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Improving Your Local Area Citizen Scientists and Community Stakeholders

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Employing citizen science to enhance active and healthy ageing in urban environments

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ABSTRACT

Engaging older residents in problem definition and solution-building is key to the success of place-based initiatives endeavouring to increase the age-friendliness of urban environments. This study employed the *Our Voice* framework, engaging older adult citizen scientists (n = 14) and community stakeholders (n = 15) across the city of Birmingham, UK. With the aim of identifying urban features impacting age friendliness and co-producing recommendations for improving local urban areas, citizen scientists participated in 12 technology-enabled walkability assessments, three in-person discussion groups, two one-to-one online discussions, and two workshops with community stakeholders. Together, citizen scientists co-produced 12 local and six city-wide recommendations. These recommendations were embedded into an implementation framework based on workshop discussions to identify age-friendly pathways in urban environments.

1. Introduction

Population ageing and urbanization are two global demographic mega-trends that are simultaneously transforming society (United Nations, 2019a). While the 703 million individuals aged 65 years and above will more than double by 2050 (United Nations, 2019b), over half of the global population will transition to residing in urban environments (United Nations, 2019a; Leeson, 2018). Urban environments, referring to physical environments with built and natural features that form settlements and local places such as cities and towns (Annear et al., 2014; Dahly and Adair, 2007), are recognised to influence health, well-being and the ability for individuals to be active as they age (WHO, 2007a). As 43.2% of older adults from developed countries already reside in cities (OECD, 2015), alongside the expectation that the majority of population ageing will occur in urban environments (Van Hoof and Yu, 2020), understanding the pathways to creating age-friendly urban environments is crucial for promoting active and healthy ageing.

Urban environments encompass a multitude of characteristics that influence healthy and active ageing (WHO, 2007a). These include the quality of places, accessibility of services, street connectivity, well-maintained pavements, and social and economic opportunities (Andonian and MacRae, 2011; Annear et al., 2014; Klein et al., 2021; Stathi et al., 2012; Van Hoof et al., 2018). Such urban characteristics intersect across the individual, environmental, socio-cultural, economic and political domains (Frank et al., 2017; Sallis et al., 2006). However, the characteristics and their interactions are often specific to the places and contexts in which they occur, with neighbourhood demographics, financial circumstances, socio-economic inequalities, alterations to local places and the availability of local destinations and services influenced by the many actors, behaviours, resources and agendas across each social-ecological domain (Barnett et al., 2017; Buffel and Phillipson, 2016; Chao, 2019; Lager et al., 2015; Stephens et al., 2018; Ward Thompson et al., 2014). In turn, urban environments are hotspots for complex social-ecological and multi-level interactions that can create both challenges and opportunities for ageing residents (Chao, 2019; Frank et al., 2017; Phillipson, 2014).

Global agendas and frameworks have been developed to address the health and well-being needs of older adults in urban environments, including the Active Ageing Policy framework (WHO, 2002), the Age-Friendly Cities model (WHO, 2007a) and policies to promote

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ageing-in-place (Lui et al., 2009; Steels, 2015). The Age-Friendly Cities model provides guidance for altering and enhancing urban places, structures and services to promote active and healthy ageing (Greenfield, 2018). Eight specific domains are identified in the model: *Outdoor spaces and buildings; Transportation; Community Support and Health Services; Communication and Information; Civic Participation and Employment; Respect and Social Inclusion; Social Participation; and Housing* (WHO2007a). Ageing-in-place, when promoted across sectors, is a policy approach that also fosters opportunities to remain at home and age independently while staying connected to local support and places (van Hees et al., 2017; Wiles et al., 2012). This approach is shown to be positive for enhancing health, quality of life and reducing health care demands (Sixsmith and Sixsmith, 2008).

These frameworks have raised increasing awareness of age-related concerns about remaining healthy in urban places (Buffel et al., 2012; Lui et al., 2009; van Hees et al., 2017). Yet their applicability across diverse urban settings, with different contexts, pressures and local-level needs, require further attention (Buffel and Phillipson, 2016; Wood et al., 2022a).

Additionally, some accuse age-friendly initiatives of being ageist by implicitly or explicitly over-relying on stereotypes of older age in design planning and implementation (van Hoof et al., 2019, 2021; Biggs and Carr, 2015). In other instances, tensions can arise when "age-friendly" initiatives intersect with economic discourse and political agendas (Buffel et al., 2019, 2020). For example, when critics posit that the provision of age-friendly environments is meant to reduce government responsibility and spending on the health needs of older adults (Finlay and Finn, 2020; Joy, 2018). Perhaps most fundamentally, what at times have been purported to be age-friendly policies and agendas can be ineffective in capturing and addressing the self-defined needs of older adults in urban environments. Clearly, there is a need for further consideration of ageing experiences in local places (Buffel and Phillipson, 2016; Pani-Harreman et al., 2020; van Hees et al., 2017).

