Contribution of health behaviours and clinical factors to socioeconomic differences in frailty among older adults

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ABSTRACT

Background To examine the association between socioeconomic status (SES) and risk of frailty, and to assess whether behavioural and clinical factors (BCF) mediate this association.

Methods Cohort of 1857 non-institutionalised individuals aged ≥60 years recruited in 2008–2010 and followed through 2012. Education, occupation, and BCF were ascertained at baseline, and incident frailty was assessed at follow-up with the Fried frailty criteria.

Results Men showed no differences in frailty risk by education or occupation. Compared with women with university education, the adjusted OR (aOR) adjusted for age and the number of frailty criteria at baseline for incident frailty in women with primary or lower education was 3.02 (95% CI 1.25 to 7.30); once fully adjusted for BCF, the OR was 2.00 (95% CI 0.76 to 5.23). No alcohol intake (vs light–moderate), longer time spent watching TV, less time spent reading, and a higher frequency of obesity, depression and musculoskeletal disease in those with primary or lower education accounted for most of the decline in OR. BCF explained 50.5% of the excess frailty risk associated with lower education. The aOR of frailty incidence for manual versus non-manual occupation was 2.24 (95% CI 1.41 to 3.56) versus a fully aOR of 2.05 (95% CI 1.24 to 3.37). BCF explained 15.3% of the association, with individual mediators being similar to those for education-related differences.

Conclusions A lower education or a manual occupation was associated with higher frailty risk in older women. These associations were partly explained by lower alcohol consumption, higher sedentariness, and higher obesity and chronic disease rates in women with lower SES.

INTRODUCTION

Frailty is a medical syndrome resulting from age-related or disease-related decline in physiological reserve, which leads to augmented vulnerability to even minor stressors manifesting as increased risk of falls, disability, and death.[1–5] Frailty is associated with several behavioural and clinical factors (BCF) such as reduced physical activity,[6] poor diet,[6] obesity,[7] smoking,[8] inflammatory markers[9 10] and many chronic conditions, particularly cardiovascular disease,[11] diabetes mellitus,[12] and depression or use of antidepressants.[9] Most of these BCF, in turn, vary by socioeconomic status (SES).[13–19]

Several studies have assessed the association between SES and frailty. Most of these,[20–26] though not all,[27] have found a cross-sectional link between lower SES and frailty. Nevertheless, we are aware of only four longitudinal studies on this topic. In two of these studies, lower education predicted a higher risk of frailty in older women[8] and in both genders combined,[28] while in the other two studies, lower educated as compared with higher educated older adults had a higher risk of worsening in frailty state.[29 30] Moreover, only two of these studies have investigated the mediators of the SES-related disparities in frailty. Hoogendijk *et al*[28] found that the studied factors made a substantial contribution to the educational differences in frailty prevalence, whereas mediators in Etman *et al*[31] explained only a small-to-moderate part of frailty worsening. However, no previous investigation has studied the mediators of occupation-based disparities in frailty incidence. Moreover, the role of specific behaviours, such as diet or sedentary lifestyle, as potential mediators of the association between lower SES and higher frailty risk is uncertain.

We analysed data from a prospective cohort of older adults in Spain to estimate the gender-specific associations of educational and occupational levels (OL) with risk of frailty and further to assess whether BCF, including diet and sedentariness, mediate such associations.

METHODS

Study design and participants

We analysed data from the Seniors-ENRICA cohort[6 32] which was established in 2008–2010 with 2614 non-institutionalised residents of Spain aged ≥60 years. At baseline, data on sociodemographic variables, lifestyle, health status, and morbidity were collected through a telephone interview. Also a physical examination, collection of blood and urine samples, and diet history were conducted during the two home visits. The average time between the phone interview and the second home visit was 14 days. In 2012, a new wave of data collection was performed to update information on the 2519 surviving respondents.

The study protocol was approved by the Clinical Research Ethics Committee of the University Hospital *La Paz* in Madrid (Spain).

Study variables

Frailty

Frailty was assessed at the home visit with a modification of the definition proposed by Fried *et al*.[3]

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We classified as frail those individuals meeting ≥3 of the following 5 criteria: (1) exhaustion: "feeling that anything I did was a big effort" and "feeling that I could not keep on doing things" at least 3–4 days a week; (2) muscle weakness: the cohort-specific lowest quintile of grip strength of the dominant hand, after adjusting for sex and body mass index (BMI) (Grip strength was measured twice with a Jamar dynamometer, and the highest value was selected); (3) low physical activity: walking ≤2.5 h/week in men or ≤2 h/week in women; (4) low walking speed: the cohort-specific lowest quintile for the 3 m walking speed test, adjusted for sex and height and (5) weight loss: involuntary weight loss ≥4.5 kg in the preceding 12 months.

Socioeconomic status

Educational level (EL) was classified as the self-reported highest level of education achieved (primary or less, secondary, or university studies). OL was based on the self-reported current or last employment held. Occupation was coded according to the National Classification of Occupations in Spain, and classified into manual and non-manual jobs. Housewives were assigned the occupation of their husband (21.3% of the women sample).

