Walk-along and cycle-along:

Assessing the benefits of the Connswater Community Greenway in Belfast, UK

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Foreword from the Chair of the Property Research Trust

We are all affected by the physical environment in which we live - not just the buildings that we inhabit, but our wider surrounding; the roads and pathways, green and open spaces and our waterways. All these help to shape our behaviours, our moods and thinking, and can have profound impacts on our health, well-being and sense of security. Also, if they are welcoming and well-designed they can have a positive influence on how physically active we are. City and local governments around the world have long been aware of this, and many have invested in initiatives such as pocket parks and urban greenways to improve their residents' experiences of, and hence participation in, the outdoor world.

Unfortunately, the evidence base on how people respond to such developments is not as rich as it should be, partly because of difficulties in collecting the necessary information in ways in which those approached will engage openly and constructively. This paper, by a cross-disciplinary team of academics, is therefore very welcome, utilising as it does a newly-emerging research methodology—Walk along and Cycle along—and setting out some of the insights gained. The method has succeeded in gaining results which will be of use to spatial planners and developers to guide future initiatives, and so help residents to live potentially healthier, happier lives. I am delighted that the Property Research Trust was able to fund and now publish this research.

Sarah Sayce
Chair
Property Research Trust

Key points

- Physical inactivity is a risk factor for numerous chronic diseases, and a mounting global health problem.
- It is likely that the outdoor physical environment, together with social environmental factors, has a tendency to either promote or discourage physical activity, not least in cities and other urban areas.
- However, the evidence base on this is sparse, making it hard to identify the best policy interventions to make, at the local or city level.
- This study seeks to assess the impact of one such intervention, the Connswater Community Greenway CCG), in Belfast, in Northern Ireland, UK.
- To do that it uses innovative methodologies, such as wearable sensors and video footages, to improve our understanding of the impact of the CCG on local residents.
- We call this research approach 'Walk-along and Cycle-along'.
- The findings suggest that four characteristics of the CCG affect people's activity and the benefits that the CCG created. These are physical factors, social factors, policy factors and individual factors. Each of these has many elements, with different impacts on different people using the greenway.
- The benefits are also diverse, including improving social bonds and mental health as well as physical fitness.
- Evidence such as this help local and city governments identify what characteristics of interventions, of which the CCG is an example, are most

likely to improve people's well-being, and what potential barriers or difficulties to avoid.

Executive summary

Physical inactivity, a risk factor for numerous chronic diseases, is a mounting global public health problem. The WHO estimates that 3.3 million deaths each year are attributable to insufficient physical activity, making it the fourth leading underlying cause of mortality.

Both the physical built environment and social environmental features are likely to facilitate or constrain physical activity. The provision of footpaths, pedestrian crossings, segregated bicycle facilities on major roads, traffic signals for pedestrians and bicyclists, and traffic-calming approaches, are all known to increase physical activity. In contrast, car dominance, the absence of activity-friendly infrastructure, and restricted access to green and public spaces, are barriers to physical activity. Factors in the social environment that influence physical activity include those related to perceptions of safety, violence, and social disorder in general, and more specific factors related to the type, quality, and stability of social connections, including social cohesion, trust, social support, social participation, and social capital.

However, most of the evidence for the health benefits of environmental interventions stems from small, short-term quasi-experimental or cross-sectional observational studies, and to a lesser extent from longitudinal observational studies. The evidence from intervention studies is sparse, and knowledge of the effectiveness of environmental interventions or policies remains limited by a lack of evaluation evidence. Thus, it remains a challenge to identify and implement specific environmental interventions that are likely to have the most significant impacts on physical activity in individuals or populations.

The purposes of this study are two-fold.

First, we explore the influences of individual, community and environmental factors on physical activity, as hypothesised in ecological models. Specifically, we describe and assess the impact of an urban greenway, the Connswater Community Greenway (CCG), in an area of high deprivation in Belfast, in Northern Ireland, UK.

Second, we investigate the value of innovative methodologies such as wearable sensors and video footage towards developing an improved understanding of the direct and indirect health benefits of an intervention such as the CCG.

Our interdisciplinary study crosses traditional boundaries between broadly defined fields representing health, including public health, exercise science, and behavioural sciences; city planning, including travel behaviour, land use planning and urban design; and parks, recreation, and leisure sciences. We

demonstrate the feasibility of assessing the impact of an environmental intervention in real-time, using emerging technologies, and we discuss how this information can guide decisions about what must change in order to create healthy and sustainable cities.

Central to our research was the use of 'Walk-Along and Cycle-Along' techniques whereby we arranged to interview people while they were walking or cycling through the greenway. This meant that their responses to our questions were directly affected by the experience of being in the environment, rather than being garnered subsequently in the very different conditions of an interview room.

We used modern wearable technologies to capture people's experiences of the greenway, alongside recording their words, so that we could assess how one shaped the other.

We see this as a vital complement to another technique, that of analysing 'Big Data', which also has a role to play in shaping how initiatives such as the CCG are designed or remodelled.

Several key results with regard to the CCG emerge from our work. Our analysis suggested that the characteristics of the greenway affected people's use of it in four broad ways, which we have labelled physical factors; social factors; policy factors; and individual factors. We take them in turn.

Regarding **physical factors**, the CCG walkways and cycle paths were the most commonly used physical activity areas, while participants with younger children preferred play parks and green spaces, easily accessible and near their homes. Participants emphasised the supportive features that made it possible for pedestrians and cyclists to co-exist in the same space. At the micro-scale, good lighting in the evening and at night and availability of wide, even surfaces and pathways were important issues for cyclists. Participants appreciated pleasing views of the blue and green spaces along the CCG and the simple pleasure of experiencing wildlife in an urban situation. However, risks from traffic and perceived safety were key concerns among several residents, with many commonly-reported barriers to physical activity, including for example fear of collisions between pedestrians and cyclists perceived lack of safe street crossings, and concerns over the attitudes of car drivers towards cyclists and pedestrians and the need to educate different users of the greenway including cyclists and dog walkers. More positively, participants appreciated the development of new hotels, restaurants, heritage and tourism trails that have attracted visitors and created multicultural, vibrant spaces.

Regarding **social factors**, participants described the greenway as a catalyst for meeting new people and improved social interaction. The greenway was perceived as a place that attracted new people and enriched the local community. While personal goals or desires were achieved, community building and increased social capital also emerged. Individual and community benefits, improved health, and social resilience were reported as key outcomes. Participants also appreciated

the social and cultural events organised by the CCG leadership team, which helped residents to develop social bonds. Activity along the CCG and the presence of other people provided participants with a sense of security and older adults expressed a feeling of nostalgia and a sense of feeling at home along the CCG while being around various age groups.

Where **policy factors** were mentioned, participants were critical of local civic authorities for prioritising parking and motorised traffic in planning regulations, while neglecting the needs of other vulnerable road users. Threats from motorised traffic, and lack of priority given to pedestrians and bicyclists in local planning policy, emerged as key issues.

Some interviewees emphasised **individual factors** that affected their active travel along the greenway, including parameters such as commute times, destination distance, route convenience, weather, and the time of day, and also health including mental health. Differences were observed between participants who were experienced cyclists and used the bicycle for daily commutes to work, in comparison with others who only walked or cycled for recreation and leisure purposes.

