Exploring barriers to green space use and how these differ by chronic health condition

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Abstract

Background: Using green space has been shown to improve health and well-being. However, use is unequal across many groups, such as those defined by age and income. Poor health is one of the most commonly reported barriers to green space use, despite individuals with poor health having the most potential benefit. Further research is required to understand the health-related barriers to green space use and how these differ by type of chronic condition, including physical and mental health conditions. The Covid-19 pandemic may have further exacerbated barriers to green space use and therefore requires further investigation to understand the influence of the novel restrictions/lockdowns on green space use.

Aims: The thesis aims to explore how general barriers to use of green space, those specifically related to physical health, and those related to the Covid-19 pandemic, vary between people with different chronic health conditions and socio-demographic characteristics.

Methods: Two nationally representative surveys were used to explore general and health-related barriers to green space use: Natural England's People and Nature Survey (PANS) and a new survey administered through YouGov. In PANS, data were collected between November 2020-March 2021 (N=10,415 English adults aged 16+), and the YouGov survey consisted of three survey waves in April 2020, November 2020, and April 2021 (N=6,713 UK adults aged 18+). A question capturing the types of chronic health condition experienced by individuals was included in both surveys. Data were also collected on frequency of green space use, barriers to green space use, and demographic characteristics including sex, age, and income. The surveys also collected data on barriers to green space use introduced or exacerbated by the Covid-19 pandemic. Associations between the outcome variables (the barriers to green space use) and predictors (the health conditions and socio-demographic variables) were assessed using Structural Equation Modelling (SEMs) and multiple binary logistic regression models.

Findings: The most commonly reported barrier to green space use for those with chronic health conditions was 'poor physical health'. The findings indicated that those with physical disabilities and progressive illnesses reported physical

health-related barriers (mobility and health, lack of disabled facilities, unsuitable/poorly maintained sites, and having no-one to go with/help them) as important in stopping them from visiting green spaces in the last 14 days. A lack of disabled facilities was found to be a particularly important issue for respondents with heart/circulatory conditions, physical disabilities, and progressive illnesses. Poor mental health was more likely to be reported as a barrier by those with mental health conditions, diabetes, and respiratory conditions, as well as by respondents aged 16-24 years. The Covid-19 pandemic was found to have exacerbated existing inequalities in both green space use and reporting of barriers with the introduction of new issues, such as worrying about social distancing and green spaces being too busy.

Conclusions: Overall, there were differences by type of health condition and socio-demographic characteristics when reporting barriers to green space use. The findings outlined in this study emphasise that a 'one size fits all' approach to increasing green space use and mitigating barriers to use for individuals with chronic health conditions will not work, with a more targeted approach required to ensure that green spaces are accessible and provide health and well-being benefits for all.

Table of Contents

List of Tables

List of Figures

List of Accompanying Material

The analyses and findings reported in Chapter 5 are based on two published papers:

1. ***Burnett, H.**, Olsen, J. R., Nicholls, N. and Mitchell, R. (2021) Change in time spent visiting and experiences of green space following restrictions on movement during the COVID-19 pandemic: a nationally representative cross-sectional study of UK adults. BMJ Open, 11(3), e044067. (doi: 10.1136/bmjopen-2020-044067)*

2. ***Burnett, H.**, Olsen, J. R. and Mitchell, R. (2022) Green space visits and barriers to visiting during the Covid-19 pandemic: a three-wave nationally representative cross-sectional study of UK adults. Land, 11(4), 503. (doi: 10.3390/land11040503)*

A statement of the authors contributions:

1. BMJ Open publication: Hannah Burnett (HB) collated ideas for the focus of the paper, which were reviewed by Jonathan Olsen (JRO) and Rich Mitchell (RM). The YouGov survey used for the paper was firstly designed by HB and reviewed by JRO and RM, with feedback from colleagues from the Places and Health programme at the University of Glasgow. HB conducted data analysis, which was reviewed by Natalie Nicholls (NN). All data visualisations were created by HB. HB wrote the first draft of the paper, with all authors then contributing to editing / revising the draft.

2. *Land* publication: The conceptualisation of the paper was lead by HB, and reviewed by JRO and RM. The YouGov survey used for the paper was firstly designed by HB and reviewed by JRO and RM, with feedback from colleagues from the Places and Health programme at the University of Glasgow. HB conducted data analysis, including the creation of data visualisations. HB wrote the first draft of the paper, with JRO and RM then contributing to revising the draft and agreeing on the final version of the paper.

List of Appendices

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Finally, I would like to dedicate this thesis to my grandma, Kathleen Howman. She was, and will forever be, a big part of my life. My grandma was always so supportive and excited to hear how my PhD was going, and I hope that she would be proud of me.

Author's declaration

I declare that, except where explicit reference is made to the contribution of others, this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Printed Name: Hannah Burnett

Signature:

Chapter 1 Introduction

1.1 Aim of chapter

The aim of this chapter is to provide an overview of the thesis. Within the chapter, the research field and gaps will be outlined, as well as the aims and research questions to be answered. There is then a short overview of the key theoretical frameworks that underpin the study. Finally, the structure of the thesis is provided.

1.2 Background

There is a wide range of literature which outline the connections between green space and health, with the amount of research exploring these connections increasing greatly in the past decade. A topic search on Web of Science ((“green space*” OR “greenspace*”) AND (“health”)) found 29 results in 2012 and 392 results in 2022, with only 2 results in 2000. The health benefits of green space that have been investigated in the literature are varied, including social cohesion, physical activity promotion, stress reduction, and reduced exposure to noise, air pollution, and heat (Hartig *et al.*, 2014; Adlakha *et al.*, 2021). For example, green spaces improve air quality by reducing particulate matter, improve social cohesion by increasing interaction with neighbours and providing a sense of community, and reduce stress via the acquisition of coping resources and a decrease in exposure to stressors (Hartig *et al.*, 2014). The green space and associated biodiversity itself have been found to positively impact health and well-being; even if those using green space think that the space is wildlife rich, they report more positive emotions, even if biodiversity levels are not necessarily enhanced (Cameron *et al.*, 2020).

Throughout the thesis, green spaces will be defined as places where an individual can see and experience vegetation, such as plants and trees, and nature outside of the household. With a focus on use and visitation, the definition must be narrowed to only include green spaces that can be walked, cycled, or wheeled through, such as public parks, sports fields, agricultural land, woodlands, coastal paths, and nature reserves (Taylor and Hochuli, 2017).

When researching green space, from a methodological standpoint, it is important to firstly consider *how* green space exposure is measured. This can include measuring distance from a residential address to the nearest green space, or the level of greenness in a neighbourhood (Tarek *et al.*, 2023). Many studies explore access to green space, such as having a park within 15 minutes from an individual's house, which differs from use of green space, such as walking or cycling through the park (McCormick, 2017; Pitt, 2019). Access to green space does not necessarily mirror actual use of green space, and therefore may not entail a health impact (Nordbø *et al.*, 2018). Previous research has reported that those examining the impact of green space on health and well-being should consider including a measure of green space use in addition to, or instead of, green space access or neighbourhood greenness (Tarek *et al.*, 2023). It has also been suggested that quality plays an equally important role as quantity in the relationship between green space and health (Brindley *et al.*, 2019). Throughout this thesis there will be a focus on use of green space, rather than access, due to the focus on both health and reasons for non-use of green space (barriers), with aspects of quality being introduced as potential barriers to green space use.

