Measuring frailty in older adults using multiple surveys: insights from the Italian case for health and social policy

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Abstract

Detection and measurement of frailty are essential for providing targeted care to older adults and informing health policy. Numerous frailty tools exist, differing in conceptual frameworks, data requirements, and application settings, resulting in substantial variation in estimated prevalence across populations.

This study focuses on Italy, adopting a policymaker's perspective to identify practical, nationally applicable tools for frailty assessment using multiple representative survey data. We evaluated three bio-psycho-social indicators—the Tilburg Frailty Indicator (TFI), the Groningen Frailty Indicator (GFI), and the Edmonton Frail Scale (EFS)—across four datasets: the international SHARE survey (benchmark) and three Italian surveys (EU-SILC, EHIS, and AVQ).

The study proceeded in three steps. First, each indicator was reconstructed within each dataset to assess whether the available variables allowed replication of all original items. Second, reproducible indicators were validated by examining their psychometric properties, such as internal consistency and criterion validity. Third, prevalence estimates and predictive validity for relevant health outcomes were compared across datasets to illustrate the strengths and limitations of each indicator.

Results indicated that the GFI was the most replicable across surveys, while the EFS showed superior predictive ability. Among datasets, EHIS emerged as the most suitable platform for frailty assessment, offering broad item coverage and strong predictive accuracy. Regional analyses of EHIS data revealed a clear North–South gradient, with higher frailty prevalence in Southern regions. Multivariable analyses confirmed that frailty measures add significant explanatory power for outcomes such as activity limitations, beyond biological age and other predictors including gender and education.

By providing a comparative framework for operationalizing frailty indicators across data sources, this study offers practical guidance for policymakers and researchers to monitor frailty in aging populations and evaluate health vulnerabilities.

Introduction

The increasing number and proportion of people aged 60 years and older poses unprecedented, yet unavoidable, societal challenges. One of the greatest challenges is the increasing pressure on healthcare systems, particularly in primary care and long-term care services (Rudnicka et al., 2020). Frailty is widely recognized as one of the most critical and problematic manifestations of population ageing (Clegg et al., 2013). Frailer individuals have been documented to report worse health trajectories (Grabovac et al., 2019) characterized by cognitive impairment (Kojima, Taniguchi, et al., 2016), limitations in basic activities of daily living (Kojima, 2017), falls (Kojima, 2015), low quality of life (Kojima, Iliffe, et al., 2016), and a higher use of healthcare services (Roe et al., 2017, p. 20) such as emergency admissions(Kojima, 2019), hospitalizations (Street et al., 2025) and care home admissions (Sánchez-García et al., 2017).

The widespread awareness of the limited resources available to deal with increasing healthcare demand calls on policymakers to strengthen the adoption of evidence-informed policies. In this regard, the evidence from frailty studies has not yet been fully translated into health care policy making (Drennan et al., 2018), despite its potential to diminish the impact of aging on health care systems and strengthen their sustainability makes it an urgent focal point (Kojima et al., 2019). In fact, frailty represents a valuable opportunity to disentangle people that, albeit sharing the same age, may differ in their ageing process due to their level of frailty, and consequent healthcare needs.

The main challenge in monitoring frailty lies in its non-observable nature: it stems from the interaction of multiple physical and psychosocial factors and there is no clear distinction between frailty and other clinical conditions such as disability and comorbidity (Boccuzzo & Donno, 2025). No univocal definition has yet been reached within the scientific and non-scientific community. The first and most commonly applied interpretation of frailty was unidimensional and primarily related to physical functioning, that describes a complex state of increased vulnerability related to ageing. Over time, however, frailty has evolved into a multidimensional construct, incorporating physical, psychological, sensory, and social dimensions that contribute to adverse health outcomes (Fried et al., 2004; R. J. J. Gobbens, Luijkx, et al., 2010).

Detection and measurement of frailty are considered crucial both for providing appropriate, goal-directed care to frail older adults (Clegg et al., 2013; Hoogendijk et al., 2019) and for informing healthcare policy. Early identification allows policymakers to plan preventive actions and design targeted interventions to mitigate frail individuals' disproportionate use of services (Brennan et al., 2024). Reflecting this importance, numerous literature reviews have mapped the wide range of frailty measurement tools (Deng & Sato, 2024; Khezrian et al., 2017; Sobhani et al., 2021; Sutton et al., 2016; Van Damme et al., 2021). Existing tools differ not only in the adoption of mono- or multidimensional paradigms adopted, but also in the level of information required and in the settings where they can be implemented (e.g., primary care, hospitals, or community). These differences contribute to substantial variability in estimates of frailty prevalence among older adults, depending on the definitions and tools used.

Our study focuses on the case of Italy, one of the countries with highest proportion of older people, and embraces the perspective of healthcare policy makers with the aim of identifying practical, nationally applicable tools to measure frailty using nationally representative data sources.

Indeed available estimates of frailty vary widely: a recent systematic review and meta-analysis by the European ADVANTAGE Joint Action (O'Caoimh et al., 2018) estimated the prevalence of physical frailty in Italy at 13% (95% CI: 8–17), with wide variation across studies. According to the national surveillance system *PASSI d'Argento*, the proportion of frail older adults in 2020–2021 was 17% (EpiCentro). However, these estimates mirror the inconsistencies in the interpretation of frailty and range from narrowly biological definitions to broader functional approaches: for instance, *PASSI d'Argento* measures frailty based on difficulties in Activities of Daily Living (ADLs), which are often used as a proxy for disability.

Here we adopt a bio-psycho-social conceptualization of frailty, as it better reflects the multifaceted nature of vulnerability in old age. Despite previous attempts to operationalize such an approach in Italy, most studies have been limited by small samples, lack of national representativeness, or outdated data (Boccuzzo & Donno, 2025). This study addresses these gaps and assesses whether existing nationally representative survey data can be leveraged to measure and monitor frailty in the community-dwelling older population. By operationalizing multiple validated frailty scales across multiple surveys, we provide a comparative framework that highlights how prevalence estimates differ depending on the measurement tool and data source used. This approach not only advances methodological clarity, but also offers policymakers practical, low-cost tools for surveillance and planning.

Methods

Data and samples

Data were extracted from four main sources: three international surveys and one national survey. All sources are population-based and are designed to generate reliable evidence to inform policy development. For the purposes of this study, the analytic sample was restricted to respondents aged 65 years and older across all surveys.

The Survey of Health, Ageing and Retirement in Europe (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 (Börsch-Supan & Scherpenzeel, 2021). We used the ninth wave, carried out in 2022, and selected respondents aged 65 and above and resident in Italy.

The European Health Interview Survey (EHIS) is a harmonized survey conducted across EU member states that collects self-reported information on health status, health determinants, and healthcare use (*European Health Interview Survey - Microdata - Eurostat*. In Italy, EHIS is implemented by the Italian National Institute of Statistics (ISTAT), as part of its National Statistical Programme. We drew data from the 2019 wave of EHIS Italy.

The European Union Statistics on Income and Living Conditions (EU-SILC) is an annual survey providing harmonized microdata on income, poverty, social exclusion, and living conditions across EU member states (*Living Conditions (EU-SILC) - Methodology*. Similarly to EHIS, the survey's data collection is carried out individually within each participating country (including Italy), following uniform standards. We used the 2022 cross-sectional EU-SILC data for Italy, including ad hoc modules on health and quality of life.

The Aspetti della Vita Quotidiana (AVQ, Aspects of Daily Life) survey is conducted annually by ISTAT, to collect information on daily life habits, health status, and access to services among the Italian population. We used data from the 2022 AVQ survey (*Aspetti della vita quotidiana*.

Frailty indicators

We selected three indicators of multidimensional frailty from among the many measures available (Deng & Sato, 2024; Khezrian et al., 2017; Sobhani et al., 2021; Sutton et al., 2016; Van Damme et al., 2021). The selection was guided by four criteria: i) the ability to capture the multidimensional nature of frailty; ii) evidence of wide validation and frequent application in general population studies; iii) feasibility of implementation, without imposing excessive measurement burden; iv) prior demonstration of measurability using survey data (Theou et al, 2013).

The frailty measures chosen were the Tilburg Frailty Indicator (TFI), Groningen Frailty Indicator (GFI) and Edmonton Frail Scale.

The TFI was developed by Gobbens et al (R. J. J. Gobbens, Van Assen, et al., 2010). It consists of 15 items purposely spread across three dimensions: 8 questions cover the physical frailty domain, 4 questions cover psychological frailty domain, and 3 questions cover the social frailty domain. The authors proposed a cut-off score of 5 or greater to distinguish frail individuals from non-frail ones. The indicator been officially translated and validated in Italian (Mulasso et al., 2016), which facilitates its use in the AVQ survey.

The GFI was developed by Steverink et al (Steverink et al., 2001) and consists of 15 items 4 items cover aspects of daily-life mobility of the individual, 6 items are about physical and cognitive functioning, and 5 items cover psychosocial condition. According to the authors, a score of 4 or above indicates frailty. To our knowledge, the indicator hasn't been translated nor validated in Italian.

The EFS was developed by Rolfson DB et al (Rolfson et al., 2006) and assesses nine aspects of frailty: cognition, general health status, functional independence, social support, medication use, nutrition, mood, continence and functional performance. A score of 8 or above has been used to classify participants as frail. The indicator has been validated and applied within the Italian context on 366 hospitalised patients (Perna et al., 2017).

Operationalization of the frailty indicators

To operationalize each frailty indicator, we proceeded identifying, for each indicator and data source, the survey question(s) corresponding to each indicator item; subsequently we dichotomized/categorized the responses. The detailed procedure for this matching process is described in detail in the Appendix.

Participants were excluded from analysis of a specific index if they had missing values for more than 20% of that scale's items. This commonly applied criterion, already used (Theou, 2013), allows for maximum use of available data without excessive reliance on substitution procedures. For included cases, missing values were imputed with 0.

To measure the prevalence of frailty within the population, we set a threshold to distinguish frail from non-frail individuals, according to literature. Specifically, in this study setting, for each dataset, the threshold was derived by proportionally rescaling the cut-off identified in the literature to the ceiling of

the operationalized scale (e.g., the original TFI threshold is 5 out of a maximum score of 15; our corresponding threshold in EHIS is 4 out of 11).

Analysis Plan

Psychometric properties

For the indicators deemed sufficiently replicable using the selected data sources, psychometric properties were computed. Specifically, we assessed the reliability and validity of each indicator across the four data sources.

Reliability was evaluated in terms of internal consistency and parallel forms reliability. Internal consistency is widely used in research that aims to assess the psychometric properties of frailty indexes (R. J. J. Gobbens, Van Assen, et al., 2010; Metzelthin et al., 2010; Mulasso et al., 2016; Peters et al., 2012). It refers to the extent to which all items in a test measure the same concept or construct. Overall Internal Consistency of the scores was assessed for each indicator and each data source 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 were 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. Parallel forms reliability examines the correlation between two versions of a measurement instrument; in this study, it was assessed through the correlation among the three frailty indicators within each data source via Pearson's correlation (Rogers, 2010).

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. The choice of external criteria varied across data sources, depending on data availability, and included self-rated health, hospitalizations, presence of chronic conditions, limitation in daily activities, visits to practitioner, domestic accidents, life satisfaction (See Table 11 of the appendix for the description of the operationalization of the criteria).

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 and the parametric one-way ANOVA. Groups considered included gender, age (operationalized as 5-year age classes) and socioeconomic status (operationalized as highest educational attainment achieved and categorized as none, elementary, lower secondary, upper secondary, degree and above).

