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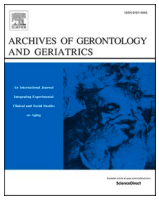

Association of neighborhood physical environment with falls and fear of falling in older adults: A prospective cohort study

Lucía Arias-Fernández [a], Lucía Carcedo-Argüelles [a], Esther García-Esquinas [b,c], Francisco Félix Caballero [c], Fernando Rodríguez-Artalejo [c,d], Alberto Lana [a,c,*]

[a] Department of Medicine, Universidad de Oviedo/ISPA, Oviedo, Spain
[b] National Center of Epidemiology, Instituto de Salud Carlos III, Madrid, Spain
[c] Department of Preventive Medicine and Public Health, School of Medicine, Universidad Autónoma de Madrid, and CIBERESP (CIBER of Epidemiology and Public Health), Madrid, Spain
[d] IMDEA-Food Institute, CEI UAM+CSIC, Madrid, Spain

HIGHLIGHTS

- Better neighborhood physical features were associated with lower risk of falls.
- Fear of falling was also lower in walkable and physically active environments.
- Policies to improve the built environment can contribute to healthy aging.

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ABSTRACT

Objectives: To explore the prospective association between physical environment characteristics of the neighborhood and risk of falls/fear of falling among community-dwelling older adults.
Study Design: Prospective cohort analysis using data from the Seniors-ENRICA-2 cohort (metropolitan Madrid, Spain).
Methods: At baseline (2015–17), a neighborhood physical characteristics score was developed using the Physical Activity Neighborhood Environment Scale and an additional indicator of distance to green areas. In the second wave of follow-up (2019–20) we collected self-reported incident falls and fear of falling, assessed with the Short Falls Efficacy Scale International. Adjusted odds ratios (OR) and 95 % confidence intervals (CI) for the association between neighborhood environment perception and incidence of falls/fear of falling were calculated using logistic regression.
Results: Among 1823 participants, 27.7 % reported a fall during the previous year and 32.1 % were concerned about having a fall. Better neighborhood environment was associated with lower risk of falls (OR: 0.75; 95 %CI: 0.57–0.99) and fear of falling (0.73; 0.55–0.96). Specifically, low traffic intensity (0.68; 0.52–0.90) and sidewalks in good condition (0.75; 0.59–0.95) were associated with lower risk of falling. Moreover, available facilities for biking (0.77; 0.61–0.96), sidewalks in good condition (0.67; 0.52–0.86), night security (0.80; 0.60–0.99) and day security (0.62; 0.44–0.98) were independently associated with lower fear of falling.
Conclusions: Better neighborhood physical environments could play a key role in the prevention of falls and fear of falling among older adults. Policies aiming to improve residential environments can have broad implications for achieving healthy aging.

* Corresponding author at: Department of Medicine, School of Medicine and Health Sciences, University of Oviedo and Health Research Institute of Asturias, C/ Julián Clavería; s/n, 33006, Spain.
E-mail address: lanaalberto@uniovi.es (A. Lana).

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1. Introduction

Falls in older adults are common, disabling, but also preventable. (Montero-Odasso et al., 2022; Colón-Emeric et al., 2024) More than 25 % of community-dwelling adults aged ≥65 years experience at least one fall per year (Coulter et al., 2024; Kakara et al., 2023) and many of these falls result in injury. Consequently, falls are the leading cause of fatal and non-fatal injuries among older adults. (Centers for Disease Control & Prevention, National Center for Injury Prevention & Control, 2024) Although many older people make a full physical recovery, they often do not return to their previous state due to a loss of confidence and an increased sense of vulnerability.