Enabling older adults to define their own lived experiences at the neighbourhood level can promote an in-depth understanding of the conditions, contexts and everyday interactions that influence their health and well-being (Scott, 2021; OECD, 2015). For instance, directly exploring the elements of healthy ageing valued by older adults in urban New Zealand revealed their realities of healthy ageing. This included the need for physical comfort, independent decision-making and social integration, which were identified by older adults to support meaningful participation in urban places (Stephens et al., 2015). In the United Kingdom (UK), the "15-to-20-min neighbourhood" concept aims to create local environments in which everyday needs can be met within 20 min of an individual's residence. While this policy agenda aims to promote greater accessibility of services (O'Gorman and Dillon-Robinson, 2021), at times it has resulted in the amplification of voices of younger people to the exclusion of perspectives and insights from older adults. In one notable example, older adults in Newcastle, UK expressed increased feelings of marginalisation as the design of the 15-to-20 min neighbourhood underscored their own lack of local opportunities relative to the younger population (Scott, 2021). A place-based approach that more intentionally engages community expertise can avoid exacerbating socio-economic and spatial inequalities already present and both recognise and address local concerns and needs of older residents in their own places (O'Gorman and Dillon-Robinson, 2021; Calafiore et al., 2022).

Citizen science (CS), a branch of participatory action research, is a methodological approach that engages local residents to collect data based on their perspectives and experiences (Roger and Motion, 2021; Rosas et al., 2022). Through various levels of engagement, including contributory, collaborative and co-production activities, CS can actively engage older adults to directly process and collect, interpret and share their own data (Bonney et al., 2009; King et al., 2019). This provides the opportunity to generate real-world and locally-relevant knowledge based on the concerns of local residents, alongside complementing and ultimately strengthening more traditional research methods (King et al., 2016; Okop et al., 2021). CS has also successfully informed urban age-friendly planning by engaging older adults in sharing their views, experiences and co-producing solutions for their local places (King et al., 2020; Barrie et al., 2019).

In this study, the *Our Voice* CS method (King et al., 2016) was used. This method engages community members in a scientific process that aims to enable the creation of health-promoting environments so that all members of society have access to a healthy and vital life (King et al., 2021). Developed at Stanford University, *Our Voice* comprises four steps, beginning with training local residents, as citizen scientists, to collect data using a simple mobile app called the Stanford Discovery Tool. The app allows users to gather geotagged photos, audio/text comments and ratings documenting environmental features impacting healthy living. In a facilitated process, citizen scientists then review and analyse group data and use them for collective cross-sector dialogue and solution-building with community stakeholders (King et al., 2019; Hinckson et al., 2017). This method has effectively engaged older adults in promoting local community health and age-friendliness across a wide diversity of cultures and contexts globally (King et al., 2020; Tuckett et al., 2017).

In the current study, we applied the *Our Voice* CS method across the city of Birmingham, UK to engage older adults as citizen scientists and community stakeholders, with the aims of: 1) identifying self-described barriers and facilitators that influence older adults' active and healthy ageing in the city of Birmingham; and 2) co-producing a set of relevant and actionable recommendations for improving local urban areas to promote age-friendliness.

2. Materials and methods

2.1. Study context

This study is part of the *Improving Your Local Area Citizen Science project*, which included preliminary work undertaken to inform location-specific adaptation of Stages one to three of the *Our Voice* CS method. The preliminary stage consisted of six online discussion groups (60–90 min) with older adult citizen scientists (n = 16) and community stakeholders (n = 11), with details and outcomes published elsewhere (Wood et al., 2022b). The study reported here presents Stages one to three (Fig. 1) of the *Our Voice* CS method.

2.2. Study setting and participants

This study took place in the city of Birmingham, UK, from August 2021 to January 2022. Birmingham is the second largest city in the UK and has a growing population of older adults aged 65 and above, with an expected rise from 150,600 to 194,100 older adults by 2040 (Birmingham City Council, 2021). Birmingham is characterised as a superdiverse city (Birmingham Policy Commission, 2014; Department for Communities and Local Government, 2014); that is a city that encompasses a diverse range of populations from different countries, migration channels, ethnicities, religions, age and sex that form multi-cultural communities without one predominant ethnic group (Pemberton and Phillimore, 2016; Thompson 2014). It is the third most deprived city in the UK based on indices of multiple deprivation, with 43% of the population living in 10% of the most deprived areas (Birmingham City Council 2018, 2019). At the same time, Birmingham is an urban setting with green spaces, corridors and parks covering 4700 ha, making it one of the greenest European cities (Birmingham City Council 2013, 2022).

