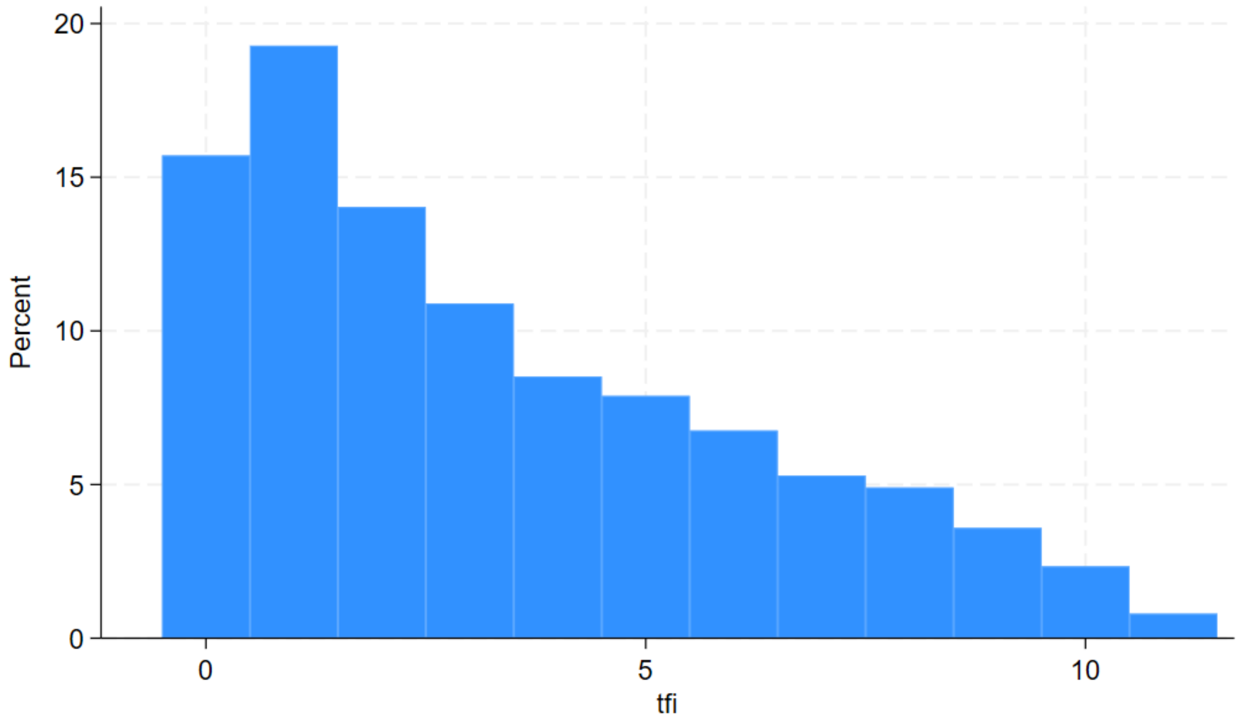
Where $Pr(u_j = 1|C_k = k)$ denotes the conditional probability of the item being equal to 1 the class is equal to k and $Pr(C_k = k)$ is the probability of class k. $\prod_{j=1}^{J}$ assumes local independence: given latent class, item responses are independent.

1-step approach

Table A2 Descriptive statistics of SHARE data

SHARE	Males (N=1,155)	Females (N=1,414)	Total (N=2,596)
Physical frailty			
Self-rated health	46.2	52.3	49.6
Unwanted weight loss	11.3	15.1	13.4
Problem with walking	10.1	17.5	14.2
Problem with balance	19.0	24.5	22.0
Hearing problems	26.1	20.9	23.2
Eyesight problems	26.1	29.3	27.9
Handgrip strength	27.5	22.1	24.6
Lack of energy	31.1	43.7	38.0
Psychological dimension			
Problems with memory	36.3	37.3	36.8
Feeling down or depressed	32.5	48.7	41.4
Irritability	35.4	35.4	35.4
Feeling a failure	6.3	10.3	8.5
Social dimension			
Living alone	10.3	29.8	21.1
Engagement in social activities	61.9	59.6	60.6
No help from other people	31.1	37.5	34.6
Age			
65-69	24.2	24.1	24.1
70-74	24.6	26.5	25.7
75+	51.2	49.4	50.2
Education			
Primary education or less	36.1	48.7	43.0
Lower seconday education	30.6	23.3	26.6
Upper secondary education or above	33.3	28.0	30.4
Marital status			
Partnered	87.5	65.5	75.4
Widowed	6.8	27.2	18.1
Single or divorced/separated	5.7	7.3	6.6
Income quintile			
1st	16.8	22.6	20.0
2nd	16.2	23.3	20.1
3rd	20.4	19.9	20.1
4th	22.3	18.1	20.0
5th	24.4	16.1	19.9