Fear of falling (FoF) is recognized as a specific health problem in aging. (Tinetti & Powell, 1993) From a clinical perspective, FoF is defined as a persistent concern about falling, stemming from a sense of unpredictability and personal vulnerability, which is significant enough to interfere with participation in activities of daily living. (Tinetti & Powell, 1993; Lee & Tak, 2023) Consequently, FoF contributes to activity limitation as a strategy to reduce the perceived risk of falling, (Denkinger et al., 2015) leading to a vicious cycle of loss of independence and functional capacity. (Immonen et al., 2020) The prevalence of FoF is estimated to be between 20 and 40 % in the general population, increasing to 40–70 % in those with a history of falls. (Baltes et al., 2023; MacKay et al., 2021)

Preventing falls and FoF is considered a critical challenge for healthy aging. (Seppala & van der Velde, 2022; Eckstrom et al., 2024; Close & Lord, 2022) Regular physical activity is the main recommendation for older adults to reduce the risk of falls. (Colón-Emeric et al., 2024; Coulter et al., 2024; Moncada & Mire, 2017; Grossman & Curry, 2018) This recommendation often focuses on encouraging walking. Paradoxically, about half of falls in community-dwelling older adults occur while walking. (Li et al., 2006) It is well known that some features of the built environment encourage older adults to engage in regular leisure-time physical activity, such as traffic safety, accessibility of destinations, presence of green space, and density. (You et al., 2023) However, it is important to know whether promoting walkable and physically active neighborhoods is also a safe public health strategy in terms of fall risk. Some previous studies have suggested that public health interventions focused on modifying the neighborhood attributes related to recreational physical activity have the potential to reduce falls and FoF effectively. For instance, Li et al. (Li et al., 2006) found that outdoor falls were associated with the presence of uneven sidewalks and road surfaces. Nicklett et al. (Nicklett et al., 2017) observed that the risk of falling was higher in areas with street litter and nighttime insecurity. Conversely, the proximity of public transportation stops and the presence of safe walking environments are associated with a lower risk of FoF. (Canever et al., 2021)

The perception of the physical characteristics of the neighborhood and their impact on falls/FoF may vary across different environments. (Avendano et al., 2009; Ogliari et al., 2022) Analyzing how the neighborhood physical environment impacts the risk of falls/FoF in different contexts will provide a comprehensive list of elements that should be controlled, allowing public health decision-makers to tailor interventions. The aim of our study was to assess the prospective association between the perception of physical characteristics of the neighborhood and the risk of falls/FoF among community-dwelling older adults in the metropolitan area of Madrid (Spain).

2. Methods

2.1. Study design and participants

We conducted a prospective analysis using data from the Seniors-ENRICA II cohort, which includes non-institutionalized older adults living in metropolitan Madrid (Spain), including five densely populated areas: central Madrid (5264 inhabitants/km2), Alcorcón (5008 inhabitants/km2), Torrejón de Ardoz (3948 inhabitants/km2), Getafe (2268 inhabitants/km2), and Alcalá de Henares (2205 inhabitants/km2). The Seniors-ENRICA II cohort was established in 2015–17, recruiting 3273 people aged 65 years and older.

Data collection instruments and procedures were similar to those used in the Seniors-ENRICA I cohort. (Rodríguez-Artalejo et al., 2011; Arias-Fernández et al., 2024) Information on sociodemographic characteristics, residential characteristics, health behaviors, and health status was collected through telephone interview conducted by trained personnel. Subsequently, two consecutive home visits were performed to obtain biological samples, physical examinations, and a complete dietary history. Participants were re-interviewed in 2019–2020. The Madrid Health Service, a public health system providing universal assistance, granted permission to access the electronic medical record information. The quality of the primary care medical record was previously validated for research purposes. (de Burgos-Lunar et al., 2011)

The protocol of the Seniors-ENRICA II cohort was approved by the Clinical Research Ethics Committee of the *La Paz* University Hospital in Madrid.