Regarding barriers to green space use, these can come in the form of general barriers, such as bad weather and lack of interest, and physical health-related barriers, such as poor mobility and a lack of facilities for those with disabilities. Use of green space, the influence of the barriers on use, and health benefits arising from use have been found to differ by socio-demographic characteristics. For example, in England, at an individual level, females, older adults, those in lower socio-economic status group, those with a long-term illness/disability, and those with a car were all more likely to report being infrequent users of green space (Boyd *et al.*, 2018). Inequalities in green space use are increasingly prevalent, however it has been reported that accessibility and provision of green space does not privilege socio-economically advantaged groups (Mears *et al.*, 2019).

The health impacts associated with green space have been explored using different measures of green space exposure. For example, regarding use of green space, it has been reported that spending two hours or more in green space could significantly increase the likelihood of reporting good health and well-being (White *et al.*, 2019). When exploring exposure to green space, lower

odds of prevalent diabetes have been observed with 1% increases in total green space and tree canopy exposure (Astell-Burt and Feng, 2020). Similarly, exposure to 30% or more tree canopy compared with 0-9% tree canopy has been associated with 31% lower odds of incident psychological distress (Astell-Burt and Feng, 2019). Regarding access to green space, such as household proximity to green space using average NDVI (normalised difference vegetation index), significantly lower depression scores were associated with green space (or NDVI) within both 300m and 500m from the household (Reid, Rieves and Carlson, 2022). These findings emphasise the breadth of research on green space and health and the many different methods used to measure green space exposure.

These health benefits associated with green space use have influenced the introduction of green social prescribing, a nature-based health intervention which involves a monitorable activity where time is spent in a natural environment for the benefit of health and well-being (Jepson, Robertson and Cameron, 2010; Robinson and Breed, 2019). This can include horticultural therapy (i.e., gardening), a regular walk through a green space, or taking part in some form of habitat creation/restoration. Green social prescribing involves the linking of individuals to nature-based activities for health through a healthcare provider (e.g., a General Practitioner (GP)) and link workers, who work with GPs to connect patients to local community services and activities (Husk and Thompson, 2021). Green prescriptions are seen as providing reactive and proactive solutions to public health issues, providing a form of health care whilst also being health promoting (Robinson and Breed, 2019).

Patient interest in green social prescribing has been found to differ by frequency of green space use and health condition. For example, an Australian study of 3,319 adults reported that for respondents with cardiovascular diseases, those spending less than 2 hours per week in green space had 65% lower odds of interest in green prescriptions when compared to those spending 2 hours or more per week in green space (Astell-Burt *et al.*, 2023). Similar results were found across multiple health conditions. The study's conclusions emphasised that there was a high interest in green social prescriptions, however significant differences in green space use between health groups remained, indicating a need for tailored interventions across the communities with different needs and preferences. This study highlighted the potential benefit of spending time within

green space for those with a pre-existing health condition. However, it is known that individuals with long-term health conditions are more likely to be infrequent green space users than those without long-term health conditions (Boyd *et al.*, 2018). In order to increase their green space use, we need to understand their current barriers to using green space. This could provide evidence for future interventions to improve green space use for the groups that could benefit the most. Currently missing from the existing literature on green social prescribing, and green space use in general, is exploration into how barriers to green space use and experiences differ by health condition. For example, individuals with mental health conditions may experience different barriers to using green space than those with diabetes or respiratory conditions. This information could be used to tailor green social prescribing, and other green space projects, to those with different types of chronic health conditions.

The existing research, which will be discussed in more detail in the subsequent literature review section (Chapter 2), highlights who is *not* using green space, and some of the reasons for infrequent use, but there has been a lack of focus on unpacking the 'why' and understanding barriers to use in more detail. Additionally, the lack of connection between infrequent use and health conditions is a key research gap. Data collected on this could be used to explore how infrequent users can be encouraged to change their existing behaviour, attitudes, and perceptions, which could have impacts on both individual and population level health.

1.3 The impact of Covid-19

1.3.1 Covid-19 background

In 2020, the UK experienced major disruption to everyday life with the Covid-19 pandemic. The infectious disease, Covid-19, was first identified in the city of Wuhan, China in December 2019. As a response to the Covid-19 pandemic, the UK announced a series of restrictions on movement from 23rd March 2020, with daily life changing rapidly (The Institute for Government, 2021). These restrictions included rules around social distancing, meaning that people could only leave their households to make 'essential trips' for food, medication, and exercise (Johnson, 2020). Parks were allowed to remain open for exercise, but

any gatherings were dispersed. The restrictions were often confused or conflated, with guidance stating that the UK population be limited to exercising once per day, but this stipulation was not reflected in legislation (House of Commons, 2021). During the peak of the pandemic, individuals with serious underlying health conditions which put them at very high risk of severe illness from Covid-19 were advised to follow shielding measures (Ministry of Housing Communities & Local Government, 2020). These measures included staying at home at all times and avoiding face-to-face contact with others.

The restrictions were relaxed and re-instated multiple times between 2020 and 2022, with the initial restrictions being eased from June 2020 when schools and non-essential shops re-opened in England, for example. Local lockdowns were introduced from July 2020, with restrictions re-implemented across the UK in October/November 2020, and a third national lockdown was implemented in England in January 2021 (The Institute for Government, 2021).

The restrictions on movements implemented during the lockdowns changed the everyday lives of individuals worldwide. In the UK, green spaces remained open for use throughout which emphasised the importance placed on green space in maintaining a small sense of normality despite the changes happening to every other aspect of life. The impact on health has been found to be vast. For example, in the UK, throughout the pandemic there was evidence of increased relapse in people with pre-existing mental health conditions and increased mental health problems in those with no previous mental health disorders (O'Connor *et al.*, 2020; Byrne, Barber and Lim, 2021). Therefore, with a focus on barriers to green space use, the influence that the restrictions had on green space use and barriers, as well as how these interacted with health, was important to explore and would provide novel findings that could be used as the pandemic continued and in future.

1.3.2 Covid-19's impact on the research questions and study design

The pandemic caused interruption to the planned data collection, however it also provided opportunity, which will be discussed in more detail in Chapter 5. Originally, the aim was to conduct in-situ audits of individuals to ask if they did

or did not frequently use local parks and the reasons why to further understanding of infrequent and non-use of green space. Due to the Covid-19 pandemic, collecting data in-person was no longer feasible, therefore the aims and research questions being answered throughout the thesis were revised due to the importance of understanding the immediate impact of the pandemic on green space use and barriers. This was also necessary to provide further understanding of how the pandemic was changing green space use at the time and provide context to the data being collected for this thesis. The focus of the project was also influenced by the interest of Public Health Scotland (PHS) in the research on green space, health, and Covid-19. My supervisors were involved in PHS's Social Systems Recovery Environment and Spaces group, which was created to gather evidence on the impact of the pandemic on the populations use of space. Survey data collected for this thesis was utilised by PHS, with the addition of new questions to later waves of the YouGov survey and associated reports published in collaboration with PHS.