Applied analysis of frailty indicators

Finally, for the best-performing indicators, further analyses have been carried out as practical examples of the informative value that policymakers could derive from the use of these tools.

First, prevalence estimates have been compared across samples to evaluate how prevalence may vary depending on the data source and indicator selected. More precisely, to allow the comparability across groups with different age structures, age-standardized prevalence rates were calculated. Using the

direct method, age-specific prevalence estimates were applied Italian population according to ISTAT statistics(*Demo - Statistiche Demografiche*). Results were visually represented using geographic maps, showing prevalence estimates at regional level.

Secondly, logistic regression models have been estimated to assess the predictive power of the different frailty indicators on various health outcomes, while controlling for several sociodemographic characteristics — in particular age. Considering the health outcome as dependent variables and age, gender and education level as independent variables in a first analysis, the frailty index was then added as independent variable to assess its incremental contribution to explaining variability in the outcomes. The rationale for this step was to determine whether frailty provides additional information relevant to healthcare status and/or access that is not fully captured by sociodemographic characteristics. The change in explained variance was quantified to evaluate the informative gain obtained by including the frailty index in the models.

Results

Indicators' reproducibility

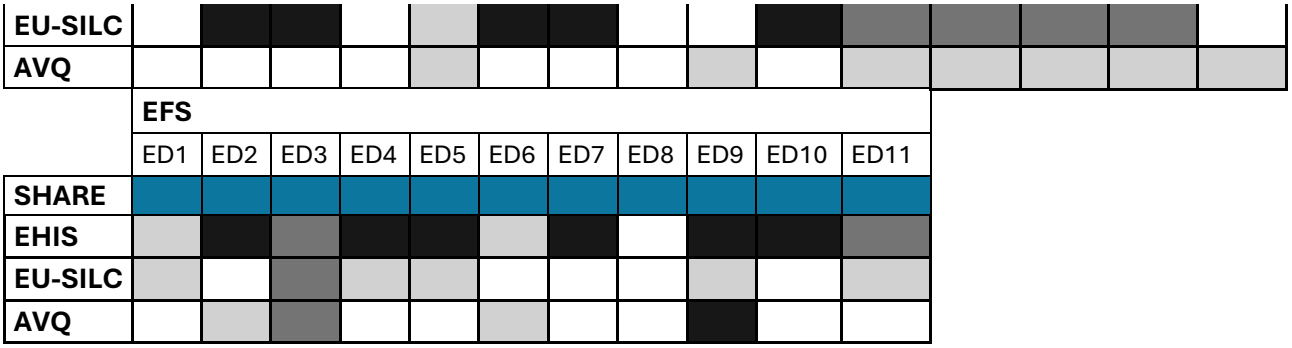
Table 1 visually reports the results of the index item-survey question matching process. Each column corresponds to a specific item of a frailty indicator, and each row refers to a data source. Cells colours indicate the degree of matching between the survey information and original item. For SHARE all cells in blue indicate that all items across all indicators have already been validated (Theou et al., 2013) and are replicable in wave 9. Tables with the exact questions selected to match each item for the three frailty indicators and four data sources are available in the Appendix.

The ability to operationalize each indicator was expressed as the proportion of its items that could be reproduced within a given survey data. This was, on average, 86% in EHIS (73% TFI, 93% GFI, 91% EFS); 61% in EU-SILC (60% TFI, 67% GFI, EFS 55%) and 46% in AVQ (47% TFI, 47% GFI, EFS 45%). In this regard, EHIS emerged as the most usable source, consistent with its intended purposes. Despite its potential, however, it lacks information on weight loss and handgrip strength, which are elements potentially coherent with the survey's scope. In contrast, AVQ appears clearly out of scope and inadequate for measuring frailty.

Across surveys, the GFI was the most successfully replicated indicator, with 69% of its items matched to survey questions, compared to 63% for the EFS and 60% for the TFI.

Table 1. Availability of Items for Each Frailty Indicator Across Four Data Sources

	TFI														
	TIL1	TIL2	TIL3	TIL4	TIL5	TIL6	TIL7	TIL8	TIL9	TIL10	TIL11	TIL12	TIL13	TIL14	TIL15
SHARE															
EHIS															
EU-SILC															
AVQ															
	GFI														
	GR1	GR2	GR3	GR4	GR5	GR6	GR7	GR8	GR9	GR10	GR11a	GR11b	GR11c	GR11d	GR11e
SHARE															
EHIS															



Note: cell colour indicates the degree of matching. **Black:** Exact/close match with the original question; **Dark grey:** Exact/close match with the SHARE question; **Light grey:** Partial match with SHARE question or independently selected question not closely aligned with the original; **Blank:** Question not available. **SHARE:** All cells in blue indicate items that are already validated (Theou, 2013) and treated as the reference match.

Descriptive tables

Table 2 reports the basic characteristics of the samples from the four data sources, for comparative purposes. Age distribution, sex and education do not remarkably vary across data sources, which supports meaningful comparisons of item prevalence. The mean value (and standard deviation) as well as the prevalences of the three frailty indicators are shown at the bottom of the table. The prevalence of each item of each indicator are available in tablesA4-A6 of the appendix.

Table 2 Descriptive characteristics of respondents across data sources

Characteristic	SHARE	EHIS	EU-SILC	AVQ
	N = 2,825	**N = 13,719**	**N = 15,462**	**N = 10,991**
Age class				
65-69[1]	658 (23%)	3,493 (25%)	3,555 (23%)	5,418 (49%)
70-74	694 (25%)	3,249 (24%)	3,687 (24%)	
75-79[2]	606 (21%)		3,066 (20%)	
80-84[3]	498 (18%)	6,977 (51%)	5,154 (33%)	5,573 (51%)
85+	369 (13%)			
Gender				
Male	1,271 (45%)	6,045 (44%)	6,806 (44%)	4,896 (45%)
Female	1,554 (55%)	7,674 (56%)	8,656 (56%)	6,095 (55%)
Education				
None	791 (28%)	6,525 (48%)	865 (5.6%)	691 (6.3%)
Primary[4]	777 (28%)		5,425 (35%)	3,834 (35%)
Lower Secondary	421 (15%)	3,359 (24%)	4,335 (28%)	2,959 (27%)
Upper Secondary	551 (20%)	2,732 (20%)	3,885 (25%)	2,530 (23%)
Tertiary or more	244 (8.8%)	1,102 (8.0%)	1,817 (12%)	977 (8.9%)
Missing	41	1		
Frailty score				
TFI mean (sd)	4.32 (2.81)	3.35 (2.87)	2.75 (2.17)	2.27 (1.62)
TFI %	43%	40%	47%	62%
Missing	109	336	1,279	
GFI mean (sd)	3.67 (2.83)	3.7 (3.1)	2.23 (1.95)	2.48 (1.63)

GFI %	42%	42%	35%	68%
Missing	88	218	597	1,591
EFS mean (sd)	4.5 (3.0)	3.7 (3.3)	2.46 (2.35)	1.73 (1.35)
EFS %	16%	20%	20%	27%
Missing	10	259	681	333

[1] 65-74 for AVQ
[2] 75-79=75+ for EHIS and AVQ
[3] 80-85=80+ for EUSILC
[4] Primary or less for EHIS
[5] Scale threshold and ceiling: SHARE= score of 5 out of 15, EHIS= score of 4 out of 11, EUSILC= score of 3 out of 9, AVQ= score of 2 out of 6
[6] Scale threshold and ceiling: SHARE=score of 4 out of 15, EHIS=score of 4 out of 14, EUSILC= score of 3 out of 10, AVQ=score of 2 out of 7
[7] Scale threshold and ceiling: SHARE=score of 8 out of 17, EHIS=score of 7 out of 15, EUSILC=score of 5 out of 11, AVQ=score of 3 out of 6

Psychometric properties

The psychometric properties of the indicators were assessed only in data sources that allowed sufficient reproducibility. Therefore, the following section is based solely on SHARE, EHIS, and EU-SILC.

Internal Consistency Reliability

Table 3 shows the raw Cronbach's Alpha coefficients for the three indicators across three data sources. Results overall show satisfactory internal consistency across all data sources and for all indicators, with TFI having all alpha larger or equal than 0.7, and measures based on EU-SILC performing best. For TFI, reliability of specific domains was also estimated. Reliability of physical component was satisfactory (alpha=0.70, 0.76 and 0.69 for the three data sources), while psychological and especially social component had poor reliability (see Table A7 of the appendix). This was coherent with results from other studies (R. J. Gobbens & Uchmanowicz, 2021). The Tables A8, A9 and A10 of the appendix also presents internal consistency for single items, through the raw alpha estimated eliminating the item and corrected item-total correlations. In general, items presented acceptable values of correlation with their indicator. Some items, however, presented poor correlation with their indicator and, symmetrically, the raw alpha estimated without that item improved. This was the case, for example, of item EFS 'someone to count on' in SHARE, the TFI 'receiving support' item, in SHARE, EHIS and EU-SILC) to 0.72 (EFS help with daily activities in EHIS) and 0.68 (EFS cognitive functioning in SHARE).

Table 3 Internal Consistency Reliability of Frailty Indicators (Raw Cronbach's Alpha) Across Three Data Sources

Data source	**TFI**	**GFI**	**EFS**
SHARE	0.70	0.67	0.68
EHIS	0.81	0.72	0.80
EU-SILC	0.70	0.63	0.75

SHARE=Survey of Health, Ageing and Retirement in Europe; EHIS = European Health Interview Survey; EU-SILC = European Union Statistics on Income and Living Conditions; TFI=Tilburg Frailty Indicator; GFI=Groningen Frailty Indicator; EFS; Edmonton Frail Scale

Parallel forms Reliability

Reliability was also assessed measuring the correlation between indicators. Pearson's correlation coefficients are illustrated in Table 4. Overall, correlation was high. This was particularly true between the indicators calculated in EHIS.

Table 4. Parallel form reliability between the indicators, Pearson's correlation coefficients

Data Source	TFI vs GFI	TFI vs EFS	GFI vs EFS
SHARE	0.850	0.818	0.762
EHIS	0.892	0.887	0.875
EU-SILC	0.876	0.828	0.779

SHARE=Survey of Health, Ageing and Retirement in Europe; EHIS = European Health Interview Survey; EU-SILC = European Union Statistics on Income and Living Conditions; TFI=Tilburg Frailty Indicator; GFI=Groningen Frailty Indicator; EFS; Edmonton Frail Scale

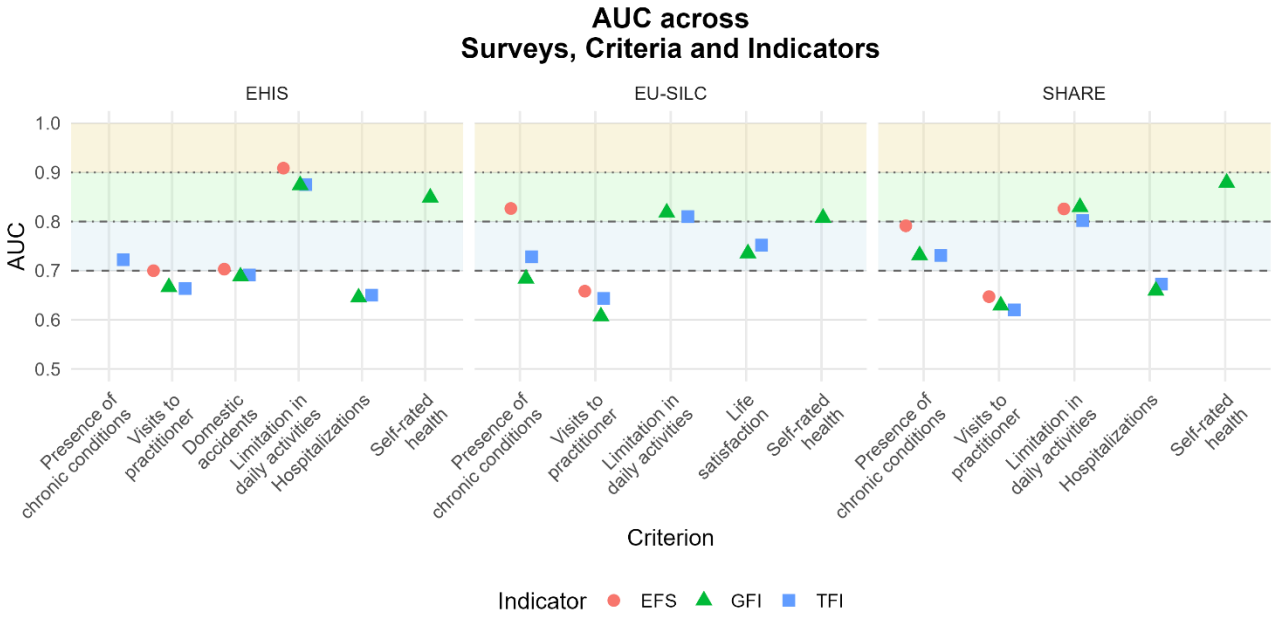
Criterion Validity

Figure 1 reports the AUC values across surveys, external criteria and indicators (see Table 12 of the appendix for the complete list of AUC values).