2.2. Study variables

2.2.1. Neighborhood perception

Baseline perception of the neighborhood physical environment was assessed using 13 items of the Physical Activity Neighborhood Environment Scale (PANES) which best fit the characteristics of metropolitan neighborhoods in Spain. (Sallis et al., 2010) PANES items assess neighborhood environmental characteristics related to recreational physical activity. Specifically, we considered the presence of the following items: (1) single-family homes (as opposed to apartment buildings); (2) nearby shopping (i.e., within walking distance); (3) nearby transit stops (i.e., less than a 10–15 min walk); (4) sidewalks on most neighborhood streets; (5) cycling facilities (i.e. special lanes, separate paths, etc.); (6) free or low cost recreation facilities (i.e. parks, gyms, etc.); (7) nighttime safety for walking; (8) low traffic; (9) physically active people in the neighborhood; (10) interesting things to look at while walking; (11) well maintained sidewalks (i.e. paved, with few cracks) and no obstacles for walking; (12) daytime safety for walking; (13) many places to walk within easy walking distance of home. Additionally, another item available from the dataset was incorporated, related to the distance to a green area where one could walk and rest (>1000 meters, 251–1000 meters, 50–250 meters, ≤50 meters). PANES assesses each item on a 4-point Likert scale ranging from "1: Totally disagree" to "4: Totally agree", so the perception of the neighborhood environment was summarized in an overall score ranging from 14 to 56 points, with higher scores indicating a better environment.

2.2.2. Falls and FoF

During the 2019–20 home visit, participants were asked, "How many times have you fallen in the past year?" If a fall occurred, participants were asked whether the fall required health care (i.e., emergency room visit, or hospital admission). Based on their responses, participants were then categorized into three groups: "no falls", "falls not requiring medical attention", and "falls requiring medical attention".

FoF was assessed using the Short Falls Efficacy Scale International (FES-I). (Kempen et al., 2008) Participants were asked about their level of concern about falling (from "1: not at all concerned" to "4: very concerned") while performing seven daily activities: (1) dressing and undressing, (2) taking a bath or shower, (3) sitting down and getting up from a chair, (4) going up and down stairs, (5) reaching for something on the floor or at a height, (6) going up and down a ramp, (7) attending a social event. The sum of the item scores resulted in a total score ranging from 7 to 28 points, with higher scores indicating a higher level of worry. Participants were then categorized into "low worry" (≤8 points) and "moderate/high worry" (>8 points) using predetermined cut-off points. (Delbaere et al., 2010)

2.2.3. Confounders

Information on several potential confounders was also collected. We obtained sex, age, level of education (primary, secondary, university), and income level (high, medium, low), estimated by the difficulties reported by people to make ends meet (very difficult, moderately difficult, no difficulty). We also gathered data on two important falls and FoF-related health behaviors: leisure-time physical activity (METs-h/week), assessed by the International Physical Activity Questionnaire, and alcohol consumption (g/day), measured by validated diet history. (Guallar-Castillón et al., 2014) Finally, we assessed health status of the participants through: (1) BMI (kg/m^2) calculated as measured weight divided by height squared; (2) self-reported nocturnal urinary incontinence and regular use of sleep medication; (3) physical performance as per the Short Physical Performance Battery (SPPB), a set of three tests including balance, leg strength, and walking speed; and (4) diagnosed morbidity from the primary care medical records of the National Health System. Since Spain has a universal public health system, all study participants had a standardized and updated primary care registry. Specifically, information was collected on medical diagnoses of Parkinson's disease, dementia, hypertension, diabetes, coronary heart disease, stroke, congestive heart failure, and chronic obstructive pulmonary disease (COPD).

2.3. Statistical analysis

Of the initial sample of 3273 individuals, 1333 were lost to follow-up, and 46 died during follow-up. In addition, participants without data on perception of the residential environment ($n = 29$) and on potential confounders ($n = 42$) were excluded. Thus, analyses were conducted using a complete dataset from 1823 individuals. **Supplementary Table 1** shows the baseline characteristics of both participants retained at follow-up (analytic sample) and participants lost to follow-up. Overall, participants lost to follow-up were older, of lower socioeconomic status, less physically active, and had more morbidity. T-test and chi-squared test were used to compare the characteristics of participants and non-participants.