Some participants who cycled to work in areas without defined or segregated cycle lanes expressed safety concerns and said they tended to avoid peak traffic hours. But several participants reported improved physical and mental health, and some shared that the segregated, safe greenway paths were supporting their recovery from illness and contributing to better mental health

1 Existing research base & policy agenda

1.1 Evidence on the importance of activity to health

Levels of physical inactivity are rising worldwide and are estimated to be the principal cause for 30% of chronic or non-communicable diseases such as obesity, diabetes, cancer and cardiovascular diseases.[4, 14] Public Health England estimate that physical inactivity is responsible for one in six deaths in the UK (equal to smoking), and is the fourth-largest cause of mortality. Inactive lifestyles lead to increases in healthcare expenditure, productivity losses and reduced quality of life.[5] The consequent economic burden imposed by physical inactivity on society is considerable. Physical inactivity is estimated to cost £7.4 billion annually, including a direct expenditure of £0.9 billion incurred by the National Health Service, causing a considerable financial public health burden.[5] Around 1 in 3 (34%) of men and 2 in 5 (42%) of women are not active enough for good health, and people with disabilities or long-term conditions are twice as likely not to be active enough for good health.[5, 6] The UK population is around 20% less active than in the 1960s, and if current trends continue, it will be altogether 35% less active by 2030.[4]

Walking and cycling are recommended forms of moderate-to-vigorous physical activity that can serve as means of travel to substitute for short car trips and are feasible ways for people to incorporate regular physical activity into their daily lives. The use of public transport usually involves walking or cycling to and from transit stops and can contribute to overall physical activity. The promotion of walking, bicycling, use of public transport, and other non-motorised means of travel, collectively referred to as active travel or active mobility, is a key strategy to increase physical activity.[15] Active travel can be incorporated into people's daily routines, and can therefore be more easily adopted and maintained than other forms of physical activity.[16]

Active commuters tend to achieve greater levels of physical activity than those who use cars.[17] Active travel can also bring a range of environmental, economic and social benefits by alleviating the effects of air pollution caused by vehicular traffic, reducing traffic-related injuries and mortality rates, encouraging social interactions and promoting good health.[16, 18, 19] Scientific guidelines issued by various international organisations such as the United Nations and the World Health Organisation have recommended increasing physical activity as a key strategy for reducing the impact of non-communicable diseases, with

modification of the built environment to support physical activity as an important focus area.[1, 20]

1.2 Evidence on activity-friendly neighbourhoods

A growing body of research has established that walkable, activity-friendly neighbourhoods promote healthy living patterns.[21, 22] Studies have demonstrated that individuals in more walkable, mixed-use, and transit-accessible neighbourhoods tend to walk or bicycle more and have a lower likelihood of obesity than those in automobile-dependent neighbourhoods.[23, 24] Walkable neighbourhoods depend upon an appropriate integration of land use and transportation infrastructure, including higher densities, a mix of residential and commercial land use, connected systems of footpaths (sidewalks), bicycle lanes, greenways, and public transit.[7, 9] Mounting research evidence also suggests that dense, walkable settlement patterns are an important strategy to respond to the challenges of sustainable development given their tremendous potential for reducing automobile travel and lowering greenhouse gas emissions.[25]

Many features of the built and social environment can facilitate or constrain physical activity. Footpaths, crosswalks, protected bicycle lanes, the availability of bike storage, and access to public transport make it easier for people to have active commutes.[7] Similarly, access to public transport is linked to increased physical activity since it gives people a chance to walk to and from a train station or bus stop.[26] An essential aspect of walkability is having local shopping areas near the places people live and work. The presence and proximity to shops, essential services, and amenities are positively correlated with the probability of residents walking or cycling.[27] Parks, playgrounds, and other urban green and blue spaces are also proven to improve mental health and well-being by reducing stress, stimulating cognitive function, enhancing social cohesion, and supporting physical activity.[28]

The social environment has also been examined in relation to physical activity. High crime rates, antisocial behaviour, personal safety concerns, risk of traffic injury, and limited public transport infrastructure (poor street access, number of roads to cross, traffic density/speed) are related to decreased levels of physical activity.[29, 30] Signs of social disorder such as litter, broken glass, unkempt grass, poor lighting, or lack of recreational equipment in playgrounds and parks are negatively associated with physical activity.[31-33]

Variations in perception of safety across different age groups have also been documented. For example, older adults may be less likely to go to an area because of uneven footpaths or roads that are perceived to be dangerous for those with reduced mobility or a decreased ability to react to danger.[34] Others may associate an area where youths display antisocial behaviour as unsafe, while the youths themselves may see it as a fun area to 'hang out'.[35] These perceptions of the built environment may be subjective—some may find a park peaceful and tranquil,

whereas others may avoid the same area because they perceive the space to exhibit high noise levels.[36]

The environment impacts both individuals and whole communities. Environmental interventions have been recommended worldwide for physical activity promotion, because they can influence large groups and result in population-wide change.[37] Such interventions include the provision of cycle infrastructure, the pedestrianisation of streets, or the creation of local parks which create or improve active travel routes.

1.3 Methods of collecting the evidence: big data & city planning

Any policies that involve changing the environment to increase population-level physical activity should ideally be based on evidence-based data and precise measurements.[38] Much of the existing evidence for health benefits of urban interventions stems from small, short-term quasi-experimental or cross-sectional observational studies, and to a lesser extent longitudinal observational studies, but the evidence from intervention studies is limited.[13] To date, studies seeking to quantify how features or changes in the environment impact physical activity have employed extensive in-the-field observation, often providing a limited view of behaviours at a specific point in time.[39] Objective, real-time assessment of environments where physical activity occurs is challenging, due to methodological weaknesses and data gaps.

In recent years there has, however, been a surge in the use of big data to analyse complex urban planning problems and improve decision-making.[40] Although the term 'big data' is relatively new, its origin dates back to the 1960s and 1970s when the first data centres were established. Big data is defined as a collection of large data sets that require advanced methods of analysis and efficient processing of large heterogeneity of information.[41] Big data includes more extensive, complex data sets, especially from new data sources.

A growing body of research uses digital city models and metrics to calculate and quantify different aspects of urban form. New data technology offers numerous opportunities to measure complex urban environments efficiently.[42] Current applications of big data in urban planning have provided enhanced insights into public behaviour and citizens' needs via space-time information. Big data has become essential for providing additional information, usually not covered through traditional data collection methods. For example, online surveys, imagery databases and mobile apps can be ground-breaking for understanding the relationship between the environment, physical activity, travel behaviour and effects on people's lifestyles.[39]

Technological advances in the capture and storage of data affect our potential to monitor both human behaviour and the environment, thus providing possibilities to track and triangulate diverse data sets. Recent studies have explored the potential of big data integration with sustainable transport planning policies

and applied big data analytics for real-time monitoring of transport systems.[43-45] Researchers have investigated the impact of walking and cycling infrastructure using publicly accessible data from web cameras, GPS and bike-sharing programs, mobile apps, social media data and Google Street View.[45, 46] Studies have also used big data to analyse features such as streetscapes, greenery, lighting, and the impacts of environmental factors on residents' physical activity.[47]

However, there are some challenges. Studies analysing user-generated data, for example, pedestrians and cyclist counts from one big data source such as social media or tracking devices, are limited in accuracy as they do not adequately connect physical activity to the environment.[48] The environmental context where behaviour is performed strongly influences habit formation, yet few studies capture user perceptions, emotions and characteristics about their behaviour in the physical setting.[49] Most of the studies on physical activity are quantitative and do not capture the real-time lived experience of users. Key variables linking physical activity and socio-demographic conditions may not be fully represented when referring to information from one data source. Big data can fill these gaps, and improve accuracy by supplementing details that cannot be solely obtained from traditional qualitative and quantitative research methods.

1.4 Wearable technologies to track urban mobility

It can reasonably be argued that big data sources need to be combined, both with geodata (e.g., land-use, terrain morphology), and with self-reported information and sample information, based on surveys and interviews, to better support users and inform planners and policymakers.[46]

To date, the vast majority of research on built environment exposures has used either self-reported instruments or census data. Studies seeking to quantify how features or changes in the built environment impact individuals' health behaviours have employed extensive in-the-field observation. However, these methods provide a limited view of behaviours at a specific point in time, their context, and how each changes as a function of the environment.[39] Researchers have therefore called for systematic, comprehensive measures and methods to quantify the impacts of built environment features on human health.[50]

The advent of new technologies such as webcams, live video streaming, social media, and crowdsourcing may address this need, by offering new opportunities to obtain geospatial data about neighbourhoods that may circumvent the limitations of traditional data sources used in urban planning research.[50, 51]

Over the last five years, the use of wearable technology, comprising devices whose embedded sensors and analytic algorithms can track, analyse and guide wearers' behaviour, has increased. Although people have long used simple, analog devices to record, reflect upon and regulate their bodily states and processes (for example, diaries, scales, wristwatches, thermometers), we are witnessing a

dramatic rise in the use of digital technology to self-track.[52] These new technologies offer the opportunity for real-time surveillance and monitoring of human behaviour, with significant health promotion and evaluation potential.