All of the data for this thesis were collected during the Covid-19 pandemic, therefore it was important to explore how the pandemic influenced green space use and barriers. However, it felt important to remain focused on covering the research gaps and answer the research questions created at the start of the PhD, prior to the pandemic, whilst incorporating and measuring the effect of any health related Covid-19 barriers to green space use. Therefore, I maintained focus on the original research questions on barriers to green space use, with measuring of any Covid-19 related barriers included alongside the original research questions.

The restrictions on movement were first implemented as I was starting to conduct the literature review, with a broad research focus on barriers to green space use and exploration of the differences in reporting of these barriers by health condition. Being in the early stages of the PhD as the pandemic started allowed the study design to be moulded according to these restrictions on both research and everyday life, with a focus on conducting data collection online. Discussions had started with Natural England in March 2020, as the first lockdown was being implemented in the UK, to organise adding new questions to their existing nationwide survey on green spaces, which then became more focused on the impacts of the Covid-19 pandemic on change in use and

experiences of green space. The pandemic also encouraged rapid primary data collection and the creation of a new online survey, which will be discussed in more detail in Chapter 5.

1.4 Research questions

This thesis explores differences in green space use and barriers to use by health condition, and the impact of the Covid-19 pandemic on green space use and barriers.

The following six research questions will be answered in this thesis:

1. How does the type of chronic health condition reported differ by socio-demographic characteristics?

2. How does the reporting of general barriers to green space use differ by type of chronic health condition and socio-demographic characteristics (sex, age, income, and ethnicity)?

3. How does the reporting of physical health-related barriers to using green space differ by type of chronic health condition and socio-demographic characteristics?

4. How did green space visits change during the Covid-19 pandemic?

5. Which barriers to green space visits were reported during the Covid-19 pandemic?

6. How did green space visits and barriers change over time and by sex, age, and socio-economic position during the Covid-19 pandemic?

The thesis includes three interlinked stages which address six research questions. The research questions 1 and 2 will be answered in the first stage, with a focus on the general barriers to green space use for individuals with chronic health conditions. The third research question will be covered in the second stage, exploring physical health-related barriers to green space use for those with chronic health conditions. Finally, research questions 4-6, which

investigate the impact of the Covid-19 pandemic on green space use and barriers to use, will be answered in the third stage.

1.5 Theoretical frameworks

Green space use has been found to benefit health and well-being in multiple ways, and there are several theories that aim to understand why this is. One of the earliest theories is the 'biophilia hypothesis', with biophilia translating to "love of life" in ancient Greek (Fromm, 1976; Barbiero and Berto, 2021). This theory was first published by Erich Fromm, and later popularised by E.O. Wilson in 1984. They theorised that humans are innately attracted to other living organisms (Frumkin, 2001). Fromm (1976, p858-859) defined biophilia as the "passionate love of life and of all that is alive; it is the wish to further growth, whether in a person, a plant, an idea, or a social group". This thinking has offered a starting point for investigations into 'human-nature-health' relationships and continues to be the basis of theoretical models linking green space and health to date (Day *et al.*, 2012).

In order to answer the research questions and understand behaviours and outcomes relating to green space use and health, further information was required on:

1. How green space could improve health
2. How physical health conditions (that affect mobility) influence use of green space
3. Other social and individual factors that might influence use of green space

Theoretical frameworks can be used to better understand behaviours and outcomes focusing on green space and health, as well as social and individual factors that influence green space use. To begin exploring these questions, two of the most widely used and influential theories in green space literature will be outlined within this section, namely the Attention Restoration Theory and Stress Reduction Theory (Hedblom *et al.*, 2019). Additionally, theoretical frameworks exploring the barriers to green space use will be outlined, specifically the Theory of Planned Behaviour and leisure constraints model, and those focusing

on the interconnections between health and mobility, including a theoretical framework for mobility.

1.5.1 Attention Restoration Theory

Attention Restoration Theory (ART) suggests that mental fatigue can be improved by nature experiences. Kaplan and Kaplan (1989) propose that there are two attention types: directed/voluntary attention, used when sustained attention is required for a task, and involuntary attention, which requires no effort. Attention fatigue is caused from directed attention, which leads to mental fatigue, with involuntary attention (or 'soft fascination') having the ability to restore capacity for directed attention (Kaplan and Kaplan, 1989).

According to Kaplan (1995) and Kaplan and Kaplan (1989), there are four requirements for a restorative environment: **getting away, fascination, extent,** and **compatibility**. Natural environments that are easily accessible offer an important resource for resting directed attention, and '**getting away**' (Kaplan, 1995). Regarding **fascination**, nature has many processes that people find engrossing, including 'soft' fascinations, such as clouds, sunsets, and snow patterns that hold attention in an effortless way. Even a small green space can provide **extent**, with Japanese gardens given as an example of a green space that combines giving the sense of scope as well as connectedness. Finally, the natural environment provides **compatibility** between nature and human inclinations. For some, functioning in natural settings requires less effort than functioning in more 'civilised' urban settings, despite greater familiarity (Kaplan, 1995).

1.5.2 Stress Reduction Theory

The Stress Reduction Theory (SRT) proposes that natural environments reduce stress, whilst urban environments hinder recovery from stress (Ulrich, 1981). Ulrich (1981) found that nature views significantly improved the emotional states of stressed individuals. The results suggested that the importance of visual contact with nature extends beyond aesthetics and benefits psychological and physiological well-being. Ulrich's exploration of the influence that window views have on surgery recovery found that the patients with a view of trees had

shorter post-operative hospital stays, compared to patients with a view of a wall (Ulrich, 1984). This further supports the idea that green space, even viewed through a window, can positively influence health and well-being.

Ulrich *et al.* (1991) discuss evolutionary perspectives to explain the SRT. They propose that because humans evolved over a long period in natural environments, we are physiologically and perhaps psychologically adapted to natural settings, rather than urban settings. This caused humans to have a predisposition to respond positively to nature, such as vegetation and water (Ulrich *et al.*, 1991). This aligns with the idea outlined in the biophilia hypothesis that humans are innately attracted to other living organisms and may begin to explain why green spaces are so beneficial to our health and well-being (Frumkin, 2001).