Odds ratios (ORs) and their 95 % confidence intervals (CIs) were estimated for the association between baseline perception of neighborhood environment, modeled in tertiles (T1=worse; T2: intermediate; T: better), and incident falls/FoF in 2019–20 using multivariate logistic regression models. Multinomial models were also used to summarize the association between neighborhood perception and categories of fall consequences (no fall/falls not requiring healthcare/falls requiring healthcare). In all models, the first tertile (worst perception) score of the neighborhood characteristics and the "no falls" category were used as the reference. Three sequentially adjusted regression models were constructed. The first model was adjusted for sex, age, educational level, income level, leisure-time physical activity, alcohol consumption and BMI. The second model further adjusted for nocturnal urinary incontinence, use of sleeping medication, morbidity (including Parkinson's disease, dementia, hypertension, diabetes, coronary disease, cerebrovascular disease, heart failure, and COPD) and physical function. Finally, given that history of falls is a major predictor of incident falls and FoF, a third model was additionally adjusted for fall experience at baseline.

To better understand the role of baseline multimorbidity (i.e., two or more chronic diseases), physical performance, and physical activity, which are strong intrinsic determinants of falls and FoF in older adults, we conducted stratified analyses by such variables.

Finally, the separate effect of each of the PANES items on falls/FoF was examined using a fully-adjusted logistic regression model. For this purpose, the categories of each of the 4-point Likert scales were merged into two (disagree and agree). Similarly, the distance to green spaces was also dichotomized (>250 meters and ≤250 meters).

P-values <0.05 were considered statistically significant. Analyses were performed with Stata version 18.0 (Stata Corp, College Station, TX).

3. Results

Among study participants, 27.7 % a fall in the past year, and 67.9 % had a moderate/high level of FoF. Table 1 shows the baseline characteristics of the study sample according to the occurrence of falls/FoF. Compared with participants who did not experience falls/FoF, those who fell or had FoF were more likely to be female, older, and to have a lower income and a primary school education. They also reported lower alcohol consumption and higher intake of sleep medication. In terms of morbidity, subjects who suffered a fall/FoF had a higher prevalence of dementia, hypertension, cerebrovascular disease and lower physical function. Finally, the percentage of participants reporting history of falls was higher among those who fell or had FoF.

During follow-up, the risk of falls/FoF was lower in participants with a better baseline perception of neighborhood (Table 2). After adjustment for sociodemographic and lifestyle variables, morbidity, and history of falls, an association was found between better perception of neighborhood characteristics (tertile 3) and lower risk of falls (OR: 0.75; 95 %CI: 0.57–0.99; p-trend: 0.042) and FoF (OR: 0.73; 95 %CI: (0.55–0.96); p-trend: 0.027). In stratified analyses (**Supplementary Table 2**), a better perception of neighborhood was associated with a lower risk of falling among subjects without multimorbidity (OR: 0. 67; 95 %CI: 0.48–0.93; p-trend: 0.016), with good physical performance (OR: 0.64; 95 %CI: 0.51–0.99; p-trend: 0.049) and who did more physical activity (OR: 0.70; 95 %CI: 0.45–1.04; p-trend: 0.070). A better perception of neighborhood characteristics was also associated with a lower risk of FoF in those who without multimorbidity (OR: 0.68; 95 %CI: 0.48–0.96; p-trend: 0.032). However, a lower risk of FoF was observed among individuals with good neighborhood perception and poor physical performance (OR: 0.64; 95 %CI: 0.44–0.91; p-trend: 0.016), and low physical activity (OR: 0.55; 95 %CI: 0.37–0.81; p-trend: 0.003).