Wearable devices can be divided into head-mounted and bodily-placed devices.[53] Head-mounted devices are visual systems that enable hands-free use, and are currently used in surgery, healthcare simulation, education, and navigation for partially sighted people.[53] Bodily-placed instruments can be either wearable or portable. Wearable technologies include pedometers, accelerometers and GPS monitors that measure energy expenditure, movement patterns, physical activity levels and geolocations.[54] These devices are equipped with sensors that can detect human physiological statuses, such as heartbeat, blood pressure, body temperature, and complex vital signs (e.g., electrocardiograms).[55]

These modern devices are lightweight, small in size, and wearable on users' wrists. Consumer products from vendors such as Apple, with their Apple Watch, and Fitbit with their line of fitness bands, have become increasingly commonplace. With the introduction of these and similar devices, wearable sensors have become not only unobtrusive but a regular part of daily life for many people.[56]

These new technologies can also be used for research purposes. Researchers have employed wearable sensors and cameras with GPS devices to closely examine the relationship between physical activity and the built environment.[57] To best examine which properties of the built environment have the strongest influences on walking and cycling, wearable tracking devices can aid in tracking and quantifying human behavioural patterns in real-time.[55]

2 Applying new research methods in Belfast

The purpose of this study is two-fold. Firstly, we explore the concurrent influences of individual, community and environmental factors on physical activity, as hypothesised in ecological models of behaviour. Specifically, we describe and assess the impact of an urban greenway in a deprived region of Belfast (Northern Ireland, UK) to inform future interventions, and city planning policy.

Secondly, we investigate the value of innovative methodologies such as wearable sensors and video footage to provide an understanding of the direct public health benefits of this systems-level intervention, and related co-benefits in the environmental and socio-economic sectors. We also document policy barriers and facilitators of active travel along the greenway intervention.

2.1 The Connswater Community Greenway

The Connswater Community Greenway, http://www.communitygreenway.co.uk/, (CCG) is a major inner-city urban regeneration project in Belfast, in Northern Ireland. In November 2007, EastSide Partnership, a local community organisation dedicated to the redevelopment of East Belfast, secured funding totalling £40m for the development of the CCG from the Big Lottery's Living Landmarks programme, along with other funding from local government departments and the local city council. The original intention was for a three-year design-and-build project, with construction commencing in 2010. However, legal and contractual issues led to several substantial delays in the development of the CCG. Construction was completed in April 2017, and the CCG was opened officially in September 2017.

Specific aspects of the regeneration include: the creation of a nine km urban greenway along the course of three rivers (Connswater, Knock and Loop rivers), 16 km of new or improved foot and cycle paths, 5 km of remediated water courses, development of a new civic square, development of eight tourism and heritage trails, 23 new or improved bridges or crossings, 22 new signage points, installation of public art and sculptures, 13 hectares of upgraded parks, two multi-use outdoor play areas and two new public toilet facilities. A wildlife corridor was also created, following extensive landscaping and biodiversity enhancement efforts.

Due to decades of underinvestment in the area, the open spaces alongside the rivers were previously underused, inaccessible, unsafe and disconnected from the communities. The CCG has created a safe and welcoming public space for residents and visitors to East Belfast. It offers enhanced physical activity and outdoor recreation opportunities through an interconnected network of parks, green

spaces, pedestrian and bicycling infrastructure. The safety of the area was improved through CCTV cameras and 24 hour-a-day lighting, making it the first urban green space available 24 hours a day in Northern Ireland. Around 100,000 people living adjacent to CCG benefit from the CCG through new opportunities for physical activity, active travel, recreation, supporting a healthier lifestyle and a better living environment.

Community engagement, participation and provision of volunteering opportunities were key elements in the development of the CCG. The local community was involved in the naming of local bridges. Several community interventions to promote physical activity, ranging across the individual, community and environmental dimensions, were implemented. Education officers were employed to engage the schools and colleges near the CCG. To date, park wardens and greenway leaders have encouraged residents to be involved in maintaining their local section of the CCG. Social engagement and CCG promotion activities and events have also occurred, in parallel with physical changes to the intervention site.

This engagement was aimed at providing individuals with a sense of community ownership to the place. Overall, the CCG regeneration project has delivered environmental and socio-economic benefits by creating vibrant, attractive, safe and accessible parkland for leisure, recreation, community events and activities.

2.2 Methodological innovation: walk-along and cycle-along interviews

The development of the CCG provided an opportunity to evaluate the public health impact of a major urban regeneration project in Belfast.[58] For this project we examined the impact of this systems-wide community intervention on physical activity using novel technologies such as wearable sensors and video footage. Walk-along and cycle-along interviews using body-worn video cameras were conducted with residents to elicit responses during a journey along the CCG. These walk-along and cycle-along interviews provided a real-time, in-situ method of recording participants' experiences along the CCG.[59]

Walk-along and cycle-along interviews allow us to fill the gaps in knowledge that other forms of interviewing may not be able to offer.[34, 59] They allow the researcher the opportunity to study an area with specific social, cultural or historical context, and generate definitive information regarding environment and health that is dependent on a variety of theories and formats, each complementing one another by one's strong points overcoming another's weak points.

In framing our research, we recognized that it is plausible that in-person walk/cycle along interviews may be biased by the researcher's presence. In our study, remote recording using video cameras therefore allowed participants to choose their routes independently, thus providing

a truer picture of their experience in the environmental context.

This novel format of walk-along and cycle-along interviewing, also a form of physical activity, was the core research tool in this study, underpinned by the reasons described above. It allowed participants to observe and comment as they responded to various stimuli and factors in their immediate environment.

Using semi-structured interviews, we further explored how and why these environmental factors may influence the levels of physical activity of an individual, and why they chose a particular route along the CCG. Video recordings of journeys were used to facilitate these interviews with predetermined questions and a few improvised questions that varied depending on what the participant experienced.

2.3 Sampling and data collection

The study area for this project was defined as 22 electoral wards in the political constituency of the CCG, with a total population of approximately 87,500 residents. Seven of the wards are within the top 25% most deprived wards in Northern Ireland, as determined by the Northern Ireland Multiple Deprivation Measure.[60]

Between June 2019 and February 2020, participants (n=25) were recruited using a convenience sampling approach. Information about the study was distributed through flyers, social media and the CCG mailing list, requesting interested individuals to contact the research team for more information. A description of the project was provided to interested and eligible participants. Eligibility criteria for participants included: (i) aged 18 years or above, (ii) able to converse in English, (iii) able to walk or cycle for 30-45 minutes, and (iv) no visible signs of cognitive impairment.

An appointment to meet the researcher in a designated location along the CCG was made with individuals who agreed to participate. Participants provided written consent and agreed to participate in the walk-along or cycle-along. Study procedures were approved by the Research Ethics Committee at Queen's University Belfast, UK (reference number EPS 19_180).

Study participants ranged in age between 22 and 75 years (median age = 46 years), of which half (50.5%) were female. Key themes on the role of the environment for physical activity emerged through the process of inductive analysis. Participants discussed the benefits of urban green spaces, park quality and barriers to active travel. Experiences of the CCG varied among regular users, compared with new visitors who were unfamiliar with the area.

Although the journeys were unique to participants, there were many similarities in the participants' perceptions of built environment features. Some constraints were unique to individuals, but a majority were shared by participants. Notably, safety was perceived differently among the participants.

Each interview consisted of two stages, both of which were audio recorded. During the first stage of the interview, participants were asked questions that

assessed demographic characteristics, frequency of visits to local public spaces in a usual week, duration of visits, and types of physical activities normally performed in those spaces. In the second stage, participants completed walking (n=12) or cycling (n=13) journeys along the CCG. Participants selected their own routes and used a body-worn or bicycle-mounted portable digital video camera (GoPro HERO 3+ camera) to record the journey. This camera provided a high-quality, three-dimensional video of participants' journeys. The camera was only pointed at the surrounding area and was not used to record the participants' facial expressions or reactions.

After the walk or cycle ride, the recorded video was replayed to the participants. A semi-structured interview was conducted with each participant, using an interview guide developed for this study consisting of open-ended questions that encouraged participants to speak freely about what they felt was relevant and important in terms of their journey along the CCG.

The interviewee adopted a conversational style. The interview guide was used to navigate the conversation, with questions on perceptions of the built environment, quality of the greenway, neighbourhood parks and playgrounds, travel behaviours, choice of route, and social interactions with the community. Interviews were conducted during daylight hours and under good weather conditions, with each interview lasting between 55 to 75 minutes (mean=62 minutes). The routes (mean=1.5km) were determined by the participants and took place in plain sight along the main walking or cycling paths of the CCG, avoiding hidden or sheltered areas (e.g., densely planted paths, forest areas).