Behavioural and clinical factors

In addition to participants' sex and age, we included a range of baseline BCF potentially associated to SES and frailty: tobacco and alcohol consumption, diet, sedentary behaviour, obesity, morbidity, and the number of medications used. Participants were classified into never-smokers, former smokers, and current smokers. Alcohol consumption in the preceding 12 months was collected with a validated diet history.[32] Participants were classified as non-drinkers, ex-drinkers, light–moderate drinkers, and heavy drinkers. The threshold between light–moderate and heavy drinking was alcohol intake ≥40 g/day in men and ≥24 g/day in women. Based on diet history and the Mediterranean Diet Adherence Screener (MEDAS) index,[33] we estimated accordance with the Mediterranean diet. Sedentary behaviour was assessed with the Nurses' Health Study questionnaire validated in Spain.[34] Weight, height, and waist circumference were measured with standardised procedures.[7 32] General obesity was defined as BMI≥30 kg/m^2, and abdominal obesity as waist circumference >102 cm in men and >88 cm in women.

Individuals also reported the following physician-diagnosed diseases: cardiovascular disease (myocardial infarction, stroke, heart failure), diabetes, cancer, chronic lung disease, musculoskeletal disease (osteoarthritis, arthritis, hip fracture), or depression requiring drug treatment. Finally, drug prescriptions used were collected through self-report and checked against prescription containers at home. Polypharmacy is a possible major contributor to the pathogenesis of frailty, resulting from adverse events of drug treatments and interactions between them.[2]

Table 1 Incidence of frailty during a 3.5-year follow-up according to educational level and occupation at baseline in older men and women

	Men		Women	
	N	Per cent	N	Per cent
Total	904	4.20	953	9.97
Educational level				
Primary or less	402	5.97	592	13.34
Secondary	254	2.36	211	4.74
University	248	3.23	150	4.00
Occupation				
Manual work	278	3.60	341	15.84
Non-manual work	626	4.47	612	6.70

Statistical analysis

Of the 2519 follow-up participants, 1953 had complete baseline and follow-up data on frailty status. Baseline sociodemographic variables and BCF were similar in participants successfully followed and those lost to follow-up, except that the former were slightly younger, better educated, reported lower morbidity, and consumed fewer prescription drugs. We excluded 42 participants who were frail at baseline, 11 for lack of data on SES measures, and 43 for missing data on at least one of the BCF of interest. Thus, main analyses were conducted on 1857 individuals (904 men and 953 women).

Analyses were conducted separately for each gender. We first examined if baseline BCF and number of frailty criteria varied across EL and OL categories. Second, we assessed the associations between each BCF and frailty incidence using logistic regression adjusted for age and the number of frailty criteria (0, 1 or 2) at baseline. Only those BCF that were simultaneously associated with EL and frailty incidence (or OL and frailty incidence) could mediate the SES disparities in frailty incidence.

The associations between EL or OL and frailty incidence were summarised with OR and their 95% CI obtained from logistic regression adjusted for age and the number of baseline frailty criteria (model 1). Next, we evaluated the mediation of BCF to the associations between EL or OL and frailty incidence by adding each BCF separately to model 1. We then built a full model adjusting simultaneously for all the studied BCF. The proportion of the association between EL or OL and incident frailty explained by each BCF (or all studied BCF) was calculated as follows: $[OR_{(model\ 1)} - OR_{(full\ model)} \times 100]/[OR_{(model\ 1)} - 1]$, where the full model included age, number of frailty criteria at baseline, and each BCF (or all BCF).[35] Finally, to account for the inter-relation among BCF, we calculated the percentage of EL or OL disparities in incident frailty independently explained by the main BCF groups as well as by their overlap.[28]

RESULTS

Table 1 shows the distribution of incident frailty across categories of EL and OL.

Educational disparities in incident frailty

Several BCF were associated simultaneously with EL and incident frailty. Compared with those with university education, lower EL women were less likely to be light–moderate drinkers. Also, men and women with lower EL reported more time spent watching TV, and less time on reading, and suffered more frequently from obesity, depression and musculoskeletal disease. Meeting one or two frailty criteria was more common among those with the lowest EL. The magnitude of these SES-related differences was usually higher in women than men (table 2). Light–moderate drinking, especially among women, and time spent reading and listening to music showed a protective association with frailty incidence (OR<1), whereas time spent watching TV, obesity, depression, and the number of medications taken increased the risk of incident frailty significantly (table 3).