Several observations can be drawn by looking at the complete results from the survey, indicator or criterion perspective, respectively: i) the EHIS survey is associated to the highest AUC values; ii) the EFS indicator emerges as performing better than TFI and GFI whenever it is possible to replicate it; iii) the criteria on the limitation in daily activities (GALI) and visits to practitioner are characterized by the highest replicability across surveys.

Focusing on those criteria that are observable across multiple surveys, the EHIS survey appears associated with better performance for both the criteria GALI and visits to practitioner. In other cases, such as the hospitalization criterion, the performance across surveys appears very similar. Similar AUC values can be noticed also across indicators built from the same survey in case of the criteria domestic accidents (e.g., EFS, GFI and TFI built with EHIS survey data) and life satisfaction (e.g., GFI and TFI built with EU-SILC data).

Figure 1. Values of the ROC's Area Under the Curve (AUC) for various response variables (criteria), for the three frailty indicators and data sources.



Known-Group Validity

Mean differences in frailty score between age groups, sex and education behave as expected for all indicators, i.e., frailty is higher among older, female and poorly educated respondents. Both Kruskal-Wallis and ANOVA tests (corresponding p-values not presented here) show that such group differences are all significant, for every indicator, in every dataset. This support the hypothesis that our indicators can discriminate between groups that are known to differ in levels of frailty.

Table 5. Known-Groups Validity: Mean Differences in frailty score by basic sociodemographic groups, by indicator and data source, Kruskall Wallis test

	SHARE			EHIS			EUSILC		
	TFI	GFI	EFS	TFI	GFI	EFS	TFI	GFI	EFS
Age									
65-69[1]	3.03	2.56	3.12	1.96	2.32	2.12	1.75	1.46	1.46
70-74	3.54	2.88	3.69	2.46	2.72	2.65	2.17	1.75	1.85
75-79[2]	4.60	3.77	4.75	4.48	4.82	4.96	2.74	2.15	2.39
80-84[3]	5.39	4.57	5.46				3.91	3.15	3.63
85+	6.55	5.97	6.62						
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sex									
Male	3.93	3.30	4.15	2.67	3.03	3.02	2.39	1.97	2.17
Female	4.64	3.97	4.75	3.88	4.19	4.19	3.04	2.44	2.69
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Education									
None	5.29	4.70	5.52				4.54	3.73	4.40
Primary [4]	4.55	3.86	4.75	4.20	4.53	4.62	3.43	2.80	3.22
Lowe Secondar	3.69	2.95	3.78	2.91	3.22	3.22	2.52	2.06	2.14
Upper Secondary	3.63	2.90	3.66	2.37	2.73	2.61	2.19	1.71	1.87

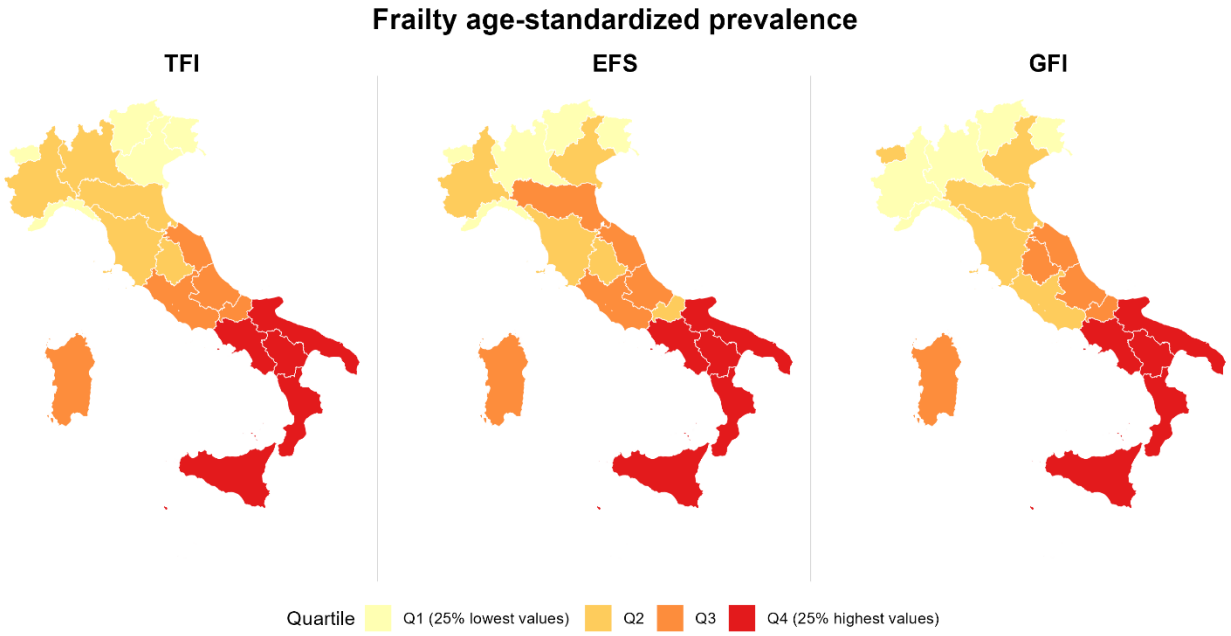
Tertiary or more	3.21	2.61	3.15	2.14	2.42	2.20	2.03	1.59	1.65
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[1] 65-74 for AVQ
[2] 75+ for EHIS and AVQ
[3] 80+ for EUSILC
[4] Primary or less for EHIS

Applied analyses of frailty indicators

Figure 2 presents geographic maps on the age-standardized prevalence of frailty at the regional level. Leveraging the best performance shown in terms of psychometric properties, the different frailty indicators have been built based on EHIS survey data. Each map illustrates the percentage of frailty individuals by region, with regions classified into quartiles to facilitate visual comparison of the spatial distribution of frailty across Italy. The maps reveal a consistent geographic pattern across all three indicators, with Southern regions generally exhibiting higher frailty prevalence compared to Northern regions. However, differences emerge when examining specific regional classifications, since the choice of indicator influences quartile assignments for several regions (e.g., depending on the indicator used, the Umbria Region switches from Q2 to Q3).

Figure 2. Frailty age-standardized prevalence at regional level (TFI: Tilburg Frailty Indicator; EFS: Edmonton Frailty Scale; GFI: Groningen Frailty Indicator). Colours correspond to the quartiles calculated for each frailty indicator. Source: EHIS



Following the results produced for the criterion validity, logistic regression models were run with EHIS survey data and focusing on the outcomes visits to the practitioner, GALI and domestic accidents. Table 6 reports the regression results for the three outcomes, considering two multivariable models, one excluding and another including the frailty indicator among predictors. Here we report the results for the EFS indicator, which has been previously shown to outperform the others in terms of predictive ability.

Table 6. Results from logistic regression models. Odds Ratios (OR) and 95% Confidence Intervals (. p< 0.1, * p < 0.05, **p < 0.01, ***p < 0.001)

Independent variables		Outcome (Dependent variable)					
		Visits to practitioner		Limitation in daily activities		Domestic accidents	
Age class (vs. 65-69)	70-74	1.26** (1.09, 1.47)	1.17* (1.00, 1.36)	1.23* (1.04, 1.44)	0.96 (0.79, 1.17)	1.24 (0.94, 1.64)	1.15 (0.86, 1.52)
	over 75	1.73*** (1.50, 1.99)	1.07 (0.93, 1.25)	3.49*** (3.06, 3.99)	0.99 (0.83, 1.17)	2.15*** (1.71, 2.74)	1.27 (0.99, 1.64)
Sex: women vs. men		1.32*** (1.18, 1.49)	1.10 (0.98, 1.24)	1.37*** (1.25, 1.50)	0.82** (0.73, 0.93)	2.03*** (1.69, 2.45)	1.73*** (1.44, 2.09)
Education level (vs. primary or less)	Lower secondary	1.01 (0.87, 1.17)	1.15 (0.98, 1.34)	0.82*** (0.73, 0.92)	1.10 (0.94, 1.28)	1.02 (0.81, 1.26)	1.15 (0.92, 1.43)
	Upper secondary	0.97 (0.83, 1.14)	1.24** (1.06, 1.46)	0.70*** (0.61, 0.79)	1.39*** (1.17, 1.65)	1.22 (0.97, 1.53)	1.57*** (1.25, 1.98)
	Tertiary	0.80* (0.65, 0.98)	1.08 (0.88, 1.34)	0.40*** (0.32, 0.50)	0.88 (0.66, 1.16)	1.17 (0.83, 1.60)	1.64** (1.15, 2.27)
EFS			1.31*** (1.27, 1.35)		1.82*** (1.78, 1.86)		1.21*** (1.18, 1.24)
R^2		0.016	0.082	0.104	0.541	0.03	0.084
ΔR^2		0.066		0.437		0.054	
LRT		$\chi^2(1) = 426.15, p < 0.01$		$\chi^2(1) = 4676.6, p < 0.01$		$\chi^2(1) = 225.55, p < 0.01$	

Adding the frailty indicator to the regression models led to an increase in explained variance across all outcomes considered, as confirmed also by the Likelihood Test Ratio. This improvement indicates that the frailty index contributes additional explanatory power beyond sociodemographic characteristics, particularly for the GALI outcome (the R-squared improving from 0.104 to 0.541). In other words, frailty provides information relevant to individuals' health status, condition and access to healthcare services that is not fully captured by age, gender, or education. The increase in explained variance (ΔR^2 = 0.05–0.43 across models) confirms that including frailty improves the model's ability to account for variability in healthcare service access.

Discussion

This study was set out to examine how frailty can be meaningfully captured within existing population surveys and how these indicators can inform public health policy. Our findings demonstrate that the replication of multidimensional frailty indicators across national datasets is both feasible and reliable,

extending previous methodological work. Beyond methodological relevance, these indicators hold practical value for policymakers, as they can help identify vulnerable subgroups and, as results show, anticipate healthcare demand more effectively than using chronological age alone.

