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Effects of the bio-psycho-social frailty dimensions on healthcare utilisation among elderly in Europe: A cross-country longitudinal analysis

Stefano Calciolari [a,b,*], Cecilia Luini [b]

[a] Università degli Studi di Milano-Bicocca, Piazza dell'Ateneo Nuovo 1, 20126, Milano, Italy
[b] Università della Svizzera Italiana, Via G. Buffi 13, 6900, Lugano, Switzerland

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ABSTRACT

Frailty represents an emerging challenge and has major implications for clinical practice, public health, and the sustainability of health systems. It is a geriatric condition, related to but distinct from disability and multimorbidity and characterized by a diminished physiological reserve of multiple organs. Despite limited consensus and evidence, it has been argued that cognitive and social aspects influence the condition. Therefore, we aim to provide evidence on the importance of taking a broader approach in defining frailty, by investigating the role of its physical, social, and psychological subdomains to predict healthcare utilisation in elderly Europeans.

The study is based on the Survey of Health, Ageing and Retirement in Europe (SHARE), and uses 185,169 total observations from 12 European countries included in wave 4, 5, 6, and 8. The analysis investigates the influence of the physical frailty index (a proxy of the Frailty Phenotype definition), psychological and social frailty indexes (built to proxy the Tilburg Frailty Index) on the likelihood of hospitalisation and the number of doctor visits.

We addressed missing values due to item non-response with fully conditional specification multivariate imputation and exploited the longitudinal structure of the data to control for time-fixed unobserved characteristics. In addition, our two multivariate models included regressors to correct for demand side factors (health status, socio-economic status, and behavioral risk) as well as for country-specific characteristics.

Physical and psychological frailty positively influence the likelihood of hospitalisation (OR = 1.90 and OR = 1.31, respectively) and the number of doctor visits (IRR = 1.30 and IRR = 1.07), while social frailty reduces the two types of health services utilisation (OR = 0.53 and IRR = 0.90).

The three frailty dimensions are relevant risk stratification factors in elderly Europeans, and health policies should focus more on the psycho-social aspects of this condition, as a strategy to both contain expenditures and avoid potential healthcare inequalities.

1. Introduction

The growth of population aging in developed countries has raised concerns about the sustainability of health systems because of the burden of delivering appropriate health and social care to a growing number of elderly people (Anderson and Hussey, 2000; de Meijer et al., 2013; Gregersen, 2014; Miller, 2001; Payne et al., 2007; Reinhardt, 2000; Westerhout, 2006; Williams et al., 2019).

The relationship between ageing and growth in health expenditure has often been debated. The "*red herring theory*" argued that health care costs are positively correlated with age mainly because the likelihood of mortality rises with age (Carreras et al., 2018; Fuchs, 1984; Howdon and Rice, 2018; Zweifel et al., 1999). However, this theory does not hold up when other factors associated with ageing are considered.

Based on the conceptual model developed by Andersen and Newman (1973), de Meijer et al. (2013) argue that health-service utilisation is driven by three factors: *predisposing*, *enabling*, and *need determinants*. *Predisposing determinants* are demographic and social conditions that influence the individual's decision to use services, such as age and socio-economic status (SES). *Need factors* reflect perceived health and are related to illness; examples include chronic diseases and mental illness. Finally, *enabling determinants* are circumstances that facilitate healthcare use, ranging from the level of health insurance coverage to informal care supply. Once controlled for the *need determinants* the effect of ageing on acute healthcare use is modest (de Meijer et al., 2011, 2013), whereas such an effect is strong when analysing long-term care

* Corresponding author. Università degli Studi di Milano-Bicocca, Piazza dell'Ateneo Nuovo 1, 20126, Milano, Italy.
E-mail addresses: stefano.calciolari@unimib.it, stefano.calciolari@usi.ch (S. Calciolari).

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and primary care expenditures (Atella and Conti, 2014; de Meijer et al., 2013). Therefore, this relationship may vary across different care levels and needs, and its investigation calls for more refined analytical approaches.

As far as the *need determinants* are concerned, frailty is a condition associated with ageing and a growing challenge for health systems, in terms of both clinical practice and financial sustainability (Cesari et al., 2016). Frailty is a clinical geriatric condition characterised by increased vulnerability resulting from diminished physiological reserves and function of multiple organs, compromising the ability to cope with every-day or acute stressors (Clegg et al., 2013; Fried et al., 2001, 2005; Fried L.P. & Walston J., 2003; Mitnitski et al., 2001; World Health Organization, 2017b). Frailty and chronic diseases represent the clinical manifestations of accumulated biological deficits that occur with age. However, the conceptualization and assessment of frailty have not reached a general agreement yet.

Such a lack of agreement hinders the utilisation of a standardized, comprehensive instrument for consistently measuring frailty, with relevant consequences. Indeed, such an approach helps identifying accurately the target population and allows to effectively employ frailty in risk stratification. Moreover, it enables the accurate estimation of both clinical and economic burdens, facilitates the design of targeted intervention strategies, and allows meaningful comparisons across diverse studies and care settings (Angel et al., 2019; World Health Organization, 2017a, 2017b).

The extant literature has focused on the effects of physical frailty on the patterns of healthcare utilisation and costs in different contexts: Canada (Mondor et al., 2019), the United States (Wilkes et al., 2019), France (Sirven and Rapp, 2017), Belgium (Hoeck et al., 2012), Germany (Bock et al., 2016; Hajek et al., 2018), England (Han et al., 2019), Spain (Álvarez-Bustos et al., 2022; García-Nogueras et al., 2017), Ireland (Roe et al., 2017), Sweden (Zucchelli et al., 2019), and ten European countries (Ilinca and Calciolari, 2015). Several studies have found evidence of adverse health outcomes attributable to social and psychological frailty (Rothman et al., 2008; Tanskanen and Anttila, 2016; Teo et al., 2019; Yamada and Arai, 2018), suggesting increased healthcare use. However, while the above-mentioned empirical evidence indicates that physical and psychological frailty are associated with increased supplied care, the literature on informal care suggests that social frailty is likely to hinder healthcare access (Bolin et al., 2008; Torbica et al., 2015; Weaver and Weaver, 2014).