Citizen scientists aged 60 years and above were recruited through convenience and snowball sampling, with an aim of recruiting older citizen scientists across the 69 wards of Birmingham. The study and recruitment material were shared via targeted emails to urban planning and Ageing Well services across Birmingham. Interested older adults contacted the study team and were telephone-screened for their

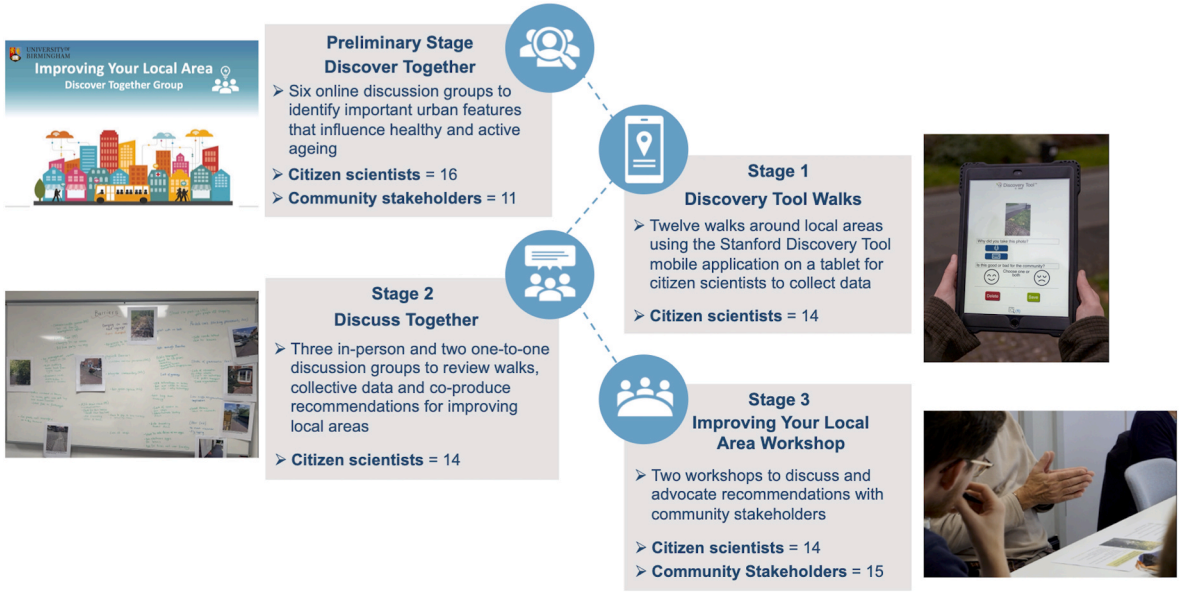

Fig. 1. The stages of the "*Improving Your Local Area*" *Citizen Science project.*

eligibility, with those eligible signing consent forms prior to study commencement. Citizen scientists received £35 compensation meeting the guidance of the National Institute for Health and Care Research (2022a). This amount covered their time involvement (a total of 5 h composing of one Discovery Tool walk, two in-person discussion groups and one preliminary online discussion group), travel and subsistence. The compensation provided support for those who may otherwise not have been able to engage and at the same time facilitated equal partnerships across citizen scientists and researchers (National Institute for Health and Care Research, 2022b). In our study, only those citizen scientists who completed all stages were eligible for compensation (n = 4 stages), with four participants declining payment altogether.

During the time of this study, the global Covid-19 pandemic occurred. This was likely to have impacted the number of citizen scientists we were able to engage. Citizen scientists were recruited from 11 of the 69 wards so were not representative of older adult communities across all the different administrative and geographical areas of Birmingham. Community stakeholders in urban planning and Ageing Well services were recruited via convenience and snowball sampling through targeted emails to their organisations. Community stakeholders engaged only in the preliminary discussion groups and in Stage three workshops, with verbal consent given prior to participation.

2.3. Study methods informed by the Our Voice CS method

2.3.1. Stage one – Discovery Tool walks

In August 2021, citizen scientists (n = 14) used the Stanford Discovery Tool mobile application (Buman et al., 2013) on a project electronic tablet to complete 12 data collection walks in their local areas. Four citizen scientists completed two walks together. The citizen scientists received online Discovery Tool training materials and were able to practice using the application prior to starting walks. The objective was for citizen scientists to collect geo-tagged photos, audio or text narratives and ratings to document barriers and facilitators to active and healthy ageing in their local areas. Each individual was asked to choose a walk that was meaningful to them and the choice of location or length of walks was not influenced by the researchers.

GW was present during each walk, initially to provide technical support and alleviate safety concerns. Only two of the 14 citizen scientists felt comfortable using the Discovery Tool on a e-tablet whilst walking, with concerns about tripping, needing to use a walking aid, or glare reflected from the sun impacting vision. To address this, GW carried the iPad during the walk and followed instructions from citizen scientists on when to collect data, including being instructed to take photos and write textual descriptions. Due to Covid-19 restrictions, GW was unable to pass the e-tablet back to citizen scientists when they indicated data were to be collected. At the end of each walk, GW uploaded the anonymous data to a secure Institutional Review Board-approved server at Stanford University.