In our cohort, EL showed a statistically significant inverse association with incident frailty in women but not in men. Compared with men with university studies, the OR (95% CI) for frailty incidence, adjusted for age and the number of frailty

Table 2 Demographic, behavioural and clinical characteristics of the study participants by educational and occupational level

	Educational level						Occupation			
	Men			Women			Men		Women	
	University N=248	Secondary N=254	Primary or less N=402	University N=150	Secondary N=211	Primary or less N=592	Non-manual N=626	Manual N=278	Non-manual N=612	Manual N=341
Age (years)	68.0±0.4	67.2±0.4	69.5±0.3	67.9±0.5	67.0±0.4	69.8±0.3	68.5±0.3	68.3±0.4	68.7±0.2	69.1±0.3
Tobacco, alcohol and diet										
Tobacco smoking, %										
Never-smoker	30.2	30.7	36.1	68.0	66.4	89.4	34.7	29.1	77.5	87.1
Ex-smoker	48.8	49.2	51.0	20.7	24.2	6.8	48.9	51.8	15.0	8.8
Current smoker	21.0	20.1	13.2	11.3	9.5	3.9	16.5	19.1	7.5	4.1
Alcohol consumption, %										
Non-drinker	18.2	17.3	15.2	44.7	46.5	58.5	16.8	16.2	49.7	60.7
Ex-drinker	7.7	6.3	9.5	4.7	6.6	9.3	7.5	9.4	7.2	9.4
Light–moderate drinker*	62.1	65.0	61.4	48.7	39.3	29.1	63.9	59.7	37.9	28.2
Heavy drinker*	12.1	11.4	13.9	2.0	7.6	3.2	11.8	14.6	5.2	1.8
Mediterranean Diet Score	7.3±0.1	7.3±0.1	7.4±0.1	7.0±0.2	7.1±0.1	7.0±0.1	7.3±0.1	7.5±0.1	7.0±0.1	7.0±0.1
Sedentary behaviour										
Watching TV (h/week)	14.2±0.6	16.0±0.6	18.8±0.6	14.4±0.8	18.1±0.7	20.0±0.5	15.9±0.4	18.7±0.7	18.0±0.5	19.9±0.6
Seated in transportation (h/week)	2.8±0.2	2.9±0.2	2.2±0.2	1.8±0.2	1.5±0.2	0.8±0.1	2.7±0.2	2.1±0.2	1.2±0.1	0.9±0.1
Reading (h/week)†	9.6±0.5	7.0±0.4	4.6±0.3	7.8±0.5	6.1±0.4	3.5±0.2	7.7±0.3	4.2±0.3	5.5±0.2	3.3±0.3
Listening to music (h/week)‡	2.6±0.3	1.3±0.2	1.2±0.2	1.3±0.3	0.9±0.2	0.9±0.1	1.9±0.2	0.9±0.2	1.0±0.1	0.9±0.2
Obesity measures										
Body mass index (kg/m^2)										
<25	22.6	15.0	12.7	36.7	28.4	17.2	16.6	14.8	26.1	16.7
25–29.9	53.6	57.5	52.5	48.0	46.5	45.4	55.4	51.4	47.6	43.4
≥30	23.8	27.6	34.8	15.3	25.1	37.3	28.0	33.8	26.3	39.8
Abdominal obesity†	43.2	46.9	55.7	50.7	52.6	70.6	48.7	52.2	60.0	70.0
Morbidity										
Depression	2.0	2.0	3.2	6.7	7.6	14.7	2.2	3.2	10.1	15.0
Diabetes	18.2	12.6	14.4	5.3	3.3	12.3	15.2	14.4	7.4	12.6
Cancer	2.0	2.8	2.7	1.3	1.0	1.5	2.1	3.6	1.1	1.8
Cardiovascular disease	5.7	5.5	5.2	4.0	4.3	5.2	6.1	4.0	4.4	5.6
Chronic lung disease	24.1	20.4	55.6	10.7	8.1	9.1	5.3	7.6	9.2	9.1
Musculoskeletal disease	21.4	32.7	34.6	51.3	53.1	69.8	29.6	32.4	59.8	69.2
Number of medications	2.0±0.1	1.7±0.1	2.1±0.1	1.7±0.1	1.4±0.1	2.2±0.1	2.0±0.1	1.9±0.1	1.8±0.1	2.2±0.1
Frailty criteria at baseline§										
0	90.3	90.9	82.8	74.0	84.4	67.7	88.0	85.3	77.0	64.2
1	6.9	7.9	13.9	20.7	12.3	24.8	9.3	12.6	19.0	25.8
2	2.8	1.2	3.2	5.3	3.3	7.4	2.7	2.2	4.1	10.0

Continuous variables are expressed as mean±SE.
*The threshold between moderate and heavy drinking is alcohol intake ≥40 g/day in men and ≥24 g/day in women.
†Abdominal obesity: waist circumference >102 cm in men and >88 cm in women.
‡Excludes while in transportation.
§Number of frailty criteria based on Fried *et al*.[3]