1.5.3 Theoretical framework for mobility

Generally, when using green space rather than viewing green space through a window, some level of mobility is required, with the theoretical framework of mobility being particularly relevant when exploring green space use and barriers to use. In this context, mobility is defined as being able to move oneself, for example, by walking or using an assistive device, whether in the home, the local neighbourhood, or further afield (Webber, Porter and Menec, 2010). Multiple determinants that influence mobility were collated by Webber *et al.* (2010) to conceptualise mobility in a more holistic way. Concentric areas of expanding locations from home with increasing requirements for independent mobility are included in the framework (Figure 1-1). Included as mobility zones are:

- The room where one sleeps
- The home (e.g., house, apartment, institution)
- The outdoor area surrounding the home (e.g., yard, parking lot)
- The neighbourhood (e.g., nearby streets or parks)
- The service community (e.g., shops, banks, health care facilities)
- The surrounding area (e.g., within one's country)
- The world

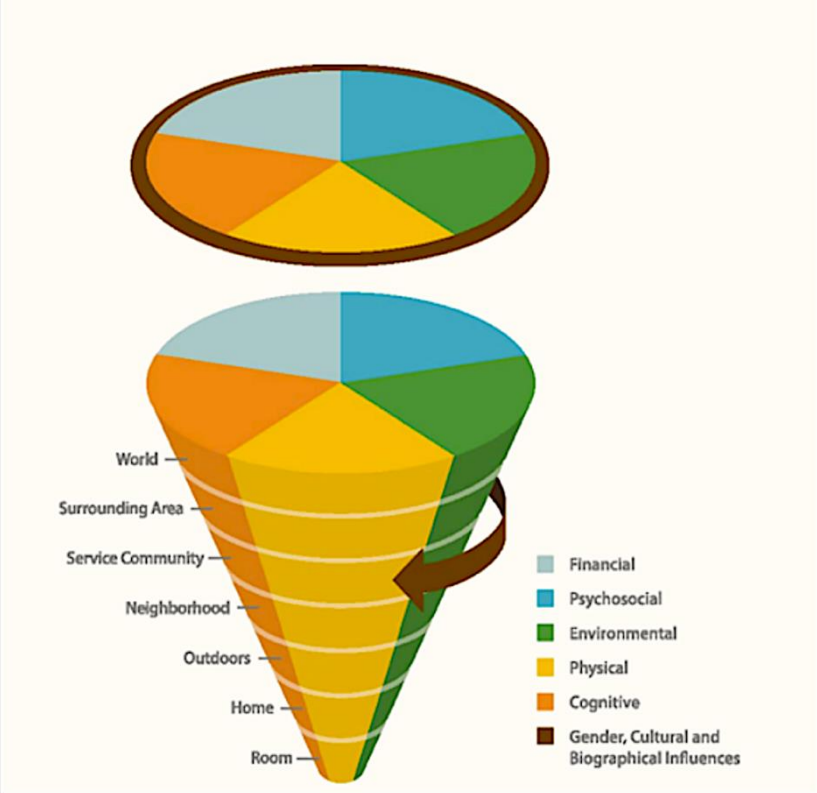


Figure 1-1: Conical model of the theoretical framework for mobility. The legend presents the determinants of mobility. A ring representing gender, culture, and biographical influences surrounds the cone as it exerts influence on all mobility determinants (Webber, Porter and Menec, 2010).

Each life-space shown in the vertical order may be represented by a cross-section made up of five categories of determinants that influence mobility, both within and between the vertical levels (Webber, Porter and Menec, 2010). These determinants are:

- Financial – e.g., lower income individuals have a greater risk of mobility disability, economic resources dictate activity options away from home
- Psychosocial – e.g., self-efficacy, coping behaviours, depression, fear, relationships with others that affect motivation to be mobile
- Environmental – e.g., slippery surfaces due to weather
- Physical – e.g., physical capability
- Cognitive – e.g., mental status, memory, executive functioning

The model recognises that gender, culture, and personal life history shape individuals' experiences and behaviours, and act as cross-cutting influences on mobility. Within an outdoors mobility zone, some level of mobility is required to use green space, therefore the theoretical framework of mobility can be utilised when exploring green space use for those with chronic health conditions.

1.5.4 Leisure constraints model

The leisure constraints model was invaluable in strengthening my understanding of barriers, and if, how, and why these should be categorised. The leisure constraints model, which aims to explain constraints to participating in leisure activities, was first created and discussed in detail by Crawford and Godbey (1987). The model was particularly influenced by family-related constraints, such as the decision-making patterns of the family unit, parent-child relationships, and spousal interaction. They categorised the constraints to participating in leisure activities into three groups - **intrapersonal, interpersonal,** and **structural barriers** - and discussed how preference, barriers, and participation in leisure activities are all interconnected:

1. **Intrapersonal barriers** involve individual psychological states/attributes which interact with leisure preferences rather than intervening between preferences and participation (Figure 1-2). Examples include stress, depression, religion, perceived self-skill, and subjective evaluations of the appropriateness and availability of various leisure activities. Some of these barriers are socially influenced, such as appropriateness and availability of activities, and are sometimes capable of being modified over time (Crawford and Godbey, 1987).

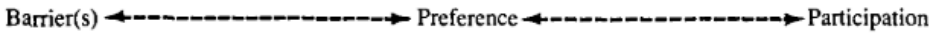


Figure 1-2: A diagram of intrapersonal barriers (Crawford and Godbey, 1987).

2. **Interpersonal barriers** are the result of interactions/relationships between individual characteristics. With their family leisure focus, Crawford and Godbey (1987) suggested that interpersonal barriers can be the product of the intrapersonal barriers which accompany spouses into the marital relationship, and then affect joint preference for leisure activities, and can also include barriers which arise from spousal interaction. Therefore, interpersonal barriers interact with both preference for, and participation in, companionate leisure activities

(Figure 1-3). Examples include social conflicts, decision-making processes, and parent-child relationships (Crawford and Godbey, 1987.

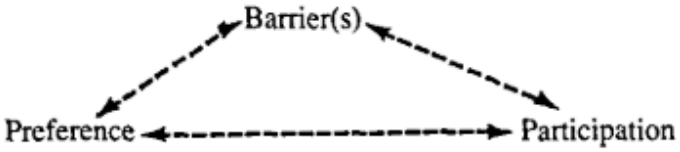


Figure 1-3: A diagram of interpersonal barriers (Crawford and Godbey, 1987).

3. **Structural barriers** represent constraints as intervening factors between leisure preference and participation (Figure 1-4). These include financial resources, season/climate, scheduling of work time, and availability of opportunity (and knowledge of such availability) (Crawford and Godbey, 1987). At the structural level, if preference for an activity is significantly greater than the constraints, the leisure activity may be undertaken despite the presence of these constraints.

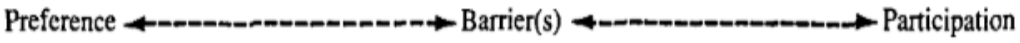


Figure 1-4: A diagram of structural barriers (Crawford and Godbey, 1987).

This initial model was critiqued and revised by Crawford *et al.* (1991), who published a more comprehensive model of leisure constraints (Figure 1-5). They believed that the original model was conceptually disconnected, failing to indicate anything about the dynamic process of *how* people might negotiate constraints through to participation in leisure activities. Therefore, three key changes to the model were made (Crawford, Jackson and Godbey, 1991):

1. Multiple factors were arranged sequentially, as leisure participation is heavily dependent on a process of negotiating through an alignment of factors that must be overcome. They also stated that the entire array of constraints should be investigated simultaneously.