2.3.2. Stage two – discuss together groups

Three in-person discussion groups (n = 12 participants) and two online one-to-one discussions (n = 2 participants) were completed in September to October 2021, lasting 60–90 min each. The aim was for citizen scientists to discuss the urban barriers and facilitators identified in Stage one in order to produce area-specific recommendations. Following this, citizen scientists as a group co-produced city-wide recommendations for enhancing active and healthy ageing. The in-person discussion groups were facilitated in two steps: 1) participatory mapping and photo-elicitation exercises (Brookfield et al., 2020) using photos and narratives collected during stage one to thematically review and prioritise data; and 2) discussion of the reviewed data to produce area-specific information and recommendations as a group for promoting active and healthy ageing city-wide. For each recommendation, citizen scientists were asked i) to identify what needed to be done and why; ii) how and when it should happen; iii) and who would need to be involved. Area-specific and city-wide recommendations were written down by both citizen scientists and GW, with GW repeating back all recommendations at the end of each discussion group for confirmation.

Two citizen scientists were unable to attend in-person due to Covid-19 and other health reasons. One-to-one discussions (n = 2) were held via Zoom (Version 5.8.4). Individual-level data collected at Stage one during the Discovery Tool walks were shared with each of the citizen scientists prior to these discussions. Each citizen scientist then worked on the data they had collected and used this to identify area-specific recommendations for their area of residence. The city-wide recommendations (co-produced during the Stage two group discussions) were also shared with the two citizen scientists unable to attend in-person and discussed to determine their relevance and suitability. At the end of all discussion groups, as per *Our Voice* guidelines, each citizen scientist received a community advocacy handbook describing generic steps and processes for engagement in advocacy activities.

2.3.3. Stage three – discuss together workshops

Two public engagement workshops were held with citizen scientists (n = 14) and community stakeholders (n = 15) in Birmingham City Centre during November 2021. The workshop aimed to: 1) facilitate discussions of the data-informed city-wide recommendations among citizen scientists, community stakeholders and researchers; and 2) strengthen the city-wide recommendations by identifying actionable routes to their implementation. GW facilitated the workshops by sharing the six city-wide recommendations and for each recommendation, asking stakeholders four questions to identify barriers and facilitators to implementation and stakeholder involvement. These discussions led citizen scientists and community stakeholders to propose actions taking into account individual- and organisational-level factors as well as partnerships and/or resources required.

2.4. Data analysis

Data generated in Stages one and two were co-produced and interpreted directly by the citizen scientists. Discussions held during Stages two and three were audio-recorded and transcribed, with reflective and summative notes taken by GW. All audio data and transcripts were anonymised and stored securely on a University of Birmingham research data server. Using NVivo 12 Software (QSR International Australia), transcripts were analysed through inductive thematic analysis (Braun and Clarke, 2006; Saldaña, 2016). Both latent and semantic coding (Terry et al., 2017) were completed to capture the barriers and facilitator themes to implementing the city-wide recommendations discussed by citizen scientists and stakeholders. The themes informed the development of an implementation framework for putting the city-wide recommendations into action across the local and city levels of Birmingham, alongside the production of a user-friendly guide for making Birmingham more age-friendly. The implementation framework was also mapped against the World Health Organization (WHO) Age-friendly cities model (WHO 2007a; 2007b) to identify similarities and differences (See Supplementary Material 1).

The area-specific and city-wide recommendations co-produced at Stage two and the implementation framework developed at Stage three were shared via email with citizen scientists and community stakeholders, with an invitation to review and provide feedback. Email, Zoom and telephone discussions were held with citizen scientists and stakeholders during this member checking process, with further clarifications made by GW to the ideas based on these discussions. Employing this type of "member checking" allowed citizen scientists and stakeholders to review the study data, ideas guide, analysis description and interpretation for validity and accuracy of what was collected or discussed (Caretta and Pérez, 2019). This facilitated the opportunity for those engaged to be reflective about the interactions that occurred and build a consensus towards priority findings to be disseminated to the wider public (Cahill and Torre, 2007; Madill and Sullivan, 2018).

3. Results

Fourteen citizen scientists (Mean age = 72 [SD 7.6] years) engaged in Stages one, two and three (See Appendix 1). For Stage one, walks ranged from 20 to 120 min [Average minutes = 62 (SD 34.5)]. Due to health reasons, one citizen scientist was unable to engage in Stage three. Citizen scientists were predominantly women (n = 9), White British (n = 8), retired (n = 12), educated to university level and above (n = 10) and lived in Birmingham for over 30 years (n = 10). Citizen scientists lived in 11 of the 69 wards across Birmingham, representing areas where older adults aged 60 and above make up 15.6%–33.1% of the population. Based on the indices of multiple deprivation, nine wards represented 10%–40% of the most deprived areas nationally in the UK and two wards represented the least deprived 50% of areas nationally (Birmingham City Council, 2019). Fifteen community stakeholders took part in Stage three only and were predominantly women (n = 9) and from Ageing Well and urban planning community organisations, charities and municipal services. No other demographic information was collected from stakeholders.

