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A participatory virtual audit of the built environment for age-friendliness

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Abstract

Background Geospatial studies that consider the relationships between the built environment and health typically rely on researcher-led 'objective' measurement of geospatial attributes of the built environment. Some studies can fail to find expected associations between environments and health outcomes where the geospatial measures do not reflect the experiences or perceptions of people themselves. We took a participatory approach to work with older adults with a concern for falling to assess the built environment in order that we could understand how their assessments relate to researcher assessments. We also wanted to assess whether specific demographic characteristics explained differences in assessments of the built environment between participants. Age-friendly environments can contribute to healthy active ageing. Falling and a fear of falling can lead to restricted outdoor activity. Therefore, understanding how the built environment contributes to fear of falling is important for age-friendly environments.

Methods The study is a cross-sectional retrospective observational study of the built environment. We worked with older adults in workshop settings to undertake community audits of the built environment in Google Street View. They assessed locations where a fall had occurred. Researchers separately audited the same locations. We used descriptive statistics and ordinal regression cumulative link mixed models to estimate the odds that community members would rank a location one level higher than the researchers.

Results There are significant differences in researcher and community auditor assessments of locations of attractiveness. Site related and individual attributes explain variation in how difficult locations were rated for walking, and for concern about falling. Only individual attributes explained variation in site attractiveness. Locations with more trip hazards and steeper slopes were rated as being more difficult to walk and were associated with greater concern for falling.

Conclusions Attributes of the built environment influence perceptions of difficulty walking and concern or falling at specific locations. Furthermore, there are some differences in how researchers and community auditors assess the same locations, meaning that geospatial studies which rely only on researcher assessments may be prone to bias. Involving older people in geospatial studies that measure age-friendly environments can make measurement more reflective of their experiences.

Keywords Perceptions, Participatory methods, Built environment, Pedestrian falls, Older adults

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Introduction

Creating age-friendly environments is one of four key action areas for the United Nations Decade of Healthy Ageing (2021–2030). There is clear evidence of associations between neighbourhood environments and health and wellbeing, particularly for older adults who may spend a greater proportion of their time in their local neighbourhood [25, 52].

Social and built aspects of the environment are determinants of health [25, 28]. Environments can be both health promoting and harmful to health. There are multiple pathways between neighbourhood environments and health outcomes in later-life [25]. Aspects of the environment such as population density, walkability, access to services, green/blue space, environmental quality, noise, pollution, sense of community or (perceived) safety influence the types of activities people participate in, in their neighbourhoods. Exposure to both positive and negative environments can influence health directly, and through the activities that people participate in. In particular, the environments we are exposed to can influence physical activity and social connection [25] by supporting walking in the neighbourhood environment.

Walking is associated with a range of positive physical and mental wellbeing outcomes and as such is increasingly the focus of "active ageing" agendas. Walking can constitute a greater proportion of people's travel time as they age, and is a reasonably accessible and available form of physical activity for most people. Walking is a preferred mode of habitual physical activity among older adults [2, 47]. Given that older people are more likely to spend more time in their local neighbourhood [25, 53] much of the walking older adults do takes place close to home [3, 11]. Several studies have considered aspects of the built environment that can support walking, including for older adults [70, 72].

However, while the environment can promote healthy behaviours such as walking, walking can also result in harmful exposures [26], including an increased risk of falling making the relationships between the environment and health outcomes complex. Fear of falling can lead to restriction of outdoor physical activity [67].

In their review, Finlay et al. identified falls as a health outcome that can be influenced by various aspects of the built environment [25]. There is an emerging body of research that considers aspects of the built environment associated with falls risk and fear of falling [12–14, 17, 24, 39, 41, 43, 60] More in-depth understanding of the relationship between built environment factors and falling, and concern for falling among older adults would allow for targeted interventions to develop age-friendly environments that support active ageing while reducing risk of falls. Micro-features of the built environment are important in the literature on falls risk [24] and more broadly for walkability for older adults [69] but can be overlooked in walkability measures that focus on availability or accessibility of destinations.

To understand connections between the built environment and health outcomes, including falls, it is necessary to establish a method by which to measure the built environment. Attributes of the built environment can be measured using geospatial data related to physical attributes such as road type, density of intersections, elevation, greenspace cover or availability of different types of destinations. Such data may be administrative datasets or volunteered data such as Open Street Map. Such spatial datasets can be used by researchers to assess the built environment. While such datasets have been used to characterise environments where falls happen [73] and assess walkability [42, 57], they are not detailed enough to capture micro environmental factors associated with pedestrian falls [24]. Another approach, that can collect more detailed data on environmental conditions, such as footpath quality is through researcher-led audits of the environment that can be undertaken on the ground [16, 48], or increasingly, using tools such as Google Street View [6, 8, 61]. Such assessments of the built environment, whether they use secondary datasets or primary data collection (audits) are typically intended to construct an objective measure of the built environment that can be used to explain variation in health behaviours or health outcomes [9, 59]. There are also examples of crowdsourcing and citizen science approaches using Google Street View (or other Street View Imagery) to capture public perceptions of the built environment [10]. These approaches still typically seek to develop an average perception or average score for environmental attributes. However, we argue that understanding how older adult's perceptions of the environment differ from those of researchers, according to individual characteristics should be paid greater attention.

While a large body of research demonstrates associations between such environmental measures and health outcomes, there are also limitations in terms of the ability of such tools to capture the realities of older adults' experiences in the environment. There can be a disconnection between such 'objective' measures of the environment and their predictive ability because they do not always account for how people themselves experience or would assess that environment. Geospatial assessments that seek objectivity are reinforcing or measuring a particular view of the world that may not accurately reflect the lived experiences of people. While geospatial assessments may have been developed based on research understanding the needs of particular groups, assessments undertaken without community input are still open to misrepresentation. The result of using 'expert' driven approaches to the built environment can be that assessments are gendered, ageist, ableist and/or racist [23]. By perpetuating a particular assessment of the environment as objective, and not considering the perspectives of diverse older adults, any interventions or changes to the built environment that occur may not achieve desired health outcomes if they do not address issues that are pertinent to the community. Interventions may also perpetuate existing health inequities if they do not consider the needs of different population groups.