criteria at baseline, was 0.80 (0.26 to 2.45) for those with secondary education and 1.63 (0.69 to 3.84) for those with primary education or less (data not shown). Among women, the corresponding figures were 1.58 (0.54 to 4.62) (data not shown) and 3.02 (1.25 to 7.30) (table 4, model 1). Given that the risk of frailty differed only between women with primary studies or lower education versus university education, the results shown in table 4 are only those for these two categories of EL. After adjustment for all the studied BCF, the OR (95% CI) of frailty incidence for women with lower EL was reduced to 2.00 (0.76 to 5.23). The individual BCF which contributed most to the reduction in OR were no alcohol consumption versus light–moderate intake (−13.9%), longer time spent watching TV (−14.3%), less time spent reading (−8.9%), BMI-based obesity (−23.3%), abdominal obesity (−16.8%), depression (−4.9%), and musculoskeletal disease (−6.9%) in those with lower EL. Taken together, the BCF explained 50.5% of the excess frailty risk associated with having primary or lower education (table 4); this resulted from the independent contributions of tobacco, alcohol and diet (1.49%), sedentariness (8.42%), obesity (13.87%), morbidity (3.97%), the number of medications (1.00%), and the overlap between the different groups of mediators (21.75%) (table 5). This means that a substantial part (21.75% over 50.5%) of the mediation by BCF

Table 3 OR (95% CI)† for incident frailty according to behavioural and clinical variables at baseline in older men and women

	Men OR† (95% CI)	Women OR† (95% CI)
Age (years)	1.14 (1.09 to 1.19)*	1.12 (1.08 to 1.16)*
Tobacco, alcohol and diet		
Tobacco smoking, %		
Never-smoker	Ref.	Ref.
Ex-smoker	1.72 (0.71 to 4.16)	1.11 (0.54 to 2.29)
Current smoker	1.56 (0.47 to 5.14)	0.48 (0.11 to 2.05)
Alcohol consumption, %		
Non-drinker	Ref.	Ref.
Ex-drinker	0.86 (0.25 to 2.95)	0.68 (0.31 to 1.50)
Light–moderate drinker	0.81 (0.34 to 1.92)	0.49 (0.28 to 0.86)*
Heavy drinker	0.64 (0.16 to 2.58)	0.44 (0.10 to 1.96)
Mediterranean Diet Score	0.78 (0.66 to 0.94)*	0.89 (0.79 to 1.02)
Sedentary behaviour		
Watching TV (h/week)	1.11 (0.96 to 1.29)	1.13 (1.03 to 1.23)*
Seated in transportation (h/week)	1.01 (0.59 to 1.75)	0.55 (0.24 to 1.26)
Reading (h/week)	0.78 (0.60 to 1.00)	0.84 (0.67 to 1.06)
Listening to music (h/week)	0.61 (0.30 to 1.24)	0.88 (0.62 to 1.26)
Obesity measures		
Body mass index (kg/m^2)		
<25	Ref.	Ref.
25–29.9	0.82 (0.28 to 2.40)	2.09 (0.95 to 4.61)
≥30	2.29 (0.79 to 6.68)	3.87 (1.77 to 8.45)*
Abdominal obesity	1.50 (0.73 to 3.05)	3.62 (1.86 to 7.05)*
Morbidity		
Depression	4.56 (1.17 to 17.74)*	1.52 (0.81 to 2.85)
Diabetes	1.53 (0.66 to 3.54)	1.78 (0.96 to 3.31)
Cancer	1.49 (0.28 to 7.84)	0.88 (0.15 to 5.11)
Cardiovascular disease	1.64 (0.57 to 4.68)	0.71 (0.27 to 1.83)
Chronic lung disease	0.55 (0.12 to 2.68)	0.97 (0.47 to 2.01)
Musculoskeletal disease	1.44 (0.72 to 2.87)	1.71 (0.96 to 3.06)
Number of medications	1.23 (1.06 to 1.42)*	1.14 (1.01 to 1.28)*

*p<0.05.
†ORs adjusted for age, number of frailty criteria (0, 1 or 2) at baseline.

groups in EL differences in frailty risk is exerted though other BCF (eg, the contribution of obesity may work through morbidity).

Occupational disparities in frailty risk

For each gender and as compared with non-manual workers, those with a manual occupation were less likely to report light–moderate alcohol consumption, spent more time on reading, and were more likely to have obesity, depression, and musculoskeletal disease. As with EL, the magnitude of these differences was more pronounced for women than men. Also women with manual occupation were more likely to suffer from diabetes and to meet one or two frailty criteria (table 2). As described above, all these BCF had an OR for frailty risk >1, except moderate alcohol intake and time spent reading for which OR was <1 (table 3).

Like EL, OL showed an association with incident frailty only among women. Compared with those with a non-manual occupation, manual workers had an OR (95% CI) for incident frailty, adjusted for age and the number of frailty criteria at baseline, of 0.85 (0.39 to 1.82) in men (data not shown) and of 2.24 (1.41 to 3.56) in women (table 4, model 1). Thus, only results for women are described below (table 4). The fully adjusted OR of frailty incidence for women in manual versus non-manual occupation was reduced to 2.05 (1.24 to 3.37). The BCF that most accounted for the reduction in OR were lower alcohol intake (−11.3%), less time spent reading (−7.3%), and BMI-based obesity (−7.3%) among women with a manual occupation. Overall, all the BCF studied only explained 15.3% of the association (table 4) and the main independent contributors to the explanatory power of the full model were tobacco, alcohol and diet (3.22%), sedentariness (2.42%) and the overlap between the different groups of mediators (8.87%) (table 5).