This synthesis shows that different definitions and measures of frailty have been developed, with the concept evolving from emphasising physical (or biological) factors to embracing social and cognitive aspects (Gobbens et al., 2017; Panza et al., 2015; Rockwood, 2005). Drawing from the Andersen & Newman model, we considered simultaneously all three aspects, categorizing physical and psychological frailty as need factors, while including social frailty among the enabling factors (Fig. 1). The inclusion of all three dimensions of frailty is important, because each component might contribute to explain healthcare use (Andersen, 1995). Therefore, we addressed the paucity of literature investigating the effects of different frailty dimensions on health care utilisation and their eventual cumulative effects.

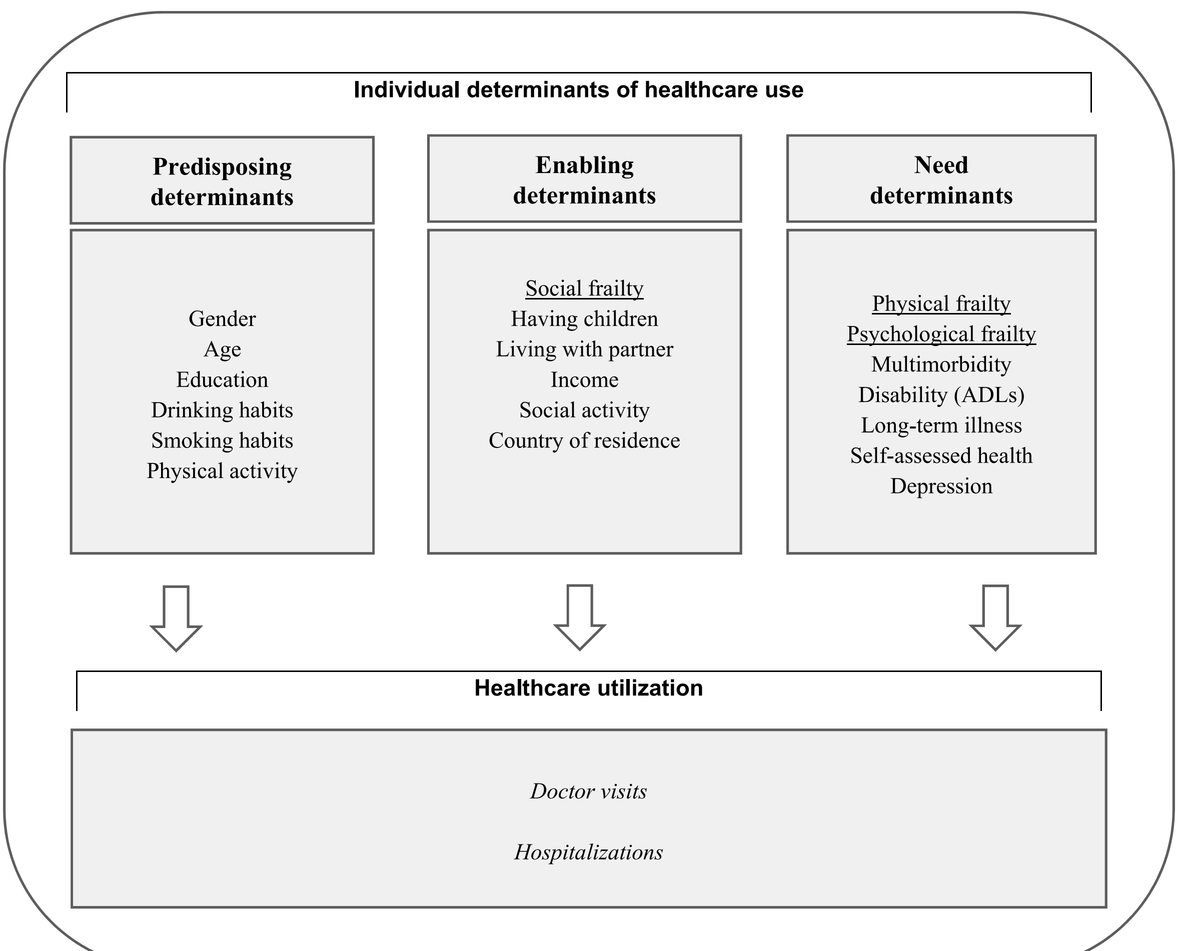

Fig. 1. Conceptual framework.

1.1. Scope of the study

This study aimed to provide evidence of the importance of adopting a broader approach in defining and measuring frailty to explain healthcare utilisation in Europe. In particular, we addressed the question: "does the physical, social and psychological frailty status influence healthcare utilisation among the elderly?". To this end, we analyzed repeated measures of frailty from a multi-wave cohort study of individuals aged 50 years or older, covering a period of nine years. The measurement of health service utilisation focuses on hospitals and ambulatory care, as they account for the largest proportion of healthcare expenditures (40% and 25%, respectively) in almost all European countries (OECD Health Statistics, 2022) and are expected to further increase because of population ageing.

We use a multivariate, non-linear regression modelling approach that controls for individual-level characteristics and for country effects and exploits the longitudinal structure of the data to control for time-fixed unobserved heterogeneity (Wooldridge, 2010). This allowed us to account for potentially confounding factors and thus draw sound conclusions about the effects of frailty.

Based on the previously reviewed literature on the relationship between the three frailty dimensions and health-service utilisation, we defined three hypotheses:

H1. Individuals with higher levels of physical frailty tended to utilize healthcare more often.

H2. Individuals with higher levels of social frailty tended to have lower levels of healthcare utilisation.