Research demonstrates that subjective, perception or experiential based measures tend to be better predictors of behaviour than objective measures [7]. Participatory GIS (PPGIS) approaches have been used with a variety of population groups, including older and younger people [1, 29, 33, 68]. Such approaches engage members of the public in collecting geographic information and as such offer the potential to reflect the lived experience that may differ from data that seeks objectivity. There is increasing recognition of the need to consider perceptions of accessibility and/or walkability alongside spatial measures that have tended to focus on proximity [18, 19, 36–38, 71]. This is true, especially for groups, such as older adults and others whose needs and experiences have not typically informed approaches to measuring walkability and accessibility. For example, walk speeds of older adults are typically slower than average [4], meaning that approaches such as fifteen minute cities, calculated based on an average walk speed are likely to over-estimate the access of older adults [20, 50]. Furthermore, as already noted such macro level assessments of walkability do not capture the micro-environment that are important to older people when considering the supportiveness of neighbourhoods for walking.

While recognising the importance of research which attempts to objectively measure the built environment, we also note the limitations in the pursuit of objective measurement, and the views that it excludes. Consequently, our approach sought to involve older adults in the research process and to engage them in collecting spatial data using Google Earth. We worked with older adults with experience of or concern for falling to assess different locations, and to examine differences in how older adults and researchers assess locations where falls have happened, in terms of their attractiveness, difficulty walking, and concern for falling. Our participatory approach allows the perspectives and experiences of those affected to assess the environment from their perspective and help to counter a perspective where the researcher is the authority on a given issue.

Study aim and objectives

The aims of this study are to:

- Use a participatory approach to audit the built environment for pedestrian falls risks
- Examine differences in researcher led assessments and assessments undertaken by community members
- Examine whether specific demographic characteristics can account for differences in assessment of locations between participants

Methods

Study design

This is a cross-sectional retrospective observational study of the built environment. The study is designed to assess the built environment from a falls risk perspective. We compared assessments of specific locations undertaken by researchers, with those undertaken by members of the community. The approach combined geospatial methods with participatory measurement.

Study setting

The research was conducted in Aotearoa New Zealand in 2020. We previously developed an assessment tool and researchers used Google Street View to assess 2117 locations where falls had occurred across Aotearoa between 1 July 2016 and 20 June 2018 (reference removed for peer review). Further details on the development of the full assessment tool and characteristics of the full street audits are published elsewhere (reference removed for peer review). Researchers were trained in using the tool and had research expertise related to older adults, the built environment and health. However, they are also younger in age than those most at risk of falls and therefore might be expected to have different perspectives.

We are using this already created dataset to compare with participant assessments collected in this study. To reduce participant burden we took a limited number of items from the full tool to use in the participatory workshops. The questionnaire that participants completed is included in the supplementary information.

Community audits took place in a workshop style format in Ōtautahi Christchurch, in-person with researchers present to assist. Community workshops were held during 2020, while New Zealand's borders were restricted and during COVID alert levels 1 and 2. We adhered to all public health advice and safety measure regarding mask wearing and had masks and hand sanitiser available to participants.

Participants and recruitment

Community audits were undertaken by research participants

Participants were eligible for inclusion if they had some experience with walking or wheeling outside in the past six months and expressed any concern about falling. While we expected most participants to be older adults (age 65+), we did not exclude participants based on age as we wanted to be inclusive of those who had concerns about falling outside, which might include some younger people, especially Tāngata Whaikaha (disabled people). Furthermore, Māori are known to experience age-related health conditions at a younger age and so taking an inclusive rather than age-specific cut off was favoured.

We use purposive sampling to recruit participants into workshops. We arranged workshops and advertised for participants through community organisations including Age Concern Canterbury, Aranui Community Trust and Age Friendly Waimakariri (District Council). We held the workshops in different community locations across Christchurch and Waimakariri.

Purposive sampling was appropriate for this study because we we sought participants with particular characteristics in particular experience of falling outdoors., We were not intending that research participants held views representative of the population but did intend to seek a range of perspectives and experiences of the built environment. These workshops were developed with the intention of including people from a wide range of sociodemographic backgrounds.

The main unit of analysis is the *location* of a fall. The main consideration in determining participant sample size was that we had enough participants to assess around 10% of the fall locations assessed by researchers, and not place undue burden on any participant. We therefore aimed to recruit around 50 community auditors, with the intention they would assess 10 locations each, with each location being assessed twice, giving us capacity to assess 250 different locations.

Data collection

In the workshops we started with a brief overview of the research and context of outdoor falls. We then asked participants to read the information sheet (if they had not done so already) and complete a consent form and brief participant information questionnaire (Appendix 1, and measures described below). We then allowed time for an open discussion on outdoor falls and the built environment using an image of the local area to prompt discussion (we audio-recorded the discussion and results will be reported elsewhere). Then participants used iPads to complete a shorter version of the researcher assessment tool (reference removed for peer review) for each of 10 pre-programmed locations in Google Earth (see Appendix 2). Community researchers used the drop and spin approach to conduct virtual street audits [58]. Google Earth provides the same 360° imagery for each point as Google Street View but enabled access to be simplified to a list of clickable links so that participants could automatically move from one location to the next Once they were 'flown' to the pre-programmed location, participants could freely scroll and zoom around at the location. Figure 1 shows a typical scene that a participant would assess.

Fig. 1 An iPad with a typical scene shown to participants

A stratified sample of 250 sites (~10%) of the available fall locations were selected to ensure that community auditors sites across the range represented in the full dataset. The strata included local authority (e.g. city), walk score (positive or negative), and deprivation (more deprived or less deprived).

We then concluded with a final discussion. We returned to all locations to give a feedback workshop later in 2020 or 2021.