DISCUSSION

Our results showed substantial educational and occupational disparities in frailty risk among older women in Spain. Women with primary or lower education had three times more risk of frailty than those with university education; BCF explained half of this association. As regards to OL, results were in the same direction although BCF only explained 15% of the excess risk of frailty linked to a manual occupation.

As in the Women's Health Initiative Observational Study (WHIOS),[10] we found a higher risk of self-reported frailty in lower educated older women. However, the educational gradient in frailty in the WHIOS was narrow (12% difference in frailty between extreme educational categories), and much smaller than the income gradient. In the San Antonio Longitudinal Study of Aging (SALSA) study, conducted on an ethnically diverse population in Texas, including 55% of women, each additional year of education was associated with a 4% lower risk of progression of frailty state, defined as per the Fried frailty criteria.[29] The Survey of Health, Ageing and Retirement in Europe (SHARE) study also evinced an inverse association between EL and worsening frailty state, though there were substantial variations in the magnitude of the association across the 11 countries included.[31] Finally, in the Longitudinal Aging Study Amsterdam (LASA) study in the Netherlands, older adults of both sexes with lower EL showed three times higher odds of being frail than those with higher EL.[28]

We can only speculate about the reasons why an association between SES and incident frailty was found in women but not in men. One plausible reason is that SES differences in risk factors for frailty incidence (eg, sedentarism, obesity, depression) were greater in women than in men, which may lead to a larger social gap in frailty risk among women. Future research should confirm our findings.

In our study, lack of alcohol intake, more time spent on watching TV and less time on reading, as well as higher frequency of obesity, depression and musculoskeletal disease accounted for most of the excess risk of frailty in older women with lower versus higher SES. In the SHARE study, low alcohol intake, depression, suffering from chronic diseases, and lower social participation were more prevalent among the lower educated, but only small-to-modest proportions of educational inequalities in frailty worsening were explained by these factors.[31] Moreover, while these factors accounted for 20% of the educational gap in frailty worsening for the total study sample, these failed to explain any part of the gap in the Spanish subsample.[31] By contrast, in the LASA study, the examined factors explained 76% of educational disparities in frailty with their most important mediators being income, self-efficacy, cognitive impairment, obesity, and the number of chronic diseases.[28] In the SHARE study[31] and in the current one, abstention versus light–moderate alcohol consumption seemed to mediate the EL disparities in frailty risk. There is evidence of the social gradient in alcohol intake and moderate alcohol consumption may protect from developing frailty;[8] however, future

Table 4 OR (95% CI) for incident frailty according to educational level or occupation, with adjustment for BCF, as well as percentage change in OR of model 1 after additional adjustment for BCF among older women

	Primary or less vs university education		Manual vs non-manual occupation	
	OR (95% CI)	Percentage of change	OR (95% CI)	Percentage of change
Adjusted for age and number of frailty criteria (model 1)	3.02 (1.25 to 7.30)	–	2.24 (1.41 to 3.56)	–
Adjusted for tobacco, alcohol or Mediterranean diet				
Model 1 and tobacco	3.07 (1.26 to 7.49)	2.4	2.24 (1.40 to 3.57)	0.0
Model 1 and alcohol	2.74 (1.13 to 6.66)	−13.9	2.10 (1.32 to 3.36)	−11.3
Model 1 and Mediterranean Diet Score	3.07 (1.27 to 7.42)	2.4	2.28 (1.43 to 3.63)	3.2
Model 1 and tobacco, alcohol, Mediterranean diet	2.82 (1.15 to 6.91)	−9.9	2.14 (1.33 to 3.44)	−8.1
Adjusted for sedentary behaviours				
Model 1 and watching TV	2.73 (1.12 to 6.61)	−14.3	2.22 (1.39 to 3.54)	−1.6
Model 1 and seated in transportation	2.86 (1.17 to 6.94)	−7.9	2.19 (1.38 to 3.48)	−4.0
Model 1 and reading	2.84 (1.15 to 7.00)	−8.9	2.15 (1.34 to 3.44)	−7.3
Model 1 and listening to music	3.02 (1.25 to 7.30)	0.0	2.23 (1.40 to 3.55)	−0.8
Model 1 and sedentary behaviours	2.49 (1.00 to 6.20)	−26.2	2.11 (1.31 to 3.40)	−10.5
Adjusted for obesity measures				
Model 1 and BMI	2.55 (1.04 to 6.28)	−23.3	2.15 (1.35 to 3.44)	−7.3
Model 1 and abdominal obesity	2.68 (1.09 to 6.55)	−16.8	2.29 (1.43 to 3.67)	4.0
Model 1 and obesity measures	2.53 (1.02 to 6.22)	−24.3	2.23 (1.39 to 3.58)	−0.8
Adjusted for morbidity				
Model 1 and depression	2.92 (1.21 to 7.07)	−4.9	2.22 (1.40 to 3.53)	−1.6
Model 1 and diabetes	3.03 (1.25 to 7.38)	0.5	2.22 (1.39 to 3.53)	−1.6
Model 1 and cancer	3.02 (1.25 to 7.30)	0	2.24 (1.41 to 3.56)	0.0
Model 1 and cardiovascular disease	3.05 (1.26 to 7.37)	1.5	2.23 (1.40 to 3.54)	−0.8
Model 1 and chronic lung disease	3.03 (1.25 to 7.32)	0.5	2.24 (1.41 to 3.56)	0.0
Model 1 and musculoskeletal disease	2.88 (1.19 to 6.97)	−6.9	2.22 (1.39 to 3.53)	−1.6
Model 1 and morbidity	2.78 (1.13 to 6.83)	−11.9	2.16 (1.35 to 3.45)	−6.5
Adjusted for the number of medications				
Model 1 and number of medications	2.91 (1.20 to 7.05)	−5.4	2.19 (1.38 to 3.49)	−4.0
Model 1 and all above variables	2.00 (0.76 to 5.23)	−50.5	2.05 (1.24 to 3.37)	−15.3