Figure A1. TFI distribution



Pyschometric properties

Table A3. Reliability: Internal Consistency of items with total score, by data source – Tilburg Frailty Indicator

	EHIS		SHARE	
Items	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation
TIL1	0.8	0.456	0.652	0.519
TIL2			0.684	0.307
TIL3	0.777	0.663	0.672	0.417
TIL4	0.777	0.662	0.663	0.467
TIL5	0.803	0.416	0.676	0.359
TIL6	0.805	0.4	0.679	0.337
TIL7			0.689	0.251
TIL8	0.795	0.511	0.662	0.46
TIL9	0.792	0.529	0.69	0.252
TIL10	0.793	0.522	0.67	0.399
TIL11			0.699	0.181
TIL12	0.802	0.426	0.694	0.192
TIL13	**0.828**	0.155	**0.703**	0.123
TIL14			0.692	0.242
TIL15	0.793	0.537	**0.712**	0.074

SHARE=Survey of Health, Ageing and Retirement in Europe; EHIS = European Health Interview Survey; EU-SILC = European Union Statistics on Income and Living Conditions
Item–Total Correlation: Correlation of the item with the overall scale score (including itself).
Corrected Item–Total Correlation: Correlation of the item with the total scale score excluding that item.
Numbers in bold refer to improvement in internal consistency (ie the item worsens the indicator's performance)

Table A4 Criterion Validity of the TFI: Receiver Operating Characteristic Curve

Data source	Criterion	Cut Point	Specificity	Sensitivity	AUC (95% CI)
EHIS	Hospitalization	>3	0.627	0.592	0.650 (0.637-0.663)
	Chronic Condition	>1	0.641	0.698	0.724 (0.713-0.736)
	GALI	>4	0.796	0.797	0.869 (0.862-0.876)
	Doctor Visits	>2	0.715	0.534	0.664 (0.649-0.679)
	Domestic Accidents	>4	0.594	0.695	0.689 (0.668-0.710)
SHARE	Hospitalization	>4	0.586	0.670	0.663 (0.63-0.670)
	Chronic Condition	>3	0.602	0.751	0.727 (0.708-0.745)
	GALI	>4	0.635	0.789	0.770 (0.748-0.792)
	Doctor Visits	>4	0.750	0.449	0.620 (0.586-0.654)

GALI=global activity limitations index

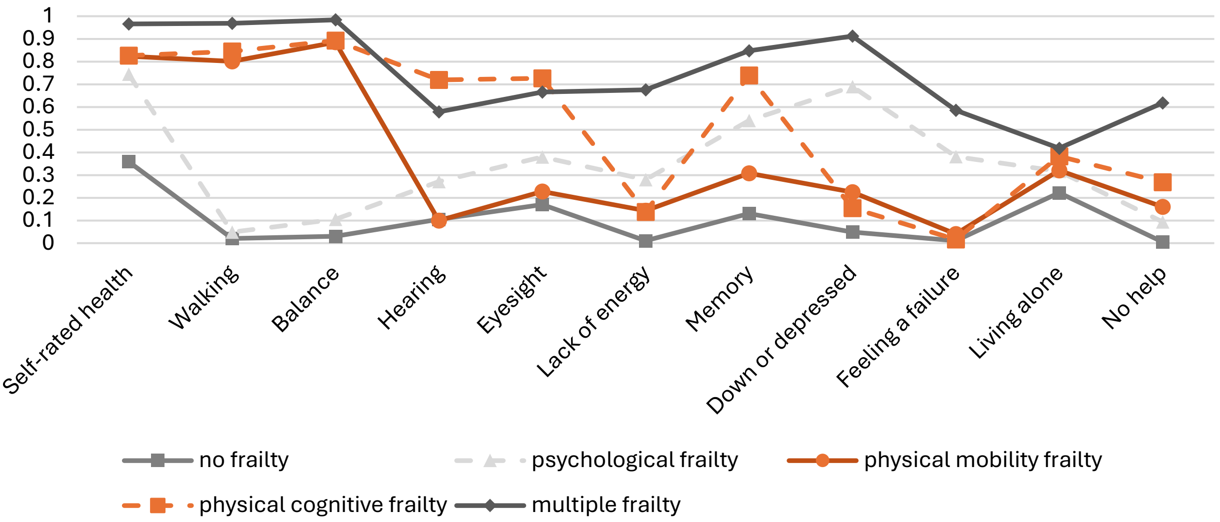
Table A5 Known-Groups Validity: Mean Differences in frailty score by basic sociodemographic groups