Measurement and data sources

Fall location data

We obtained the co-ordinates of locations where an ambulance attended a fall for adults aged 65+, where the fall occurred on the road or footpath between 1 July 2016 and 30 June 2018. Data were obtained from Hato Hone St John (the main ambulance service in New Zealand). The locations cover all of Aotearoa, except for Wellington which operates a different ambulance service. Participants were not likely to be familiar with the locations assessed. Selected records included those where the attending clinician recorded a 'fall' as the presenting complaint and a site than included 'footpath' or 'road' in the electronic patient record form.

Outcome measures

All items come from the Fall-SAFE audit tool we developed and tested . The outcome measures included in the audit tool based on our review of existing literature . In this study we include these as the outcome measures as they are perception-based items, covering aspects of the environment important to older adults.

Site attractiveness

We used a measure of attractiveness from the NZ-SPACES instrument developed by [6], which was developed specifically for the New Zealand context based on the validated SPACES instrument [57]. Site attractiveness was rated on a five-point scale from very attractive (1) to very unattractive (5).

Difficulty of walking at site

Our difficulty of walking measure was also from the NZ-SPACES instrument. Sites were rated based on how physically difficult they were for walking on a four-point scale from easy (1) to very difficult (5).

Fear of falling at site

We adapted the FES-I falls efficacy scale to include a site level measure of fear of falling [74]. FES-I asks about a general fear of falling. We amended this question to ask about concern about falling at the specific location being viewed. Level of concern was rated on a four-point scale from not concerned (1) to very concerned (5).

Site specific predictors

Site specific predictors are those that relate to characteristics of the site assessed by participants. Given that participants assessed multiple sites each, there is more than one of each of these predictors per participant in the model. Site specific predictors are used in the models testing the difference between researcher and participant ratings. In this analysis we used only the researcher site assessments, as these items were considered more objective and in initial testing showed more consistency between researcher and participant ratings.

Trip hazards

We measured trip hazards using an item from Millstein et al. [49] Microscale Audit of Pedestrian Streetscapes (MAPS). Sites were rated based on presence of 'poorly maintained sections of the footpath that constitute trip hazards' on a four-point scale from None to Many.

Path Obstructions

We measured path obstructions using an item from NZ-SPACES [6], originally based on MAPS [49]. Participants were asked if they noticed the presence of the following obstructions at a site: poles, signs, litter bins, utility boxes, planters or trees, manholes and grates, overhanging vegetation, or other. For the analysis, the total number of obstructions was calculated for each location.

Slope

Slope was measured using an item from NZ-SPACES. Participants rated slope on a three-point scale from flat or gentle slope to steep slope.

Participant predictors

Physical activity

Physical activity was assessed through the short International Physical Activity Questionnaire (IPAQ) [56]. The item asks about time spent doing vigorous or moderate physical activity, and walking in the past seven days. Estimates of metabolic minutes of activity are then classified into high, medium and low categories of physical activity.

Activities of Daily Living

To assess difficulties with activities of daily living (ADL), participants reported their level of difficulty with five daily activities on a six-point scale from "not hard at all" to "too hard to do". These items were chosen based on previous use in studies of older adults' mobility and falls in outdoor settings [17, 65]. A score was calculated from 6 to 30, with a higher score indicating greater difficulty with daily activities.

Fallen in previous year

Participants were asked if they had fallen in the 12 months prior to the study. If they answered yes, they were asked to provide details on how many times they had fallen (once, two to three falls, four or five falls, or more than five), and the location of any falls (in their home, in their garden or driveway, in the street, or somewhere else). We used the same questions in a previous study [17].

Fear of falling

Fear of falling was assessed using an adapted version of the Falls Efficacy scale (FES-I) [74] focused on outdoor falls, following [17]. Participants were asked to report their general level of concern about falling in nine settings, using seven of the sixteen items from FES-I that are specific to outdoor activities, and a further two items from an expanded version of FES-I specific to outdoor activities [31]. The four-point scale was averaged to give a score ranging from 9 to 36 with higher scores indicating a greater fear of falling. We then converted this to a 0–3 scale for analysis. In contrast to the site-specific assessment of fear of falling used as an outcome measure, this item measures a general underlying fear of falling at the individual level, rather than in specific locations.

Demographic information

Each participant's approximate age as of 2020 was calculated based on their year of birth. Age was used either as a continuous or categorical variable (age brackets 30–65 years, 65–70 years, 70–75 years, 75–80 years, and 80–95 years). Participants were asked demographic questions about their suburb of residence, ethnicity, and gender.

Statistical methods

Descriptive statistics were carried out to explore participant characteristics and to summarise the relationships between participant and researcher assessments of each site. The symmetry of crosstabulations was assessed using the McNemar-Bowker's test, to see if there was an obvious bias to the researchers' scores relative to participants. Ordinal regression cumulative mixed link models were used to estimate the odds that community members would rank a location one level higher than the researcher. These models include site characteristics (number of trip hazards, slope, presence and total number of obstructions) as independent variables.

We then used ordinal regression cumulative link mixed models to examine whether demographic characteristics accounted for differences in the ways in which participants rated each location. Researcher audits were not included in this analysis. Individual participants (N = 37) and site locations (N = 222) were treated as random effects in these models to account for potential differences in how each participant would score across multiple sites. The following demographic characteristics were used: gender, age group, falls in previous 12 months, physical activity category (IPAQ), ADL score, fear of falling.

The assumption of ordinal regression models that random effects are normally distributed around a grand mean was then tested by plotting the means and confidence intervals of participant and locations (figures not shown). We compared the models with a null model containing only the random effects using a likelihood ration test and calculated the McFadden Pseudo R^2. Data analysis was conducted in R.

Researcher characteristics

The researcher audits were undertaken by two different researchers (and separately tested for agreement). In this paper we are treating the researcher audits as an 'objective' measure, we are not interested in this paper in whether the demographic characteristics of the researchers influence the outcomes, although that would be a worthwhile endeavor.