3.1. Area-based recommendations

Citizen scientists created 12 area-based recommendations (Table 1). Citizen scientists highlighted green spaces in six of the 12 recommendations, underscoring the need for increased maintenance and development services to facilitate accessible green spaces. Providing accessible and good quality toilet and water facilities was also important for older residents to spend time in green spaces. Citizen scientists highlighted the importance of outdoor spaces in six recommendations, demonstrating a need to provide maintenance and repair services, such as cutting back trees and cleaning up leaves. This included mending and maintaining broken pavements, as well as using tarmac rather than slabs, to reduce falls on pavements that are caused by parked cars. The citizen scientists also recommended altering the location of a "low-traffic neighbourhood" initiative due to subsequent increase of traffic impacting air quality in diverted areas.

Private transportation and parking were express concerns of the citizen scientists in four recommendations. They highlighted a need to provide stronger enforcement of cars parking on pavements, particularly during school drop-off and pick-up times. Lastly, two recommendations underscored a need for community integration and cohesion in public and green spaces. Meeting these needs requires long-term plans and joined-up thinking for local services and spaces that could better support older adults in integrating into their communities. This includes providing opportunities for intergenerational interaction, care and maintenance of local and green spaces.

3.2. City-wide recommendations

Citizen scientists co-produced six city-wide recommendations collectively for urban spaces across Birmingham (Table 2). Five out of the six collective recommendations were similar to the area-based recommendations (See Supplementary material 2), including features across the environmental, socio-cultural and economic domains of local urban areas.

3.3. Implementation framework

Based on the city-wide co-produced recommendations, Stage three

Table 1
The 12 area-based recommendations identified by citizen scientists.

Area-Based Recommendations
1. Clear public pedestrian areas and footpaths of fallen leaves, bushy areas and cut back trees
2. Put in a café, toilets, and community hub to create a community space at the local park
3. Make public toilet facilities available in public and green spaces
4. a) Provide greater access to public conveniences b) Maintain the development of beautiful green spaces across Birmingham
5. a) Make walking areas in open and green spaces clean, pleasant and well-maintained b) Provide a needed bicycle pathway throughout the city
6. a) Mend and maintain pavements b) Use tarmac rather than paving slabs
7. a) Change the location of the current Low Traffic Neighbourhoods on the high street b) Provide stronger enforcement of drivers who park cars in local areas
8. Stop drivers who park their cars in local areas for school pick-up and drop-off in residential cul-de-sac
9. Provide stricter enforcement of speeding and a 20mph speed limit in residential areas
10. Stop drivers who park their cars on pavements
11. Encourage local communities to be proud of their green spaces and appreciate how important they are to the environment
12. a) Provide a plan for integrating communities that can a) support older and younger groups, employment services b) provide maintenance of green spaces

Table 2
City-wide recommendations co-produced by citizen scientists.

City-Wide Recommendations
1. Provide funding for maintenance, services, and care for public and green spaces
2. Provide toilets in public and green spaces
3. Enforce and regulate cars parked in local areas
4. Provide digital and non-digital access to local information and resources
5. Improve green spaces and communication services from the city council
6. Improve and enhance community cohesion

workshop discussions between community stakeholders, citizen scientists and the researcher led to the development of an implementation framework. The thematic analysis of workshop discussions revealed a range of barriers to and facilitators of implementing the six city-wide recommendations (Table 2). The city-wide recommendations identified by citizen scientists to be relevant and applicable across the entire city were then discussed in detail with community stakeholders. This led to the development of actions through which urban environments across Birmingham could be altered or enhanced. Encompassing these actions, the implementation framework lays out pathways for enacting the city-wide recommendations across four levels: *local communities, public health and planning, business and private sector*, and *public health policy* (Fig. 2). Examples of these actionable pathways and their terms are explored in the sections below.

Examples of implementation actions and actors across each of the four levels were identified by this framework. *Local communities* encompass active residents who can develop a locally-focused agenda, proactively guide councils for desired services and engage younger age groups in maintenance services. *Public health and planning* can reduce their risk adversity and trust volunteers to support service delivery traditionally allocated to paid-staff in local authorities. Requested services can also be embedded in current community programmes and the proactive communication with residents about the feasible services can be provided. *Business and private sector* can generate volunteers for maintenance duties and underwrite events in green spaces to generate local funding. Lastly, *public health policy* can implement educational programmes for young people on the importance of maintenance of public toilets for all age groups as a way of "marrying-up" the issue of vandalism with maintenance of public toilets. As a strategic policy action, public health policy can also promote a city which supports independence, confidence, connections with each other and inclusive spaces where older adults can flourish. Both *public health and planning* and *business and private sector* merged across certain actions. For example, implementing the community toilet scheme requires reduction of business rates, engagement with local assets such as shops and demonstration to local assets that older adults using their toilets may become new customers. The development of an active community infrastructure also requires the creation of safe and comfortable shared community environments that can facilitate 'bumping' places in local assets where residents can casually meet and connect.