H3. Individuals with higher levels of psychological frailty tended to utilize healthcare more often.

2. Methods

2.1. Data and analysis sample

We used data from the Survey of Health, Ageing and Retirement in Europe (SHARE), a longitudinal dataset consisting of micro-data on the health and socio-economic status of individuals aged 50 or older, covering 28 European countries and Israel.

Fig. 2 shows the sample exclusion criteria followed in the study, which are based on data from regular waves 4, 5, 6, and 8 – as published in release 8.0.0. Data collection ran in the periods 2011/2012, 2013, 2015, and 2019/2020, respectively (Börsch-Supan, 2022a, 2022b, 2022c, 2022d; Börsch-Supan et al., 2013). The exclusion criteria, mainly related to our longitudinal approach, led us to retain a sample of 185,169 observations from the 12 countries that participated in all four waves (Austria, Belgium, the Czech Republic, Denmark, Estonia, France, Germany, Italy, Slovenia, Sweden, Switzerland, and Spain).

2.2. Measures

2.2.1. Outcome variables

The two outcome variables used to measure individual health care consumption are:

- Number of doctor visits in the last 12 months, a count response variable in the range 0–98.
- Having been hospitalised in the last 12 months, a binary response variable.

2.2.2. Exposure

To measure physical frailty, we adopted the phenotype definition of frailty (Fried et al., 2001), based on the assessment of five dimensions: grip strength, energy, walking speed, physical activity, and unintentional weight loss. Using SHARE data on each of the five dimensions, we built a composite physical frailty score, according to which an individual is *frail* if three or more of the above dimensions are compromised, *robust* when none of the deficits are present, and *prefrail* in intermediate situations (Romero-Ortuno et al., 2010; Santos-Eggimann et al., 2009). The estimated Cronbach's alpha of the generated Physical Frailty index was 0.58, which is consistent with the results of previous studies (Jankowska-Polańska et al., 2019; Leshabari, 2021; Zhang et al., 2020). To measure social and psychological frailty, we used the Tilburg Frailty Indicator (TFI) (Gobbens et al., 2010a; Gobbens et al., 2010b; Makizako et al., 2018). The social domains of the TFI are defined using three items: living alone, social relations, and social support. Using SHARE data on each of the three dimensions, we built a composite social frailty score, according to which an individual was classified as *socially frail* when all three domains are compromised, *socially robust* when no domain was compromised, and *socially prefrail* in any intermediate situation. The psychological domains of the TFI were identified by four items: memory problems, feeling down in the previous month, feeling anxious or nervous in the previous month, and being able to cope well with problems. Using SHARE data on each of the four dimensions, we built a composite psychological frailty score, according to which an individual was classified as *psychologically frail* when all four domains were compromised, *psychologically robust* when no domain was compromised, and *psychologically prefrail* in any intermediate situation. The estimated Cronbach's alpha of the generated Social Frailty index was 0.31, similar to that reported in other studies (Freitag et al., 2016), and the estimated Cronbach's alpha of the Psychological Frailty index was 0.46, aligned with previous research on the matter (Gobbens and Uchmanowicz, 2021).

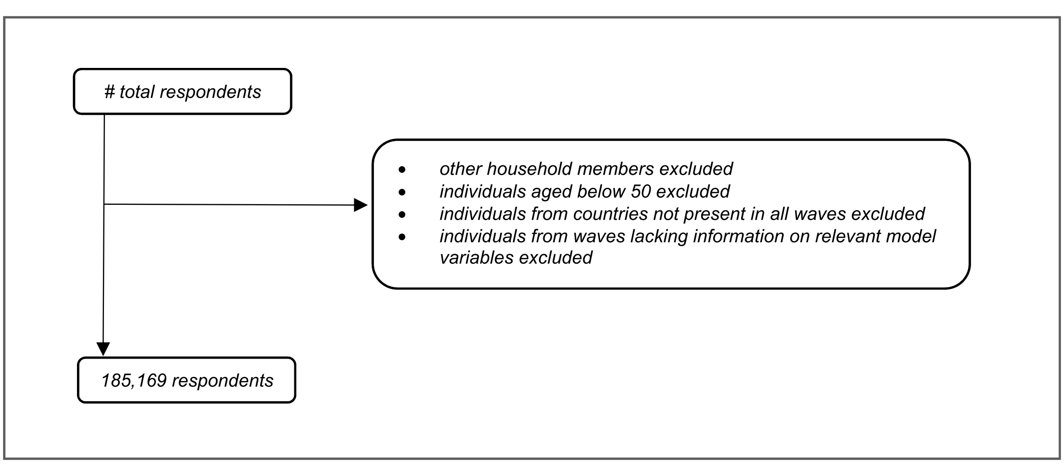

Fig. 2. Sample exclusion criteria flow chart.

2.2.3. Covariates

Our analyses include the two main correlates of frailty, that is, multimorbidity and disability (Buchman et al., 2009; Heuberger, 2011) – the latter measured as the number of activities of daily living (ADLs) limitations accumulated in six dimensions (Katz et al., 1970) – together with a number of additional control variables grouped into four categories, that is, health status, socio-economic and demographic status, behavioural risks (Espinoza and Fried, 2007; Woods et al., 2005), context (country) and time (see Table 1). Hence, the estimation was controlled for demand-side factors at the individual level and country-specific characteristics. Finally, we included the interactions between each frailty index and multimorbidity. This approach was driven by the fact that physical frailty and multimorbidity often co-exist in elderly individuals, and the latter potentially acts as a moderator of the effect of frailty on adverse outcomes (Lujic et al., 2022). Therefore, we decided to test whether the effects of psychological and social frailty on healthcare use were moderated by multimorbidity. In addition, the first interaction term helps fostering comparability with the results in

Table 1
Descriptive statistics.

