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Housing conditions and limitations in physical function among older adults

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ABSTRACT

Introduction Housing conditions are an important social determinant of health. However, to the best of our knowledge, no previous study has systematically assessed the association between housing conditions and physical function limitations in older adults; moreover, whether this association is independent of the socioeconomic status achieved earlier in life is still uncertain.

Methods Cross-sectional analysis conducted among 2012 non-institutionalised individuals aged ≥60 years, who participated in the Seniors-ENRICA cohort. Participants reported the following poor housing conditions: living in a walk-up building, lacking heating, or feeling cold frequently. We assessed lower extremity performance with the Short Physical Performance Battery (SPPB), mobility or agility limitations with standardised questions, frailty according to the Fried criteria, and disability in instrumental activities of daily living (IADL) with the Lawton and Brody questionnaire.

Results In analyses adjusting for demographic, behavioural and comorbidity variables, when compared with those living in homes without poor housing conditions, those with ≥2 poor conditions showed worse scores in the SPPB (β −1.06; 95% CI −1.46 to −0.65) and a higher frequency of agility limitation (OR 1.62; 95% CI 1.00 to 2.61) and frailty (OR 8.78; 95% CI 3.00 to 25.60). These associations held after adjustment for educational and occupational levels. Living in a walk-up building was associated with a higher frequency of frailty, while lacking heating was linked to lower scores in the 3 SPPB tests, as well as with an increased frequency of frailty and 4 of its components (exhaustion, slow walking speed, low physical activity and weakness). Feeling cold was linked to increased exhaustion. No association was found between housing conditions and IADL disability.

Conclusions Poor housing conditions, particularly living in a walk-up building and lacking heating, are independently associated with limitations in physical function in older adults. This entails serious inequalities in functional status, which should be firmly addressed.

INTRODUCTION

Housing conditions are an important social determinant of health,[1] with evidence showing that housing renovation can lead to health improvements, especially where changes are targeted at those with inadequate warmth or chronic respiratory disease.[2] Despite this evidence, fuel poverty and cold housing are enduring problems whose frequency has increased during the recent economic crisis because of higher energy prices and lower household incomes. For instance, in England, the number of fuel poor households increased dramatically between 2004 and 2010, from 1.2 to 4.6 million.[3] In Spain in 2010, 10% of households were in fuel poverty, defined as spending a disproportionate share of its annual income (10%, twice the national average) on energy, or being unable to keep the home adequately warm in the winter.[4] In addition, 14.5% of the households lacked any heating system.[5] Besides, in 2012, about 65% of the Spanish population lived in apartment buildings,[6] and only about half of them had an elevator; specifically, only 21% of the buildings with four or more stories had a lift.[7] This seriously limits home accessibility for people with reduced mobility, which is particularly frequent in the oldest segment of the population.

Studies focusing on the elderly[8] have shown that poor housing conditions are associated with a higher risk of falls,[9 10] worse respiratory and mental health,[11 12] and higher risk of disease-specific and all-cause mortality.[13–16] However, less is known about the influence of housing conditions on functional status; specifically, no study has comprehensively examined its association with a wide variety of physical function limitations, both self-reported and objectively measured, in older adults.[8] Moreover, while housing conditions and functional impairment are strongly linked to socioeconomic status (SES),[3 17–19] it is still uncertain if the association between housing conditions and physical function is independent of SES attained in early life (eg, education) and in adult life (eg, occupation).

This study assessed the association of housing conditions with lower extremity performance, limitations in mobility or agility, frailty and disability in instrumental activities of daily living (IADL) in older adults from Spain. Additionally, it investigated if the study association held after accounting for educational and occupational levels.

METHODS

Study population and design

During the years 2008–2010, 2614 men and women were selected through stratified random sampling from the non-institutionalised Spanish population aged 60 years and older.[20] In total, 2519 of these individuals were followed up until 2012.[21] The present study was based on this 2012 second phase, in which computer-assisted telephone interviews were conducted to collect data on the main sociodemographic factors, health behaviours and morbidity of study participants. Additionally, two home visits were performed to conduct a physical examination, collect information on drug treatments and assess diet.[21] All

participants gave written informed consent, and the Clinical Research Ethics Committee of the 'La Paz' University Hospital in Madrid approved the study.