The progressive ageing of the population poses a major challenge to public health systems, particularly in contexts of limited healthcare resources. In this perspective, frailty—rather than chronological age—represents a more meaningful determinant of healthcare needs and service utilization (Hoogendijk et al., 2019). Recognizing frailty as a dynamic and multidimensional process supports the shift from reactive to preventive health care, focusing on maintaining functional ability and independence. The ability to identify frail individuals within the population therefore becomes a strategic prerequisite for evidence-based planning and prevention. Achieving this goal requires tools that are not only valid and reliable, but also accessible, replicable, and compatible with existing data infrastructures.

A growing number of frailty indices have been developed, each with distinct conceptual foundations, operational definitions, and psychometric properties. Even though scholars agree that no single tool can be considered universally valid or optimal (Lee et al., 2023), it is also true that the heterogeneity of the elderly population prevents from addressing it as a whole: in the absence of a gold standard, what matters is an informed choice of the most appropriate tool for the specific purpose and population (Sobhani et al., 2021). In our research, we have chosen the policy makers' purpose, thus prioritizing the replicability of the process while building awareness on the precision of the emerging picture.

Our study contributes to this discussion by adopting three widely used frailty measures—the Tilburg, Edmonton, and Groningen indicators—implemented through four major European and national surveys (AVQ, EHIS, SHARE, EU-SILC). This approach widens the scope of previous research (Theou et al., 2013), extending the comparison both within and between surveys to better capture the variability linked to data source and context. The use of multiple surveys widens the space for discussion with policy makers, who might prefer one to the others for its geographical scope (e.g., international that allows for cross-country comparisons) or for its focus on additional aspects such as access to public services (i.e., AVQ), detailed health conditions (i.e., EHIS) or socio-economic conditions (EU-SILC), also enabling comprehensive cross-sectoral policy discussions beyond single-domain approaches.

Our comparative analyses revealed several insights. In terms of replicability across surveys, the GFI proved to align slightly better with the available variables, allowing a more complete reconstruction of its components. By contrast, the EFS showed stronger predictive ability than the TFI and GFI for the subset of outcomes where such comparison was possible, in line with previous evidence (Theou et al., 2013). From an implementation standpoint, the EFS remains particularly attractive in clinical and operational settings due to its short administration time (3–5 minutes) and multidomain coverage (Deng & Sato, 2024). At the same time, the TFI continues to be the most extensively examined in the literature, with strong evidence of reliability and validity, particularly in community and research contexts (Sutton, 2016). Taken together, these patterns underscore that each instrument has a distinct strength—replicability across surveys for GFI, predictive performance and clinical practicality for EFS, and accumulated validation for TFI—thereby reinforcing the view that the selection of a frailty instrument should be context-driven.

Among the surveys, EHIS emerged as the most suitable platform for frailty assessment overall, showing broad item coverage and strong predictive accuracy. Nevertheless, the choice of data source may reasonably depend on the specific outcome of interest: for instance, criteria such as the Global Activity Limitation Indicator (GALI)—a standard measure of limitations in daily activities—performed robustly

across all surveys, suggesting that other datasets could still be appropriate when a given health or functional dimension is prioritized by policymakers.

Regional analyses based on EHIS survey data displayed a clear North–South gradient, with higher frailty prevalence in Southern regions. Nonetheless, several regions appeared to occupy borderline positions, shifting quartiles depending on the frailty indicator used—illustrating how measurement choice may subtly influence the interpretation of territorial disparities. This sensitivity has direct policy relevance: small definitional differences may translate into substantial differences in the identification of priority areas or target populations.

The regression analyses further highlighted the explanatory value of frailty indicators. Adding the frailty index to models predicting outcomes such as activity limitation, medical consultations, and domestic accidents increased the explained variance, confirming that frailty captures aspects of vulnerability not accounted for by age, gender, or education. In a public health perspective, this means that frailty provides a complementary layer of information. These findings underline the potential of frailty indicators to enhance predictive models of health service utilization and to support more efficient resource allocation.

Beyond technical assessment, our work raises questions of strategic importance for public health governance related to the applicability, usability and replicability of the frailty tools. Policy makers need indeed tools that are not only valid but also practical and scalable. In this respect, the use of survey data represents a key strength: they are readily available, cost-free, widely disseminated, and representative of large populations. This enables reproducibility of frailty estimates across regions and over time, allowing decision makers to monitor trends and evaluate the impact of targeted interventions. Moreover, we differentiated from previous attempts (Kleinenberg-Talsma et al., 2024) relying on existing indicators, thus avoiding the proliferation of new measures in an already crowded landscape.

These considerations point to a broader issue: the use of frailty measures, intended as a foundation to inform policy decisions, guide resource allocation, and support the evaluation of interventions that can improve health outcomes and system efficiency. If policy makers can quantify frailty at the population level, they can target resources toward those who need them most and subsequently assess the effectiveness of such programs. Yet, evidence on the impact of policies specifically addressing frail populations remains limited (Khor et al., 2022), and the effectiveness of comprehensive care programs, including integrated care models, is still insufficiently established (Hoogendijk, 2016; Hopman et al., 2016). Strengthening the evaluation of these initiatives requires standardized, adoptable tools to measure frailty consistently across contexts and over time.

Like any study based on secondary data, ours faces inherent limitations. Population surveys were not originally designed to capture frailty, and item variability across datasets may affect comparability. We addressed this by providing detailed analyses of cross-survey differences to quantify the extent of this issue. Likewise, although our comparison of the Tilburg, Edmonton, and Groningen indicators cannot establish one as superior, it offers a pragmatic evaluation of their respective strengths and weaknesses to inform their policy applicability.

Frailty assessment should not remain a purely methodological exercise, but rather serve as a basis for guiding decisions, setting priorities, and evaluating outcomes. By demonstrating that multidimensional frailty can be measured using existing national data sources, this study contributes to building the groundwork upon which future evaluations of public health interventions can be developed(Dent et al.,

2019, p. 2), supporting the design of policies that promote more equitable and effective responses to the challenges of ageing societies.

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Appendix

Operationalization of the frailty indicators across the four data sources

The procedure to operationalize the frailty indicators across the four data sources was as follows. We identified, for each indicator and data source, the survey question(s) corresponding to each indicator item; subsequently we dichotomized/categorized the responses. When an indicator item corresponded to a survey question, the match was straightforward. When this was not the case, we followed the approach by Theou and colleagues (2013) as a reference e.g., 'Do you experience problems in your daily life due to poor hearing?' y/n → 'Is your hearing [using a hearing aid as usual] (1) Excellent, (2) Very good; (3) Good; (4) Fair; (5)'). For SHARE, we replicated Theou's approach, adapting only those questions that had changed in wave 9 compared with wave 1. For the other data sources, we searched for the same questions identified by Theou in SHARE. If no such match was possible, we selected the question that best approximated the indicator item based on our judgment. This latter case was carried out independently and in double-blind by two researchers (TA and BP; TA and EL), and inter-rater agreement was tracked. Selections were then compared and discussed among all authors (TA, BP, EL) until consensus was reached. Once the survey question was determined, the same double-blind and consensus procedure was applied to the classification of responses (e.g., dichotomization).

The overall process is summarized in the decision tree presented in Figure A1.

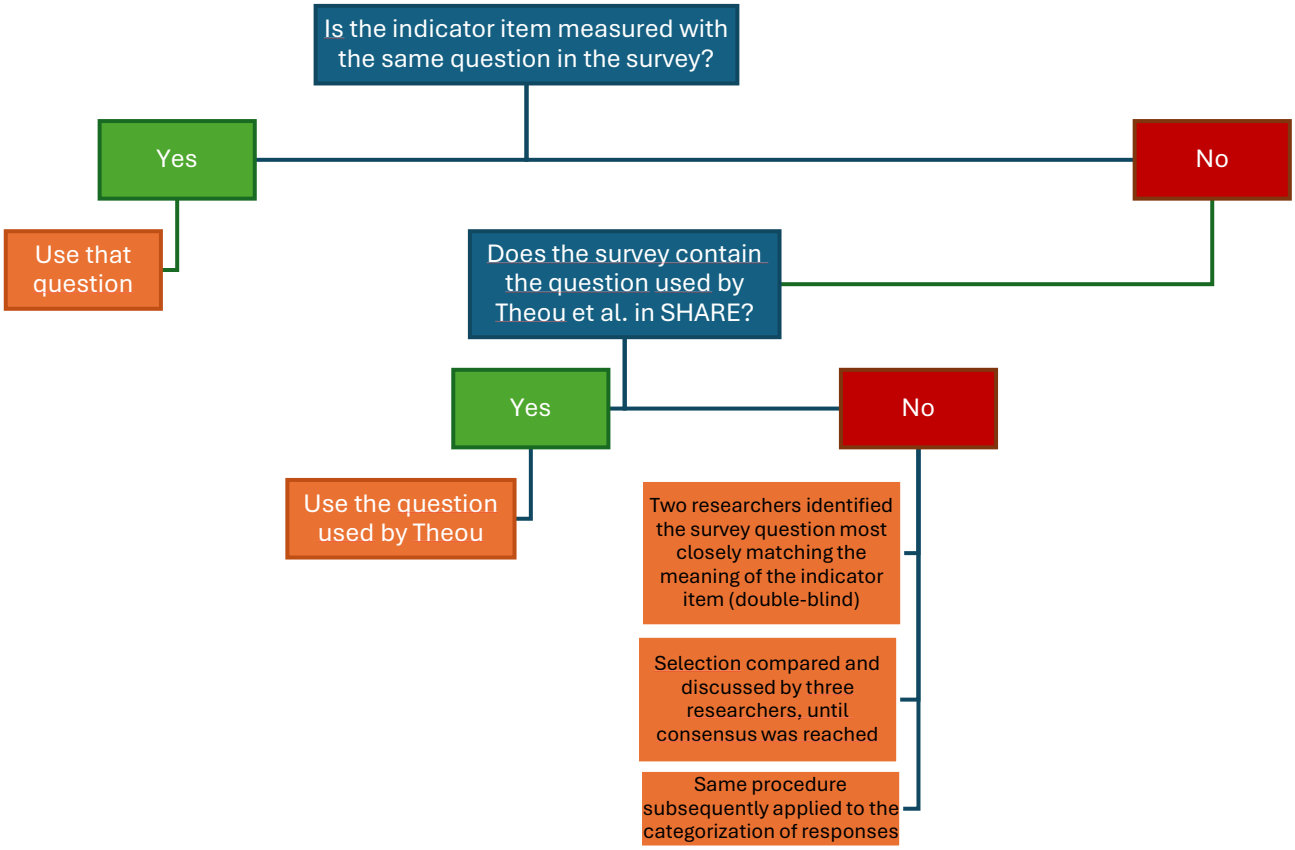
Is the indicator item measured with the same question in the survey?
Yes
No
Use that question
Does the survey contain the question used by Theou et al. in SHARE?
Yes
No
Use the question used by Theou
Two researchers identified the survey question most closely matching the meaning of the indicator item (double-blind)
Selection compared and discussed by three researchers, until consensus was reached
Same procedure subsequently applied to the categorization of responses