Finally, Table 3 shows the results for the separate association of each of the neighborhood perception items with the risk of falls/FoF. In the fully adjusted models, low traffic (OR: 0.68; 95 %CI: 0.52–0.90) and good sidewalk conditions (OR: 0.75; 95 %CI: 0.59–0.95) were associated with a lower risk of falls. Cycling facilities (OR: 0.77; 95 %CI: 0.61–0.96), good sidewalk conditions (OR: 0.67; 95 %CI: 0.52–0.86), nighttime safety (OR: 0.81; 95 %CI: 0.60–0.99) and daytime safety (OR: 0.62; 95 %CI: 0.44–0.98) were associated with a lower risk of FoF.

4. Discussion

Our prospective study of community-dwelling older adults found an association between a better perception of the neighborhood's physical characteristics and a lower risk of falls/FoF, particularly for well-maintained sidewalks, low traffic, and daytime and nighttime safety.

Our findings provide further evidence to support the existing scientific literature. The National Health and Aging Trends Study (NHATS) found that people who fell were more likely to live in areas with a higher proportion of architectural barriers and poor sidewalk conditions. (Lee et al., 2019) Similarly, de Souza Moreira et al. (de Souza Moreira et al., 2022) found that improving walkability in a large Brazilian urban area would reduce falls by 19 %. In our analysis, good sidewalk condition was a strong protective factor against falls, suggesting that poor sidewalks act as a risk factor. Obviously, uneven, slippery or broken tile surfaces increase the risk of tripping and force people to make avoidance maneuvers while walking (e.g., long steps, sudden changes of direction etc.), which increases the risk of falling. Moreover, in our study, low traffic density was associated with a lower falls risk. Areas with high traffic density are more sensory demanding and force older people to make quicker decisions and act more hastily, leading to a greater propensity to fall. Previous studies have also identified other protective factors for falls that appear to be less relevant in Spain. According to Nicklett et al. (Nicklett et al., 2017), street cleanliness, lighting and night

Table 1
Baseline (2015–17) characteristics of study participants according to presence of falls and fear of falling in 2019–20 ($n = 1823$).

	Total participants	Falls			Fear of falling		
		No	Yes		No	Yes	
Participants, n (%)	1823	1319 (72.4)	504 (27.7)		585 (32.1)	1238 (67.9)	
Women, n (%)	928 (50.9)	578 (43.8)	350 (69.4)	***	501 (40.5)	427 (73.0)	***
Age, y (SD)	71.4 (4.20)	71.1 (4.14)	72.2 (4.27)	***	70.9 (3.94)	585 (72.5)	***
Primary education or less, n (%)	1090 (59.8)	787 (59.7)	303 (60.1)		692 (55.9)	398 (68.0)	***
Low income level, n (%)	240 (13.2)	149 (11.3)	91 (18.1)	***	123 (9.94)	117 (20.0	***
Physical activity, METs-h/w (SD)	67.7 (36.7)	68.2 (37.2)	66.4 (1.58)		68.1 (36.5)	66.9 (37.0)	
Alcohol intake, g/d (SD)	9.32 (13.7)	10.1 (14.4)	7.30 (11.4)	***	10.7 (14.5)	6.40 (11.1)	***
BMI, kg/m^2 (SD)	27.8 (4.41)	27.7 (4.32)	28.1 (4.63)		27.4 (4.00)	28.6 (5.15)	
Urinary incontinence, n (%)	340 (18.7)	342 (25.9)	109 (21.6)		904 (73.0)	468 (80.0)	***
Sleeping medication, n (%)	309 (17.0)	189 (14.3)	120 (23.8)	***	147 (11.9)	162 (27.7)	***
Morbidity, n (%)							
Parkinson	23 (1.26)	15 (1.14)	8 (1.59)		12 (0.97)	11 (1.88)	
Dementia	20 (1.10)	10 (0.76)	10 (1.98)	*	5 (0.40)	15 (2.56)	***
Hypertension	1099(60.3)	770 (58.4)	329 (65.3)	**	708 (57.2)	391 (66.8)	***
Diabetes	331 (18.2)	245 (18.6)	86 (17.1)		193 (15.6)	138 (23.6)	***
Coronary disease	167 (9.16)	125 (9.50)	42 (8.33)		116 (9.37)	51 (8.72)	
Stroke	135 (7.41)	86 (6.52)	49 (9.72)	**	82 (6.62)	53 (9.06)	
Heart failure	44 (2.41)	30 (2.27)	14 (2.78)		17 (1.37)	27 (4.62)	***
COPD	124 (6.80)	88 (6.67)	36 (7.14)		80 (6.46)	44 (7.52)	
Multimorbidity (≥2 diseases), n (%)	491 (26.9)	352 (26.7)	139 (27.6)		288 (23.3)	203 (34.7)	***
SPPB, score (SD)	9.21 (1.92)	9.39 (1.79)	8.73 (2.16)	***	9.53 (1.61)	8.51 (2.30)	***
One or more falls, n (%)	319 (17.5)	152 (11.5)	167 (33.3)	***	147 (11.9)	172 (29.4)	***