Study variables

Housing conditions

Participants reported whether they lived in a walk-up building, or in a house that lacked running hot water, heating, a bathtub or shower, an individual bedroom, a fridge, an automatic washing machine or a telephone, as well as whether they frequently felt cold at home. This questionnaire has previously been shown to predict mortality among patients with heart failure.[14]

Limitations in physical functioning

We considered a variety of function impairments, from less severe problems, such as poor lower extremity performance and mobility or agility limitations, to more serious conditions, such as frailty and disability in IADL. All these functional impairments have been shown to predict adverse outcomes in older adults, including falls, hospitalisation, nursing home admission or death.[22–24]

Performance of the lower extremity: It was objectively measured with the Short Physical Performance Battery (SPPB), which includes three components: balance testing, a 3 m walking speed test, and a sit-to-stand test.[25] Each component was scored on a 0–4 scale, and the total SPPB was calculated by the sum of the three components (range 0–12). A higher score in each test and across them indicates better performance.

Balance testing included a side-by-side, a semitandem and a tandem stand. Participants were first asked to stand with their feet together. Those who were able to stand for 10 s in this position were tested in the semitandem stand position, where the heel of one foot is placed to the side of the big toe of the other foot. Those who were able to stand for 10 s in the semitandem position were then tested in the full-tandem stand, where the heel of one foot is placed in front of the toes of the other foot. A score of 0 in the balancing test indicates the inability to stand in any of the positions, while a score of 4 indicates a full-tandem stand for 10 s.

Participants were also asked to walk 3 m, and their gait speed was calculated as the distance in metres divided by the time in seconds. In this test, 0 points indicated the inability to perform the walk, and 4 indicated being in the lowest quartile of the sample-specific walking speed, adjusted for sex and height.

Finally, participants were asked to stand up from a chair and sit down again five times repeatedly, without leaning on anything, as quickly as possible. A score of zero was given if a participant was unable to perform five chair stands, while a score of 1, 2, 3 or 4 was assigned to a participant who completed five chair stands in ≥16.7, 13.7–16.6, 11.2–13.6 and ≤11.1 s, respectively.

Mobility limitation: It was defined as an affirmative answer to any of the following questions: (1) 'Do you experience any difficulty in picking up or carrying a shopping bag?' (2) 'Do you experience any difficulty in climbing one flight of stairs?' or (3) 'Do you experience any difficulty in walking several city blocks (a few 100 m)?'.[23]

Agility limitation: An affirmative answer to the question 'Do you experience any difficulty in bending or kneeling?'.

Frailty: According to the definition proposed by Fried *et al*,[26] we assessed the following criteria: (1) exhaustion—any of the following responses to two questions taken from the Center for Epidemiologic Studies Depression Scale: 'I felt that everything I did was a big effort' or 'I felt that I could not keep on doing things' at least 3–4 days a week; (2) weight loss—unintentional loss of ≥4.5 kg of body weight in the preceding year; (3) low physical activity—walking ≤2.5 h/week in men and ≤2 h/week in women; (4) weakness—the lowest quintile in the study sample of grip strength, measured with a Jamar dynamometer and adjusted for sex and body mass index (BMI), with the highest value in two consecutive measures used in the analyses and (5) slow walking speed—the lowest quintile in the study sample for the 3 m walking speed test, adjusted for sex and height. Frailty was defined as having ≥3 of the above criteria and prefrailty as having 1 or 2 of them.

Disability in IADL: It was assessed with the Lawton and Brody Scale.[27] This scale evaluates the individual's ability to use the telephone, go shopping, prepare meals, do housework, do laundry, use different means of transportation, take medication and manage finances. Owing to cultural issues, the questions on meal preparation, housework and laundry were excluded in men; thus, summary scores ranged from 0 (no disability) to 5 in men, and from 0 to 8 in women.

Other variables

During telephone interviews, information was obtained on age, sex, education, occupation, tobacco and alcohol consumption, physical activity in leisure time, sedentary behaviour (as approximated by the number of hours/day spent watching TV) and physician-diagnosed morbidity (ischaemic heart disease, stroke, heart failure, diabetes, cancer, asthma, chronic bronchitis, osteoarthritis, arthritis or hip fracture).[20] Educational level was classified as the self-reported highest level achieved (primary or less, secondary or university studies). Occupational level 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.[28] Housewives were assigned the occupation of their husband.