Ethical considerations

The research was undertaken in accordance with the Declaration of Helsinki. Participants gave informed consent to participate in the research. Information sheets and consent forms made it clear that participation was on an individual and voluntary basis. We were concerned that some participants might feel compelled to participate as the information came to them through community groups, so were clear to emphasise that there was no requirement to participate because they had been invited by their groups. We kept identifying information and contact details separately from research data. Ethical approval and locality approval was also obtained for use of the Hato Hone St John fall location data. We used only anonymised data and while location of the incident and demographic data was available to the research team, this was kept on secured university servers and is only published as aggregated results. The University of Otago Human Ethics Committee (Health) approved the project H19/143. The study was reviewed through the Māori Health research consultation processes at our institution, and we worked with the Hato Hone St John Hauora Māori clinical advisor to try and host a workshop with Māori older adults. Ultimately this was unsuccessful, likely, at least in part to the timing in 2020 and 2021 when there were lots of other demands on the community. This is noted as a limitation of the research.

Results

We held 12 workshops with 37 participants at a range of locations across the Greater Christchurch region.

A total of 222 unique locations were assessed by 37 community auditors. The final dataset consists of 592 records, made up of 222 researcher site assessments and 370 completed community assessments. We excluded some community assessments with large amounts of missing data. Community auditors each audited multiple sites and some sites were assessed by more than one community auditor. This is accounted for by including both the site and the individual auditor as random effects in the model.

Participant characteristics

Table 1 shows the characteristics of the study participants. Participants were predominantly female (73%), with a mean age of 71 years (range 32—92 years). Among all participants, 14 (38%) had fallen in the previous 12 months, and of those 21% had fallen more than three times; 19% of participants had fallen over in the street.

Ethnicity was not included in subsequent analysis as most participants were New Zealand European/Kiwi, with the only other ethnicities being Irish, South African, and dual Australian/New Zealand. These ethnic groups fall under the same Level 1 Classification category used in official statistics ("European") [64] and are unlikely to contribute meaningfully to the other analyses.

Researcher and participant assessment of sites

The distribution of responses from participants and researchers across the attractiveness, difficulty and concern about falling at site variables can be seen in Fig. 2. Participants were likely to rate sites as one level more unattractive, compared with researchers (OR = 10.3, 95%CI [2.64,39.9]). There were no significant differences in the ratings of difficulty (OR = 1.2, 95%CI [0.15,9.76]) or

Table 1 Participant characteristics

Characteristic	Number (%) of participants Median (IQR), N = 37
Gender	
Male	10 (27%)
Female	27 (73%)
Ethnicity	
NZ European	33 (89%)
NZ European and Other	2 (5%)
Other	2 (5%)
Age Median (IQR)	71 (67, 75)
Age (categorical)	
30–65	7 (20%)
66–70	6 (17%)
71–75	12 (34%)
76–80	6 (17%)
81–95	4 (11%)
Unknown	2 (5%)
Fallen in previous 12 months	14 (38%)
Times fallen in previous 12 months	
Once	6 (16%)
Two or three times	5 (14%)
Four or five times	3 (8%)
Fallen in home	8 (22%)
Fallen in garden or driveway of home	5 (14%)
Fallen in street	7 (19%)
Fear of falling score Median (IQR)	20 (16, 21)
ADL score Median (IQR)	8.4 (7, 13)
Physical activity category	
High	19 (51%)
Medium	7 (19%)
Low	11 (30%)

fear of falling (OR = 3.88, 95%CI [0.47,32.3]) among participants and researchers.

Table 2 shows the results of the mixed cumulative link ordinal regression models showing site characteristics (measured by researchers) and assessor type. Including the site-specific characteristics does not meaningfully change the results for assessor type, we still find differences in researcher and participant assessments for unattractiveness, but not for difficulty or concern about falling.

Sites with trip hazards present were likely to be rated as one level more unattractive and one level greater concern for falling. Steeper locations were rated with a higher level of difficult for walking and with a greater concern for falling. Path obstructions did not have any significant influence on increasing the unattractiveness, difficulty or fear of falling.

The likelihood ratio tests indicate that the fitted model explains the data better than the null model. McFadden R^2 is interpreted in the same manner as conventional R^2 for a linear model but is typically much smaller even for a well fitted model and has additional limitations due to the methods of calculation. Regardless, the results indicate that only a small amount of variability in the outcomes is explained by the models, meaning there are unmeasured variables likely accounting for much of the variation.

Participant characteristics and site assessments

Table 3 shows models how participant characteristics are associated with their odds of rating locations one level higher for unattractiveness, difficulty walking and fear of falling. Gender and age were not significantly associated with the outcomes. Having fallen over in the past 12 months or having a general (not site specific) fear of falling did also not significantly impact how participants rated the locations. Physical activity and functional status (ADL) influenced assessments of difficulty walking, and fear of falling at sites, but interestingly those with low levels of physical activity were less likely to report a site as being difficult to walk at, and less likely to report a fear of falling at a particular location. Those with greater levels of functional difficulty were more likely to rate sites as difficult to walk at and have a fear of falling at the specific site.

As with the previous models, the likelihood ratio tests indicate that the fitted model explains the data better than the null mode, except for the attractiveness model, but overall the explanatory power of the model is weak. Figures 3, 4 and 5 show visually the adjusted odds ratios of a site being rated one level more unattractive, difficult, or concern for falling respectively.

Discussion

Our aim was to understand whether there were differences in how researchers and community members assessed locations where falls have occurred, in terms of site attractiveness, difficulty of walking and level of concern about falling. Furthermore, we sought to understand whether site-specific or person-specific characteristics accounted for any differences in the way locations were assessed.