	EHIS	SHARE
Age		
65-69[1]	1.94	3.03

70-74	2.44	3.54
75-79[2]	4.44	4.58
80-84[3]		5.33
85+		6.36
p-value	<0.001	<0.001
Sex		
Male	2.66	3.95
Female	3.85	4.64
p-value	<0.001	<0.001
Education		
None		5.26
Primary [4]	4.16	4.54
Lowe Secondar	2.9	3.68
Upper Secondary	2.36	3.62
Tertiary or more	2.13	3.2
p-value	<0.001	<0.001

p-value obtained from Kruskal-Wallis test

Figure A2 Probability of each frailty item estimated by the 5-class model



No frailty (50.1%); Psychological frailty (12.5%); Physical mobility frailty (12.8%); Physical cognitive frailty (9.3%); Multiple frailty (15.4%)

Table A6. Fit Statistics and Classification Coefficients - Latent Class Analysis Models on Frailty Components by sex

MALES

Class	AIC	BIC	SABIC	CAIC	AWE	VLMR LRT (p-value)
2 class	57117.0	57270.8	57197.7	57180.8	57313.5	<0.001
3 class	56023.4	56257.3	56146.1	56120.4	56322.4	<0.001
4 class	55012.4	55326.6	55177.2	55142.7	55414.0	<0.001
5 class	54784.8	55179.1	54991.7	54948.3	55288.8	<0.001
6 class	54595.5	55070.1	54844.5	54792.3	55202.1	<0.001
7 class	54487.3	55042.04	54778.285	54717.3	55196.3	0.0037

FEMALES

Class	AIC	BIC	SABIC	CAIC	AWE	VLMR LRT (p-value)
2 class	85574.5	85733.6	85660.5	85640.6	85775.6	<0.001
3 class	83666.2	83908.4	83797.1	83766.8	83972.3	<0.001
4 class	82154.4	82479.5	82330.2	82289.4	82565.4	<0.001
5 class	81885.7	82293.9	82106.4	82055.2	82401.7	0.0188
6 class	81693.8	82185.0	81959.4	81897.8	82314.8	<0.001
7 class	81572.1	82146.32	81882.6	81810.6	82298.0	0.0827

Note AIC= Akaike Information Criterion; BIC = Bayesian Information Criterion; SABIC = Sample-size adjusted BIC; CAIC = Consistent Akaike Information Criterion; AWE = Approximate Weight of Evidence Criterion; VLMR-LRT_p = Vuong-Lo-Mendell-Rubin adjusted likelihood ratio test

Table A7. Model classification diagnostics of the 4-class and 5-class solutions, by sex

MALES

4-class	**Entropy=0.829**			
	Model estimated proportion for class *k*	**Modal class assignment proportion for class k**	**Average posterior probability for class k**	**Odds of corrected classification**
class 1	0.132	0.107	0.839	34.2
class 2	0.608	0.635	0.929	8.4
class 3	0.100	0.098	0.919	102.5
class 4	0.160	0.160	0.878	37.7
5-class	**Entropy=0.751**			
	Model estimated proportion for class *k*	**Modal class assignment proportion for class k**	**Average posterior probability for class k**	**Odds of corrected classification**
class 1	0.094	0.096	0.895	82
class 2	0.140	0.131	0.914	65.3
class 3	0.067	0.069	0.786	50.9
class 4	0.489	0.517	0.861	6.5
class 5	0.210	0.187	0.698	8.7

FEMALES

4-class	**Entropy=0.801**			
	Model estimated proportion for class *k*	**Modal class assignment proportion for class k**	**Average posterior probability for class k**	**Odds of corrected classification**
class 1	0.135	0.116	0.852	36.8
class 2	0.214	0.213	0.911	37.5
class 3	0.238	0.239	0.853	18.5
class 4	0.412	0.432	0.915	15.3
5-class	**Entropy=0.779**			
	Model estimated proportion for class *k*	**Modal class assignment proportion for class k**	**Average posterior probability for class k**	**Odds of corrected classification**
class 1	0.093	0.087	0.725	25.7
class 2	0.408	0.421	0.921	16.9
class 3	0.132	0.116	0.84	34.6
class 4	0.169	0.171	0.77	16.5
class 5	0.199	0.205	0.891	33