*p<0.05.
BCF, behavioural and clinical factors; BMI, body mass index.

research should confirm these results, and identify potential frailty mediators.

We found that spending more time reading was associated with lower frailty risk, and further that it contributed to reduced frailty incidence among higher SES women compared with their lower SES counterparts. This may simply reflect that reading is a marker for healthy behaviours and/or access to health information which were not specifically considered in the study. Finally, despite the emerging evidence that the Mediterranean diet protects from frailty risk,[6] this dietary pattern did not explain the SES differences in incident frailty given the almost negligible educational or occupational gradient in the Mediterranean diet observed among the study participants.

Our study has several limitations. First, despite using validated questionnaires for several BCF, errors in reporting may vary by SES, for example, higher SES individuals may be more prone to response desirability bias than others. This may have limited the capacity of BCF to explain a larger part of SES differences in frailty risk. Second, we lacked data on screen times other than TV viewing (eg, computers, video games with grandchildren) which are rapidly increasing among the elderly and would count as sedentary time. In addition, computer time is very likely to vary by SES and could also be an important source of health information, thus further contributing to SES disparities.[36] Third, occupation was defined as either manual or non-manual. Although dichotomising occupational status as a proxy for social class is common practice,[22 37] it results in heterogeneous groups of jobs with diverse income level, job-related physical activity, and health risks. This heterogeneity may have underestimated occupational-related differences in frailty incidence, thus reducing the ability of BCF to explain the study association. Fourth, we cannot rule out a certain level of reverse causality (eg, prefrailty leading to lower physical activity leading, in turn, to frailty). To minimise this limitation, all analyses have been adjusted for the number of frailty criteria at baseline. Finally, our findings based on Spain should be confirmed in other countries since culture-specific sociocultural factors may influence the pathways linking SES to incident frailty.[31]

This study also has several strengths. First, research on sedentary behaviours, such as time spent watching TV, as risk factors for frailty incidence is scarce,[38] and none have as yet assessed if these mediate the SES differences in frailty risk. This is noteworthy because older women with primary or lower education reported about 4 more hours of TV viewing per week than university-educated women. Second, the prospective study design as well the SES measures used, such as education and occupation that are attained early in adulthood, reduces possibility of social mobility as an explanation for the SES disparities in frailty incidence.

Future studies with longer follow-up and objective measures of behaviour (ie, accelerometry for sedentary behaviour) must replicate these results. Future research should also consider psychosocial variables (mastery, self-efficacy social network, cognition), living environment and biomarkers, among other factors not

Table 5 Percentage of the educational and occupational differences in frailty incidence among older women which is independently explained by the main groups of biological and clinical factors (mediators), and by their overlap

	Primary or less vs university education Per cent	Manual vs non-manual occupation Per cent
Tobacco, alcohol and diet	1.49	3.22
Sedentary behaviour*	8.42	2.42
Obesity measures†	13.87	0
Morbidity‡	3.97	0
Number of medications	1.00	0.81
Overlap	21.75	8.87
Unexplained	49.50	84.68

The percentage of the educational disparities in frailty incidence which is independently explained by each group of mediators and by their overlap were calculated as follows: Two models were assessed: (A) educational level+age+number of baseline frailty criteria+all explanatory mediators except those of group X, and (B) educational level+age+number of baseline frailty criteria+all explanatory mediators (full model). The independent contribution of group X is then calculated as the percentage reduction in the OR of model B minus the percentage reduction in the OR of model A. The overlap, interpreted as the non-independent contribution of all groups of mediators, is calculated by subtracting the sum of the independent contributions of all groups of mediators from the percentage reduction in the OR of the full model (model B). The same method was used for the occupational differences in frailty incidence.
*Watching TV, seated in transportation, reading, listening to music.
†Body mass index, abdominal obesity.
‡Depression receiving treatment, diabetes, cancer, cardiovascular disease, chronic lung disease, musculoskeletal disease.

included in our study, to increase the explanatory power of the SES–frailty risk relationship. Nevertheless, based on these and past findings, including those from randomised clinical trials, increasing physical activity by reducing sedentariness might be an effective intervention to ameliorate SES disparities in frailty.[3 39] Finally, the study of SES differences in frailty faces the challenge of bridging a substantial time gap between the proximate determinants of frailty (eg, comorbidity, physical activity, and obesity at older ages) and its distal determinants (early life health behaviours, occupational exposures) influenced by early life to mid-life achievements such as education and occupation. Applying a life-course perspective is the most appropriate approach to this challenge.