MET: metabolic equivalent; BMI: body mass index; COPD: chronic obstructive pulmonary disease; SD: standard deviation; SPPB: short physical performance battery.
* <0.05.
** $p < 0.01$.
*** $p < 0.001$.

security were protective factors of falls in participants of the Health Retirement Study (HRS) cohort. In addition, using data from 14 countries participating in the SHARE cohort (Survey of Health, Ageing and Retirement in Europe), Ogliari et al. found that perception of vandalism and crime was associated with a greater likelihood of falls among women with impaired physical function living in urban areas. (Ogliari et al., 2022)

Although to a lesser extent, the role of the residential environment on FoF (de Souza Moreira et al., 2022) has also been studied previously. Canever et al. (Canever et al., 2021) observed an inverse association between proximity to public transport stops, gyms and safe walking areas and the development of FoF. In contrast, accumulation of litter, presence of open sewers, and high crime rates increased the risk of FoF. In most previous studies, the negative effect of the neighborhood on the development of FoF is closely related to the perception of safety in terms of traffic and crime (Lee et al., 2018; Merom et al., 2015), results that were confirmed in our study.

Mechanisms of the effect of neighborhood characteristics on falls/FoF can be both direct and indirect. First, it is clear that certain architectural characteristics of the neighborhood (e.g., narrow sidewalks, steps, etc.), the maintenance of the pavement, and the coexistence on the sidewalks of pedestrians, exercisers, and vehicles can directly cause trips or slips resulting in a fall/FoF. Second, these and other characteristics, such as high traffic density, dangerous intersections, the absence of benches for resting, as well as high crime rates, can lead to choices that indirectly put older people at higher risk of falls/FoF, such as suddenly changing cadence or direction of walking to avoid an obstacle, rushing to cross a street, increasing walking speed, etc. However, there is a more indirect but equally plausible route such as the influence of physical neighborhood characteristics on major causes of morbidity and mortality. Living in a neighborhood with poorer physical conditions is known to increase the risk of cardiovascular disease, diabetes, cancer, and mental health problems. (Fullin et al., 2023; Bilal & Auchincloss, 2018; Namin et al., 2021; Sui et al., 2022) Consequently, multimorbidity in older people is associated with a higher risk of falls/FoF. (Arias-Fernández et al., 2024) Therefore, living in a neighborhood with poorer physical characteristics could indirectly increase the risk of falls/FoF linked to a high burden of morbidity.

Our stratified analyses provided interesting clues on the association between physical neighborhood characteristics and falls/FoF. The protective effect of a better physical neighborhood on falls was stronger in older adults without multimorbidity, with preserved physical performance and moderate/high physical activity, since these individuals are more exposed to the neighborhood environment. (Arias-Fernández et al., 2023) In contrast, the protective effect of the neighborhood on FoF was more pronounced in people with a greater propensity to stay at home (i.e., poor physical performance and low physical activity). Therefore, improving the physical environment in the neighborhood would be beneficial for all older people in terms of the falls/FoF binomial. Older adults in better physical condition who walk more would reduce their risk of falling, and people in worse physical condition who are more sedentary would reduce their FoF, which could be a first step to preserve physical activity.