At home, study participants reported their medical treatments, which were checked against the drug packages. Weight and height measurements were performed twice, using electronic scales (model Seca 841, precision to 0.1 kg) and portable extendable stadiometers (model Ka We 44 444Seca). Mean values of the two measurements were used for analyses, and BMI was calculated as weight in kilogram divided by square height in metre. Finally, food consumption was assessed with a validated computerised diet history developed from that used in the EPIC cohort study in Spain, and energy intake (kcal/day) was calculated with standard food composition tables.[29] Adherence to the Mediterranean diet was summarised using the Mediterranean Diet Adherence Screener (MEDAS) index, and a higher score (range 0–14) indicates better adherence.[30]

Statistical analysis

From the initial 2519 participants, we excluded 434 individuals with no information on frailty and 73 individuals with missing data on potential confounders, leading to a final analytical sample of 2012 individuals.

The association between housing conditions and the SPPB score was assessed with linear regression, while the association with the rest of the limitations in physical function was evaluated using logistic regression. Housing conditions were classified into three categories: no poor conditions (reference), 1 poor condition, and ≥2 poor conditions, based on whether the individual lived in a walk-up building, in a household with no heating or in a household where he/she felt cold frequently; the

rest of the poor conditions were excluded from the analysis because only 10 individuals reported having at least one of them.

Several regression models were built. Model 1 adjusted for age, sex, tobacco and alcohol consumption, physical activity, sedentary behaviour, energy intake, MEDAS score, BMI, morbidity (cancer, diabetes, cardiovascular disease, osteomuscular disease, respiratory disease) and number of drug treatments. Models 2 and 3 further adjusted for education or occupation, respectively, while model 4 adjusted for both educational and occupational levels.

We tested whether the study association varied with sex, by using interaction terms defined as the product of the housing conditions by sex. Statistical significance was assessed with likelihood ratio tests, which compared models with interaction terms and without.

Analyses were performed using STATA (V.13.0, College Station, Texas, USA: StataCorp LP).

RESULTS

Among the study participants, 986 (49.0%) lived in a walk-up building, 91 (4.5%) lived in a home without heating, and 127 (6.3%) frequently felt cold at home. Table 1 shows the distribution of sociodemographic variables, behavioural factors and medical conditions according to the number of poor housing conditions. Compared with those living in homes with no poor conditions, those with ≥2 poor housing conditions were more likely to be current smokers, heavy drinkers and obese, as well as suffering from diabetes, osteomuscular or cardiovascular disease and taking more medications. Moreover, they more often have a lower educational level and a manual occupation.

Among study participants, the mean (SD) SPPB score was 8.5 (2.3). In total, 824 and 1095 individuals had mobility or agility limitations, 967 were prefrail, 163 were frail and 168 had IADL disability. In comparison to those who lived in homes without poor conditions, those with ≥2 poor housing conditions showed lower scores in the SPPB (β −1.02; 95% CI −1.39 to −0.66) and a higher frequency of agility limitation (OR 1.62; 95% CI 1.00 to 2.61), prefrailty (OR 2.15; 95% CI 1.31 to 3.53) and frailty (OR 8.78; 95% CI 3.00 to 25.60) (model 1). These associations were slightly attenuated after adjustment for educational level (model 2) and turned somewhat stronger after adjustment for occupation (model 3) and after adjustment for education and occupation (model 4) (table 2).

The association between each poor housing condition and the studied outcomes is presented in table 3. In full adjusted analyses (model 4), individuals living in walk-up buildings showed

Table 1 Age-adjusted and sex-adjusted characteristics of study participants, by home services (N=2012)