2. The model was structured hierarchically – with the sequential ordering of constraints representing a hierarchy of importance (Figure 1-5). Intrapersonal constraints were conceptualised as the most powerful, due to the fact that they condition the 'will to act' or the motivation to participate in an activity.

3. The experience of constraints was related to a hierarchy of social privilege, with social class having a more powerful influence on leisure participation and non-participation than was currently being accepted (Crawford, Jackson and Godbey, 1991).

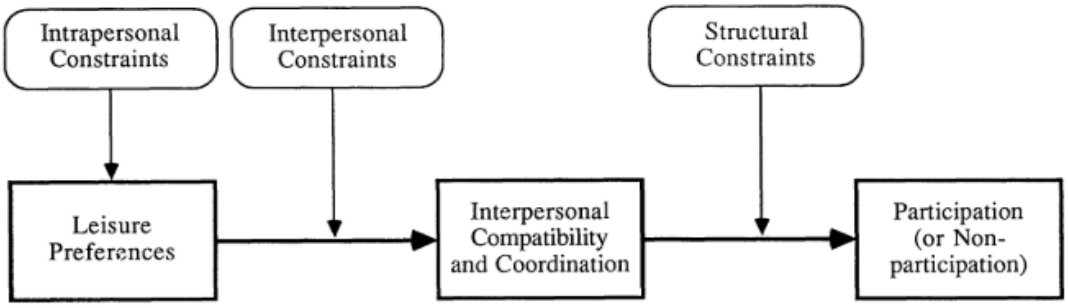


Figure 1-5: The hierarchical model of leisure constraints (Crawford, Jackson and Godbey, 1991).

The leisure constraints model can be utilised when exploring barriers to green space use. The development of the model highlights the importance of exploring intrapersonal, interpersonal, and structural barriers whilst realising the influence that social class has on these barriers. It also emphasises the need to constantly re-evaluate our thinking regarding barriers/constraints and to explore why these barriers exist further.

1.5.5 Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) shaped my thinking when exploring motivation and behavioural intention, both are important to consider when exploring reasons for non-use of green space. The TPB was created as an extension of the Theory of Reasoned Action (TRA), used to explain individual's actual behaviour through behavioural intention (Ajzen, 1985, 1991). Intentions are assumed to capture the motivational factors that influence a behaviour,

reflecting how hard an individual is willing to try in order to perform the behaviour. The TPB proposes that there are three factors that influence behavioural intention and, in turn, behaviour itself (Figure 1-6):

1. **Subjective norm**: this refers to the perceived social pressure to perform (or not to perform) the behaviour.

2. **Attitude toward the behaviour**: the degree to which a person has a favourable (or unfavourable) evaluation of the behaviour.

3. **Perceived behavioural control**: the perceived ease (or difficulty) of performing the behaviour. It is assumed that this reflects past experience, as well as anticipated obstacles (Ajzen, 1991; Huang *et al.*, 2021).

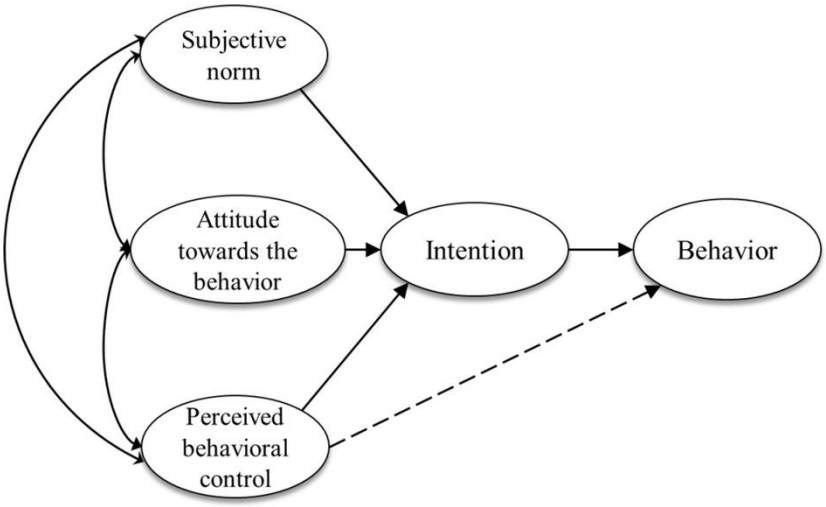


Figure 1-6: The theory of planned behaviour (Ajzen, 1991; Huang *et al.*, 2021)

In the context of green space use, the 'behaviour' can be assumed to be use of green space (Wan and Shen, 2015)(Wan and Shen, 2015). TPB provides an open-ended and adaptable model, which is able to fit specific research contexts. For example, one study included two additional variables to the model – accessibility of green space and past use of green space – and new paths to examine their relative contribution to intention to use green space (accessibility → intention and past use → current intention) (Wang *et al.*, 2015).

1.5.6 Summary

The combination of the theoretical frameworks outlined in this section encapsulates the focus of this thesis. Firstly, with ART and SRT exploring the connections between green space and health and start to explain *why* these connections are present. These two theories also highlight some inequalities in the experience of the beneficial impacts of green space on health – with the SRT proposing that urban environments hinder recovery from stress (Ulrich, 1981). Throughout the thesis, inequalities are explored, such as inequalities in use of green space by health, age, income, and sex, and whether these inequalities were exacerbated during the Covid-19 pandemic.

Movement and behaviour, focused on in the theoretical framework for mobility, were also included in the thesis by using the framework to consider the extent of the mobility zones captured within the data, whether the focus was purely on neighbourhood zones, or should include the service community, and how experience of these zones may differ depending on health and socio-demographic characteristics.

The leisure constraints model was invaluable in strengthening my understanding of barriers, and if, how, and why these should be grouped. The importance of social class and privilege is also highlighted in the model, which should be considered in public health work that explores inequalities. This has to be reflected on when researching differences by health and socio-demographic characteristics.

The TPB shaped my thinking when exploring motivation and behavioural intention. Particularly the influence of personal preferences and past experiences on current behaviours (in this case, use of green space), and the importance of motivation and facilitators in the intention and behaviour. It emphasises the importance in acknowledging that intention does not always equate to the behaviour.

Despite these theoretical frameworks shaping the thesis, none of the frameworks delve deeper into health, or explore the connections from the other direction of

health influencing behaviour (i.e., green space use) rather than the behaviour influencing health.

1.6 Thesis structure

The subsequent chapters aim to provide answers to the six research questions outlined in this first chapter.

In Chapter 2, the key literature will be outlined, explored, and reviewed following a systematic literature search. This literature review covers the existing patterns in infrequent use of green space and the barriers to green space use driving these patterns, the barriers to green space use for individuals with chronic health conditions, and facilitators of green space use. The chapter concludes with a summary of the key gaps in the literature that are explored in this thesis.

Chapter 3 describes the survey data collection, which is used for both Chapter 3 and Chapter 4, as well as the data cleaning and preparation methods used prior to analysis. Following this, the methods considered and applied, including the analysis undertaken to investigate the relationship between different types of health conditions, socio-demographic variables, and general barriers to green space use will be outlined. The results and interpretations of the results will be discussed, followed by a summary. In this chapter, research questions 1 and 2 are answered.