Table A1. Operationalization of the Tilburg Frailty Indicator

Item	Original Scale	SHARE scale	EU-SILC scale	EHIS scale	AVQ scale
TIL1	Do you feel physically healthy? ☐yes☐ 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	Self Perceived General Health (1) Very good; (2) Good; (3) Fair; (4) Bad; (5) Very Bad Very good, Good, = 0; fair, Bad, Vary Bad= 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	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
TIL2	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	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	NA	NA	NA
TIL3	Do you experience problems in your daily life due to: difficulty in walking? ☐yes☐ 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 or climbing steps? 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot walk at all No, no difficulty=0; Yes..., Cannot walk=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	NA
TIL4	Difficulty maintaining your balance? ☐yes☐ 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	NA	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	NA
TIL5	Poor hearing? ☐yes☐ 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	Difficulty in hearing, even when using a hearing aid 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot hear at all No, no difficulty=0; Yes..., Cannot hear=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	NA
TIL6	Poor vision? ☐yes☐ 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) Excellent; (2) Very good; (3) Good; (4) Fair (5) Poor Excellent, Very good, Good = 0; Fair, Poor, or blind = 1	Difficulty in seeing, even when wearing glasses or contact lenses 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot see at all	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 No difficulty=0; Some difficult; A lot of difficulty, Unable to do it =1	NA

			No, no difficulty=0; Yes..., Cannot see=1		
TIL7	Lack of strength in your hands? ☐yes☐ 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	NA	NA	NA
TIL8	Physical tiredness? ☐yes☐ no	In the last month, have you had too little energy to do things you wanted to do? No = 0; Yes = 1	NA	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	NA
TIL9	Do you have problems with your memory? ☐yes☐ sometimes ☐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, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot remember/focus at all No, no difficulty=0; Yes..., Cannot remember=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	NA
TIL10	Have you felt down during the last month? ☐yes☐ sometimes ☐no	In the last month, have you been sad or depressed? No = 0; Yes = 1	"How much of the time over the last four weeks have you been happy?" If the answer is Rarely/Never (/Some of the time?) 1 All of the time 2 Most of the time 3 Some of the time 4 A little of the time 5 None of the time 99 Do not know All of the time; most of the time; some of the time=0; A little of the time; none of the time=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	How much of the time over the last four weeks have you been sad? 1 Always 2 Very often 3 Often 4 Sometimes 5 Almost never 6 Never Almost never, never = 0 Always, very often, often, sometimes = 1
TIL11	Have you felt nervous or anxious during the last month? ☐yes☐ sometimes ☐no	Have you been irritable recently? No = 0; Yes = 1	NA	NA	How much of the time over the last four weeks have you been anxious? 1 Always 2 Very often 3 Often 4 Sometimes 5 Almost never 6 Never Almost never, never = 0

					Always, very often, often, sometimes = 1
TIL12	Are you able to cope with problems well? ☐yes☐ 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	NA	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	How much of the time over the last four weeks have you been that you would rather be dead? 1 Always 2 Very often 3 Often 4 Sometimes 5 Almost never 6 Never Almost never, never = 0 Always, very often, often, sometimes = 1
TIL13	Do you live alone? ☐yes☐ no	Number of people living in household >1 = 0; 1 = 1	NA	Number of household members =1=1; >1=0	Number of household members =1=1; >1=0
TIL14	Do you sometimes miss having people around you? ☐yes☐ sometimes ☐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	NA	"How much of the time over the last four weeks have you been feeling lonely?" 1 All of the time 2 Most of the time 3 Some of the time 4 A little of the time 5 None of the time 99 Do not know Always/Almost Always; Some of the time=1 Rarely; Never=0	**CHIES** – How often do you usually go to church or another place of worship? 1. Every day 2. Several times a week 3. Once a week 4. A few times a month (less than 4 times) 5. A few times a year 6. Never **INCSPI** – In the last 12 months, have you participated in meetings or initiatives organized or promoted by parishes, congregations, or groups of religious or spiritual inspiration? **PPAPO** – In the last 12 months, have you attended meetings of political parties? (Y/N) **PSIND** – In the last 12 months, have you attended meetings of trade union organizations (confederated, autonomous, or any category, including pensioners' unions, etc.)? (Y/N) **PGRVO** – In the last 12 months, have you attended meetings of associations or volunteer groups? (Y/N) **VOLON** – In the last 12 months, have you carried out unpaid

					activities for associations or volunteer groups? (Y/N) **PCULT** – In the last 12 months, have you attended meetings of cultural, recreational, or other types of associations? (Y/N) **SPRIV** – In the last 12 months, have you taken private lessons or sports courses at your or your family's expense? (Y/N) **RETTA** – Do you pay an annual or periodic fee for a sports club or circle? (Y/N) **PASPRO** – In the last 12 months, have you attended meetings of professional or trade associations? (Y/N) **LEZPR** – In the last 12 months, have you taken private lessons or courses: school tutoring? **INFOR** – In the last 12 months, have you taken private lessons or courses: computer science? **LING** – In the last 12 months, have you taken private lessons or courses: languages? **ARTCUL** – In the last 12 months, have you taken private lessons or courses: artistic and/or cultural activities? **AMICI** – How often do you meet with friends in your free time? 1. Every day 2. More than once a week 3. Once a week 4. A few times a month (less than 4 times) 5. A few times a year 6. Never 7. I have no friends If *CHIES* ≤ 3 (goes to church at least once a week) **or** *AMICI* ≤ 3 (meets friends at least once a week) **or** Practices at least one of the other activities == 0; In any other case == 1.

TIL15	Do you receive enough support from other people? ☐yes ☐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	NA	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	**PARENT** – Do you have other relatives you can rely on (besides parents, children, brothers and sisters, grandparents, and grandchildren)? **AMICI2** – Do you have friends you can rely on? **VICINI** – Do you have neighbors you can rely on? **Derived variable:** = 1 if **relatives = "no"** AND **friends = "no"** AND **neighbors = "no"** = 0 otherwise (i.e., if at least one among relatives, friends, or neighbors = "yes")

Table A2. Operationalization of the Groningen Frailty Indicator

Item	Original Scale	SHARE scale	EU-SILC scale	EHIS scale	AVQ scale
GRO1-GRO4	Is the patient able to carry out these tasks single handed without any help? (The use of help resources such as a walking stick, walking frame, wheelchair, is considered independent); (1) Shopping; (2) Walking around outside (around the house or to the neighbors); (3) Dressing and undressing; (4) Going to the toilet For each item, Independent = 0; Dependent = 1 (four possible points)	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) (1) Shopping for groceries; (2) Walking 100 m; (3) Dressing, including putting on shoes and socks; (4) Using the toilet, including getting up or down. For each item, No = 0; Yes = 1 (four possible points)	Do you have difficulty walking or climbing steps? 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot walk at all No, no difficulty=0; Yes…, Cannot walk=1 Do you have difficulty with self-care, such as washing all over or dressing? 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot walk at all No difficulty, Some difficulty =0, a lot of difficulty, cannot wash or dress at all = 1	Have you difficulties in: Going to the grocery shop; Waliking 500 meters; Dressing or undressing by yourself; Going to the toilette by yourself. Every question goes from: 1 No difficulty 2 Some difficulty 3 A lot of difficulties 4 I cannot do it For each Item: No difficulty, Some difficulty=0 A lot of difficulties, Cannot do it=1 (four possible points)	**Question:** Do you ever engage in any physical activity in your free time — such as walking at least 2 kilometers, swimming, cycling, or similar activities — at least occasionally during the year? **Response options:** 1. **No** 2. **Yes, once or several times a week** 3. **Yes, once or several times a month** 4. **Yes, less often** No = 1 Yes, once or several times a week; Yes, once or several times a month; Yes, less often = 0
GRO5	What mark does the patient give himself/herself for physical fitness? (scale 0 to 10) 7–10 = 0; 0–6 = 1	How often do you engage in activities that require a low or moderate level of energy	PH132 Now consider the physical activity that you perform in your free time or on the move. How often do you engage in these activities in a	How many days per week you walk for at least 10 minutes continuously? Never One day Two days	NA

		such as gardening, cleaning the car, or doing a walk? (1) More than once a week; (2) Once a week; (3) One to three times a month; (4) Hardly ever, or never More than once a week or Once a week = 0; One to three times a month or Hardly ever, or never = 1	typical week? Please refer to activities that you do continuously for at least 10 minutes and that involve at least a slight increase in breathing or heart rate, such as brisk walking, cycling, swimming. 1 Twice or more a day 2 Once a day 3 4 to 6 times a week 4 1 to 3 times a week 5 Less than once a week 6 Never Never = 1, else = 0	Three days … Seven days At least one day=0 Never=1	
GRO6	Does the patient experience problems in daily life due to poor vision? No = 0; Yes = 1	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) Excellent; (2) Very good; (3) Good; (4) Fair (5) Poor Excellent, Very good, Good = 0; Fair, Poor, or blind = 1	Difficulty in seeing, even when wearing glasses or contact lenses 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot see at all No, no difficulty=0; Yes…, Cannot see=1	Difficulty in seeing, even when wearing glasses or contact lenses 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot see at all No, no difficulty=0; Yes…, Cannot see=1	NA
GRO7	Does the patient experience problems in daily life due to being hard of hearing? No = 0; Yes = 1	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	Difficulty in hearing, even when using a hearing aid 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot hear at all No, no difficulty=0; Yes…, Cannot hear=1	Difficulty in hearing, even when using a hearing aid 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot hear at all No, no difficulty=0; Yes…, Cannot hear=1	NA
GRO8	During the last 6 months has the patient lost a lot of weight unwillingly? (3 kg in 1 month or 6 kg in 2 months) No = 0; Yes = 1	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	NA	NA	NA
GRO9	Does the patient take four or more different types of medicine? No = 0; Yes = 1	Do you currently take drugs at least once a week for problems mentioned on this card?	NA	In the last two weeks did you take medications prescribed by a practitioner? Yes No	Are you affected by any of the following chronic conditions? • Diabetes

		(1) high blood cholesterol; (2) high blood pressure; (3) Drugs for coronary or cerebrovascular diseases; (4) other heart diseases; (5) asthma; (6) diabetes mellitus; (7) joint pain or joint inflammation; (8) other pain (e.g. headache, backpain, etc.); (9) sleep problems; (10) anxiety or depression; (11) osteoporosis—hormonal (12) osteoporosis—other than hormonal; (13) stomach burns; (14) chronic bronchitis Drugs for <2 conditions = 0; Drugs for ≥2 conditions = 1		In the last two weeks did you take medication not prescribed by a practioner? Yes No Do you have any of these conditions? Asmae, Chronic bronchitis or emphysema, hearth attack, angina, hypertension, other hearth diseases, stroke, arthritis/arthrosis, chronic back pain, chronic neck pain, diabetes, allergy, hepatic cirrhosis, incontinence, renal problems, chronic renal insufficiency, depression, generalized anxiety, cancer, Alzheimer, Parkinson disease, other If at least 2 chronic conditions and take medicines = 1, Else 0.	• High blood pressure (hypertension) • Myocardial infarction (heart attack) • Angina pectoris or other heart diseases • Chronic bronchitis, emphysema, or respiratory failure • Bronchial asthma • Allergic diseases • Cancer (including lymphoma and leukemia) • Gastric or duodenal ulcer • Gallstones or diseases of the liver or bile ducts • Liver cirrhosis • Kidney stones • Osteoarthritis or arthritis • Osteoporosis If 2 or more conditions =1
GRO10	Does the patient have any complaints about his/her memory or is the patient known to have a dementia syndrome? No and sometimes = 0; Yes = 1	Four cognition tests: Numeracy performance (fail if score >2/4) Orientation (fail if score > 3/4) Verbal fluency test (fail if score < 15) Delayed recall test (fail if score < 3) 0–2 failures = 0; 3–4 failures = 1	Do you have difficulty remembering or concentrating? 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot remember/focus at all No, no difficulty=0; Yes..., Cannot remember=1	Do you have difficulty remembering or concentrating? 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot remember/focus at all No, no difficulty=0; Yes..., Cannot remember=1	NA
GRO11	(1) Does the patient sometimes experience an emptiness around him/her? No = 0; Sometimes and yes = 1 (five possible points)	Score out of 12 on the EURO=D scale, which includes the presence of (1) depression, (2) pessimism, (3) suicidality, (4) guilt, (5) sleep, (6) interest, (7) irritability, (8) appetite, (9) fatigue, (10) concentration, (11) enjoyment, (12) tearfulness EURO-D score 0–1 = 0; 2–3 = 1; 4–5 = 2; 6–7 = 3; 8–9 = 4; 10–12 = 5	"How much of the time over the last four weeks have you been feeling lonely?" 1 All of the time 2 Most of the time 3 Some of the time 4 A little of the time 5 None of the time 99 Do not know Always/Almost Always; Some of the time=1 Rarely; Never=0	**EHIS uses the PHQ-8 to measure psychological well-being (MH1*)** 1. Little interest or pleasure in doing things 2. Feeling down, depressed, or hopeless 3. Trouble falling or staying asleep, or sleeping too much 4. Feeling tired or having little energy 5. Poor appetite or overeating	**The Mental Health Index (MH)** is a measure of **psychological distress** obtained by combining the scores reported by individuals aged 14 and over on **five questions** taken from the **SF-36 (36-Item Short Form Survey)**. These questions refer to the four main dimensions of mental health: • anxiety,