	Home services*			
	All services N=935	Lacking 1 service N=959	Lacking ≥2 services N=118	p Value
Age, years	72.1 (0.2)	71.7 (0.2)	71.5 (0.6)	0.29
Men, %	50.4	47.3	41.2	0.11
Smoking status, %				
Never smoker	56.7	64.6	66.4	
Ex-smoker	34.6	27.5	23.4	
Current smoker	8.7	7.9	10.2	0.01
Drinking status, %				
Never drinker	20.0	21.9	30.6	
Ex-drinker	6.0	7.0	9.5	
Moderate drinker†	67.8	67.1	52.9	
Heavy drinker	6.2	4.0	7.0	0.02
Physical activity, MET-h/week	53.5 (0.9)	58.6 (0.9)	53.6 (2.6)	<0.01
Watching TV, hours/week,	19.2 (0.3)	19.8 (0.3)	20.2 (1.0)	0.34
Energy intake, kcal/day	2009.4 (13.4)	2005.5 (13.2)	2017.1 (37.2)	0.95
Mediterranean Diet Adherence Screener score	4.4 (0.1)	4.3 (0.1)	4.1 (0.2)	0.10
Body mass index, kg/m^2, %				
<25	24.5	18.5	19.1	
25–29.9	46.8	45.5	41.7	
≥30	28.7	36.0	39.2	<0.01
Cancer, %	2.5	3.8	1.6	0.17
Diabetes, %	15.6	18.9	23.6	0.04
Cardiovascular disease, %	5.7	5.2	11.3	0.03
Osteomuscular disease, %	44.2	52.0	62.5	<0.01
Chronic respiratory disease, %	8.3	10.4	7.2	0.22
Number of drug treatments	3.7 (0.1)	4.0 (0.1)	5.1 (0.3)	<0.01
Educational level, %				
Primary or less	43.2	62.9	64.0	
Secondary	28.5	21.1	22.9	
University	28.3	16.0	13.1	<0.01
Occupational level, manual, %	24.1	40.7	34.8	<0.01

For continuous variables, the mean (SD) is provided.
*Poor conditions: apartment building without an elevator, no heating at home, or the individual feels cold frequently.
†The alcohol intake threshold between moderate and heavy drinking is 40 g/day in men and 24 g/day in women.
MET, metabolic equivalents.

Table 2 Association between housing conditions and limitations in physical function in older adults

				Frailty		
	Short Physical Performance Battery β (95% CI)	**Mobility limitations** OR (95% CI)	**Agility limitations** OR (95% CI)	**Prefrail (vs robust)** OR (95% CI)	**Frail (vs robust)** OR (95% CI)	**IADL disability** OR (95% CI)
Model 1						
No poor conditions	–	1.00	1.00	1.00	1.00	1.00
1 Poor condition	0.03 (−0.19 to 0.19)	0.94 (0.76 to 1.16)	0.95 (0.77 to 1.17)	1.00 (0.81 to 1.23)	1.35 (0.76 to 2.38)	1.55 (1.04 to 2.31)
≥2 Poor conditions	**−1.06 (−1.46 to −0.65)**	1.08 (0.68 to 1.73)	**1.62 (1.00 to 2.61)**	**2.15 (1.31 to 3.53)**	**8.78 (3.00 to 25.6)**	1.09 (0.50 to 2.39)
p-Trend	**<0.01**	0.84	0.41	0.08	**<0.01**	0.15
Model 2 (adjusted as model 1 plus education)						
No poor conditions	–	1.00	1.00	1.00	1.00	1.00
1 Poor condition	0.04 (−0.15 to 0.23)	0.90 (0.72 to 1.12)	0.93 (0.75 to 1.14)	0.99 (0.81 to 1.22)	1.24 (0.70 to 2.21)	1.52 (1.01 to 2.27)
≥2 Poor conditions	**−1.02 (−1.42 to −0.61)**	1.04 (0.65 to 1.67)	1.57 (0.97 to 2.53)	**2.12 (1.28 to 3.45)**	**8.22 (2.75 to 24.56)**	1.07 (0.49 to 2.35)
p-Trend	**<0.01**	0.61	0.56	0.10	**<0.01**	0.19
Model 3 (adjusted as model 1 plus occupation)						
No poor conditions	–	1.00	1.00	1.00	1.00	1.00
1 Poor condition	−0.00 (−0.21 to 0.19)	0.93 (0.74 to 1.17)	0.95 (0.76 to 1.18)	0.98 (0.79 to 1.22)	1.30 (0.68 to 2.48)	1.27 (0.82 to 1.96)
≥2 Poor conditions	**−1.24 (−1.66 to −0.84)**	1.09 (0.68 to 1.76)	**1.64 (1.01 to 2.67)**	**2.37 (1.43 to 3.94)**	**15.81 (4.72 to 53.04)**	1.12 (0.50 to 2.51)
p-Trend	**<0.01**	0.86	0.38	0.06	**<0.01**	0.43
Model 4 (adjusted as model 1 plus education and occupation)						
No poor conditions	–	1.00	1.00	1.00	1.00	1.00
1 Poor condition	0.02 (−0.18 to 0.22)	0.91 (0.72 to 1.14)	0.93 (0.74 to 1.16)	0.99 (0.79 to 1.23)	1.26 (0.66 to 2.41)	1.29 (0.83 to 2.00)
≥2 Poor conditions	**−1.21 (−1.63 to −0.81)**	1.07 (0.66 to 1.72)	**1.61 (0.99 to 2.63)**	**2.35 (1.41 to 3.90)**	**15.21 (4.51 to 51.36)**	1.15 (0.51 to 2.57)
p-Trend	**<0.01**	0.71	0.47	0.06	**<0.01**	0.39