Variable	Physically robust Mean (SD)/Proportion	N	Physically pre-frail Mean (SD)/Proportion	N	Physically frail Mean (SD)/Proportion	N	Range
Healthcare utilisation							
No of doctor visits	4.8 (6.3)	91,977	7.9 (10.5)	73,798	13.4 (17.7)	18,048	0–365
Hospital admission	0.1	91,980	0.2	73,806	0.4	18,072	0–1
Health Status							
Social Frailty							
Robust	8.3	7634	9.6	7085	11.6	2094	0–1
Pre-frail	89.3	82,139	85.5	63,101	81.6	14,733	0–1
Frail	2.4	2208	4.9	3616	6.8	1228	0–1
Psychological Frailty							
Robust	42.0	38,631	18.7	13,800	6.0	1083	0–1
Pre-frail	57.0	52,427	75.0	55,348	77.3	13,948	0–1
Frail	1.0	920	6.3	4649	16.7	3013	0–1
Multimorbidity	0.4	91,982	0.6	73,807	0.8	18,074	0–1
Long-term illness	0.4	91,972	0.6	73,789	0.9	18,072	0–1
Limitations with ADLs[1]	0.0 (0.2)	91,982	0.2 (0.7)	73,807	1.6 (1.9)	18,074	0–6
SAH[2]							
Excellent	11.6	10,669	3.4	2509	0.3	54	0–1
Very good	25.9	23,823	10.5	7750	1.1	199	0–1
Good	43.2	39,734	34.4	25,389	10.3	1862	0–1
Fair	17.6	16,188	39.3	29,005	37.7	6814	0–1
Poor	1.7	1564	12.4	9152	50.6	9146	0–1
EURO-D[3]	1.3 (1.4)	91,978	3.3 (2.1)	73,795	5.2 (2.5) 2.479	18,054	0–12
Demographic and Socio-Economic Status							
Male	0.5	91,982	0.4	73,807	0.4	18,074	0–1
Living with the partner	0.7	91,981	0.7	73,804	0.5	18,072	0–1
Have children	0.9	91,982	0.9	73,807	0.9	18,073	0–1
Age							
50-60	28.1	25,847	21.6	15,942	7.7	1391	0–1
60-70	40.9	37,621	31.6	23,323	16.1	2910	0–1
70-80	24.6	22,628	29.5	21,773	30.0	5423	0–1
80+	6,4	5887	17.3	12,769	46.2	8351	0–1
Education							
Primary or less	13.9	12,785	22.9	16,900	44.2	7987	0–1
Secondary	59.0	54,268	57.5	42,435	46.8	8457	0–1
Tertiary or more	27.1	24,927	19.6	14,465	9.0	1626	0–1
Financial Distress[4]							
With great difficulty	5.2	4779	10.7	7866	18.8	3332	0–1
With some difficulty	20.0	18,380	27.6	20,290	32.8	5813	0–1
Fairly easily	32.1	29,500	31.6	23,231	28.1	4980	0–1
Easily	42.7	39,241	30.1	22,128	20.3	3598	0–1
Household Wealth Quartile							
Low	20.3	18,661	30.1	22,166	43.2	7730	0–1
Middle-low	21.7	19,948	24.2	17,821	24.9	4455	0–1
Middle-high	27.7	25,463	25.0	18,410	20.5	3668	0–1
High	30.3	27,853	20.7	15,244	11.4	2040	0–1
Behavioural risk							
Has ever smoked	0.5	91,975	0.5	73,782	0.4	18,051	0–1
Frequent drinker	0.2	91,918	0.2	73,660	0.1	17,913	0–1
Socially Active	0.9	91,900	0.9	73,517	0.6	17,722	0–1

Notes:
Standard Deviations (SD) in parenthesis.
ADLs = Activities of Daily Living; [2] SAH = Self-Assessed Health (1 = excellent; 5 = poor); [3] EURO-D = European Depression Scale; [4] The levels reported are answers to the question "Are you able to make ends meet?"

Ilinca and Calciolari (2015).

2.3. Statistical analysis

SHARE suffers from sample attrition: repeated observations in the dataset account for 59.2% of the total observations, despite refreshment samples aimed at compensating for the reduction in panel sample size due to attrition (Bergmann et al., 2017). We refrained from using a balanced longitudinal subsample because death and incapacity are likely to be important sources of nonresponse; therefore, such an

Table 2
Estimates of the two models.