Mapping the city-wide recommendations and their implementation framework actions against the WHO Age-Friendly Cities model and its eight topics (Fig. 2) highlighted several similarities (See Supplementary Material 1). This demonstrated that the WHO domains are universal and suitable for application across diverse cities. WHO Domain #5, *Respect and Social Inclusion*, for example, was an element of all six city-wide recommendations (e.g., listening to older adult voices, facilitating intergenerational interactions, public education to raise awareness of ageing and facilitating older adults to have an inclusive role in local places). WHO Domain #1, *Outdoor Spaces and Buildings*, was identified in five recommendations (e.g., provide pleasant, clean and safe outdoor environments with age-friendly pavements, adequate public toilets,

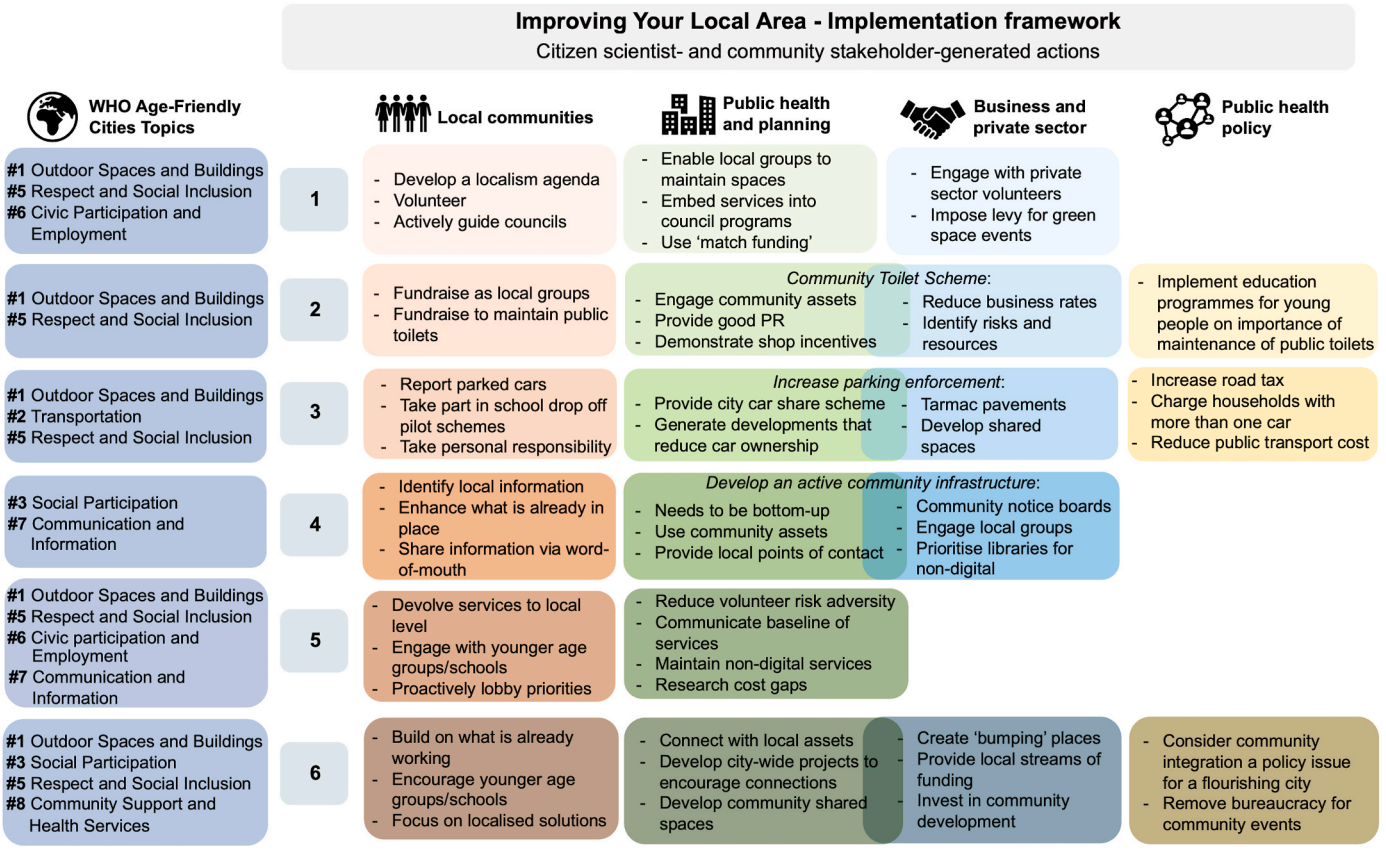

Fig. 2. Implementation framework: Birmingham Citizen Scientists City-Wide Recommendations and Corresponding WHO Age-Friendly Cities Domains (WHO, 2007a; 2007b).

well-maintained green spaces and services that are situated close together). WHO Domains #3 *Social Participation*, #6 *Civic Participation* and Employment and #7 *Communication and Information* were identified in two recommendations. WHO Domain #2, *Transportation,* was identified in recommendation three only and WHO Domain #8, *Community support and health services,* was identified in recommendation six only. Lastly, WHO Domain #4 *Housing*, was a topic not identified in any of the city-wide recommendations.