Poor conditions: apartment building without an elevator, no heating at home, or the individual feels cold frequently.
Model 1 is adjusted for age, sex, tobacco (never-smoker, ex-smoker, current smoker) alcohol consumption (never-drinker, ex-drinker, moderate-drinker, heavy-drinker), physical activity (MET-h/week), watching TV (hours/week), total energy intake (kcal/day), MEDAS score, body mass index (<25, 25–29.9, ≥30 kg/m^2), cancer, diabetes, cardiovascular disease, osteomuscular disease, chronic respiratory disease and number of drug treatments.
Statistically significant results are presented in bold.
IADL, instrumental activities of daily living.

Table 3 Association between each type of poor housing condition and limitations in physical function in older adults

	Short Physical Performance Battery	Mobility limitations	Agility limitations	Frailty		IADL disability
	β (95% CI)	OR (95% CI)	OR (95% CI)	Prefrail (vs robust) OR (95% CI)	Frail (vs robust) OR (95% CI)	OR (95% CI)
No elevator	−0.02 (−0.22 to 0.18)	0.90 (0.72 to 1.13)	0.97 (0.78 to 1.21)	1.03 (0.83 to 1.28)	**1.90 (1.03 to 3.53)**	1.33 (0.87 to 2.03)
No heating	**−1.83 (−2.27 to −1.39)**	1.01 (0.60 to 1.71)	1.23 (0.73 to 2.08)	**2.68 (1.53 to 4.71)**	**6.40 (1.74 to 23.51)**	0.81 (0.34 to 1.91)
Frequently feeling cold	−0.25 (−0.64 to 0.14)	1.14 (0.73 to 1.79)	1.35 (0.87 to 2.11)	1.31 (0.84 to −2.05)	1.79 (0.58 to 5.52)	1.08 (0.51 to 2.30)

Models are adjusted as in model 4, table 2.
Statistically significant results are presented in bold.
IADL, instrumental activities of daily living.

an increased frequency of frailty (OR 1.90; 95% CI 1.03 to 3.53) and a non-significant increased frequency of IADL disability (OR 1.33; 95% CI 0.87 to 2.03), while those who lacked heating at home had a lower score in the SPPB (β −1.61; 95% CI −2.00 to −1.21) and a higher frequency of prefrailty (OR 2.68; 95% CI 1.53 to 4.71) and frailty (OR 6.40; 95% CI 1.74 to 23.51). Additionally, a non-statistically significantly increased prevalence of agility limitations (OR 1.35; 95% CI 0.87 to 2.11) was observed among individuals who felt frequently cold.

Table 4 shows the results for the association between housing conditions and each component of the SPPB and each frailty criterion. When compared with participants who lived in homes without poor conditions, those with a greater number of poor conditions showed lower scores in the walking speed and sit-to-stand tests, as well as greater frequency of all frailty criteria (p for trend <0.01). When housing conditions were considered separately, similar results were observed for living in a home without heating, which showed a strong negative association with all SPPB tests and frailty criteria (except weight loss). Feeling frequently cold was also linked to a lower score in the sit-to-stand test and with a higher prevalence of exhaustion.

In sensitivity analyses, effect modification by sex was observed for the association between housing conditions and the SPPB score and frailty. Although both men and women with ≥2 poor housing conditions showed a lower SPPB score and increased frequency of frailty than their counterparts, these associations were stronger among women (see online supplementary table S1).