Significant differences in assessments between researchers and participants were found for site attractiveness ratings. Researchers we ten times as likely as participants to rate a site as one level more attractive for walking. As seen in Fig. 2 community members rates over 40% of sites at unattractive for walking, compared to less than 10% of sites rated as unattractive by researchers. This difference indicates that there were clear differences in what a researcher and our community participants viewed as an attractive walking environment. Understanding this in more depth would require qualitative research into what an attractive environment is, but also with both researchers and participants into what informed their assessments. Nevertheless, on an assumption that attractiveness of the environment might

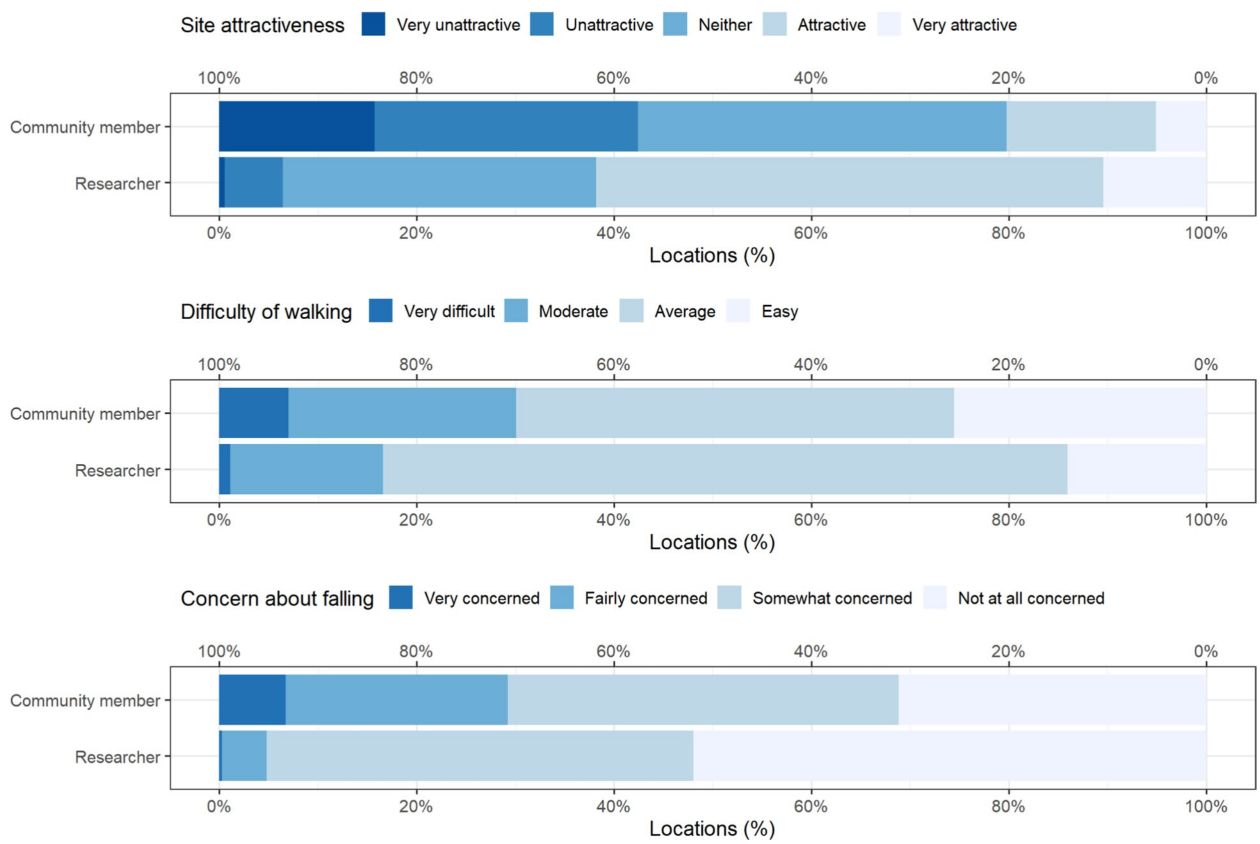

Fig. 2 Distribution of location ratings for community members (participants) and researchers

Table 2 Odds ratios for assessor type and site characteristics associated with site assessments (n = 222)

Characteristic	Unattractiveness			Difficulty walking Fear of falling (site)			Fear of falling (site)		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Assessor type			0.001			0.9			0.2
Researcher	—	—		—	—		—	—	
Participant	10.4	2.53, 42.6		1.22	0.14, 10.8		4.05	0.46, 35.6	
Tripping hazards			<0.001			0.14			<0.001
None	—	—		—	—		—	—	
One	2.54	1.56, 4.12		1.15	0.74, 1.79		1.78	1.15, 2.75	
A few	1.92	1.22, 3.03		1.51	0.99, 2.29		2.40	1.59, 3.62	
Many	1.88	0.81, 4.39		1.96	0.90, 4.27		2.91	1.34, 6.28	
Slope of site			0.2			<0.001			<0.001
Flat or gentle slope	—	—		—	—		—	—	
Moderate slope	0.93	0.54, 1.60		2.67	1.58, 4.52		1.52	0.91, 2.53	
Steep slope	0.54	0.28, 1.05		9.28	4.96, 17.4		5.30	2.98, 9.42	
Path obstructions			0.10			>0.9			>0.9
None	—	—		—	—		—	—	
One	0.91	0.40, 2.06		0.99	0.46, 2.10		1.02	0.48, 2.15	
Two	0.67	0.28, 1.58		1.04	0.47, 2.30		1.02	0.46, 2.26	
Three or more	1.35	0.68, 2.68		0.92	0.49, 1.74		1.11	0.59, 2.07	
McFadden R^2		0.05			0.09			0.08	
Likelihood Ratio test (p-value)		<0.01			<0.01			<0.01	

CI = Confidence Interval, OR = Odds Ratio

Table 3 Odds ratios for participant characteristics associated with age-friendly ratings of locations (n = 222)