This qualitative study employed a grounded theory approach to estimate the sample size. Theoretical saturation of data was used as a parameter to determine the number of participants required for a detailed analysis.[61] There are no fixed sample sizes or standardised tests to estimate the amount of data needed for achieving saturation.[62] In this study, theoretical saturation was achieved where no new information, concepts or themes were emerging from the data.

2.4 Analysis

Audio recordings of interviews were transcribed verbatim and anonymised, and their accuracy double-checked by two members of the research team. The analysis was carried out through inductive thematic coding.[61] A nested coding structure was developed by the research team, and data was categorised into key themes by identifying and interpreting emerging patterns of meaning or common constructs within the qualitative data.[63]

All interview transcripts were analysed and independently coded by two members of the research team for consistency.

The coding structure was validated with the wider research team to refine and agree on codes, and ensure the validity of themes emerging from the data. This process was used to resolve any disagreements and reach a consensus for coding and data analysis. The coding was conducted alongside the video footage of

the journeys. Images from the videos were saved to capture the context for comments and added alongside the coding structure. Privacy was upheld throughout the data collection process, and images did not capture identifiable features of participants.

3 Results

Four broad regarding how the characteristics of the greenway affected people's use of it emerged from the data: (1) physical factors; (2) social factors; (3) policy factors; and (4) individual factors. We take them in turn.

3.1. Physical factors

The CCG walkways and cycle paths were the most commonly used physical activity areas. Participants with younger children preferred play parks and green spaces that were easily accessible and near their homes. The design and layout of the cycling and walking infrastructure and microscale street features were discussed. Participants emphasised the supportive features that made it possible for pedestrians and cyclists to co-exist in the same space. At the microscale, good lighting in the evening and at night and availability of wide, even surfaces and pathways were important issues for cyclists:

"It's a lovely space, big wide path around it now, which can comfortably accommodate cyclists and pedestrians, so feels very safe." (Male, age 65)

"That bit we just looked at the video that would be more what I would come here for leisure on a Sunday with a family or every Saturday come down, would come down this way to go to the park. It's not the quickest way but we do it because it's scenic." (Female, age 31)

"I like this bridge especially at night and because it's well lit up, so this is real kind of attraction and a safety feature. You don't feel like you're going to hit a pedestrian." (Female, age 28)

"I think because it is lit, it is flat, and it is open. You don't feel claustrophobic in the space or again you don't feel vulnerable in the space." (Male, age 48)

Participants appreciated pleasing views of the blue and green spaces along the CCG. The rejuvenated parks, rivers and woodland areas offered the simple pleasure of experiencing trees, birds, squirrels, and other wildlife in an urban situation:

"Wonderful again, because you're seeing the city, you're seeing the water, you're seeing the reflections, and if you look to your right, you're seeing all the boats. So really pleasant, feels spacious with the Odyssey building [a sports and entertainment complex] on your left. It's a nice, pleasant approach to the city centre and the new bridge." (Male, age 52)

"It really does feel like you're almost in the countryside here." (Female, age 66)

"It is green, I mean there's no wildflowers or anything particularly of interest along the side. It's pleasant enough but possibly it could be sort of more wildflowers… I really like the path, they've just cut the grass and I noticed that, so you know

possibly they could have let the grass grow a bit wild and got some more wildflowers and see wildflowers later in the park which are really dramatic." (Female, age 45)

"I did notice that it was going along, so you do hear some birds, bird song and things which is really nice, does give you the feel that you're actually, you know in the countryside in a nice rural setting." (Male, age 71)

"Along here is nice...something really exciting about it. There's just trees and stuff. Get a couple of squirrels every so often." (Female, age 56)

Some participants acknowledged the role of nature as a motivating factor to visit the greenway often and engage in physical activity:

"I think it's quite nice. And then there is lake here, and I saw some swans there, it is very lovely to see some wild animals in parks. And you can see the kids play with the birds...it's very nice park and in summertime I know this park is really beautiful. You can see the swans and pigeons. It's not very frequent to see these animals in parks in Belfast. So maybe that would be a motivation for me to visit this park again." (Female, age 48)

However, risks from traffic and perceived safety were key concerns among several residents. Lack of safe walking and cycling infrastructure (e.g., safe footpaths, crossings) and street lighting were commonly reported barriers to physical activity. Cyclists experienced difficulty in safely navigating a narrow poorly lit section that goes through a tunnel shared by cyclists, walkers and cars, and expressed concerns about visibility and street lighting:

"An issue I have with this part coming into the tunnel is that you really risk getting hit by a car because as the tunnel is really long and very dark you can't see out." (Male, age 33)

"The tunnel is a bit awkward. It's hard to see who's coming through the tunnel. On the way out, it's evident cars coming down and there's also some pedestrians in the tunnel so trying to manoeuvre around a car and pedestrians in the tunnel." (Female, age 41)

"Challenge is really going into Victoria Park because you've got a tunnel, so you do have to be careful particularly if you are with a group, you have to look out for the traffic, the visibility going into the park is a bit of a blind corner, dark in the tunnel, and it is not lit." (Male, age 44)

In contrast to sections that had wide footpaths, fear of collisions between pedestrians and cyclists was a concern in areas where cycle lanes and footpaths were not well-defined or segregated and the width of the footpath was narrower. Selecting a safe gap in which to cross in front of oncoming traffic was a challenge for cyclists at some street intersections:

"This is particularly a bad area now, from a cyclist point of view, because that not really thought out how best to cross here, now there's a new road going in, and we hope that they'll improve this crossing. This is again a safe wide footpath. You just need to be mindful that there's traffic about, and traffic cutting in here. So, good

sign to let you know you're on a route for pedestrians and cyclists." (Male, age 52)

Another cyclist expressed concerns about the lack of safe street crossings and the layout of streets:

"I think that Belfast is not very well designed for cyclists. There is no cycle path, if you want to cycle, technically you need to cycle on the roads. I don't feel quite safe to cycle if that is case." (Female, age 36)

"Like I'm in the middle of that tunnel, again, it's not really pleasant cycling closer to one side and the other, so you want to stay at the centre line." (Female, age 34)

Attitudes of car drivers towards cyclists and pedestrians were perceived as a threat. Participants expressed the need to educate different users of the greenway including cyclists and dog walkers. Some participants were discouraged by the lack of awareness of drivers within an industrial estate adjacent to the greenway:

"They don't tend to think that people are using that walkway. Because it's an industrial estate there is an assumption that it's cars and stuff so there's not a lot of foot passenger and so there's sometimes issues with them blocking the paving." (Female, age 46)

"A group of youth who were sitting in one of the play areas, smoking and drinking and others were throwing stones and bottles at each other… it was just sort of a riot situation, it was unpleasant." (Male, age 38)

"Try to educate people and make them think a bit more about their use of the greenway, whether it's cyclists who go too fast, and people with dogs either who should be on leads, or dogs that are on big, long leads, and people who just stop suddenly in the middle of the greenway." (Female, age 53)

Participants appreciated the development of new hotels, restaurants, heritage and tourism trails that have attracted visitors, tourists and created multicultural, vibrant spaces:

"Associating service with greenway if it was developed and even with like shops or retail units alone there. And bring up sort of the whole Connswater along. And, you know it would encourage more people to use that as a route into the square." (Male, age 62)

"It's more of a space regarded for the local community. It might be nice if there was maybe more international feel to it, something it was sort of benefiting tourists, maybe from the sort of international mix bringing visitors from the city centre here." (Female, age 56)

3.2. Social factors

Participants described the greenway as a catalyst for meeting new people and improved social interaction. The greenway was perceived as a place that attracted new people and enriched the local community. While personal goals or desires were achieved, community building and increased social capital also emerged. Individual and community benefits, improved health, and social resilience were reported as key outcomes.

"In terms of the greenway, and this infrastructure that currently is in place, it is

kind of a factor enabling people to talk to people who they don't know, talking to strangers that maybe you wouldn't normally do… I think it's hugely important. I mean along the greenway or in the park or C.S. Lewis square you meet people from different areas. On your street you meet your neighbours who are all maybe the same social status as yourself, but down here middle-class people can meet working-class, kids can meet adults. It's a big benefit, I think, of having a greenway." (Female, age 41)

"But I think particularly for people you know living in maybe you know built up areas or areas where they don't necessarily have a garden, having something like this on your doorstep as really a fabulous open space for people." (Female, age 45)

Participants appreciated the social and cultural events organised by the CCG leadership team. These events provided opportunities for social interaction and helped residents develop social bonds.