GRO12	(2) Does the patients sometimes miss people around him/her? No = 0; Sometimes and yes = 1 (five possible points)		"In case of need, can you count on the help of relatives, friends, neighbours or acquaintances? Exclude people living with you. Consider both material help (e.g. money or food) and non-material help (e.g. comfort or moral support)." Yes=0 No=1	6. Feeling bad about yourself — feeling like a failure or that you have let yourself or your family down 7. Trouble concentrating on things, such as reading the newspaper or watching television 8. Moving or speaking so slowly that other people could notice, or being unusually fidgety or restless **Derived variable (MH)** MH == 0 → 0 MH == 1 or MH == 2 → 1 MH == 3 or MH == 4 → 2 MH == 5 or MH == 6 → 3 MH == 7 → 4 MH == 8 → 5	• depression, • loss of behavioral or emotional control, and • psychological well-being. The index ranges from 0 to 100, with higher values indicating better psychological well-being. **Categorization rule:** MH ≥ 75 → 0 60 ≤ MH < 75 → 1 50 ≤ MH < 60 → 2 40 ≤ MH < 50 → 3 20 ≤ MH < 40 → 4 MH < 20 → 5
GRO13	(3) Does the patient sometimes feel abandoned? No = 0; Sometimes and yes = 1 (five possible points)		Thinking about all aspects of your life, how much do you agree with the statement "I feel excluded"? Consider for example your social relationships, work, access to public services. 1 Strongly agree 2 Agree 3 Neither agree nor disagree 4 Disagree 5 Strongly disagree Strongly agree or agree =1, else 0		
GRO14	(4) Has the patient recently felt downhearted or sad? No = 0; Sometimes and yes = 1 (five possible points)		"How much of the time over the last four weeks have you been happy?" If the answer is Rarely/Never (/Some of the time?) 1 All of the time 2 Most of the time 3 Some of the time 4 A little of the time 5 None of the time 99 Do not know All of the time; most of the time; some of the time=0; A little of the time; none of the time=1		
GRO15	(5) Has the patient recently felt nervous or anxious? No = 0; Sometimes and yes = 1 (five possible points)				

Table A3. Operationalization of the Edmonton Frail Scale

Original Scale		SHARE scale	EU-SILC scale	EHIS scale	AVQ scale
EDM1	Please imagine that this pre-drawn circle is a clock. I would like you to place the numbers in the correct positions then place the hands to indicate a time of 'ten after eleven' No errors = 0; Minor spacing errors = 1; Other errors = 2	Four cognition tests: Numeracy performance 2(numeracy2) (fail if score <3/5) Orientation (orienti) (fail if score <=3/4) Verbal fluency test (fail if score < 15) Delayed recall test (fail if score < 3) No failures = 0; Any 1 failure = 1; >1 failure = 2	Do you have difficulty remembering or concentrating? 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot remember/focus at all No, no difficulty=0; Yes..., Cannot remember=1	Do you have difficulty remembering or concentrating? 1 No, no difficulty 2 Yes, some difficulty 3 Yes, a lot of difficulty 4 Cannot remember/focus at all No, no difficulty=0; Yes..., Cannot remember=1	NA
EDM2	In the past year, how many times have you been admitted to a hospital? 0 times = 0; 1–2 times = 1; >2 times = 2	During the last 12 months, have you been in a hospital overnight? If yes, How often have you been a patient in a hospital overnight during the last 12 months? 0 times = 0; 1–2 times = 1; >2 times = 2	NA	Considering all hospital stays in the past 12 months, how many nights have you spent in the hospital in total? **Response** **Description** 0 No hospital stays 01 1 night 02 2 nights 03 3 nights 04 4 nights 05 5 nights 06 6 nights 07 7 nights 08 8–10 nights 09 11–19 nights 10 20 or more nights **Derived variable rule:** 0 nights → 0 1–8 nights → 1 >8 nights → 2	**RICOV** – In the last 3 months, have you been admitted to a hospital, an accredited (contracted) care facility, or a private clinic? **Derived variable rule:** 0 times → 0 1 or more times → 2
EDM3	In general, how would you describe your health? Excellent, Very good, Good = 0; Fair = 1; Poor = 2	Would you say your health is (1) Excellent; (2) Very good; (3) Good; (4) Fair; (5) Poor Excellent, Very good, Good = 0; Fair = 1; Poor = 2	Self Perceived General Health 1 Very good 2 Good 3 Fair (neither good nor bad) 4 Bad 5 Very bad Very good, Good = 0; Fair = 1; Bad, very bad = 2	Self Perceived General Health 1 Very good 2 Good 3 Fair (neither good nor bad) 4 Bad 5 Very bad Very good, Good = 0; Fair = 1; Bad, very bad = 2	Self Perceived General Health 1 Very good 2 Good 3 Fair (neither good nor bad) 4 Bad 5 Very bad Very good, Good = 0; Fair = 1; Bad, very bad = 2
EDM4	With how many of the following activities do you require help? (meal preparation, shopping,	Please tell me if you have any difficulty with these because of a physical, mental, emotional or memory	LIMITATION IN ACTIVITIES BECAUSE OF HEALTH PROBLEMS (1) Severely limited	Do you usually have difficulty performing the following activities **without help from another person**	NA

	transportation, telephone, housekeeping, laundry, managing money, taking medications) 0–1 activities = 0; 2–4 activities = 1; 5–8 activities = 2	problem (exclude any difficulties you expect to last < 3 months) (1) Dressing, including putting on shoes and socks; (2) Walking across a room; (3) Bathing or showering; (4) Eating, such as cutting up your food; (5) Getting in or out of bed; (6) Using the toilet, including getting up or down; (7) Using a map to figure out how to get around in a strange place; (8) Preparing a hot meal; (9) Shopping for groceries; (10) Making telephone calls; (11) Taking medications; (12) Doing work around the house or garden; (13) Managing money, such as paying bills and keeping track of expenses 0–1 difficulties = 0; 2–4 difficulties = 1; >4 difficulties = 2	(2) Limited but not severely (3) Not limited at all (3) Not limited at all == 0; (2) Limited but not severely == 1; (1) Severely limited == 2	**or assistive devices** (such as canes, crutches, wheelchairs, etc.)? 1. Eating by yourself, including cutting up food 2. Lying down and getting up from bed, or sitting down and getting up from a chair by yourself 3. Dressing and undressing by yourself 4. Using the toilet by yourself 5. Bathing or showering by yourself 6. Preparing meals 7. Using the telephone 8. Doing the shopping 9. Doing light housework (washing dishes, ironing, making the bed, etc.) 10. Occasionally doing heavy housework (cleaning windows, moving heavy furniture, carrying heavy grocery bags for more than 5 minutes, deep cleaning, etc.) 11. Managing your financial resources and routine administrative tasks (paying condominium fees, utility bills, etc.) **Response options:** (1) No difficulty (2) Some difficulty (3) A lot of difficulty (4) Unable to do **Derived variable rule:** If no difficulty in all activities → 0 If at least some difficulty in 1–2 activities → 1 If at least some difficulty in 3 or more activities → 2	
EDM5	When you need help, can you count on someone who is willing and able	Thinking about the activities that you have problems with, does anyone ever help you with these activities? If yes,	In case of need, can you count on the help of relatives, friends, neighbours or acquaintances?	Do you usually have difficulty performing the following activities **without help from another person or**	NA

	to meet your needs? Always = 0; Sometimes = 1; Never = 2	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" = 1; "Hardly ever" or "no help received" = 2	Exclude people living with you. Consider both material help (e.g. money or food) and non-material help (e.g. comfort or moral support).
			
			1 Yes
			2 No
			
			If (1) yes = 0,
			If (2) no = 1
				assistive devices (such as a cane, crutches, or wheelchair)?
				1. Eating by yourself, including cutting up food
				2. Lying down and getting up from bed, or sitting down and getting up from a chair by yourself
				3. Dressing and undressing by yourself
				4. Using the toilet by yourself
				5. Bathing or showering by yourself
				6. Preparing meals
				7. Using the telephone
				8. Doing the shopping
				9. Doing light housework (washing dishes, ironing, making the bed, etc.)
				10. Occasionally doing heavy housework (cleaning windows, moving heavy furniture, carrying heavy grocery bags for more than 5 minutes, deep cleaning, etc.)
				11. Managing your financial resources and routine administrative tasks (paying condominium fees, utility bills, etc.)
				