Characteristic	Unattractiveness			Difficulty walking			Fear of falling (location)		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Gender			0.2			0.091			0.2
Man	—	—		—	—		—	—	
Woman	1.69	0.79, 3.65		2.08	0.89, 4.84		1.80	0.70, 4.64	
Age (years)			0.5			0.5			0.12
[30,65)	—	—		—	—		—	—	
[65,70)	1.45	0.52, 3.99		2.73	0.91, 8.20		4.01	1.17, 13.7	
[70,75)	1.60	0.66, 3.92		1.84	0.69, 4.88		3.89	1.31, 11.5	
[75,80)	0.84	0.30, 2.31		2.23	0.73, 6.82		2.87	0.83, 9.88	
[80,95)	1.91	0.54, 6.71		1.41	0.35, 5.60		1.52	0.33, 7.02	
Fallen in prior 12 months	0.82	0.43, 1.55	0.5	1.07	0.54, 2.12	0.8	1.24	0.57, 2.66	0.6
Fear of falling (0–3)	1.26	0.63, 2.51	0.5	1.47	0.69, 3.10	0.3	1.79	0.77, 4.14	0.2
Physical activity (IPAQ)			0.2			0.024			0.028
High	—	—		—	—		—	—	
Medium	1.01	0.44, 2.33		1.55	0.63, 3.80		1.06	0.39, 2.87	
Low	2.15	0.85, 5.43		0.33	0.12, 0.90		0.23	0.07, 0.73	
Activities of Daily Living (score)	0.96	0.85, 1.08	0.5	1.17	1.03, 1.34	0.019	1.18	1.02, 1.37	0.025
McFadden R^2		0.01			0.03			0.04	
Likelihood Ratio test (p-value)		0.622			0.01			< 0.01	

CI = Confidence Interval, OR = Odds Ratio

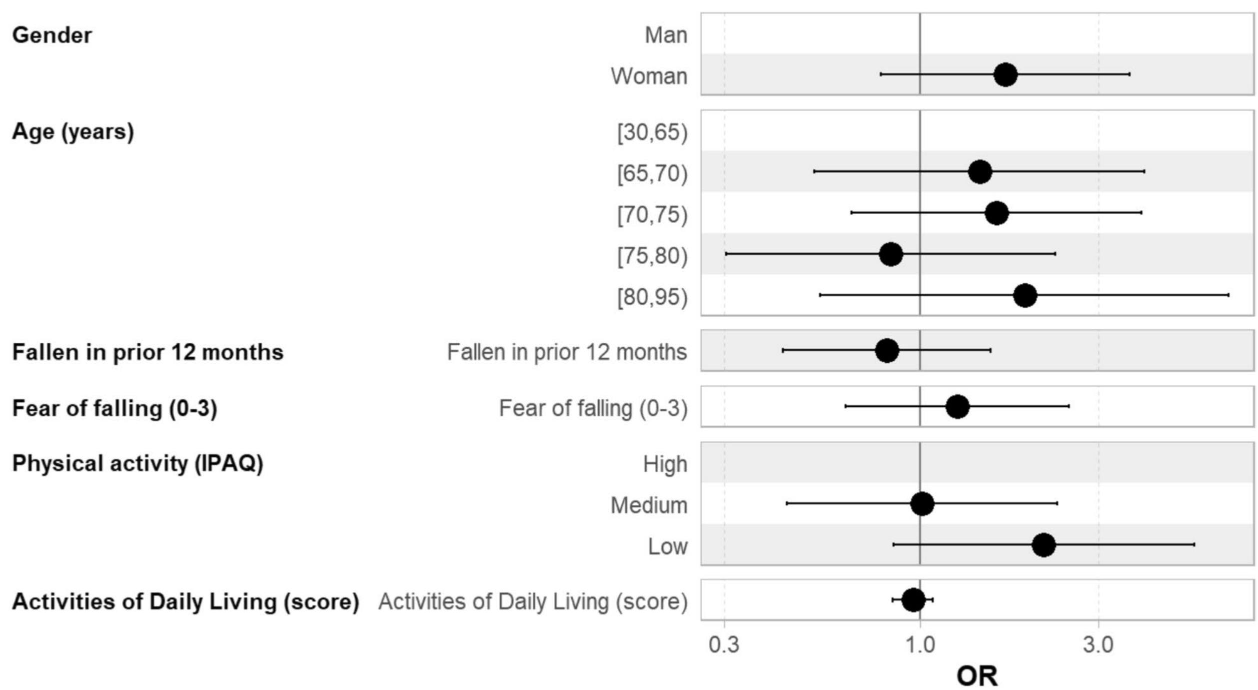

Fig. 3 Adjusted odds ratios and 95% confidence intervals for unattractiveness of sites

influence walking outdoors, it is important to note that few of the assessed locations were attractive to our participants and efforts of local authorities could focus on designing environments attractive for walking, to support active ageing.. There were no significant differences in how researchers and participants assessed locations for fear of falling or difficulty walking. This suggests that our trained research team did a reasonable job of assessing difficulty and fear of falling, that reflected the average scores of participants. It is possible this difference between attractiveness, and difficuly and fear of falling was in someway related to the training researchers received on the built environment and falls risk prior to undertaking the audit so that they were able to assess difficulty and falls risk more in line with the participant perspectives, but attractiveness may be more subjective.