"I was thinking about there's an event here on Saturday. That's the 24 hours non-stop run. So, some people will run the equivalent of five marathons without stopping. They go all night, so I was starting to think a wee bit about that because we'll come down and watch that for a bit." (Male, age 62)

"Again, got litter bins good, well maintained area, there's a new shelter which is really good, and I noticed for events, so that's good to see, a thing that's just opened recently. And there's a play park here for children, so I always feel safe when I'm cycling around here." (Female, age 46)

"I think it is really a nice area, I think it's you know, attractive, they're obviously trying to improve it all the time. And they put in this, shelter for events and things, and it is seemingly well used for sporting events, so I think it is a well-used facility." (Female, age 34)

Participants reported increased communication and non-familial interactions between residents. The newly developed green infrastructure and rejuvenated public spaces provided opportunities for residents to enjoy the outdoors at their doorsteps and meet their neighbours in a safe and pleasant environment. Successful non-familial interactions were achieved through shared experiences and meaningful outdoor activities along the CCG:

"It's hugely important I mean along the Greenway or in the park or C.S. Lewis square you meet people from different areas. I mean you know, on your street you meet your neighbours who are all maybe the same social status as yourself." (Male, age 71)

"In terms of the greenway, and this infrastructure that currently is in place. Is it kind of a factor enabling people to talk to people who they don't know. You know talking to strangers that maybe you wouldn't normally do." (Male, age 62)

"We meet a lot of people here, say on a Sunday afternoon at C.S. Lewis square and we get down as a group, run Victoria Park and come back up to the square. So, it's a good area for teaching children to cycle or scoot." (Female, age 41)

"Having something like this on your doorstep as really a fabulous open space for people particularly living you know close proximity of this particular area and they have a place for children and for themselves to get out about and to enjoy." (Male, age 38)

Activity along the CCG and presence of other people provided participants with a sense of security. Older adults expressed a feeling of nostalgia and a sense of feeling at home along the CCG while being around various age groups:

"This is quite a residential area and I kind of know there are people around me, it is not an abandoned industrial area, so I still feel quite

safe and probably it is in the daytime so I'm not too worried about safety issues." (Female, age 53)

"There's a bunch of teenagers behind me, I was reminiscing a bit, long summer days, sitting around, kicking a ball around, football pitch at home." (Male, age 38)

3.3. Policy factors

Participants were critical of local civic authorities for prioritising parking and motorised traffic in planning regulations, while neglecting the needs of other vulnerable road users. Threats from motorised traffic, and lack of priority given to pedestrians and bicyclists in local planning policy, emerged as key issues:

"We have repeatedly submitted appeals to the city council to create a linked bicycle network, but no one has acknowledged our requests." (Male, age 52)

"We need to create more greenways across the city and the island at large. But sadly, policy makers are focused on providing more parking spaces and encouraging car-dependency. The greenway should be a role model for other councils and help them realise that green infrastructure has many benefits for health, physical and mental." (Male, age 44)

"I cycle to work every day. The greenway is excellent and safe, but the stretches where I have to cycle on the road are very risky. I am a member of a local bicycling community group and we have presented these issues to the authorities, but it is obvious that motorised traffic takes greater priority." (Female, age 28)

3.4. Individual factors

Some respondents stressed individual level factors affecting active travel, including parameters such as commute times, destination distance, route convenience, weather, and the time of day, and also health including mental health.

Many participants engaged in active travel along the most direct route for work journeys:

"It's basically a route to get you from A to B. It's not for the visual experience or the environmental experience. It's simply a functional cycling route, which I would use if it's wet cold one day. You know, it's the most direct route." (Male, age 33)

"So, it's really handy that if I'm coming home, and I'm like oh I need milk, I know there's a shop where I will have secure bike parking and it's easy access and I can do it and obviously it gets more difficult when I have a bigger shop because I don't have like a car." (Male, age 38)

Choice and motives for active travel trips depended on weather conditions and the time of the day. Differences were observed between participants who were experienced cyclists and used the bicycle for daily commutes to work, in comparison with others who only walked or cycled for recreation and leisure purposes.

"The weather can be a factor, but it only becomes more of a deciding factor when it's snowing or there is ice because the greenways aren't salted." (Male, age 71)

"I don't mind the rain because I've normally got my wet gear, but if it's windy

at the same time as rain, that's tough. So yeah, probably just really bad weather." (Female, age 56)

"I don't cycle for commuting reasons, so it's probably only for leisure time, so if it is raining, it is not going to be enjoyable, so I would say I'm not going to cycle when the weather is not good here." (Female, age 34)

Participants who cycled to work in areas without defined or segregated cycle lanes expressed safety concerns and tended to avoid peak traffic hours.

"I would use it throughout the day, but I tend to actually plan my cycling around times that isn't peak traffic. I tend to not cycle during the busiest times of the day, so during rush hour, so normally, I think at the stage after six in the evening, so it's kind of a lot quieter." (Female, age 34)

"I like that it's not on a road. It's direct. You know it's a strip route from the square to the park. Cuts a lot of traffic. Cuts a lot of public highways." (Male, age 38)

"It links up with, you know it's quite a route through to take out a huge chunk of east Belfast and to get into Belfast, so I would feel comfortable to use it." (Female, age 46)

"I only live a short distance away from where I work. If I cycle then it's about half eight in the morning, if then having cycle home, it is five o'clock in the evening." (Female, age 31)

Several participants reported improved physical and mental health. In addition, some shared that the segregated, safe greenway paths were supporting their recovery and contributing to better mental health:

"Some days that you are just not feeling the best, low mood, go out cycling and it lifts you; you forget about yourself. That's a good thing. Nothing is as bad as just sitting in the house. I got into cycling, you know I had an aversion to the Newtownards Road, and I wanted to hide from people, and my health has improved, my mental health has improved significantly." (Female, age 48)

"One reason why I just love this here. It's safe. Because I had a bad accident, and I got knocked off my bicycle about two and a half years, ended up in the hospital, so and I still haven't recovered mentally to cycle on roads, I just don't like roads, don't like roads." (Female, age 46)

Participants also shared their positive experiences after the walk-along and cycle-along interviews:

"This was a really good nice cycling; I feel quite happy to do this cycle. Yeah. It's a really good exercise like lifted my spirit and refreshed my mind. Usually, at this time of Sundays, I usually stay in bed until late." (Male, age 44)

4 Discussion & conclusions

Our findings complement existing quantitative evidence and provide additional insight into the benefits of activity-friendly neighbourhoods. Ecological models posit that human behaviours have multiple interacting levels of influence that include environmental, policy and social factors.[64] Therefore, measurement techniques that capture this wide range of factors can best explain physical activity behaviour. We demonstrate the feasibility of measuring the impact of an environmental intervention in real-time using emerging technologies, and how these measurements lead to deeper understanding about what must change in order to create healthy and sustainable cities.

In our study, real-time, in-situ monitoring of participants provides a deeper understanding of the multiple pathways through which the environment influences on physical activity and commute mode decision-making. Our study adds to the evidence-base on walkable, activity-friendly neighbourhoods, and highlights specific functional, aesthetic, destination and safety features in the micro-scale environment that affect the way people travel, commute, exercise and play outdoors.[7, 65] Our study also offers a novel framework to capture objective data on physical activity behaviours and environments, to improve the precision and accuracy of measurements for future studies.

4.1 Assessing the impact of the Greenway on local people

The CCG is a large-scale, complex urban intervention comprising multiple components with the potential, individually and interactively, to affect the behaviour of a diverse population in a disadvantaged area in Belfast.[58] This initial evaluation indicates that our novel mode of research presents an unobtrusive observation method to evaluate the effectiveness of built-environment interventions. Our methods identified micro-scale factors in the built and social environment that may influence physical activity but have not been studied as extensively as macro-level factors.

Micro-scale design elements in the built environment differ from macro-level design elements such as street connectivity, land use mix, and residential density, and include details about footpaths, streets, intersections, and design characteristics (e.g., road crossing features, aesthetics, lighting, presence of trees, cycle lanes, curbs), as well as characteristics of the social environment (e.g., presence of garbage/litter/waste, graffiti, vacant lots in poor condition, abandoned buildings or cars).[66] Studying micro-scale factors allows for a more fine-grained examination of the environmental features that enable or inhibit physical activity and may be

modified more easily, cost-effectively and in less time than macro-scale characteristics.[67]

The CCG plays an important role in the community life of residents in an area of high deprivation where access to nature was previously limited. Our findings corroborate the health and social benefits of neighbourhood parks, public spaces and community centres as avenues for physical activity, social interaction, leisure, relaxation and interaction with nature. Previous studies have established that neighbourhood open spaces and parks are linked to improved health outcomes, physical activity, a sense of community and reduced stress levels.[7] Neighbourhoods with higher levels of green infrastructure foster social cohesion and reduce feelings of loneliness, which are key predictors of health.[68, 69] While the impact of the built environment on physical activity has been established, the role of the social environment is less clear, despite its equal and potentially more prominent role in shaping physical activity.[70] Our study of the CCG and its users identified important influences of the social environment on physical activity.