CONCLUSIONS

Lower EL or OL were associated with higher risk of frailty in older women. This association was partly explained by lower alcohol consumption, higher sedentariness, and higher rates of obesity and chronic disease in women with lower SES.

What is already known on this subject

- There is substantial evidence that lower educational status is associated with increased risk of frailty in older adults, but only a few studies have investigated the mediators of this association.
- No previous investigation has studied the mediators of occupation-based disparities in frailty.
- The role of specific behaviours, such as diet or sedentary lifestyle, as potential mediators of the association between lower socioeconomic status and higher frailty risk is uncertain.

What this study adds

- In women, but not men, having a primary or lower education as well as a manual occupation was associated with higher risk of frailty.
- Lower alcohol consumption, higher sedentariness, and higher rates of obesity and chronic disease partly explain the excess risk associated with lower socioeconomic status (SES) in older women.
- On the basis of these and past findings, reducing sedentary behaviours might be an effective intervention to ameliorate SES disparities in frailty.

Contributors FR-A conceived the study. HS-V, EG-E, LML-M, EL-G, JRB and FR-A conducted the research. HS-V and EG-E performed the statistical analyses. HS-V and FR-A drafted the manuscript. All the authors reviewed the manuscript for important intellectual content. HS-V and FR-A had primary responsibility for final content. All the authors read and approved the final manuscript.

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REFERENCES

1 Clegg A, Young J, Iliffe S, *et al*. Frailty in elderly people. *Lancet* 2013;381:752–62.
2 Morley JE, Vellas B, van Kan GA, *et al*. Frailty consensus: a call to action. *J Am Med Dir Assoc* 2013;14:392–7.
3 Fried L, Tangen C, Walston J, *et al*., Cardiovascular Health Study Collaborative Research Group. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001;56:M146–56.
4 Garcia-Garcia FJ, Gutierrez Avila G, Alfaro-Acha A, *et al*., Toledo Study Group. The prevalence of frailty syndrome in an older population from Spain. The Toledo Study for Healthy Aging. *J Nutr Health Aging* 2011;15:852–6.
5 Collard RM, Boter H, Schoevers RA, *et al*. Prevalence of frailty in community-dwelling older persons: a systematic review. *J Am Geriatr Soc* 2012;60:1487–92.
6 León-Muñoz LM, García-Esquinas E, López-García E, *et al*. Major dietary patterns and risk of frailty in older adults: a prospective cohort study. *BMC Med* 2015;13:11–19.
7 García-Esquinas E, José García-García F, León-Muñoz LM, *et al*. Obesity, fat distribution, and risk of frailty in two population-based cohorts of older adults in Spain. *Obesity (Silver Spring)* 2015;23:847–55.
8 Woods NF, LaCroix AZ, Gray SL, *et al*., Women's Health Initiative. Frailty: emergence and consequences in women aged 65 and older in the Women's Health Initiative Observational Study. *J Am Geriatr Soc* 2005;53:1321–30.
9 Barzilay JI, Blaum C, Moore T, *et al*. Insulin resistance and inflammation as precursors of frailty: the Cardiovascular Health Study. *Arch Intern Med* 2007;167:635–41.
10 Gale CR, Baylis D, Cooper C, *et al*. Inflammatory markers and incident frailty in men and women: the English Longitudinal Study of Ageing. *Age (Dordr)* 2013;35:2493–501.
11 Afilalo J, Alexander KP, Mack MJ, *et al*. Frailty assessment in the cardiovascular care of older adults. *J Am Coll Cardiol* 2014;63:747–62.
12 Morley JE, Malmstrom TK, Rodriguez-Mañas L, *et al*. Frailty, sarcopenia and diabetes. *J Am Med Dir Assoc* 2014;15:853–9.
13 Lakey SL, LaCroix AZ, Gray SL, *et al*. Antidepressant use, depressive symptoms, and incident frailty in women aged 65 and older from the Women's Health Initiative Observational Study. *J Am Geriatr Soc* 2012;60:854–61.
14 León-Muñoz LM, Guallar-Castillón P, Graciani A, *et al*. Adherence to the Mediterranean diet pattern has declined in Spanish adults. *J Nutr* 2012;142:1843–50.
15 León-Muñoz LM, Gutiérrez-Fisac JL, Guallar-Castillón P, *et al*. Contribution of lifestyle factors to educational differences in abdominal obesity among the adult population. *Clin Nutr* 2014;33:836–43.