In Chapter 4, there is a focus on physical health-related barriers to green space use and answers to research question 3. This chapter further explores the physical health-related barriers touched upon in Chapter 3. The chapter will outline the Structural Equation Modelling method used, the hypotheses, and results. A discussion and summary of whether the hypotheses can be accepted or rejected concludes the chapter.

Chapter 5 answers research questions 4-6 by investigating the impact of the Covid-19 pandemic on green space use and barriers to use. The context of the Covid-19 pandemic will be discussed, followed by an outline of the second survey data collection method and subsequent analysis. The chapter will

continue with the results of the analysis, interpretation of the results, and a final summary.

Finally, Chapter 6 will present the research questions being answered, thesis strengths and limitations, the implications and recommendations based on the findings of the thesis, and final comments.

Chapter 2 Literature review

2.1 Chapter aims

In this chapter I will outline and review the existing literature that focuses on infrequent use of green space, specifically the barriers and facilitators of green space use. The definition of infrequent use of green space varies in the literature from visiting green space less than once a month to never visiting green space (Boyd *et al.*, 2018; Natural England, 2021a). The review will explore the evidence related to individuals with chronic health conditions, such as physical disabilities and mental health conditions.

The inclusion of facilitators was influenced by the theoretical frameworks explored in Chapter 1, specifically the Theory of Planned Behaviour (Ajzen, 1985, 1991). The measure of behaviour (i.e., use of green space) is influenced by perceived behavioural control – the perceived ease (facilitators) or difficulty (barriers) of performing the behaviour (using green space) (Ajzen, 1991; Huang *et al.*, 2021). Previous research also suggests that motivation to use green space becomes a significant factor when considering people with long-term disabilities, and that focusing on physical improvements alone (e.g., accessible toilets and ramps) does not fully address the needs of people with chronic health issues, such as dementia (Gibson, 2018). Exploring literature focusing on facilitators of green space use may also highlight any gaps in the literature on barriers to green space use.

2.1.1 Aims and objectives of the literature review

The aim of the literature search is to explore the existing literature focusing on the barriers and facilitators of green space use, specifically related to health. The literature review aims to synthesise the literature and explore:

1. The existing patterns, generally and across sociodemographic groups, in infrequent use of green space and the barriers to green space use driving these patterns.
2. Barriers to green space use for individuals with chronic health conditions.
3. Facilitators of green space use.

This chapter will outline the database search strategy and key themes highlighted in the literature. These themes will be categorised into infrequent use and barriers, barriers to green space for individuals with chronic health conditions, and facilitators of green space use. The chapter will conclude with a summary of the existing gaps in the literature.

2.2 Search strategy

This search strategy was developed with support from an Information Scientist based at the MRC/CSO Social and Public Health Sciences Unit, University of Glasgow. The first literature search was conducted at the start of the PhD, on 13th March 2020, with a second follow-up search conducted in the final period of the PhD, on 20th September 2022, to ensure that the literature review was up to date. Three databases were searched: Web of Science (Core Collection), Medline (Ovid), and PsycInfo (EBSCO Host). These databases were chosen because of their coverage of multiple relevant disciplines, with Web of Science covering broader fields of science, social sciences, art, and humanities (among others), Medline covering medicine, nursing, pharmacy, and health care, and PsycInfo covering psychology. The keywords used for each database are included in Appendix A, Appendix B, and Appendix C, with terms searched independently and grouped using Boolean operators ("OR" and "AND"). The searches were restricted to English language, with no date range specified for the first search in March 2020, and the second search specifying publication dates between 13th March 2020 to 20th September 2022.

In the first search a total of 1,739 papers were returned, and in the second search a total of 387 papers were returned. A PRISMA flow diagram presenting the reasons for inclusion and exclusion is shown in Figure 2-1. The remaining 138 papers form the basis of this literature review, with key information extracted from each paper and included in a summary table containing the authors, year, title, methods, key findings, health condition/s mentioned, barriers mentioned, and any other comments. A PRISMA flow diagram is also included in Appendix D presenting the search results by the two search dates.

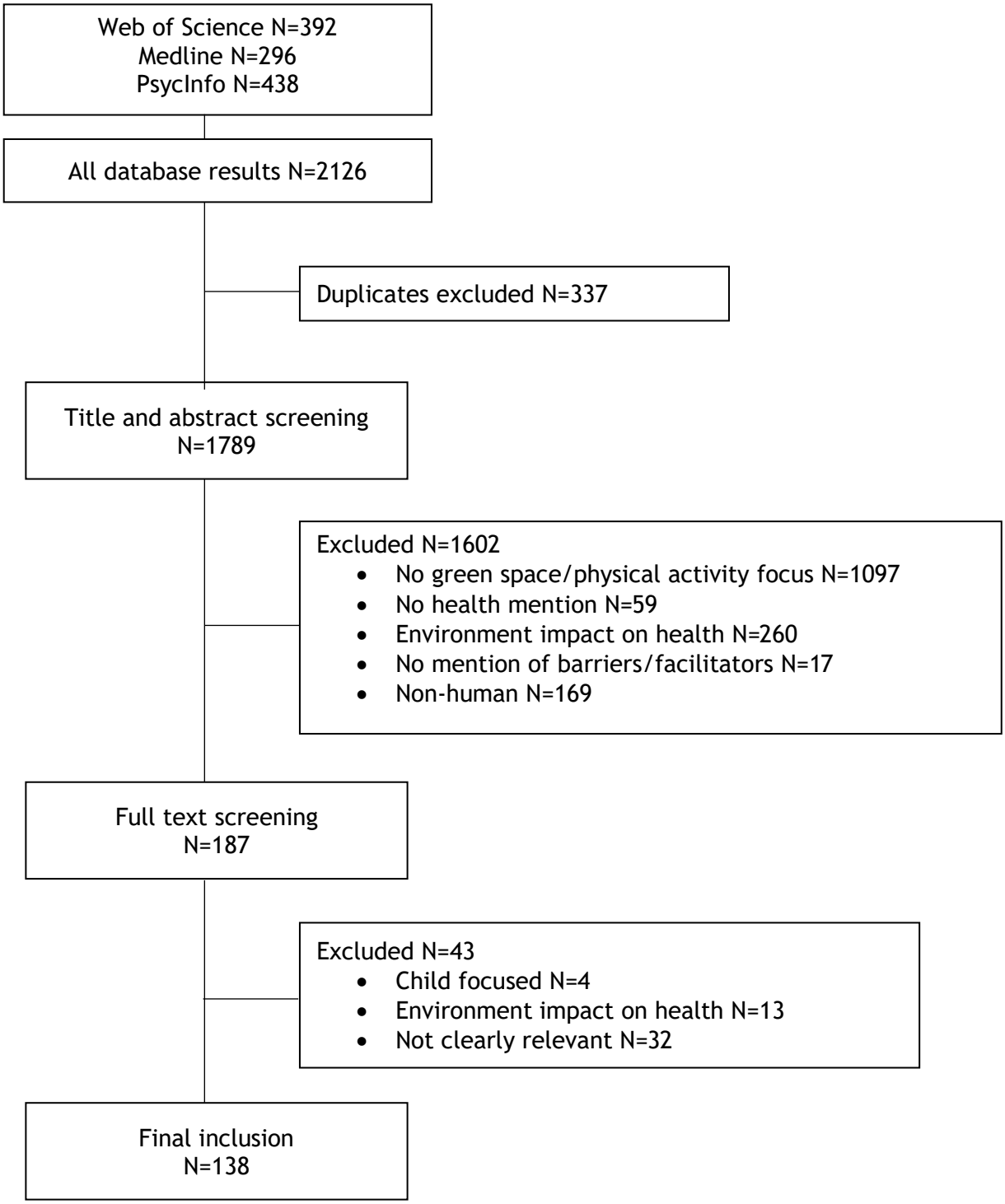


Figure 2-1: PRISMA flow diagram for the literature review.