From a public health perspective, walking is an equitable and efficient preventive activity for older people, because it is sustainable, accessible, acceptable and has a high overall impact on the physical, mental and social health at a very low cost. Therefore, we should put pressure on decision makers to create acceptable urban spaces. According to our results, the first and most critical step, because it affects falls and FoF together, is for sidewalks to be maintained in good condition. In general, urban design and maintenance should focus on the health needs and safety of the most vulnerable populations. Therefore, another function of public health workers should be to routinely monitor the physical characteristics of the neighborhood, followed by regular communication of deficiencies to stakeholders, including council decision-makers and community leaders.

Our study had some limitations. First, the retention rate was at the limit of recommended follow-up thresholds (60 %), and losses to follow-up in cohort studies are rarely random. In fact, retained participants in our study were younger, had higher socioeconomic status and better baseline health outcomes than those lost to follow-up and with missing information. Therefore, the association may be overestimated, as falls in the analytical sample would be expected to be more related to extrinsic factors, such as the physical environment, rather than intrinsic factors.

Table 2
Association between tertiles of neighborhood perception and risk of falls, consequences of falls and fear of falling in 2019–20 ($n = 1823$).

	Tertile 1 (worse)	Tertile 2 (intermediate)	Tertile 3 (better)	p-trend
Falls				
One or more falls, n (%)	231 (45.8)	145 (28.8)	128 (25.4)	
Model 1	Ref.	0.84 (0.65–1.09)	0.72 (0.55–0.94)	0.013
Model 2	Ref.	0.85 (0.65–1.10)	0.74 (0.56–0.97)	0.026
Model 3	Ref.	0.88 (0.67–1.15)	0.75 (0.57–0.99)	0.042
Consequences of falls				
Falls not requiring healthcare, n (%)	124 (46.6)	76 (28.6)	66 (24.8)	
Model 1	Ref.	0.79 (0.57–1.09)	0.67 (0.48–0.94)	0.018
Model 2	Ref.	0.81 (0.58–1.13)	0.70 (0.49–0.98)	0.033
Model 3	Ref.	0.83 (0.60–1.16)	0.70 (0.50–0.99)	0.042
Falls requiring healthcare, n (%)	107 (45.0)	69 (29.0)	62 (26.1)	
Model 1	Ref.	0.89 (0.63–1.26)	0.78 (0.54–1.11)	0.164
Model 2	Ref.	0.90 (0.64–1.28)	0.80 (0.56–1.14)	0.219
Model 3	Ref.	0.93 (0.66–1.34)	0.82 (0.57–1.19)	0.298
Fear of falling[a]				
Moderate/ high, n (%)	271 (46.3)	168 (28.7)	146 (25.0)	
Model 1	Ref.	0.85 (0.66–1.10)	0.72 (0.55–0.93)	0.013
Model 2	Ref.	0.89 (0.68–1.16)	0.71 (0.54–0.94)	0.017
Model 3	Ref.	0.91 (0.70–1.19)	0.73 (0.55–0.96)	0.027

Values are odds ratios and 95 % confidence intervals. Reference categories: "no falls" and "no fear of falling".
Model 1: Adjusted for sex, age, educational level (primary, secondary, university), income level (high, medium, low), physical activity during leisure time (tertiles of METs-h/wk), alcohol consumption (tertiles of g/d), BMI (tertiles of kg/m^2).
Model 2: Additionally adjusted for nocturnal urinary incontinence, sleeping medication, morbidity (Parkinson's disease, dementia, hypertension, diabetes, coronary disease, cerebrovascular disease, heart failure and chronic pulmonary obstructive disease), and physical function (tertiles of SPPB).
Model 3: Additionally adjusted for having one or more falls at baseline.

Table 3
Association between specific components of neighborhood perception and risk of falls and fear of falling in 2019–20 ($n = 1823$).