The CCG has created new opportunities for physical activity, new and improved cycle and footpaths, promotional events, and social activities to encourage usage and physical activity, and provide residents with opportunities for activities outside their homes. It has shaped spontaneous conversations and chance encounters with friends and neighbours, fostering social ties and improving social cohesion. Participants reported increased communication and intergenerational interaction across all age groups. Successful non-familial interactions were achieved through shared experiences, outdoor activities, and community programmes along the CCG.

Strong social connections are linked to lower rates of early mortality, less fear of crime, reduced loneliness, and better physical health in vulnerable populations.[71] Neighbourhood walking groups and other physical activity initiatives have promoted the use of the greenway by distinct targeted population segments (e.g., young mothers, unemployed, and older adults), and there have been school-based initiatives, and a variety of community-based social marketing initiatives. This dual approach combining changes to the physical environment with promotional events and programmes to encourage use was an important intervention component. Overall, participants have reported that the CCG interventions have improved community cohesion and interactivity, economic development, and public health.

It is important to note that the factors identified in this study may interact with other factors at both “higher” levels of broad social policy and “lower” levels that operate at the individual level.[72] For example, environments that discourage physical activity may also limit social interactions, with potential implications for antisocial behaviour, violence, crime and drug use.[73] The absence of public transportation may interact with personal

sources of stress (e.g., from home, work) and significantly impact unemployment rates in areas where people depend on it to reach their desired destinations.[74]

4.2 Strengths and limitations of the research

The unobtrusive and objective nature of data from video footage and its ease of use is an important strength of this study. Incorporating emerging technologies, physical activity promotion and measurement efforts can achieve greater precision. Additionally, information on routes such as distance, speed, elevation, origin, and destination allow researchers to conduct a detailed investigation on substantially larger samples of physical activity behaviour and built environments across widespread geographic locations. This is significant for physical activity promotion because more precise measurement allows investigators to better understand where, when, and how activity occurs, and the characteristics of the environments where it occurs, thus enabling more effective design and planning of public spaces, parks, streets, neighbourhoods and cities.

The emerging technologies used in this study are noteworthy because they can:

1 Continuously measure and evaluate physical activity and built environments across wide geographical areas;

2 Improve the ongoing, systematic collection and analysis of built environments for public health surveillance due to real-time capabilities;

3 Significantly increase the ability to investigate built environment and human activity patterns;

4 Significantly increase external validity of measures and findings through ease of use, transferability, and wider applicability; and

5 Address the need for research about cyber infrastructure required to cope with big data (multiple streams, aggregation, visualisation, etc.).[75]

Specifically, these technologies offer significant potential to improve study designs and methods for natural experiments, longitudinal studies, and intervention research.

Walk-along and cycle-along interviews have more methodological advantages than the traditional style of sit-down interviews. In this study, they provided a hybrid style of interviewing, where a flexible interview schedule was tailored to the participant and adapted to their responses. Unlike sit-down interviews where the participants' description of their experience is based on memory recall that may be biased or inaccurate due to social-desirability or recall biases, a walk-along or cycle-along interview captures participants' responses to environmental stimuli in real-time. This ensured that their observations, responses, and statements are directly attributed to the environment they relate to.

A key benefit of walk-along and cycle-along interviews is that they are conducted in-situ, which facilitates rapport between the interviewer and

interviewee. Being interviewed in a familiar environment helps alleviate some of the pressure an interviewee may perceive in a formal sit-down interview. When the interviewees are comfortable within the setting, they are more likely to be more open and answer questions with honesty, allowing the interviewers to be more accurate in their responses and interactions to the shared comments and thoughts.[76] Thus, the interviewer and interviewee can have a more dynamic conversation, allowing the surrounding environment to shape their questions and responses, helping to avoid awkward lulls throughout their dialogue by simply pointing out an environmental feature and asking the participant for their perspectives.

Despite the above advantages, big data and emerging technologies have certain limitations in providing complete information on physical activity and active mobility.[77] Access to wearable sensors and devices differs across user groups, and in some cases, the information input is entirely reliant on the individual's willingness to engage with and accept the technologies.[78] The use of wearable sensors raises several legal, ethical, and cultural issues associated with collecting, storing, and analysing this data. Issues include informed consent, privacy, anonymisation and balancing these issues with the benefits of using big data for the common good.[79] Digital technologies give users the option to control their data by allowing or revoking access to their data by opting in or out. However, this is not always the reality, and personal data collected using digital means has been accidentally or maliciously manipulated, shared or abused.[80] Researchers using emerging technologies should be cognizant of these issues and work with ethicists and Institutional Review Boards to ensure the privacy and confidentiality of users.

Over the past few decades, researchers have predominantly focused on preferences, practices, visitation, use and access to parks and green spaces, but little is known about the absolute amount or types of physical activity they facilitate or the demographic and socio-economic characteristics of the populations they serve.[81] Exceptions include studies using direct observation instruments like the System for Observing Physical Activity and Recreation in Communities (SOPARC), that have been able to provide objective, contextually rich information on physical activity in parks and other open environments. However, these data are static, since parks are divided into predetermined target areas and then studied by trained observers.[82] Other limitations of direct observation instruments are the time-intensive nature and costs involved in data collection.[83] In contrast, the technologies we have used provide a cheaper and efficient alternative for the precise tracking of physical activity across large spatial and temporal settings.

Taking into considerations these limitations, heterogenous mixed-methods research that combines big data approaches and traditional data collection methods can improve monitoring of real-time information for urban planning.[57, 84] Overall, the unobtrusive

nature of data from wearable sensors provides a robust method to explore the influence of outdoor environments on behaviours such as physical activity.

Our evidence suggests that future research should examine the validation of the data collected, a detailed examination of specific micro-environment attributes, park quality and features that are the most critical in influencing physical activity patterns. Innovative methods are emerging using smartphone apps to crowdsource perceptions of local environments, such as littering and street disrepair. Research is needed to explore how these technological approaches could be utilised to scale up data collection of perceptions of the influence of outdoor environments on physical activity.

To fully address these issues, future research should investigate age and gender differences in physical activity and environmental characteristics with an emphasis on vulnerable populations.

4.3 Implications for practice and policy

Environmental factors relevant to public health are directly amenable to policy. Therefore, identifying which of these factors are important contributors to health inequalities and neighbourhood disadvantage could point to interventions and policies that might reduce the disadvantage. For example, international comparisons show that levels of active transportation, such as walking or cycling, can be effectively modified by specific land use and transportation policies.[9]

Integrated city planning policies that encourage walkable, mixed-use developments so that common destinations are within easily accessible distances also support sustainability and climate change mitigation efforts with accompanying health benefits.[85] Researchers and policymakers must therefore adopt a broader, ecological approach to physical activity which considers a combination of individual, physical, social, cultural and policy correlates.

A comprehensive perspective of integrated, long-term city planning can result in lower overall costs and co-benefits across multiple sectors. Our study reinforces the need for greater synergy between departments of city planning, transportation planning, urban design, landscape architecture, road engineering, parks and recreation, and public health.

The results from this study have become far more pressing in the context of the COVID-19 pandemic. The pandemic has stimulated discussion about prioritising the inclusion of nature in urban settings as cities across the world prepare for the post-pandemic recovery.

4.4 Conclusions

Integrated city planning policies that prioritise walking, cycling and use of public transport can improve both physical and mental health by increasing levels of physical activity, social interaction and capital, promoting access to services and employment opportunities, while simultaneously reducing air and noise pollution, traffic injuries and crime rates.[12,

[25] Within that, urban green spaces have an important role to play in creating a culture of health and well-being.[86]

More work needs to be done to strengthen the underlying models shaping our understanding of physical activity. Key steps to understand this are the use of precise measurements for neighbourhood built and social environmental features. Given the potential for city planning to promote physical activity, we recommend that future research could be enhanced by a greater emphasis on multidisciplinary work, expanding focus to vulnerable populations (e.g., economically disadvantaged, racial and ethnic minorities, children, older adults), and including more rigorous measures and study designs for intervention studies.