Facilitating discussions of the citizen scientists' city-wide recommendations with a range of community stakeholders led to the identification of further detailed actions and pathways. This enabled the development of an implementation framework that reinforces and brings local focus to the WHO's eight topics whilst elucidating actions and pathways that can bring together different levels, stakeholders and actors across a city. For example, recommendation three for more enforcement of parking in local areas was also present in the WHO guidance, which identifies a need for enforcement of traffic rules and adequate parking for older adults. The implementation framework encompassed these factors and built on them further, including local residents reporting pedestrian barriers related to parked cars (*local communities*), providing a city car share scheme, developing genuine shared spaces between pedestrians and cars (*public health, planning and business*) and increasing road tax and reducing costs of public transportation (*public health policy*).

4. Discussion

Informed by the *Our Voice* CS method, this study actively engaged citizen scientists and community stakeholders to: i) identify urban barriers and facilitators and; ii) co-produce a set of actionable area-specific and city-wide recommendations for improving urban environments. . Citizen scientists directly identified urban features impacting the safety and use of everyday urban spaces, including public toilets, well-maintained green and public spaces and enforcement of car parking. These features captured the micro-scale interactions and decisions that occur in older adults' daily life in the city.

Systematically capturing and activating the wisdom or lived experience of citizen scientists can enable stronger resilience and capacities of local urban communities, as well as cities as a whole. For example, place-based initiatives can identify both contextual and compositional elements that highlight the characteristics and relationships that occur between local places and their residents. Engaging local residents directly increases the relevance and effectiveness of a broader range of health-enabling initiatives (McGowan et al., 2021; Cummins et al., 2007). Integrating this micro-scale context and local-level understanding can inform suitable and timely urban actions that meet the needs of residents whilst providing relevant pathways to sustainably address these needs as cities continue to grow and develop (Nel et al., 2018; Sharifi, 2019; Suarez-Balcazar et al., 2020). More specifically, encompassing experiential knowledge of urban residents is crucial for providing urban planning practices that can reduce the exacerbation of exclusion, health disparities and unsustainable environments for older residents (Greed, 2011).

The *Our Voice* CS method enabled a step in the direction of social transformation by actively engaging citizen scientists and stakeholders in solution-building and the formation of recommendations for mobilizing improvements in local urban areas (Benjamin-Thomas et al., 2018). Co-producing a set of recommendations with citizen scientists and sharing these with stakeholders shifted the identification of urban features past identifying and describing urban environments only. Instead, it provided a deeper dialogue of local-level understanding that encompassed collective citizen scientist urban experiences and needs and the actioning of potential stakeholder levers for initiating urban change (Needham, 2008). Shifting the power of data generation and use to citizen scientists and community stakeholders promotes democratic processes for the improvement of urban environments and stronger connections with stakeholders that can work towards positively influencing governance. This holds legitimacy for delivering more beneficial and responsive features and services to meet the needs of ageing urban residents (Cowie and Davoudi, 2015; Connelly et al., 2020).

The implementation framework (Fig. 2) was built on a foundation of age-friendly change directed by citizen scientists and was further guided by community stakeholders who identified potential levers for actioning change across a city and its different levels. Positioning this framework in a social-ecological and multi-level systems perspective (De Vos et al., 2019) enabled the identification of ways to activate these urban changes (Krefis et al., 2018) and effectively facilitate improvements within a city and its local places (Foster-Fishman et al., 2007). For example, applying this perspective to recommendation six (enhancing community integration), actions were considered across levels of the city through local responsibility (individual), community care for green spaces (environmental), bringing together different age groups and ethnicities (socio--cultural) and providing employment opportunities and funding for local services (economic and political).

Many previous age-friendly initiatives have been small-scale, focusing on individual elements such as service provision and lacking the understanding of systemic issues, capacities of actors and the complex challenges faced by older adults in the context of urban environments (Joy, 2021). In comparison, universal guidance at a level that is too high to capture the smaller yet meaningful elements of everyday life may exclude the context-specific aspects such as barriers faced by specific communities or the impact of neighbourhood alterations on social cohesion (Greed, 2011; Scharlach, 2016; Wood et al., 2022a). The comparison of the implementation framework with the WHO Age-Friendly Cities topics identified overlapping ideas and relevance of this framework for actioning this age-friendly agenda locally. The implementation framework is built on the values and preferences of local residents and city-level stakeholders and identifies the potential levers for change. This presents opportunities for these different actors and process to collaborate together to action urban change (Hogan et al., 2015; Foster-Fishman et al., 2007; Rounsevell et al., 2012).