2.3 Literature search results

The initial results of the literature search title and abstract screening highlighted the lack of literature exploring barriers to green space use. This meant that the inclusion criteria were widened to include studies exploring physical activity levels and the other outdoor environments, such as the built environment, as reflected in Figure 2-1. Physical activity has been reported as a key reason for using green space, with 'health/exercise' the most frequently cited reason for using green space in both Scotland's People and Nature survey 2013/14 (43%) and Natural England's Monitor of Engagement with the Natural Environment (MENE) survey 2017/18 (50%) (TNS, 2014; Natural England, 2018). Exploration of the built environment in regard to health often focuses on walkability to the destination or distance from home (Martin *et al.*, 2007; DeGuzman, Chu and Keim-Malpass, 2019). Studies exploring physical activity and the built environment are therefore likely to provide similar results to green space use, especially when focusing on health-related barriers such as poor mobility. However, it is also important to be cautious with these comparisons, with features such as high traffic levels and accessibility to the site likely to differ between urban and natural environments.

2.3.1 Infrequent use and barriers to using green space

The definition of infrequent use of green space varies in the literature from visiting green space less than once a month to never visiting green space (Boyd *et al.*, 2018; Natural England, 2021a). Multiple reasons for why an individual only uses green space infrequently have been reported, including not being interested in going to a green space, lack of transport to get to the green space, poor weather, lack of accessibility within the green space (such as uneven pavement or a lack of resting places), and poor health (O'Brien and Morris, 2014; Boyd *et al.*, 2018). The reasons for non-use or infrequent use of green spaces are named as barriers to green space use in throughout this thesis.

Infrequent use of green space has been found to differ by socio-demographic characteristics. For example, a study based in Detroit, Michigan reported that individuals in the group that almost never used green space tended to be older, to have more difficulty with basic self-care activities (e.g., bathing, dressing,

eating, grooming, and toileting), and to have greater difficulty with mobility and vision when compared to those who used green space on an occasional basis (at least once per week) (Clarke and Gallagher, 2013). The green space exposure was measured using a "virtual audit" of Google Street View images on Google Earth (2007-2009), with a summary urban accessibility score calculated for each street. This is reportedly a reliable indicator of land use, despite the lack of information provided on type of green space. A study in England corroborates these findings, reporting that individuals who were female, older adults, in a lower socio-economic status group, had a long-term illness/disability, and had a carer were more likely report being infrequent users of green space (Boyd *et al.*, 2018). This study used in-home interviews to collect data, asking respondents to recall visits over the last 12 months, which likely led to unreliable recall. Despite this, a representative sample of the English population was used, and the dataset included 10 individual predictor variables, including sex, age, dog and car ownership, which meant that multiple confounders were adjusted for and strengthens the reliability of the findings.

Poor health has been consistently reported as a barrier to frequent use of green space in multiple studies (Sin *et al.*, 2004; Firth *et al.*, 2016; Boyd *et al.*, 2018). In a study by Boyd et al. (2018), poor health was the second most reported reason for not visiting green space frequently (18.5%), with being too busy at work (20%) the most reported reason. In Canada, individuals with constraining health conditions were found to be less sufficiently active than their counterparts (Cutumisu and Spence, 2012a). Similarly, in a Finnish study of older adults, unmet physical activity was found to be particularly prevalent in those with musculoskeletal diseases, depressive symptoms, and mobility limitations (Rantakokko, Iwarsson, Hirvensalo, *et al.*, 2010). However, almost all studies exploring green space use have focused on 'poor health' or specific health conditions (e.g., dementia), rather than comparing use of green space by different types of health condition. This is a key weakness in existing literature, with comparisons being important to explore how the barriers to green space use differ by health condition in the population. Those that have explored differences between individuals with different types of health conditions have measured broader physical activity levels, rather than green space use.

Within the literature, the key barriers to green space use, physical activity, or general mobility were reported as poor health/mobility (N = 9 studies), crime and safety (N = 6 studies), cost (N = 3 studies), the built environment/infrastructure (N = 15 studies) and those related to personal preferences and the social environment (N = 3 studies). The majority of these studies focused solely on older age groups (65+ years), which makes the results less generalisable to other age groups. This could be explained by older adults having the worst access to high quality parks, higher likelihood of infrequent use of green space, and a decline in physical activity levels (Walsh *et al.*, 2001; Cutumisu and Spence, 2012b; Turrell *et al.*, 2014; Boyd *et al.*, 2018; Adlakha *et al.*, 2021; Smith *et al.*, 2021). This leaves an important gap in current research to explore barriers to physical activity and green space use across a representative sample to be able to explore whether barriers differ by age group.

2.3.1.1 Health and mobility barriers

From the nine studies exploring health and mobility barriers to green space use, a recurring reported barrier, particularly in the studies including older adults, was a fear of falling. Two studies, both based in Detroit, Michigan, found that a fear of falling prevented older adults from venturing outside, with older adults who had a fear of falling having almost four-times higher odds of being homebound (never going out) compared with those in the more frequent outdoor mobility group (Clarke and Gallagher, 2013; Smith *et al.*, 2016). A study of older adults in Scotland found that poor health due to age had the highest mean value out of all four perceived barriers to physical activity included in the study (poor health, lack of interest, safety, and access) (Gellert *et al.*, 2015). Physical activity was measured using accelerometers, with activity counts per minute recorded for 7 days, followed by a questionnaire to collect data on barriers. The authors suggested that physical activity interventions should target perceived health and age barriers by including planning how to overcome these perceived health barriers. The use of accelerometery data meant that various sources of bias were overcome, particularly recall bias, adding strength to these findings.