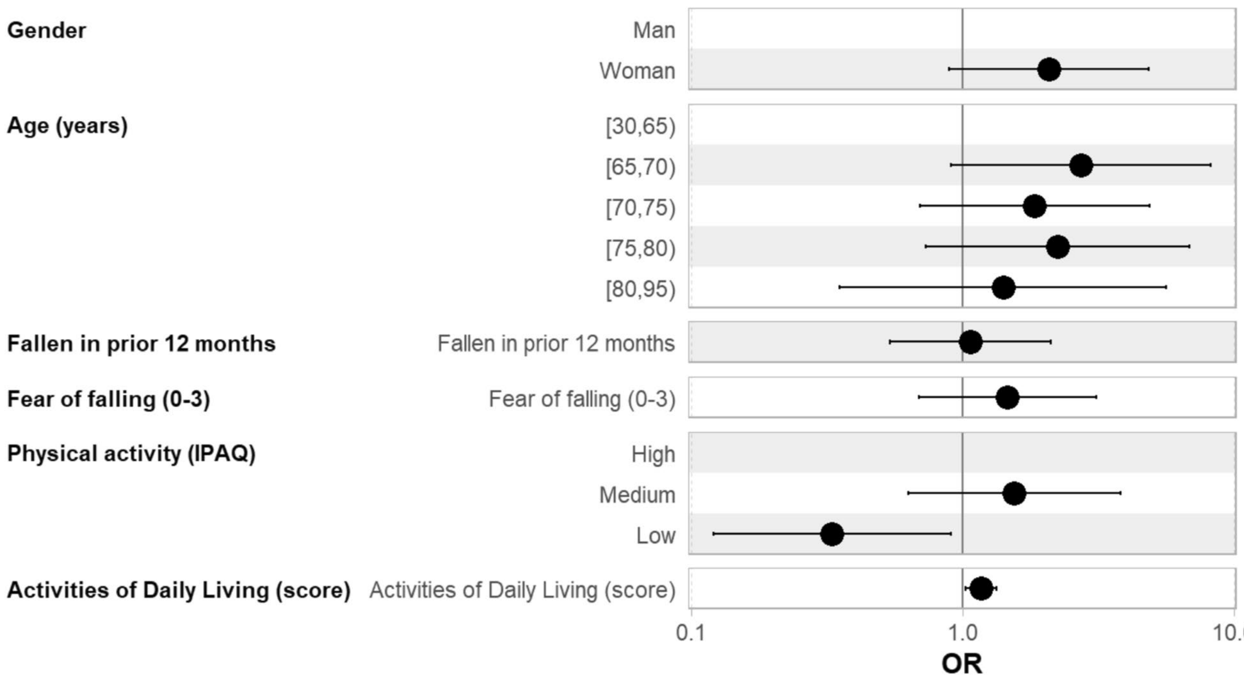

Fig. 4 Adjusted odds ratios and 95% confidence intervals for difficulty walking at sites

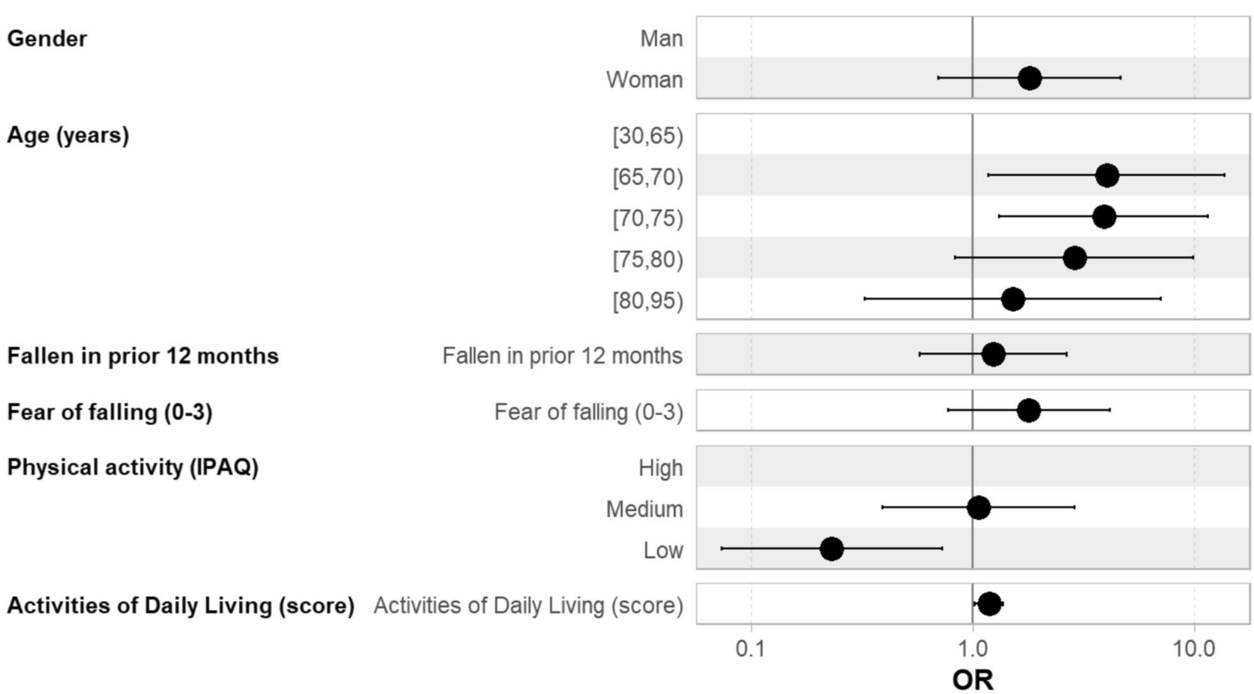

Fig. 5 Adjusted odds ratios and 95% confidence intervals for concern about falling at sites

Nevertheless, there was variation among participants meaning that there is value in understanding what demographic characteristics explain the variation in participant assessments of sites.

Other studies have found significant differences between participant perceptions of the environment and objective measures [19, 32, 45], but have not necessarily looked at factors that explain those differences. Our study both complements and extends on these existing studies. These studies have compared participant perceptions to objective measures from existing secondary geospatial datasets such as crime data, or land use. In contrast, we compare researcher and participant ratings collected using the same data collection instrument. While our researcher ratings are arguably not objective, often data collected in this way is treated as objective data, without considering that the characteristics of the researchers or research participants who collect the data might impact how particular spatial attributes are recorded.

Site-specific attributes accounted for differences in how locations were rated for attractiveness, difficulty walking and concern about falling. Sites with more trip hazards were rated as more unattractive and there was greater fear of falling at these locations. Locations with steeper slopes were rated as more difficult to walk at and with a higher reported fear of falling. These findings align with other research that have found trip hazards or footpath quality [13, 14, 30, 34, 35] and slope [21, 54] to be associated with pedestrian falls. It is likely that we did not measure other factors that account for attractiveness, which might include greenspace, trees or other features. Item mismeasurement has been highlighted as one of the main pitfalls when undertaking virtual street audits [5] and it is also possible that the ratings differed because of the use of virtual rather than in-person audits.