DISCUSSION

Our results show that housing conditions are strongly linked with physical function in older adults, independently of the educational or occupational level. Living in a walk-up building was associated with a higher prevalence of frailty, while lacking heating was the specific condition associated with lower scores in the SPPB and each of their three components, as well as with increased frequency of prefrailty, frailty and four of its components (exhaustion, slow walking speed, low physical activity and weakness). Finally, feeling frequently cold at home was associated with the prevalence of exhaustion.

The absence of an elevator in apartment buildings may prevent some older adults from going outside their homes, and has been previously associated with higher mortality among patients with heart failure.[14] Confinement of older adults in their homes is associated with feelings of loneliness,[31] and depression,[32] which in turn can increase their risk of frailty.[33 34] Additionally, older adults confined to their homes are more likely to be physically inactive, increasing their probability of developing chronic conditions such as cardiovascular disease or diabetes, which are known risk factors of frailty.[22] Finally, having difficulties going outside the home may act as a barrier for accessing adequate nutrition in older adults who live alone, and poor diet is also known to be an important determinant of frailty.[35]

With advancing age, the efficiency of adaptive mechanisms to regulate temperature declines, and thus environmental comfort in older adults requires higher ambient temperatures than in their younger counterparts. Perception of home as cold in the elderly has been found associated with poor sleep quality[36] and poor self-reported health,[37] while fuel poverty has been linked to increased winter respiratory morbidity[38] and excess winter mortality.[39] However, the effects of cold on physical function are uncertain. In a recent study, 88 community-dwelling women were exposed in random order to moderate cold (15°C) or warm (25°C) temperature in climate chambers with an interval of 1 week.[40] In line with our findings, investigators reported that physical performance was lower in 15°C compared with 25°C room temperature for leg extensor power, sit-to-stand performance velocity, gait speed and maximal quadriceps strength. However, in contrast to our results, the authors did not find any association between exposure to cold and reduced hand grip strength. Future studies should investigate the physiological mechanisms that explain why cold environments may affect the ability of older adults to maintain their normal physical function.

Associations were more marked for the lack of heating at home than for feeling frequently cold. This might be due to the fact that lacking any heating system at home represents a more serious deprivation than merely feeling cold; also, a heating system is usually a prerequisite for a warmth home, at least during several months each year, in many regions of Spain, including those in the South and East. For instance, the average minimum temperature during the winter months (December through February) in Seville, a typically southern city in Spain, is only 6.7°C. The corresponding figure for Alicante, a large city in the Mediterranean shore, is 7.7°C.[41] Moreover, there is some evidence that the effect of low temperatures on health is greater in the warmer than in the colder regions of Europe, because in the former the homes are less prepared for the cold and warm clothing is not frequently worn.[41 42]

In our study, we did not find any association between housing conditions and mobility limitation or IADL disability. One

Table 4 Association between housing conditions and each component of the Short Physical Performance Battery and each criterion of frailty in older adults

	Short Physical Performance Battery			Frailty				
	Standing balance β (95% CI)	**Walking speed β (95% CI)**	**Sit-to-stand performance β (95% CI)**	**Weight loss OR (95% CI)**	**Exhaustion OR (95% CI)**	**Slow walking speed OR (95% CI)**	**Low physical activity OR (95% CI)**	**Weakness OR (95% CI)**
Housing conditions								
No poor conditions	–	–	–	1.00	1.00	1.00	1.00	1.00
1 Poor	−0.02 (−0.09 to 0.05)	0.03 (−0.08 to 0.14)	0.02 (−0.07 to 0.10)	1.28 (0.86 to 1.89)	1.19 (0.86 to 1.65)	1.10 (0.79 to 1.53)	**2.02 (1.49 to 2.74)**	0.88 (0.69 to 1.11)
≥2 Poor conditions	−0.30 (−0.45 to −0.15)	**−0.39 (−0.62 to −0.17)**	**−0.48 (−0.65 to −0.31)**	1.63 (0.85 to 3.10)	**2.44 (1.44 to 4.15)**	**3.02 (1.78 to 5.10)**	**4.48 (2.71 to 7.42)**	1.46 (0.92 to 2.32)
p-Trend	**<0.01**	0.08	**<0.01**	0.10	**<0.01**	**<0.01**	**<0.01**	0.75
No elevator	−0.01 (−0.09 to 0.07)	0.02 (−0.08 to 0.13)	−0.03 (−0.10 to 0.04)	1.37 (0.94 to 1.99)	1.23 (0.91 to 1.67)	1.31 (0.96 to 1.80)	2.42 (1.81 to 3.25)	0.94 (0.75 to 1.19)
No heating	**−0.74 (−0.92 to −0.56)**	**−0.63 (−0.88 to −0.39)**	**−0.32 (−0.48 to −0.16)**	1.32 (0.65 to 2.66)	**1.81 (1.02 to 3.22)**	**3.39 (2.01 to 5.69)**	**2.39 (1.41 to 4.07)**	**1.77 (1.07 to 2.93)**
Frequently feeling cold	−0.04 (−0.20 to 0.12)	−0.08 (−0.29 to 0.14)	**−0.16 (−0.30 to −0.03)**	1.24 (0.66 to 2.33)	**1.86 (1.12 to 3.09)**	0.92 (0.50 to 1.71)	1.09 (0.64 to 1.86)	1.00 (0.64 to 1.56)