	Model 1 ***OR***		Model 2 ***IRR***	
	A (95% CI)	***B*** (95% CI)	***A*** (95% CI)	***B*** (95% CI)
Health Status				
Physical Frailty (ref. Robust)				
Pre-frail	1.271*** (1.180–1.370)	1.284*** (1.193–1.382)	1.129*** (1.114–1.144)	1.137*** (1.122–1.152)
Frail	1.898*** (1.617–2.229)	1.944*** (1.657–2.28)	1.296*** (1.242–1.353)	1.317*** (1.264–1.372)
Physical Frailty × Multimorbidity (ref. Robust × Multimorbidity)				
Pre-frail × Multimorbidity	.982 (.895–1.078)	.975 (.89–1.068)	.977** (.959-.996)	.968*** (.95-.986)
Frail × Multimorbidity	.819*** (.696-.964)	.799*** (.681-.937)	.919*** (.897-.942)	.901*** (.879-.923)
Social Frailty (ref. Robust)				
Pre-frail	.730*** (.653-.817)		.895*** (.881-.908)	
Frail	.529*** (.425-.660)		.896*** (.871-.922)	
Social Frailty × Multimorbidity (ref. Robust × Multimorbidity)				
Pre-frail × Multimorbidity	1.024 (.894–1.172)		1.051*** (1.032–1.070)	
Frail × Multimorbidity	1.116 (.867–1.437)		.999 (.966–1.033)	
Psychological Frailty (ref. Robust)				
Pre-frail	1.067 (.987–1.153)		1.061*** (1.050–1.073)	
Frail	1.305** (1.064–1.601)		1.074*** (1.039–1.110)	
Psychological Frailty × Multimorbidity (ref. Robust × Multimorbidity)				
Pre-frail × Multimorbidity	1.004 (.910–1.107)		.953*** (.94-.966)	
Frail × Multimorbidity	.766** (.613-.957)		.924*** (.895-.954)	
Multimorbidity	1.340*** (1.149–1.563)	1.370*** (1.277–1.47)	1.175*** (1.15–1.201)	1.190*** (1.176–1.204)
Long-term illness	1.188*** (1.127–1.251)	1.197*** (1.136–1.261)	1.173*** (1.165–1.181)	1.175*** (1.167–1.183)
Number of limitations with ADLs	1.103*** (1.074–1.132)	1.105*** (1.076–1.134)	1.046*** (1.041–1.050)	1.046*** (1.042–1.05)
Self-Assessed Health (ref. Excellent)				
Very good	1.219*** (1.077–1.38)	1.223*** (1.081–1.384)	1.158*** (1.139–1.178)	1.162*** (1.142–1.181)
Good	1.778*** (1.569–2.014)	1.788*** (1.579–2.025)	1.347*** (1.324–1.369)	1.353*** (1.331–1.376)
Fair	2.635*** (2.309–3.007)	2.663*** (2.334–3.038)	1.605*** (1.577–1.633)	1.615*** (1.587–1.644)
Poor	3.914*** (3.384–4.527)	3.948*** (3.414–4.565)	1.955*** (1.917–1.994)	1.965*** (1.927–2.004)
EURO depression scale	1.060*** (1.045–1.074)	1.062*** (1.049–1.076)	1.019*** (1.015–1.022)	1.020*** (1.017–1.023)
Demographic and Socio-Economic Status				
Male[a]	–	–	–	–
Living with Partner	.881** (.781-.995)	0.939 (.833–1.058)	1.072*** (1.05–1.094)	1.086*** (1.064–1.111)
Have Children	1.200* (.994–1.449)	1.217** (1.009–1.469)	.984 (.960–1.008)	.984 (.961–1.008)
Age group (ref- 50–60)				
60–70	.944 (.862–1.034)	0.940 (.858–1.029)	.980*** (.969-.991)	.979*** (.968-.989)
70–80	1.032 (.902–1.182)	1.023 (.894–1.172)	1.007 (.99–1.024)	1.006 (.989–1.023)
80+	1.090 (.909–1.307)	1.085 (.905–1.301)	.998 (.975–1.021)	.998 (.976–1.022)
Education (ref. Primary or less)				
Secondary	1.151 (.609–2.174)	1.158 (.613–2.188)	1.028 (.857–1.233)	1.029 (.855–1.239)
Tertiary or more	1.085 (.443–2.660)	1.091 (.448–2.656)	.990 (.8–1.224)	.991 (.801–1.23)
Able to make ends meet (ref. with great difficulty)				
With some difficulty	1.028 (.946–1.117)	1.029 (.947–1.117)	.981*** (.971-.991)	.981*** (.971-.991)
Fairly easily	1.040 (.947–1.141)	1.042 (.95–1.143)	.963*** (.952-.975)	.964*** (.952-.975)
Easily	.992 (.899–1.095)	.993 (.9–1.095)	.961*** (.947-.975)	.961*** (.947-.975)
Household Wealth quartile (ref. Low)				
Middle-low	1.014 (.948–1.085)	1.019 (.953–1.089)	1.003 (.984–1.023)	1.004 (.984–1.024)
Middle-high	1.007 (.935–1.086)	1.013 (.939–1.093)	1.014 (.992–1.036)	1.015 (.993–1.037)
High	1.034 (.953–1.123)	1.040 (.958–1.128)	1.035** (1.005–1.067)	1.037** (1.006–1.069)
Behavioral Risk				
Ever smoked daily	1.070* (.994–1.152)	1.074* (.998–1.155)	1.037*** (1.026–1.048)	1.038*** (1.027–1.049)
Frequent Drinker	.897*** (.842-.956)	.897*** (.842-.956)	.970*** (.957-.984)	.970*** (.956-.984)
Socially Active	1.090** (1.012–1.174)	1.099** (1.020–1.184)	1.036*** (1.025–1.048)	1.038*** (1.026–1.05)
Context and Time				
Country dummies[a]	–	–	–	–
Time Fixed Effects (ref. Wave 8)				
Wave 4	.833*** (.771-.9)	.819*** (.758-.884)	.852*** (.843-.861)	.849*** (.840-.857)
Wave 5	.896*** (.838-.953)	.885*** (.829-.943)	.914*** (.907-.922)	.912*** (.904-.920)
Wave 6	.927*** (.876-.980)	.924*** (.874-.977)	.893*** (.887-.9)	.893*** (.886-.899)
Number of observations	*56,442*[b]	*56,442*[b]	*161,105*[b]	*161,105*[b]

***p < .01, **p < .05, *p < .1.

[a] Time-invariant variables (male and country) omitted in the fixed effects model.

[b] The estimation sample varies across imputations, a regular circumstance when imputed variables are used as independent variables or when independent variables contain missing values (Models 1A and 1B: 56,442–56,473; Models 2A and 2B: 161,105–161,121).

approach would introduce bias by eliminating frailer individuals from the analysis (Jones et al., 2013). To ensure that attrition did not affect our estimates, we ran variable addition tests (Verbeek and Nijman, 1992), and the results rejected the hypothesis of a significant correlation between the pattern of missing values and our outcome variables.