				Response options:
				(1) No difficulty
				(2) Some difficulty
				(3) A lot of difficulty
				(4) Unable to do
				
				Derived variable rule:
				No difficulty in any activity → 0
				At least some difficulty in 1–2 activities → 1
				At least some difficulty in 3 or more activities → 2	

EDM6	Do you use five or more different prescriptions on a regular basis? No = 0; Yes = 1	Do you currently take drugs at least once a week for problems mentioned on this card? (1) high blood cholesterol; (2) high blood pressure;	NA	In the last two weeks, have you taken any medicines or herbal/vitamin supplements **prescribed by a doctor**?	Are you affected by any of the following chronic conditions? • Diabetes

		(3) Drugs for coronary or cerebrovascular diseases; (4) other heart diseases; (5) asthma; (6) diabetes mellitus; (7) joint pain or joint inflammation; (8) other pain (e.g. headache, backpain, etc.); (9) sleep problems; (10) anxiety or depression; (11) osteoporosis—hormonal (12) osteoporosis—other than hormonal; (13) stomach burns; (14) chronic bronchitis Drugs for <2 conditions = 0; Drugs for ≥2 conditions = 1		(Exclude pills or hormones taken for contraception.) In the last two weeks, have you taken any medicines or herbal/vitamin supplements **not prescribed by a doctor**? (Exclude pills or hormones taken for contraception.) **Response options:** 1 = Yes 2 = No **Chronic conditions considered:** • Asthma • Chronic bronchitis or emphysema • Myocardial infarction (heart attack) • Angina • Hypertension • Other heart diseases • Stroke • Osteoarthritis or arthritis • Low back disorder • Cervical spine disorder • Diabetes • Allergy • Liver cirrhosis • Kidney disease • Chronic urinary incontinence • Depression • Hyperlipidemia • Chronic anxiety • Malignant tumor (cancer) • Alzheimer's disease or dementia • Parkinsonism • Other chronic illness **Derived variable rule:** If number of chronic conditions ≥ 2 AND take prescriptions → 1	• High blood pressure (hypertension) • Myocardial infarction (heart attack) • Angina pectoris or other heart diseases • Chronic bronchitis, emphysema, or respiratory failure • Bronchial asthma • Allergic diseases • Cancer (including lymphoma and leukemia) • Gastric or duodenal ulcer • Gallstones or diseases of the liver or bile ducts • Liver cirrhosis • Kidney stones • Osteoarthritis or arthritis • Osteoporosis If 2 or more conditions =1

				Else → 0	
EDM7	At times do you forget to take your prescription medication? No = 0; Yes = 1	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): Taking medications No = 0; Yes = 1	NA	Do you have difficulty taking your medicines (in the correct dosage and at the right time)? **Response options:** (1) No difficulty (2) Some difficulty (3) A lot of difficulty (4) Unable to do it **Derived variable rule:** If response = 1 or 2 → 0 If response = 3 or 4 → 1	NA
EDM8	Have you recently lost weight such that your clothing has become looser? No = 0; Yes = 1	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	NA	NA	NA
EDM9	Do you often feel sad or depressed? No = 0; Yes = 1	In the last month, have you been sad or depressed? No = 0; Yes = 1	"How much of the time over the last four weeks have you been happy?" If the answer is Rarely/Never (/Some of the time?) 1 All of the time 2 Most of the time 3 Some of the time 4 A little of the time 5 None of the time 99 Do not know All of the time; most of the time; some of the time=0; A little of the time; none of the time=1	**Question:** Feeling down, depressed, or hopeless **Response options:** 1. Never 2. For several days 3. For more than half the days 4. Nearly every day -3. Proxy respondent -1. Missing **Derived variable rule:** If response = 1 → 0 If response = 2, 3, or 4 → 1	During the past 4 weeks, how often have you felt downhearted or low in spirits? **Response options:** 1. Always 2. Almost always 3. For most of the time 4. For part of the time 5. Almost never 6. Never **Derived variable rule:** If response = 5 or 6 → 0 If response = 1, 2, 3, or 4 → 1
EDM10	Do you have a problem with losing control of urine when you don't want to? No = 0; Yes = 1	For the past 6 months at least, have you been bothered by any of the health conditions on this card? Incontinence or involuntary loss of urine No = 0; Yes = 1	NA	Urinary incontinence or bladder control problems No → 0 Yes → 1	NA
EDM11	I would like you to sit in this chair with your back and arms resting. Then, when I say 'GO,' please stand up and walk at a safe and	Please tell me whether you have any difficulty doing each of the everyday activities on card because of a health or physical problem (exclude any	Do you have difficulty walking or climbing steps? 1 No, no difficulty 2 Yes, some difficulty	1. Do you have difficulty walking on a flat surface for 500 meters (about five times the length of a	NA

	comfortable pace to the mark on the floor (approximately 3 m away), return to the chair and sit down 0–10 seconds = 0; 11–20 seconds = 1; >20 seconds or patient unwilling, or requires assistance = 2	difficulties that you expect to last < 3 months): Getting up from a chair after sitting for long periods, Walking across a room No difficulties = 0; Difficulty with either one = 1; Difficulty with both = 2	3 Yes, a lot of difficulty 4 Cannot walk at all (1) No difficulty = 0: (2) Yes, Some Difficulty =1; (3) A lot of difficulty or more = 2	football field) **without any help**? 2. Do you have difficulty going up or down a flight of stairs (about 12 steps) **without any help**? **Response options:** 1. No difficulty 2. Some difficulty 3. A lot of difficulty 4. Unable to do it **Derived variable rule:** If no difficulty in both activities → 0 If some difficulty in only one activity → 0 If some difficulty in both activities → 1 If some difficulty in one and a lot of difficulty in the other → 1 If a lot of difficulty or unable to do both → 2	

Table A4 Distribution of Tilburg Frailty Indicator's items across the datasets

	SHARE	EHIS	EUSILC	AVQ
	N = 2,825	N = 13,719	N = 15,462	N = 10,991
TIL1	1,430 (51%)	8,270 (60%)	8,508 (57%)	6,915 (63%)
Missing	3		562	
TIL2	369 (14%)	0 (NA%)	0 (NA%)	0 (NA%)
Missing	99	13,719	15,462	10,991
TIL3	469 (17%)	4,753 (35%)	6,080 (41%)	0 (NA%)
Missing	5	181	548	10,991
TIL4	667 (24%)	5,147 (38%)	0 (NA%)	0 (NA%)
Missing	5	181	15,462	10,991
TIL5	688 (24%)	3,504 (26%)	3,639 (25%)	0 (NA%)
Missing	4	181	612	10,991
TIL6	828 (29%)	4,520 (33%)	5,306 (36%)	0 (NA%)
Missing	8	181	554	10,991
TIL7	560 (25%)	0 (NA%)	0 (NA%)	0 (NA%)
Missing	580	13,719	15,462	10,991
TIL8	1,029 (38%)	2,345 (18%)	0 (NA%)	0 (NA%)
Missing	105	333	15,462	10,991
TIL9	993 (37%)	5,080 (38%)	3,713 (25%)	0 (NA%)
Missing	130	181	555	10,991
TIL10	1,123 (41%)	3,933 (29%)	1,699 (13%)	3,490 (32%)
Missing	110	333	1,896	
TIL11	965 (35%)	0 (NA%)	0 (NA%)	4,128 (38%)
Missing	102	13,719	15,462	
TIL12	205 (7.5%)	2,004 (15%)	0 (NA%)	1,387 (13%)
Missing	100	333	15,462	
TIL13	603 (21%)	3,989 (29%)	4,977 (32%)	3,048 (28%)
TIL14	1,361 (48%)	0 (NA%)	4,894 (34%)	3,705 (34%)
Missing	17	13,719	1,140	
TIL15	938 (33%)	2,139 (16%)	2,550 (16%)	2,310 (21%)
Missing				1

n (%) = number of participants presenting the frailty item and percentage value on total sample

Table A5 Distribution of Groningen Frailty Indicator's items across the datasets

	SHARE	EHIS	EUSILC	AVQ
	N = 2,825	N = 13,719	N = 15,462	N = 10,991
GRO1	325 (12%)	2,105 (16%)	0 (NA%)	0 (NA%)
Missing	3	228	15,462	10,991
GRO2	469 (17%)	2,496 (18%)	1,913 (13%)	0 (NA%)
Missing	5	181	548	10,991
GRO3	247 (8.8%)	928 (6.9%)	807 (5.4%)	0 (NA%)
Missing	3	200	553	10,991
GRO4	117 (4.1%)	807 (6.0%)	0 (NA%)	0 (NA%)
Missing	3	200	15,462	10,991
GRO5	1,307 (46%)	4,820 (36%)	8,658 (56%)	6,138 (65%)
Missing	4	168		1,582
GRO6	828 (29%)	4,520 (33%)	5,306 (36%)	0 (NA%)
Missing	8	181	554	10,991
GRO7	688 (24%)	3,504 (26%)	3,639 (25%)	0 (NA%)
Missing	4	181	612	10,991
GRO8	369 (14%)	0 (NA%)	0 (NA%)	0 (NA%)
Missing	99	13,719	15,462	10,991

GRO9	1,785 (63%)	6,999 (52%)	0 (NA%)	6,030 (55%)
Missing	3	147	15,462	9
GRO10	993 (37%)	5,080 (38%)	3,713 (25%)	0 (NA%)
Missing	130	181	555	10,991
GRO11				
0	1,045 (39%)	4,674 (34%)	6,939 (52%)	4,205 (38%)
1	712 (26%)	3,995 (29%)	3,791 (29%)	3,164 (29%)
2	428 (16%)	2,351 (17%)	1,952 (15%)	1,852 (17%)
3	268 (10.0%)	1,498 (11%)	511 (3.8%)	962 (8.8%)
4	179 (6.7%)	553 (4.0%)	101 (0.8%)	638 (5.8%)
5	58 (2.2%)	648 (4.7%)		170 (1.5%)
Missing	135		2,168	

n (%) = number of participants presenting the frailty item and percentage value on total sample

Table A6 Distribution of Edmonton Frail Scale items across the datasets

	SHARE	**EHIS**	**EUSILC**	**AVQ**
	N = 2,825	**N = 13,719**	**N = 15,462**	**N = 10,991**
EDM1				0 (NA%)
0	909 (34%)	8,458 (62%)	11,194 (75%)	
1	822 (31%)	3,965 (29%)	2,981 (20%)	
2	942 (35%)	1,115 (8.2%)	732 (4.9%)	
Missing	152	181	555	10,991
EDM2			0 (NA%)	
0	2,546 (91%)	11,628 (86%)		10,152 (95%)
1	230 (8.2%)	1,275 (9.4%)		
2	37 (1.3%)	599 (4.4%)		515 (4.8%)
Missing	12	217	15,462	324
EDM3				
0	1,392 (49%)	5,337 (39%)	6,392 (43%)	4,076 (37%)
1	1,076 (38%)	5,509 (40%)	6,017 (40%)	5,366 (49%)
2	354 (13%)	2,761 (20%)	2,491 (17%)	1,549 (14%)
Missing	3	112	562	
EDM4				0 (NA%)
0	2,393 (85%)	9,304 (69%)	7,604 (51%)	
1	214 (7.6%)	1,624 (12%)	5,238 (35%)	
2	215 (7.6%)	2,604 (19%)	1,939 (13%)	
Missing	3	187	681	10,991
EDM5			2,550 (16%)	0 (NA%)
0	1,887 (67%)	8,346 (62%)		
1	27 (1.0%)	4,147 (31%)		
2	911 (32%)	1,026 (7.6%)		
EDM6	1,785 (63%)	6,922 (51%)	0 (NA%)	6,030 (55%)
Missing	3	147	15,462	9
EDM7	152 (5.4%)	0 (NA%)	0 (NA%)	0 (NA%)
Missing	3	13,719	15,462	10,991
EDM8	1,430 (51%)	0 (NA%)	0 (NA%)	0 (NA%)
Missing	3	13,719	15,462	10,991
EDM9	1,123 (41%)	3,933 (29%)	1,699 (13%)	3,490 (32%)
Missing	110	333	1,896	
EDM10	146 (5.2%)	1,755 (13%)	0 (NA%)	0 (NA%)
Missing	4	195	15,462	10,991
EDM11				0 (NA%)
0	2,191 (78%)	9,613 (71%)	8,834 (59%)	
1	529 (19%)	3,133 (23%)	4,167 (28%)	
2	103 (3.6%)	792 (5.9%)	1,913 (13%)	

Missing	2	181	548	10,991

n (%) = number of participants presenting the frailty item and percentage value on total sample

Table A7 Reliability: Internal Consistency of Domains of Tilburg Frailty Indicators (Raw Cronbach's Alpha) Across Three Data Sources

Data source	Physical Component	Psychological Component	Social Component
SHARE	0.70	0.35	0.08
EHIS	0.76	0.64	0.20
EU-SILC	0.69	0.25	0.36

SHARE=Survey of Health, Ageing and Retirement in Europe; EHIS = European Health Interview Survey; EU-SILC = European Union Statistics on Income and Living Conditions

Table A8. Reliability: Internal Consistency of items with total score, by data source – Tilburg Frailty Indicator

	SHARE		EHIS		EUSILC	
TFI item	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]
TIL1	0.652	0.519	0.800	0.456	0.669	0.417
TIL2	0.684	0.307				
TIL3	0.672	0.417	0.777	0.663	0.637	0.560
TIL4	0.663	0.467	0.777	0.662		
TIL5	0.676	0.359	0.803	0.416	0.655	0.495
TIL6	0.679	0.337	0.805	0.400	0.670	0.413
TIL7	0.689	0.251				
TIL8	0.662	0.460	0.795	0.511		
TIL9	0.690	0.252	0.792	0.529	0.645	0.543
TIL10	0.670	0.399	0.793	0.522	**0.701**	0.224
TIL11	0.699	0.181				
TIL12	0.694	0.192	0.802	0.426		
TIL13	**0.703**	0.123	**0.828**	0.155	**0.711**	0.205
TIL14	0.692	0.242			0.681	0.360
TIL15	**0.712**	0.074	0.793	0.537	**0.712**	0.161

SHARE=Survey of Health, Ageing and Retirement in Europe; EHIS = European Health Interview Survey; EU-SILC = European Union Statistics on Income and Living Conditions

Numbers in bold refer to improvement in internal consistency (ie the item worsens the indicator's performance)

[a] *Corrected Item–Total Correlation:* Correlation of the item with the total scale score excluding that item. More accurate indicator of item fit.