	Falls	Fear of falling
Presence of houses nearby	1.08 (0.80–1.46)	1.15 (0.84–1.56)
Presence of shops nearby	1.37 (0.70–2.71)	0.89 (0.46–1.72)
Transit stops nearby	0.98 (0.24–3.98)	0.88 (0.22–3.52)
Presence of sidewalks	0.73 (0.29–1.82)	0.97 (0.37–2.54)
Facilities for cyclists	1.12 (0.90–1.39)	0.77 (0.61–0.96)
Facilities to exercise	0.73 (0.53–1.06)	0.83 (0.57–1.23)
Low traffic	0.68 (0.52–0.90)	1.04 (0.78–1.40)
Physically active neighbourhood	0.82 (0.59–1.17)	1.11 (0.77–1.58)
Interesting neighbourhood	0.87 (0.70–1.09)	0.91 (0.73–1.15)
Good condition of sidewalks	0.75 (0.59–0.95)	0.67 (0.52–0.86)
Night-time safety	1.08 (0.83–1.41)	0.80 (0.60–0.99)
Day security	0.99 (0.67–1.48)	0.62 (0.44–0.98)
Presence of walkable areas	0.87 (0.54–1.43)	0.71 (0.43–1.17)
Distance to green areas	0.79 (0.57–1.10)	1.03 (0.73–1.46)

Values are odds ratios and 95 % confidence intervals. Reference categories: "no falls" and "no fear of falling".
Model was adjusted for sex, age, educational level (primary, secondary, university), income level (high, medium, low), physical activity during leisure time (tertiles of METs-h/wk), alcohol consumption (tertiles of g/d), BMI (tertiles of kg/m2), nocturnal urinary incontinence, sleeping medication, morbidity (Parkinson's disease, dementia, hypertension, diabetes, coronary disease, cerebrovascular disease, heart failure and chronic pulmonary obstructive disease), physical function (tertiles of SPPB) and having one or more falls at baseline.

Second, falls were self-reported retrospectively, rather than using a prospective monthly recording system, which is the ideal method. Therefore, falls may have been underestimated, especially those that did not require medical attention. In addition, we did not know the location where the fall occurred. Third, we lacked information on length of residence, which would be informative to test for a dose-response effect. Fourth, neighborhood characteristics were also self-reported, so those who suffered a fall/FoF might be more aware of the physical characteristics of the neighborhood. It is known that subjects with a history of falls, which is a very important risk factor for subsequent falls, or with FoF tend to have a worse perception of the neighborhood environment and a lower sense of walkability. (Plaut et al., 2021; Merom et al., 2015; Blackwood et al., 2022) Therefore, despite the prospective design, some reverse causality cannot be ruled out.

In conclusion, a better perception of the neighborhood's physical characteristics was associated with lower risk of falls/FoF in non-institutionalized older adults living in the metropolitan area of Madrid (Spain). Poorly maintained sidewalks, high traffic density, and criminal public insecurity, both during the day and at night, were the factors that contributed most to the association. The effect of the environment on the risk of falling was particularly pronounced in people without multimorbidity, with adequate physical function and who were physically active. In the future, community trials should experimentally determine whether introducing improvements in public policies to preserve the urban environment reduces the incidence of falls/FoF.

Statements of ethical approval

The protocol of the Seniors-ENRICA II cohort was approved by the Clinical Research Ethics Committee of the *La Paz* University Hospital in Madrid.

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CRediT authorship contribution statement

Lucía Arias-Fernández: Writing – original draft, Investigation, Formal analysis. **Lucía Carcedo-Argüelles:** Writing – review & editing, Investigation, Conceptualization. **Esther García-Esquinas:** . **Francisco Félix Caballero:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Fernando Rodríguez-Artalejo:** Writing – review & editing, Validation, Resources, Project administration, Methodology, Conceptualization. **Alberto Lana:** Writing – original draft, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.archger.2025.105831.

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