The SHARE dataset, similar to all large household surveys, also suffers from item non-response. We addressed the problem of missing values in two steps. First, Rubin's rule (Rubin, 1996) was used to combine the five SHARE imputed datasets (Malter and Börsch-Supan, 2015) to obtain pooled estimates and standard errors for the variables of interest. Second, after observing *missing at random* (MAR) and a non-negligible number of remaining missing values, we applied the Fully Conditional Specification (FCS) method – the same as that used by SHARE – using all our models' main variables and generating seven imputed datasets (van Buuren, 2007, 2018) to obtain pooled estimates and standard errors. The post-imputation diagnostics showed coherence between the imputed and original values (Nguyen et al., 2017), with a maximum percentage of missing values per variable equal to 0.7%.

We selected the econometric approach based on two data features: (1) the dataset is longitudinal; and (2) the selected outcomes are all limited variables: the number of doctor visits in the last year and the occurrence of hospitalisation in the last 12 months. We used Poisson regression models for the count dependent variable and logistic regression models for the binary response variable. Exploiting the panel structure of the data allowed us to relax the homogeneity assumption and control for unobserved individual heterogeneity and for potential differences between waves. Two empirical models estimated the influence of frailty on health services utilisation (Table 2): Model 1 focuses on hospitalisation assuming a logistic probability distribution, while Model 2 focuses on doctor visits assuming a Poisson probability distribution.

All statistical analyses were performed using the statistical software package STATA 15.0 (StataCorp, College Station, TX, USA).

2.3.1. Model 1: hospitalisation

A longitudinal multivariate model, assuming a cumulative standard logistic distribution, was used to analyse the influence of frailty on the probability of hospitalisation during the observation period. The model assumes that this probability over time is a function of the subject's health status, demographic and socio-economic status, behavioural risks, and country of residence.

$$y_{it} = \mathbf{X}_{it}\boldsymbol{\beta} + \mathbf{W}_i\boldsymbol{\delta} + \boldsymbol{\varepsilon}_{it} \tag{1}$$

The model has a binary dependent variable (y_{it}) and two types of covariates: time-constant variables (represented by the matrix $\mathbf{W}_i$) and observed characteristics changing over time ($\mathbf{X}_i$), with – respectively – $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ representing the vectors of the corresponding parameters. Time-invariant covariates included the subjects' gender and country of residence. The time-varying covariates (including the three dimensions of frailty and multimorbidity) fell within the four categories mentioned above.

The error term ε_{it} in the model is a linear function of two components:

$$\varepsilon_{it} = \varsigma_i + \mu_{it} \tag{2}$$

The first component (the unobserved heterogeneity ς_i) represents unobserved time-constant variables – that is, shared between the four waves on the same subject i – affecting total healthcare utilisation. The second component (μ_{it}) consists of unobserved time-varying variables – that is, unique to each wave and subject – and might include economic and health shocks.

We estimated the parameters by means of MLE (Greene, 2003), and compared the random effects (RE) with the fixed effects (FE) model, because RE is an efficient approach for analysing longitudinal data but is more vulnerable than FE to omitted variable bias caused by unobserved heterogeneity (Allison, 2009). The Hausman test (comparing FE with RE) and the Mundlak specification test (comparing FE with a correlated random effect model) were used to find evidence suggesting risks of bias in the RE (Wooldridge, 2010). The two tests provided evidence that FE was preferred to RE.

The coefficients ($\boldsymbol{\delta}$) of the time-varying covariates were interpreted as odds ratios (ORs), which are measures of the strength of the association between two events. In our case, OR measures the ratio between the odds of hospitalisation and the odds of hospitalisation not occurring, given a certain value of an explanatory variable.

2.3.2. Model 2: number of doctor visits

A longitudinal multivariate model, assuming a cumulative Poisson distribution, analyzed the influence of frailty on the likelihood of the number of doctor visits during the observation period. This model assumes that the cumulation of doctor visits is a function of the same covariates used in Model 1. We estimated the parameters using MLE and applied the same tests as those used for Model 1 to select the most appropriate approach for analysing longitudinal data. The test results led us to prefer the FE model to the RE.

Although our test of overdispersion (Cameron and Trivedi, 2009; Fávero et al., 2020) led us to reject the assumption of equi-dispersion for the outcome variable, we opted for a Poisson estimation because many scholars argue that a Negative Binomial estimation implies several important drawbacks when dealing with panel data (Allison and Waterman, 2002; Greene, 2006; Guimarães, 2008; Wooldridge, 1999). In addition, Wooldridge (1999) argued that the FE Poisson model is robust even in the presence of overdispersion.

In Model 2 the exponentiated coefficients ($\boldsymbol{\delta}$) of the time-varying covariates were interpreted as incidence rate ratios (IRRs). The IRR measures the factor change in the expected number of doctor visits, given a certain value assumed by the associated explanatory variable.

3. Results

The sample is composed of 56% female and 44% male individuals, with females being slightly more prevalent in the lowest (50–60 years old) and highest age group (over 80 years old) (see Appendix A-1). Approximately half of the sampled individuals were physically frail or pre-frail (49.9%) and suffered from multimorbidity (49.5%). The prevalence of physical frailty and multimorbidity increases over time, whereas the prevalence of social and psychological frailty showed the opposite trend (see Appendix A-2). The average respondent had visited a doctor seven times in the previous year and 16% of the sample had been hospitalised in the previous 12 months, with an increase over time (see Appendix A-3).

Table 1 shows that, with the aggravation of physical frailty, psychological frailty worsens, while social frailty increases at both its highest and lowest levels. As physical frailty worsened, all remaining variables measuring health status indicated a deterioration in the average individual's health, including mental health. In addition, physical frailty is more prevalent in females, older subjects, individuals suffering from financial distress, those with low/middle household wealth, and those who are not socially active.

The use of healthcare services increases with physical frailty. The average number of doctor visits for a frail subject is almost three times that of a robust subject, and the proportion of hospitalised frail subjects is four times the one of robust individuals. A similar pattern holds for psychologically frail individuals (see Appendix A-4). However, a lower share of socially frail respondents (18%) was hospitalised than socially robust respondents (21%), while doctor visits were the same in both groups (30%) (see Appendix A-4).