Poor conditions: lacking an elevator, lacking heating, or the individual feels cold frequently.
Models are adjusted as in model 4, table 2.
Statistically significant results are presented in bold.

possible explanation for this finding could be that older adults with more severe physical limitations may have been institutionalised and hence were not included in the study.

Associations were stronger among women, a gender difference that was to some extent expected, considering that women tend to spend more time at home than men.[43] Also, adjustment for educational and occupational levels did not reduce the magnitude of the results, indicating that current housing conditions may have an influence on physical function beyond that expected simply from SES attained over the lifetime. Interestingly, though, adjustment for social class based on occupation resulted in a substantial increase in the OR estimate for frailty; this is probably explained by higher levels of physical activity, which protect from frailty.[35]

Our study has several strengths. First, we used validated measures of physical function in older adults. Second, physical performance tests were conducted by trained staff under standardised conditions. Third, the analyses were adjusted for a large number of potential confounders, minimising the probability of residual confounding. As regard the study limitations, our results cannot be extrapolated to older populations living in countries with major differences in climate or in urban planning (ie, 'horizontal cities', where most people live in individual houses rather than in flats or apartment buildings), as well as to institutionalised populations. Perhaps the most important limitation is the cross-sectional study design, which does not allow for causal inference. However, this design has not prevented us from observing important inequalities, so that older adults with greater health needs (worse physical functioning) lived in homes with worse conditions than their counterparts with better health. Of note is that among study participants with frailty, 64% lived in a building without an elevator, 11% lacked heating at home and 9% frequently felt cold; as a result, 14.1% of individuals with frailty had ≥2 poor housing conditions. Also noteworthy is that those who more frequently had unhealthy lifestyles and serious diseases lived in homes with worse conditions.

In conclusion, poor housing conditions, particularly lack of an elevator and lack of heating, are strongly associated with limitations in physical function in older adults. This included functions that were objectively measured (eg, lower extremity performance), self-reported (eg, agility) and both measured and self-reported (eg, frailty). These results show serious inequalities in functional status in older adults, which should be addressed. Given the rapid population ageing and the high cost of institutional care, maintaining older adults in their homes is a matter of promoting personal autonomy and social justice, as well as an issue of sustainable healthcare. Public health departments should foster healthy ageing by improving existing housing and developing new and more suitable forms of housing for older adults. These strategies must include installation of elevators in apartment buildings, efficient energy use and proper insulation at home.

What is already known on this subject

- Housing conditions are an important social determinant of health.
- Poor housing conditions in the elderly are associated with a higher risk of falls, worse respiratory and mental health, and a higher risk of disease-specific and all-cause mortality.

What this study adds

- First study to systematically assess the association between housing conditions and physical function limitations in older adults.
- Results show that poor housing conditions, particularly lack of an elevator and lack of heating, are strongly associated with limitations in physical function in older adults.
- Results reveal serious inequalities in functional status in older adults.

Contributors EG-E, FR-A and JLA-M conceptualised the study. PG-C, JRB and FR-A acquired the data. EG-E and BP-H conducted statistical analyses. EG-E, BP-H and FR-A interpreted the results and drafted the initial manuscript. All the authors reviewed the manuscript for important intellectual content and approved the final version as submitted. EG-E and FR-A take responsibility for the integrity of the work.

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