Participant related factors influenced variation in difficulty walking and fear of falling at locations. Those with more difficulties with daily living activities were more likely to have concern for falling at sites. This is an important finding for built environment audit studies more broadly, as we demonstrate that individual characteristics, in particular levels of functional ability, and physical activity can influence how people rate aspects of the built environment. Our findings showing that those with lower levels of physical activity were less likely to rate locations as difficult or show fear of falling at those sites were surprising. However, it might perhaps represent an exposure effect, whereby those who are less active are exposed to outdoor environments less and therefore may be less likely to find them challenging, especially as we controlled for and found a significant effect of functional ability, measured through activities of daily living (ADL). No person specific items were significant in explaining variation in attractiveness ratings. It seems likely we did not measure factors that are important in determining attractiveness which may relate more to preferences than health status or demographic factors.

Although there is a small, but emerging body of research understanding built environment characteristics associated with falls [12–14, 17, 24, 60, 73], this paper also adds to understanding on fear of falling in specific places. Fear of falling over has been shown to have substantial impacts on quality of life. Those who are concerned about falling avoid activities [66, 67], which can lead to social isolation, reduced physical activity and increased risk of falling. Our findings corroborate other research showing that concern of falling in particular locations is not limited to those that have fallen over recently [15, 17, 66]. Although other research has shown a general relationship between assessments of neighborhood quality and fear of falling [17, 39–41], our research demonstrates that specific locations with identifiable trip hazards generate a greater fear of falling and perceived unattractiveness. However, perhaps surprisingly an individual level fear of falling was not associated with participants assessments of fear of falling in specific places. Our results suggest that while a general fear of falling may be strongly related to individual factors such as physical activity levels or functional abilities, there are likely further, location specific aspects to fear of falling which warrant further attention. While there are examples of research with older adults using go-along methods [22, 70] there is potential to explore fear of falling in more depth using methods such as Geographic Ecological Momentary Assessment (GEMA) which, along with approaches such as body worn sensors offer the potential provide rich, location specific information with potential to record physiological responses to different urban environments [55]. Research that collects quantitative data through participatory methods can ensure that measurement of the built environment incorporates perceptions and experiences, rather than only "objective" or expert led approaches.

In summary, we found significant differences in how researchers' assessments and community auditors assess locations in terms of their attractiveness. Both site related attributes and individual attributes explained variance in how locations were rated for difficulty walking and a concern for falling, but only site-specific attributes explained variance in site attractiveness.

These findings emphasise the importance of taking user perspectives into account in geospatial assessments of the built environment, as there can be differences in their understanding of and experiences of places, relative to audits that are often undertaken by research teams or city authorities. Community perspectives may differ from professionals assessing or designing environments and therefore the community should be involved in assessments of the urban environment. Although our study has focused on older adults, these findings are likely applicable to other population groups whose needs are often not well considered in the design of the built environment, such as children [44], disabled people [62], women [63] and non-white ethnic groups [27]. Professionals engaged in measuring and assessing the built environment, such as urban planners and designers, should ensure that they are capturing a range of perspectives and where possible involving members of the community in their assessments. Health and social care professionals working with older adults could benefit from awareness of how the outdoor environment might support or inhibit their outdoor activity and work with them to provide necessary supports or find suitable routes.

While we sought to involve a broad range of older people across the socio-demographic spectrum in our research through working at a range of community locations in different parts of the city, we struggled to recruit Māori participants. This limits the utility of the findings, particularly in terms of addressing health inequities related to the built environment. It is likely that Māori may find different aspects of the environment to be supportive and important for age-friendliness, and as noted by other studies, there is a need for age-friendly initiatives for Māori communities to be led by iwi (Māori kinship group or tribe) [51]. We did run a workshop with members of the Afghan refugee community, but ultimately, for a variety of reasons this was a focus group discussion that is not included in the quantitative analysis in this paper. However, this experience does demonstrate the importance of using culturally appropriate methods to engage with diverse communities in measuring the built environment. Although other research has shown a general relationship between assessments of neighborhood quality and fear of falling [17, 39–41], our research demonstrates that specific locations with identifiable trip hazards generate a greater concern for falling and perceived difficulty of walking. This adds to the literature on understanding environmental aspects associated with pedestrian falls.

Given the non-probability sample, and the geographic specificity of our research these findings on attributes of the environment associated with falls are not generalisable to a broader population. However, while geographically situated and population specific the findings contribute to and support the evidence base on the importance of the built environment to assessments of age-friendliness, specifically attractiveness, difficulty walking, and concern for falling. However, any such assessments of environments will always be context specific. Beyond this, the research acts as a demonstration of the importance of including user perspectives in geospatial assessments of the built environment, especially at a time when such processes can potentially be more automated.

New approaches, such as using Artificial Intelligence to evaluate the built environment [46] may be prone to bias, if they do not consider a range of perspectives. The result may be that interventions designed to improve built environments are not inclusive of a broad range of experiences and needs.

As the global population both ages and diversifies, it is important to pay attention to the built environment and how it can promote healthy ageing. Doing so requires working with older people and understanding their needs and perspectives of the environment, alongside researcher-led geospatial assessments. Our research demonstrates the role of the built environment in influencing concern for falling in particular places and suggests that high quality-built environments can promote healthy ageing.

Supplementary Information

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Supplementary materials 1

Supplementary materials 2

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Author contributions

AC conceptualised and designed the study, secured funding and project managed the study. VT, BD and SK provided input to the study conception and design. AW, TP, and AC designed the audit tool and AW and TP undertook researcher audits of fall locations., with advice from SK. AW, CD and AC designed and led the community workshops. AW collated and cleaned all data. JW provided biostatistical advice and oversight. AS and AW undertook quantitative analyses. VT and BD provided data from Hato Hone St John on dall locations. AS and AC drafted the manuscript. All authors reviewed the manuscript.

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Data availability

We cannot share publicly share the data due to ethical considerations and data protection.

Declarations

Ethics

The University of Otago Human Ethics Committee (Health) approved the project H19/143. All participants gave informed consent.

Competing interests

The authors declare no competing interests.

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