The first multivariate model confirmed most of the trends suggested by the descriptive statistics on hospitalisation and our three research hypotheses (Table 2). All else being equal, the odds of hospitalisation were significantly higher in physically frail and pre-frail individuals (+90% and +27%, respectively) without multimorbidity than in robust, non-multimorbidity subjects. Interestingly, frailty per se tended to increase the odds of hospitalisation much more than multimorbidity without concomitant frailty (+34%), whereas the combined effect of both conditions increased the odds of hospitalisation (+108%). Notably, a concomitant multimorbidity moderates the effect of frailty on hospitalisation by reducing (−18%) the sum of the effects associated with the two separate conditions.

Hospitalisation is also more likely for individuals who were psychologically frail without multimorbidity, with 31% higher odds compared to psychologically robust, non-multimorbidity subjects. Similar to the first frailty dimension, the joint effect of psychological frailty and multimorbidity further increased the odds of hospitalisation (+34%), with the latter having a moderating effect (−23%) on the sum of the two separate effects.

In contrast, the odds of being hospitalised were significantly lower in socially frail individuals (−27% and −47% for medium and high frailty, respectively) without multimorbidity than in socially robust non-multimorbidity subjects. The combined effect of both conditions was not subject to any moderation, with the joint condition of social pre-frailty almost fully absorbing the influence of multimorbidity on the odds of hospitalisation and social frailty reducing the odds by −29% compared with socially robust non-multimorbidity subjects.

The second multivariate model confirmed most of the trends suggested by the descriptive statistics of doctor visits and our three research hypotheses (Table 2). All else being equal, the annual number of expected doctor visits was notably higher for physically pre-frail and frail individuals without multimorbidity (+13% and +30%, respectively) than for robust and non-multimorbidity subjects. Similar to the previous measure of healthcare utilisation, frailty per se tended to increase the expected number of doctor visits more than multimorbidity without concomitant frailty (+18%), whereas the combined effect of both conditions increased the odds of seeing a doctor (+30 and + 40%, respectively). Notably, a concomitant multimorbidity moderates the effect of frailty on the number of visits reducing the sum of the effects associated with the two separate conditions (−2% and −8%, respectively).

In addition, a higher number of doctor visits is more likely for psychologically pre-frail and frail individuals without multimorbidity (with the associated IRR increasing by 6% and 7%, respectively) than for psychologically robust non-multimorbidity subjects. The joint effect of psychological frailty and multimorbidity further increases the expected number of doctor visits (+19% and +17%, respectively), with the latter having a moderating effect (−5% and −8%, respectively) on the sum of the two separate effects.

Social frailty has the opposite effect on doctor visits; social frailty without concomitant multimorbidity tends to decrease the IRR by 10% compared to socially robust individuals without multimorbidity. The concomitance of multimorbidity had a slight moderating effect on the likelihood of an increased number of doctor visits only for socially pre-frail subjects (with a joint increase of over 10%).

4. Discussion

To the best of our knowledge, this study is the first to uncover the multidimensional nature of frailty and investigate the independent role of the physical, social, and psychological traits of frailty on the use of healthcare resources in a general, large cohort of subjects from different countries. These results provide novel and robust evidence of crucial importance for the sustainability of health systems.

We confirmed previous results regarding the effect of physical (or biological) frailty on increased healthcare utilisation, after adjusting for the main *need, predisposing,* and *enabling determinants*. We confirmed the results of Ilinca and Calciolari (2015), especially regarding the fact that physical frailty alone has a stronger positive influence on healthcare utilisation than multimorbidity, and we took some further steps. First, the larger sample size and systematic approach to managing item non-response foster the accuracy and robustness of our results. Second, when considering the version "B" of each model, our updated results suggest that European health systems are progressively more stressed by demographic and epidemiologic trends in terms of resource utilisation over time, because the odds associated with the waves are progressively higher over time. Third, the three considered dimensions of frailty have a different influence on healthcare use; while physical and psychological frailty are associated with increased resource utilisation, social frailty tends to reduce healthcare use. The latter trend may highlight the issue of accessibility rather than the actual lower needs for healthcare, challenging the relevant assumptions on which universal health system access relies.

Therefore, frailty ranks highly among *need* and *enabling determinants* of healthcare access, especially in ageing societies. In this respect, using appropriate tools to measure frailty and thus identify the frail population should be the first step in prioritising such a relevant condition in health policies (Van Kan et al., 2008). However, as of today, convergence towards a standardized definition of the condition is still a "work in progress" at the international level, thus challenging prevention, clinical management, and research alike (Angel et al., 2019; World Health Organization, 2017a). In addition, several frailty instruments have been developed: some are short and fast measures, while others are sophisticated and time-consuming tools; others seem to perform better for population-level screening, while others are more suitable for clinical settings (Dent et al., 2016); several tools focus on physical frailty, while others measure cognitive and socio-psychological domains (Collard et al., 2012). The most important associations focused on aging – the International Association of Nutrition and Aging (IANA), the joint-action ADVANTAGE, the Royal College of Physicians, the French Society of Geriatrics and Gerontology – have been working to agree on a uniform definition of frailty. Although a common definition or assessment tool (Rodríguez-Laso et al., 2019; Rolland et al., 2011; Royal College of Physicians, 2020; Van Kan et al., 2008) has not been achieved yet, a consensus has been achieved on the need for such a tool to be quick to administer, easy to use in clinical settings, validated, reliable, meant for screening, inexpensive, and requiring no special equipment. According to these recommendations, instruments such as the FRAIL or Edmonton Frail scales would fulfil the aforementioned conditions (Kojima et al., 2019), although only the latter aims to measure the three domains of frailty investigated in our study. Valid and easy-to-use instruments could allow a two-step approach. In the first phase, frailty would be pragmatically measured by any physician or nurse to rapidly identify cases at risk, in the second step, a more comprehensive assessment could be performed by an experienced practice nurse or a specialized health professional (de Lepeleire et al., 2009a, b). In addition, it is important to consider that electronic medical records may help measure frailty automatically (Kojima et al., 2019), based on data collected in the clinical setting and eventually shared across care settings. In the UK and Scotland, the electronic Frailty Index (eFI) is used to identify people with frailty on a population basis, using routinely collected primary care data. (de Lepeleire et al., 2009a, b). The use of the eFI may also support the thesis of the two-steps approach, in which the eFI represents a fast, easy-to-use, and clinically valid tool for the preliminary and rapid identification of frail older people at risk.