References

1. World Health Organization. WHO Guidelines on physical activity and sedentary behaviour. Generva, Switzerland; 2020.
2. World Health Organization. Global Recommendations on Physical Activity for Health; 2019.
3. World Health Organisation. Obesity and overweight - Factsheet; 2018.
4. Guthold R, Stevens GA, Riley LM, Bull FC. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. The Lancet Global Health 2018;6(10):e1077-e1086.
5. Public Health England. Physical activity: applying All Our Health; 2019.
6. Sport England. Active Lives Survey. In: Public Health England, editor.; 2019.
7. Sallis JF, Cerin E, Kerr J, Adams MA, Sugiyama T, Christiansen LB, et al. Built Environment, Physical Activity, and Obesity: Findings from the International Physical Activity and Environment Network (IPEN) Adult Study. Annual Review of Public Health 2020;41(1):119-139.
8. Mytton OT, Panter J, Ogilvie D. Longitudinal associations of active commuting with body mass index. Preventive Medicine 2016;90:1-7.
9. Stevenson M, Thompson J, de Sá TH, Ewing R, Mohan D, McClure R, et al. Land use, transport, and population health: estimating the health benefits of compact cities. Lancet (London, England) 2016;388(10062):2925-2935.
10. Yang L, Griffin S, Khaw K-T, Wareham N, Panter J. Longitudinal associations between built environment characteristics and changes in active commuting. BMC Public Health 2017;17(1):458.
11. Goenka S, Andersen LB. Urban design and transport to promote healthy lives. The Lancet 2016;388(10062).
12. Giles-Corti B, Vernez-Moudon A, Reis R, Turrell G, Dannenberg AL, Badland H, et al. City planning and population health: a global challenge. The Lancet 2016;388(10062):2912-2924.
13. Crane M, Bohn-Goldbaum E, Grunseit A, Bauman A. Using natural experiments to improve public health evidence: a review of context and utility for obesity prevention. Health Research Policy and Systems 2020;18(1):48.
14. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. The Lancet 2012;380(9838):247-257.
15. Sahlqvist S, Song Y Fau - Ogilvie D, Ogilvie D. Is active travel associated with greater physical activity? The contribution of commuting and non-commuting active travel to total physical activity in adults. Prev Med 2012;55(3):206-11.
16. Sahlqvist S, Goodman A, Cooper AR, Ogilvie D. Change in active travel and changes in recreational and total physical activity in adults: longitudinal findings from the iConnect study. International Journal of Behavioral Nutrition and Physical Activity 2013;10(1):28.
17. Yang L, Hipp JA, Adlakha D, Marx CM, Tabak RG, Brownson RC. Choice of commuting mode among employees: Do home neighborhood environment, worksite neighborhood environment, and worksite policy and supports matter? Journal of Transport & Health 2015;2(2):212-218.

18. Jackson RJ. The Impact of the Built Environment on Health: An Emerging Field. Am J Public Health 2003;93(9):1382-1384.
19. Foley L, Panter J, Heinen E, Prins R, Ogilvie D. Changes in active commuting and changes in physical activity in adults: a cohort study. International Journal of Behavioral Nutrition and Physical Activity 2015;12(1):161.
20. United Nations. 2018 Revision of World Urbanization Prospects Population Division of the United Nations Department of Economic and Social Affairs (UN DESA); 2018.
21. Sallis JF, Owen N, Fisher E. Health Behavior and Health Education: Theory, Research, and Practice. Health Behavior and Health Education: Theory, Research, and Practice. Volume 4th 2009:465 - 482.
22. Schilling JM, Giles-Corti B, Sallis JF. Connecting Active Living Research and Public Policy: Transdisciplinary Research and Policy Interventions to Increase Physical Activity. J Public Health Pol 2009;30(S1):S1-S15.
23. Mackenbach JD, Rutter H, Compernolle S, Glonti K, Oppert J-M, Charreire H, et al. Obesogenic environments: a systematic review of the association between the physical environment and adult weight status, the SPOTLIGHT project. BMC public health 2014;14:233-233.
24. Xu Y, Wang F. Built environment and obesity by urbanicity in the U.S. Health & place 2015;34:19-29.
25. Bibri SE, Krogstie J, Kärrholm M. Compact city planning and development: Emerging practices and strategies for achieving the goals of sustainability. Developments in the Built Environment 2020;4:100021.
26. Kerr J, Emond Jennifer A, Badland H, Reis R, Sarmiento O, Carlson J, et al. Perceived Neighborhood Environmental Attributes Associated with Walking and Cycling for Transport among Adult Residents of 17 Cities in 12 Countries: The IPEN Study. Environmental Health Perspectives 2016;124(3):290-298.
27. Adlakha D, Hipp AJ, Marx C, Yang L, Tabak R, Dodson EA, et al. Home and Workplace Built Environment Supports for Physical Activity. American Journal of Preventive Medicine 2014;48(1):104-107.
28. Maller C, Townsend, M., St. Leger, L., Henderson-Wilson, C., Pryor, A., Prosser, L., Moore, M. Healthy parks, healthy people: The health benefits of contact with nature in a park context, a review of relevant literature. 2009;26(2).
29. Kaczynski AT, Johnson AJ, Saelens BE. Neighborhood land use diversity and physical activity in adjacent parks. Health Place 2010;16(2):413-5.
30. McCormack GR, Rock M, Toohey AM, Hignell D. Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. Health Place 2010;16(4):712-26.
31. Loukaitou-Sideris A, Eck JE. Crime prevention and active living. Am J Health Promot 2007;21 380 - 389.
32. Oyeyemi AL, Adegoke BO, Sallis JF, Oyeyemi AY, De Bourdeaudhuij I. Perceived crime and traffic safety is related to physical activity among adults in Nigeria. BMC Public Health 2012;12:294-294.
33. Foster S, Knuiman M, Hooper P, Christian H, Giles-Corti B. Do changes in residents' fear of crime impact their walking? Longitudinal results from RESIDE. Preventive Medicine 2014;62:161-166.
34. Cauwenberg J, Van Holle V, Simons D, Deridder R, Clarys P, Goubert L, et al. Environmental factors influencing older adults' walking for transportation: A study using

walk-along interviews. The international journal of behavioral nutrition and physical activity 2012;9:85.
35. Hipp JA, Chockalingam R, Adlakha D. Social Ecological Constraints to Park Use in Communities with Quality Access. Saint Louis: Center for Social Development, Washington University in Saint Louis; 2011.
36. Cohen DA, Marsh T, Williamson S, Derose KP, Martinez H, Setodji C, et al. Parks and physical activity: Why are some parks used more than others? Preventive Medicine 2010;50(Supplement 1):S9-S12.
37. Seaman P, Jones R, Ellaway A. It's not just about the park, it's about integration too: why people choose to use or not use urban greenspaces. International Journal of Behavioral Nutrition and Physical Activity 2010;7(1):78.
38. Heath GW, Parra DC, Sarmiento OL, Andersen LB, Owen N, Goenka S, et al. Evidence-based intervention in physical activity: lessons from around the world. The Lancet 2012;380(9838):272-281.
39. Adlakha D. Quantifying the Modern City: Emerging Technologies and Big Data for Active Living Research. Frontiers in Public Health 2017;5(105).
40. Ma R, Lam PTI, Leung CK. Big Data in Urban Planning Practices: Shaping Our Cities with Data. In; 2018; Singapore: Springer Singapore; 2018. p. 365-373.
41. Jorn Van De Wetering TD, Martin Sexton. Smart Cities, Big Data and the Built Environment: What's Required?: European Real Estate Society (ERES); 2016.
42. UK Intellectual Property Office Informatics Team. Eight great technologies, Big data: A patent overview. Cardiff, United Kingdom: Intellectual Property Office.; 2014.
43. Semanjski IB, R.; Gautama, S.; Witlox, F. Integrating Big Data into a Sustainable Mobility Policy 2.0 Planning Support System. Sustainability 2016;8(11):1142.
44. Milne D, Watling D. Big data and understanding change in the context of planning transport systems. Journal of Transport Geography 2019;76:235-244.
45. Goel R, Garcia LMT, Goodman A, Johnson R, Aldred R, Murugesan M, et al. Estimating city-level travel patterns using street imagery: A case study of using Google Street View in Britain. PLOS ONE 2018;13(5):e0196521.
46. Romanillos G, Zaltz Austwick M, Ettema D, De Kruijf J. Big Data and Cycling. Transport Reviews 2016;36(1):114-133.
47. Lu Y. Using Google Street View to investigate the association between street greenery and physical activity. Landscape and Urban Planning 2019;191:103435.
48. Gkiotsalitis K, Stathopoulos A. A utility-maximization model for retrieving users' willingness to travel for participating in activities from big-data. Transportation Research Part C: Emerging Technologies 2015;58:265-277.
49. Pitney W, Parker J. Qualitative Research in Physical Activity and the Health Professions-Google. Human Kinetics 10%.
50. Hipp JA, Adlakha D, Eyler AA, Chang B, Pless R. Emerging Technologies: Webcams and Crowd-Sourcing to Identify Active Transportation. American Journal of Preventive Medicine 2013;44(1):96-97.
51. Hipp JA. Do you see what I see crowdsource annotation of captured scenes. In; 2013. p. 24-25.
52. Wu J, Li H, Cheng S, Lin Z. The promising future of healthcare services: When big data analytics meets wearable technology. Information & Management 2016;53(8):1020-1033.
53. Tokuçoğlu F. Monitoring Physical Activity with Wearable Technologies. Noro psikiyatri arsivi 2018;55(Suppl 1):S63-S65.