This implementation framework will be employed in the next stage of our research, where advocacy and actioning of the identified recommendations will be targeted. These next steps could include bringing together the city-level stakeholders identified by across the four-levels of the framework to further discuss and explore the age-friendly actions and the resources or power required to achieve them. This holds potential for ways to identify responsibility for these actions and potential pathways for community-level and policy-level advocacy, alongside ways to develop these actions into concrete processes for enacting change to promote active and healthy ageing (Okop et al., 2021). This is currently being explored in the city of Birmingham, with the implementation framework and a user-friendly booklet containing the co-produced recommendations and ideas guide developed with community stakeholders (Supplementary material 3). This has been shared with city council members currently exploring ways to achieve WHO Age-Friendly Cities accreditation.

Key strengths of this study include the direct engagement and co-production of activities with citizen scientists and community stakeholders, facilitated by the *Our Voice* CS method. This enabled the development of area-specific and city-wide recommendations that encompassed urban features influencing active and healthy ageing and identified solutions and pathways to promoting community health. This can inform local place-based and wider city level decision-making for developing urban environments based on the needs and experiences of older adults.

Birmingham is a superdiverse city presenting a range of experiences across urban spaces (Harries et al., 2019), alongside increasing levels of health and social inequalities (Thompson, 2014). One limitation of this study was that the citizen scientists engaged were mainly White English and female. Future research should aim to engage more ethnically diverse individuals, ensuring the representation of voices from a wider

range of communities. Feedback about the ease of use of the Discovery Tool highlighted that in the future citizen scientists should also be provided with more training to enable its effective use. In addition, having trained citizen scientists take turns using the Discovery Tool in pairs could, as found in some studies, provide additional social support for using the tool (King et al., 2020).

Employing CS is an approach to further addressing health equity for citizen scientists in their local places by bringing together local community insights and drawing upon stakeholder views and resources to begin to address governance issues in the context of an urban setting. However, there was insufficient time and resources to fully engage citizen scientists and the multiple participating stakeholders in the final "action" stage (Stage four) of the *Our Voice* citizen science participatory research-to-action method. This stage involves putting into effect the specific action plans identified as high priority and feasible in Stage three of this method (King et al., 2019). It also involves the systematic evaluation of the cascade of impacts and outcomes that can occur over time as community members, stakeholders and researchers together build efficacy as agents of change in their own communities. One increasingly popular method of doing so, called Ripple Effects Mapping. This involves the collaborative participation of citizen scientists, stakeholders and researchers in a qualitative method that systematically aims to capture all of the multi-level impacts, both expected and unexpected, often accompanying this type of participatory research-to-action method over time (King et al., 2021).

The localised issues and recommendations highlighted by this study when shared across the city and its multi-levels and actors may instead contribute to collective concerns that can lead to wider scale change. Using CS approaches to bring individuals together as collective can also encourage further active participation, local capacity and heightened awareness to address urban improvements (Rubio et al., 2021; Sheats et al., 2017). Further consideration of the broader structural drivers of urban health inequalities is needed in order to produce substantial health equity impacts. Future research should aim to engage with a wider set of actors, including policymakers and further evaluate the types of governance present within a city as a way of understanding how health inequities and urban changes co-occur and might be effectively impacted. To this point, the implementation framework was informed by this local placed-based approach and provided pathways for scaling up actions across social-ecological systems and multiple levels of impact. It is important to acknowledge that local places operate within a range of interacting and competing urban elements, agendas and context-specific decision-making and political structures (Greed, 2011; Nel et al., 2018). Changes also made within one part of a city's system can influence another or multiple parts of the same system (Duit and Galaz, 2008; Pei et al., 2019). It is therefore important to consider changes made as a continual process, rather than a static end point (Foster-Fishman et al., 2007).

5. Conclusion

This study engaged citizen scientists and a range of community stakeholders across Birmingham, applying the *Our Voice* CS method. This enabled citizen scientists to directly identify urban barriers and facilitators that influence their active and healthy ageing experiences and co-produce recommendations for improving their local areas. The similarity between the area-specific and city-level recommendations, alongside their overlapping ideas with the WHO Age-Friendly Cities topics, demonstrated interconnected features across public and green spaces in Birmingham that have local level importance and foster shared benefits for both the individuals and the collective group. Sharing these recommendations through a dialogue between citizen scientists and community stakeholders also elicited an implementation framework containing a set of actionable multi-level pathways for promoting active and healthy ageing.

Ethics information

Approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee ERN_20–0222.

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Author contributions

Grace Wood led the recruitment and data collection. Grace Wood, Afroditi Stathi, Jessica Pykett, Ann Banchoff and Abby King contributed towards the study design. Grace Wood, Afroditi Stathi and Jessica Pykett led the data analysis. Grace Wood drafted the manuscript with the critical input from all other authors. Afroditi Stathi obtained funding for the study. All authors have read and approved the final draft.

Data accessibility statement

The data that support the findings of this study are available in the supplementary material and from the corresponding author upon reasonable request.

Declaration of competing interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2022.102954.

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