Frailty assessment could become a relevant factor for risk stratification and prevention; however, acknowledging its complexity and multidimensionality is fundamental for its appropriate management.

The multidimensionality of frailty, as shown in our findings, suggests the importance of designing and implementing integrated and comprehensive care strategies, addressing both somatic and psycho-social issues, and being carried forward by all providers and professionals from different sectors, including healthcare, social care, housing, and community support. Such a collaborative effort should also help identify and address the needs of socially isolated older adults who may not seek medical attention.

Most European countries, with a few exceptions, do not have frailty-specific programs in place and, overall, health systems tend to seek integration within the health care sector but neglect the lack of continuity between primary and hospital care, and between health and social care. In Norway (Norwegian Ministry of Health and Care Services, 2019) and in the Netherlands (Hoedemakers et al., 2019), the integration of health care and social care is considered a political priority to address the unmet needs of the frail elderly. The Dutch "Care Chain Frail Elderly" program targets community-dwelling frail elderly patients and aims to keep them at home and reduce secondary and long-term care by relying on well-defined primary care pathways (Hoedemakers et al., 2019). Similar models have been implemented in England (NHS England, 2014) and Scotland (Hendry et al., 2016) for complex elderly patients. In Cataluña, five-year regional health plans fostered the integration of health and social services with attention to frail chronic patients (Baltaxe et al., 2019).

The delivery of care is often fragmented and organ- or disease-specific, and healthcare provision is mostly driven by the need of cost containment, relying on easily measurable proxies for illness or disability, such as multimorbidity, polypharmacy, or symptoms, rather than treatment pathways and the patient journey. Appropriate care for frail patients requires health systems to shift away from such an approach, and attention to frailty represents a turning point towards the integration and coordination of health and social care, embracing a holistic, multidimensional, bio-psycho-social approach (De Lepeleire et al., 2009b): a view also advocated by the WHO and joint-action ADVANTAGE (Rodríguez-Laso Angel et al., 2019; World Health Organization, 2017a, 2017b). This should encourage policy makers, health care professionals, researchers in geriatrics and stakeholders in general alike, to shift from disease-to *healthy aging*-focused care.

In addition, since the influence of frailty on the likelihood of hospitalisation is greater than that on doctor visits, one might wonder whether improving the assessment and treatment of frailty may help shift the burden from acute to other care settings, with consequential economic relief at the system level, providing appropriate integration across care settings (Hendry et al., 2019; Royal College of Physicians, 2020; Wodchis et al., 2015). In fact, if frailty is detected in acute care settings, a greater level of coordination between emergency and acute medical units, and between primary and geriatric care, would likely reduce duplications while improving outcomes. In other words, the interplay between health and community care greatly influences the impact of frailty on the access and use of healthcare services.

4.1. Limitations

Our study aimed to be as representative of the European population as possible. However, we had to exclude some countries and waves because of different points-in-time country-entries in the dataset, variations in the data collection methods (that is, selected variables measured differently across waves), and an excessive share of missing values in the main selected variables in some waves. Despite this, our data and analytical approach provided results that were generalizable to several European national contexts. Nevertheless, further research at the country level may help to design interventions that are optimised for the relevant specificities of a target health system.

SHARE is not exempted from non-sampling errors, thus challenging the theoretical conditions of inference (Börsch-Supan et al., 2013). In fact, the randomness of probability sampling is not met because the SHARE baseline and refreshment samples drawn in each wave: 1) suffer from unit non-response; 2) are subject to attrition at each follow-up; 3) do not allow us to understand the evolution of the population drawn in the first wave. We addressed the first issue using the most advanced methods aimed at dealing with missing data so that the extent of the problem was almost negligible in the used dataset. However, two other issues were not addressed because out of our control.

In our study, the choices regarding the measures used to capture frailty multidimensionality were mainly driven by the information features of our dataset. In this respect, other data sources may allow for using different metrics that could help testing the sensitivity of our results and eventually improving the evaluation.

Although confident in accounting for individual unobserved heterogeneity by using fixed effects to model each of the two target outcomes, we were unable to measure some likely relevant *enabling factors*, such as health insurance status (complimentary vs. basic).

5. Conclusions

The current study provides evidence for the importance of measuring frailty along its physical, social, and psychological dimensions, especially when analysing healthcare use. Hospital admissions and number of doctor visits were significantly and differently influenced by different facets of frailty in elderly Europeans. Therefore, it is important to reach consensus on a standardised definition and measurement tool for frailty by adopting a holistic and multidimensional approach. This would be fundamental in helping professionals detect frail older adults, select the most suitable interventions which should follow an integrated care approach based on treatment pathways rather than on organ- or disease specific delivery of care, and support policymakers in defining the appropriate conditions and priorities to cope with the needs of an ageing society.

Author contributions

The study conceptualization and methodology were developed by Stefano Calciolari. Data curation and formal analysis were performed by Cecilia Luini. Stefano Calciolari supervised the research activity and validated the formal analysis. The manuscript was originally drafted by Cecilia Luini and critically reviewed and edited by Stefano Calciolari. All authors have read and agreed to the published version of the manuscript.

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Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2023.116352.

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