54. Twardzik E, Duchowny K, Gallagher A, Alexander N, Strasburg D, Colabianchi N, et al. What features of the built environment matter most for mobility? Using wearable sensors to capture real-time outdoor environment demand on gait performance. Gait Posture 2019;68:437-442.
55. Boissy P, Blamoutier M, Brière S, Duval C. Quantification of Free-Living Community Mobility in Healthy Older Adults Using Wearable Sensors. Front Public Health 2018;6:216.
56. Mohammadi N, Taylor JE. A Missing Link between Urban Mobility and Wellbeing. In: Proceedings of the 6th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation. New York, NY, USA: Association for Computing Machinery; 2019. p. 187–188.
57. Chaix B, Kestens Y, Duncan S, Merrien C, Thierry B, Pannier B, et al. Active transportation and public transportation use to achieve physical activity recommendations? A combined GPS, accelerometer, and mobility survey study. International Journal of Behavioral Nutrition and Physical Activity 2014;11(1):124.
58. Tully MA, Hunter RF, McAneney H, Cupples ME, Donnelly M, Ellis G, et al. Physical activity and the rejuvenation of Connswater (PARC study): protocol for a natural experiment investigating the impact of urban regeneration on public health. BMC Public Health 2013;13:774.
59. Cao Y, Heng CK, Fung JC. Using Walk-Along Interviews to Identify Environmental Factors Influencing Older Adults' Out-of-Home Behaviors in a High-Rise, High-Density Neighborhood. International journal of environmental research and public health 2019;16(21):4251.
60. IJpelaar J, Power T, Green B. Northern Ireland Multiple Deprivation Measures 2017. Journal of Statistical and Social Inquiry 2017;48:163-174.
61. Charmaz K, Henwood K. Grounded theory methods for qualitative psychology. In: The SAGE Handbook of Qualitative Research in Psychology. Thousand Oaks, CA: SAGE Publications Ltd; 2017. p. 238-256.
62. Nelson J. Using conceptual depth criteria: addressing the challenge of reaching saturation in qualitative research. Qualitative Research 2017;17(5):554-570.
63. Clarke V, Braun V, Hayfield N. Thematic analysis. In: Smith J, editor. Qualitative psychology: A practical guide to research methods: Sage Publications Ltd; 2015. p. 222-248.
64. Sallis JF, Owen N, Fisher EB. Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K, editors. Health Behavior and Health Education: Theory, Research and Practice. Fourth ed. San Francisco: Jossey-Bass; 2008. p. 464-485.
65. Adlakha D, Sallis JF. Activity-friendly neighbourhoods can benefit non-communicable and infectious diseases. Cities & Health 2020:1-5.
66. Steinmetz-Wood M, Velauthapillai K, O'Brien G, Ross NA. Assessing the micro-scale environment using Google Street View: the Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS). BMC Public Health 2019;19(1):1246.
67. Lopes AAdS, Kienteka M, Fermino RC, Reis RS. Characteristics of the environmental microscale and walking and bicycling for transportation among adults in Curitiba, Paraná State, Brazil. Cadernos de Saúde Pública 2018;34.
68. Van Cauwenberg J, Cerin E, Timperio A, Salmon J, Deforche B, Veitch J. Park proximity, quality and recreational physical activity among mid-older aged adults: moderating effects of individual factors and area of residence. International Journal of Behavioral Nutrition and Physical Activity 2015;12(1):46.

69. Schmidt T, Kerr J, Schipperijn J. Associations between Neighborhood Open Space Features and Walking and Social Interaction in Older Adults-A Mixed Methods Study. Geriatrics (Basel) 2019;4(3).
70. Kepper MM, Myers CA, Denstel KD, Hunter RF, Guan W, Broyles ST. The neighborhood social environment and physical activity: a systematic scoping review. International Journal of Behavioral Nutrition and Physical Activity 2019;16(1):124.
71. Kemperman A, van den Berg P, Weijs-Perrée M, Uijtdewillegen K. Loneliness of Older Adults: Social Network and the Living Environment. International journal of environmental research and public health 2019;16(3):406.
72. (US) NRC, (US) IoM. Physical and Social Environmental Factors. In: SH W, L A, editors. U.S. Health in International Perspective: Shorter Lives, Poorer Health. Washington (DC): National Academies Press (US) 2013.
73. Rees-Punia E, Hathaway ED, Gay JL. Crime, perceived safety, and physical activity: A meta-analysis. Preventive Medicine 2018;111:307-313.
74. Braveman P, Gottlieb L. The social determinants of health: it's time to consider the causes of the causes. Public health reports (Washington, D.C. : 1974) 2014;129 Suppl 2(Suppl 2):19-31.
75. Graham DJ, Hipp JA. Emerging technologies to promote and evaluate physical activity: cutting-edge research and future directions. Frontiers in public health 2014;2:66-66.
76. Dana NF. Qualitative Interviewing and the Art of Questioning: Promises, Possibilities, Problems, and Pitfalls. In; 1992; 1992.
77. Walker RK, Hickey AM, Freedson PS. Advantages and Limitations of Wearable Activity Trackers: Considerations for Patients and Clinicians. Clin J Oncol Nurs 2016;20(6):606-610.
78. Chang BL, Bakken S, Brown SS, Houston TK, Kreps GL, Kukafka R, et al. Bridging the digital divide: reaching vulnerable populations. Journal of the American Medical Informatics Association : JAMIA 2004;11(6):448-457.
79. Gilbert J-P, Ng V, Niu J, Rees EE. A call for an ethical framework when using social media data for artificial intelligence applications in public health research. Canada communicable disease report = Releve des maladies transmissibles au Canada 2020;46(6):169-173.
80. Saqr M. Big data and the emerging ethical challenges. International journal of health sciences 2017;11(4):1-2.
81. Lambert EV, Kolbe-Alexander T, Adlakha D, Oyeyemi A, Anokye NK, Goenka S, et al. Making the case for 'physical activity security': the 2020 WHO guidelines on physical activity and sedentary behaviour from a Global South perspective. British Journal of Sports Medicine 2020;54(24):1447-1448.
82. McKenzie TL, Cohen DA. System for Observing Play and Recreation in Communities (SOPARC). In: Center for Population Health and Health Disparities, editor.: RAND; 2006.
83. Ward P, McKenzie TL, Cohen D, Evenson KR, Golinelli D, Hillier A. Physical Activity Surveillance in Parks Using Direct Observation. Preventing Chronic Disease 2014;11:E03.
84. Resch BP, I.; Bluemke, M.; Kyriakou, K.; Miksch, J. A. . An Interdisciplinary Mixed-Methods Approach to Analyzing Urban Spaces: The Case of Urban Walkability and Bikeability. Int. J. Environ. Res. Public Health 2020;17(6994).
85. Fagliano JA, Diez Roux AV. Climate change, urban health, and the promotion of health equity. PLoS medicine 2018;15(7):e1002621-e1002621.

86. Kondo MC, Fluehr JM, McKeon T, Branas CC. Urban Green Space and Its Impact on Human Health. International journal of environmental research and public health 2018;15(3):445.

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