16 Eikemo TA, Hoffmann R, Kulik G, *et al*., EURO-GBD-SE Consortium. How can inequalities in mortality be reduced? A quantitative analysis of 6 risk factors in 21 European populations. *PLoS ONE* 2014;9:e110952.
17 Mackenbach JP, Stirbu I, Roskam AJ, *et al*., European Union Working Group on Socioeconomic Inequalities in Health. Socioeconomic inequalities in health in 22 European countries. *N Engl J Med* 2008;358:2468–81.
18 Espelt A, Borrell C, Roskam AJ, *et al*. Socioeconomic inequalities in diabetes mellitus across Europe at the beginning of the 21st century. *Diabetologia* 2008;51:1971–9.
19 Lorant V, Croux C, Weich S, *et al*. Depression and socio-economic risk factors: 7-year longitudinal population study. *Br J Psychiatry* 2007;190:293–8.
20 Woo J, Goggins W, Sham A, *et al*. Social determinants of frailty. *Gerontology* 2005;51:402–8.
21 Szanton SL, Seplaki CL, Thorpe RJ Jr, *et al*. Socioeconomic status is associated with frailty: the Women's Health and Aging Studies. *J Epidemiol Community Health* 2010;64:63–7.
22 Alvarado BE, Zunzunegui MV, Béland F, *et al*. Life course social and health conditions linked to frailty in Latin American older men and women. *J Gerontol A Biol Sci Med Sci* 2008;63:1399–406.
23 Lang IA, Hubbard RE, Andrew MK, *et al*. Neighborhood deprivation, individual socioeconomic status, and frailty in older adults. *J Am Geriatr Soc* 2009;57:1776–80.
24 Rodríguez López S, Montero P, Carmenate M. Educational inequalities and frailty in Spain: what is the role of obesity? *J Frailty Aging* 2014;3:120–5.
25 Romero-Ortuno R. Frailty index in Europeans: association with determinants of health. *Geriatr Gerontol Int* 2014;14:420–9.
26 Herr M, Robine JM, Aegerter P, *et al*. Contribution of socioeconomic position over life to frailty differences in old age: comparison of life-course models in a French sample of 2350 old people. *Ann Epidemiol* 2015;25:674–80.
27 Hirsch C, Anderson ML, Newman A, *et al*., Cardiovascular Health Study Research Group. The association of race with frailty: the cardiovascular health study. *Ann Epidemiol* 2006;16:545–53.
28 Hoogendijk EO, van Hout HP, Heymans MW, *et al*. Explaining the association between educational level and frailty in older adults: results from a 13-year longitudinal study in the Netherlands. *Ann Epidemiol* 2014;24:538–44.
29 Espinoza SE, Jung I, Hazuda H. Frailty transitions in the San Antonio Longitudinal Study of Aging. *J Am Geriatr Soc* 2012;60:652–60.
30 Etman A, Burdorf A, Van der Cammen TJ, *et al*. Socio-demographic determinants of worsening in frailty among community-dwelling older people in 11 European countries. *J Epidemiol Community Health* 2012;66:1116–21.
31 Etman A, Kamphuis CB, van der Cammen TJ, *et al*. Do lifestyle, health and social participation mediate educational inequalities in frailty worsening? *Eur J Public Health* 2015;25:345–50.
32 Rodríguez-Artalejo F, Graciani A, Guallar-Castillón P, *et al*. Rationale and methods of the Study on Nutrition and Cardiovascular Risk in Spain (ENRICA). *Rev Esp Cardiol* 2011;64:876–82.
33 Schröder H, Fitó M, Estruch R, *et al*. A short screener is valid for assessing Mediterranean diet adherence among older Spanish men and women. *J Nutr* 2011;141:1140–5.
34 Martínez-González MA, López-Fontana C, Varo JJ, *et al*. Validation of the Spanish version of the physical activity questionnaire used in the Nurses' Health Study and the Health Professionals' Follow-up Study. *Public Health Nutr* 2005;8:920–7.
35 Wamala SP, Wolk A, Orth-Gomér K. Determinants of obesity in relation to socioeconomic status among middle-aged Swedish women. *Prev Med* 1997;26:734–44.
36 Valkeinen H, Harald K, Borodulin K, *et al*. Educational differences in estimated and measured physical fitness. *Eur J Public Health* 2013;23:998–1002.
37 Regidor E, Gutierrez-Fisac JL, Calle ME, *et al*. Trends in cigarette smoking in Spain by social class. *Prev Med* 2001;33:241–8.
38 Keevil VL, Wijndaele K, Luben R, *et al*. Television viewing, walking speed, and grip strength in a prospective cohort study. *Med Sci Sports Exerc* 2015;47:735–42.
39 Cesari M, Vellas B, Hsu FC, *et al*., LIFE Study Group. A physical activity intervention to treat the frailty syndrome in older persons-results from the LIFE-P study. *J Gerontol A Biol Sci Med Sci* 2015;70:216–22.