Table A9. Reliability: Internal Consistency of items with total score, by data source – Groningen Frailty Indicator

	SHARE		EHIS		EUSILC	
GFI item	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]
GRO1	0.631	0.523	0.680	0.632		
GRO2	0.627	0.510	0.680	0.602	0.570	0.476
GRO3	0.643	0.440	0.701	0.520	0.600	0.407
GRO4	0.656	0.367	0.704	0.501		
GRO5	0.636	0.381	0.708	0.324	**0.630**	0.207
GRO6	0.645	0.337	0.701	0.382	0.571	0.404
GRO7	0.642	0.359	0.699	0.403	0.554	0.476
GRO8	0.640	0.415				
GRO9	0.651	0.289	0.719	0.244		
GRO10	0.657	0.251	0.681	0.531	0.541	0.520
GRO11	**0.708**	0.440	**0.744**	0.582	**0.684**	0.282

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. More accurate indicator of item fit.
Numbers in bold refer to improvement in internal consistency (ie the item worsens the indicator's performance)

Table A10. Reliability: Internal Consistency of items with total score, by data source – Edmonton Frail Scale

	SHARE		EHIS		EUSILC	
EFS items	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]	Cronbach's Alpha with the item dropped	Corrected Item–Total Correlation [a]
EDM1	**0.680**	0.251	0.776	0.566	0.702	0.539
EDM2	0.673	0.185	**0.813**	0.237		
EDM3	0.575	0.678	0.770	0.611	0.659	0.663
EDM4	0.628	0.471	0.750	0.722	0.659	0.661
EDM5	**0.752**	0.004	0.780	0.536	**0.787**	0.097
EDM6	0.645	0.392	**0.809**	0.284		
EDM7	0.662	0.374				
EDM8	0.603	0.649				
EDM9	0.661	0.287	0.788	0.491	**0.764**	0.254
EDM10	0.666	0.316	**0.800**	0.389		
EDM11	0.624	0.517	0.766	0.646	0.652	0.680

SHARE=Survey of Health, Ageing and Retirement in Europe; EHIS = European Health Interview Survey; EU-SILC = European Union Statistics on Income and Living Conditions
Numbers in bold refer to improvement in internal consistency (ie the item worsens the indicator's performance)

[a] *Corrected Item–Total Correlation:* Correlation of the item with the total scale score excluding that item. More accurate indicator of item fit.

Table A11 Criteria operationalization through survey items

Criterion	Survey	Question	Variable definition
Presence of chronic conditions	SHARE	Do you suffer from chronic conditions? Yes; No	Yes = 1 No = 0
	EHIS	Chronic conditions considered: Asthma, Chronic bronchitis or emphysema, Myocardial infarction (heart attack), Angina, Hypertension, Other heart diseases, Stroke, Osteoarthritis or arthritis, Low back disorder, Cervical spine disorder, Diabetes, Allergy, Liver cirrhosis, Kidney disease, Chronic urinary incontinence, Depression, Hyperlipidemia, Chronic anxiety, Malignant tumor (cancer), Alzheimer's disease or dementia, Parkinsonism, Other chronic illness	At least one condition = 1 else = 0
	EUSILC	Do you suffer from any chronic (long-standing) chronic condition? Yes No	Yes = 1 No = 0
Visits to practitioner	Share	Times talked to medical doctor/nurse about your health last 12 months	At least 1 talk = 1 else = 0
	EHIS	Last time you got in touch with general practitioner for a health problem? Less than 12 months ago 12 or more months ago	
	EUSILC	Number of consultations with a general practitioner or family doctor in the past 12 months? None 1-2 times 3-5 times 6-9 times 10 times or more	At least one time =1 None=0
At least five or more visits to practitioner	Share	Times talked to medical doctor/nurse about your health last 12 months	At least 5 times = 1 else = 0
	EUSILC	Number of consultations with a general practitioner or family doctor in the past 12 months? None 1-2 times 3-5 times 6-9 times 10 times or more	At least five times =1 None=0
Domestic accidents	EHIS	Domestic accident in the last 12 months	Yes = 1 No = 0
Limitation in daily activities (GALI)	Share	For the past six months at least, to what extent have you been limited because of a health problem in activities people usually do? 1 Severely limited; 2 Limited, but not severely;	Severely limited =1 else = 0

		3 Not limited	
	EHIS	For the past six months at least, to what extent have you been limited because of a health problem in activities people usually do? 1 Severely limited; 2 Limited, but not severely; 3 Not limited	Severely limited =1 else = 0
	EUSILC	For the past six months at least, to what extent have you been limited because of a health problem in activities people usually do? 1 Severely limited; 2 Limited, but not severely; 3 Not limited	Severely limited =1 else = 0
Hospitalizations	Share	During the last twelve months have you been in a hospital overnight? Please consider stays in medical, surgical, psychiatric or in any other specialized wards. Yes; No	Yes = 1 No = 0
	EHIS	Considering all hospital stays in the past 12 months, how many nights have you spent in the hospital in total?	At least one night = 1 else = 0
Self-rated health (SRH)	Share	Would you say your health is (1) Excellent; (2) Very good; (3) Good; (4) Fair; (5) Poor	Poor = 1 else = 0
	EHIS	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	Bad or Very bad=1 else = 0
	EUSILC	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	Bad or Very bad=1 else = 0
Life satisfation	EHIS	Overall life satisfaction, from 1 to 10	If at least 6=0 else = 1

Table A12 Criterion Validity of the frailty indicators across data sources. Receiver Operating Characteristic Curve

Data Source	Indicator	Criterion	Cut Point	Specificity	Sensitivity	AUC (95% CI)
SHARE	TFI	SRH (ph003)				Overlapping
		Hospitalization (hc012)	>5	0.6960227	0.5753968	0.6729 (0.6389-0.7068)
		Chronic Condition (ph004)	>3	0.7283044	0.6297209	0.7312 (0.7124-0.75)
		GALI (ph005)	>5	0.7390929	0.723192	0.8021 (0.7795-0.8247)
		Doctor Visits(hc602)	>4	0.7529412	0.4446288	0.6202 (0.5855-0.6548)
	GFI	SRH (ph003)	>4	0.7581967	0.8552189	0.8789 (0.8599-0.8979)
		Hospitalization (hc012)	>3	0.6019378	0.6459144	0.6593 (0.6243-0.6942)
		Chronic Condition (ph004)	>3	0.7323569	0.6097166	0.7314 (0.7129-0.7499)
		GALI (ph005)	>4	0.7695296	0.7398568	0.8296 (0.8081-0.8511)

		Doctor Visits(hc602)	>2	0.5921569	0.5919042	0.6292 (0.5938-0.6647)
	EFS	SRH (ph003)				Overlapping
		Hospitalization (hc012)				Overlapping
		Chronic Condition (ph004)	>4	0.7350993	0.7057471	0.7914 (0.775-0.8078)
		GALI (ph005)	>5	0.7176622	0.7905544	0.8258 (0.8049-0.8468)
		Doctor Visits (hc602)	>2	0.5576923	0.7119806	0.6472 (0.6111-0.6833)
EHIS	TFI	SRH (HS1)				Overlapping
		Hospitalization (HO12)	>3	0.6293118	0.5899946	0.6502 (0.6369-0.6636)
		Chronic Condition (CD**)	>1	0.640107	0.6972094	0.7225 (0.7111-0.734)
		GALI (HS3)	>4	0.7958735	0.8076768	0.8754 (0.8617-0.8764)
		Doctor Visits (AM2)	>2	0.7149644	0.5332233	0.6637 (0.6487-0.6787)
		Domestic Accidents (AC1B)	>4	0.594958	0.6974724	0.6912 (0.6698-0.7126)
	GFI	SRH (HS1)	>4	0.7963495	0.7352071	0.8488 (0.8408-0.8568)
		Hospitalization (HO12)	>3	0.6148346	0.6024678	0.6455 (0.6319-0.659)
		Chronic Condition (CD**)				Overlapping
		GALI (HS3)	>4	0.8009868	0.7865257	0.874 (0.8662-0.8818)
		Doctor Visits (AM2)	>2	0.6774704	0.5714169	0.6666 (0.6515-0.6818)
		Domestic Accidents (AC1B)	>4	0.5840266	0.7030741	0.6882 (0.6668-0.7096)
	EFS	SRH (HS1)				Overlapping
		Hospitalization (HO12)				Overlapping
		Chronic Condition (CD**)				Overlapping
		GALI (HS3)	>5	0.8674478	0.7947908	0.9087 (0.9024-0.915)
		Doctor Visits (AM2)	>1	0.608076	0.7032327	0.7 (0.685-0.715)
		Domestic Accidents (AC1B)	>5	0.5433333	0.756517	0.7031 (0.6821-0.7242)
EU-SILC	TFI	SRH (PH010)				Overlapping
		Chronic Condition (PH020)	>2	0.6615437	0.693959	0.7283 (0.7199-0.7366)
		GALI (PH030)	>3	0.7274213	0.7592695	0.8102 (0.8012-0.8192)
		Doctor Visits (PH090)	>2	0.7070447	0.5072983	0.6436 (0.6318-0.6554)
		Life Satisfaction (PW010)	>2	0.5831351	0.8047189	0.7521 (0.7413-0.7628)
	GFI	SRH (PH010)	>2	0.7270213	0.7483766	0.8075 (0.7982-0.8168)
		Chronic Condition (PH020)	>2	0.7573562	0.5309353	0.6839 (0.6751-0.6927)
		GALI (PH030)	>2	0.7121569	0.7768509	0.8183 (0.8082-0.8283)
		Doctor Visits (PH090)	>1	0.5770505	0.5844421	0.6071 (0.5954-0.6187)
		Life Satisfaction (PW010)	>2	0.7013468	0.6632841	0.7353 (0.724-0.7465)
	EFS	SRH (PH010)				Overlapping
		Chronic Condition (PH020)	>2	0.7742785	0.7290658	0.8266 (0.8199-0.8334)
		GALI (PH030)				Overlapping
		Doctor Visits (PH090)	>1	0.6560033	0.6015874	0.6583 (0.6469-0.6696)
		Life Satisfaction (PW010)	>2	0.6387986	0.7432932	0.7609 (0.7502-0.7716)