It has been reported that starting to perceive barriers to using green space could reflect early decline in mobility, which has not yet developed into a mobility

limitation (Rantakokko *et al.*, 2012). This was reported in a Finnish study exploring whether older people perceived their environment as problematic because of their mobility limitations, or whether the environmental barriers preceded incident mobility limitation. The study was based on prospective semi-annual follow-up data over a 3.5-year period of the control group recruited for a randomised controlled trial. They also found that, for older adults in Finland, experiencing barriers to green space use led to the risk of new walking difficulty increasing up to three-times (Rantakokko *et al.*, 2012). This finding emphasises the importance of mitigating barriers to green space use with a knock-on effect to individual health. The study did, however, only explore barriers for residents aged 75-81 in the city centre of Jyväskylä, Finland. The barriers to visiting green space could differ for older adults aged <75 or >81 years, and those that live in other areas of Finland or further afield. They also used standardised questionnaires to explore the barriers; it is possible that there are other important features that were not reported. Despite these limitations, the study used a population-based sample and longitudinal data analyses over 3.5 years, which allowed inferences to be made on the temporal order in the association between the barriers and development of walking difficulties (Rantakokko *et al.*, 2012).

2.3.1.2 Crime and safety barriers

The reporting of crime and safety as barriers to using green spaces were commonly associated with sex and ethnicity. Females were found to be more worried about safety from crime at night than males in a Singaporean study exploring green space use, with neighbourhood disorder and crime also found to be a particular barrier for older women in India in another study (Adlakha *et al.*, 2021; Mocnik, Moogoor and Yuen, 2022). There may be cultural differences related to crime and safety in green spaces, however UK-based studies have also found that women often feel more unsafe in green space than men, with women feeling too vulnerable to visit British woodlands alone (Morris *et al.*, 2011). This suggests that sex differences in perceptions of safety in green spaces are prevalent despite cultural and geographical differences. The ability to explore differences in temporality, with feelings of safety in green space explored in both daytime and night-time in these studies, is a strength, and is often not considered in green space literature.

Fear of harassment and discrimination has been found to be exacerbated by feeling 'out of place', especially when the traditional image of someone who uses green space is not met (Smith *et al.*, 2021). This fear can lead to a cultural context in which entire communities feel excluded from green spaces. This was found to be particularly prevalent in Black and Minority Ethnic (BME) groups, with barriers to green space use including feelings of insecurity due to personal attack or racism, and exclusion due to a dominant cultural group (Roe, Aspinall and Ward Thompson, 2016).

Similarly, a report by CABE (Commission for Architecture and the Built Environment) Space (2010) published results of an in-person survey conducted in England (N = 523), they found that only 50% of people of Bangladeshi origin felt safe using their local green space, compared to 80% of Indian people and 75% of white British people. These patterns reflected those found in how satisfied the individual was with their local green space, with white British and Indian respondents reporting high satisfaction with the safety and quality of local green space, and Bangladeshi respondents the least satisfied with these aspects of their local green space (CABE Space, 2010). The report collected data from urban areas in Greater Manchester, the West Midlands, and London, with the results suggesting that ethnic differences are present in cities across England. However, the perception of green space by ethnicity may differ when exploring rural areas and other UK nations; with Scotland, for example, having a much smaller BME population, which may lead to even greater domination of green spaces by specific ethnic groups. The report also focused on deprived urban areas, with inequalities in perception of green space perhaps being reduced in less deprived areas, particularly with the most economically deprived areas having less good quality public green space available (Public Health England, 2020b).

2.3.1.3 Financial barriers

Many costs associated with using green space are discussed in existing literature, included cost of equipment (e.g., appropriate clothing and shoes), funding of green space, cost of transport, and general cost of keeping healthy (Raine *et al.*, 2017; Smith *et al.*, 2021; You *et al.*, 2021). Cost as a barrier is reported more frequently by certain groups than others, for example this has been reported as

a key barrier for individuals with disabilities and low-income groups (Burns, Paterson and Watson, 2008; Morris *et al.*, 2011). For individuals with disabilities, additional costs are presented due to the need for specialist equipment, such as wheelchairs with off-road 'mountain bike' capabilities (Burns, Paterson and Watson, 2008). For those in lower income groups, the financial cost of using green space acts as a barrier, including travel, on-site fees, and refreshments, particularly for those with large families (Morris et al., 2011). Many of the cost-related barriers are associated with the reason for visiting, such as for a leisure activity or a family day out, rather than a walk in the nearest green space. Therefore, the barriers may be related to the intended use of the space or purpose of the visit. Not surprisingly, the focus has been on socio-economic status and cost, with a lack of focus on the influence of age – highlighting a limitation and key research gap.

2.3.1.4 Environmental barriers

Most environmental barriers mentioned in the literature are focused on the quality of the built environment and infrastructure. For example, poor street condition, hilliness, lack of resting places, poor accessibility, and dangerous cross-roads (Rantakokko, Iwarsson, Hirvensalo, *et al.*, 2010; Chen, Matsuoka and Tsai, 2015; Rantakokko *et al.*, 2015; Cronin-de-Chavez, Islam and McEachan, 2019). The environmental barriers experiences within and when travelling to the green space are explored below.

2.3.1.4.1 Environmental barriers within the green space

A study of older adults (N = 589, aged 75-81) in the City of Jyväskylä, Finland found that green spaces that negatively impacted on outdoor mobility were associated with poor quality of life in older adults (Rantakokko, Iwarsson, Kauppinen, *et al.*, 2010). Perceived quality of life and barriers experienced in green space were measured using a questionnaire, with participants asked whether environmental barriers (included a lack of resting places and long distances) limited their ability to move independently outdoors. This study excluded people who could not move independently. Perceived barriers in green space were associated with poorer quality of life for the physically mobile, with the association mediated by fear of moving in the space and unmet physical activity need (i.e., lack of satisfaction with their ability to do physical activity).

These results emphasise the influence that environmental barriers have on individual health and mobility, with personal perception of the space potentially exacerbating the barriers to green space use. A further study of older adults (N = 643, aged 75-81) in the City of Jyväskylä, Finland by Rantakokko *et al.* (2010) found that predictors of lower levels of physical activity included hills, loud traffic, and fear of moving outdoors. The association between these barriers and unmet physical activity were stronger in those with walking difficulties (Rantakokko, Iwarsson, Hirvensalo, *et al.*, 2010). These findings emphasise the influence that the quality of the green space itself can act as a barrier to use, particularly for the older generation.

2.3.1.4.2 Environmental barriers when travelling to the green space

Cinderby *et al.* (2018) studied adult's (aged 55+) mobility in three UK cities (Hexham, York, and Leeds) using a mixed methods design that included participatory mapping, photo diaries, interviews, use of a Geographic Information System (GIS), and an online survey. This study did not focus on green space, but more generally 'getting about town'. This study was included in this literature review because the barriers to 'getting about town' would likely be experienced when travelling to green spaces, as well as within them. The study found that three critical intersecting and interacting thematic problems for urban mobility were reported amongst the older adults: the quality of physical infrastructure (poor pavement surfaces, reduced accessibility, a lack of resting places, steps); issues around the delivery, governance, and quality of urban systems and services (bus routing, reliability and frequency, confusing road layouts, public toilet availability, poor signage); and the attitudes and behaviours of individuals that older people encounter (inconsiderate driving/cycling/pedestrians, parking on pavements) (Cinderby et al., 2018). The mixed methods approach ensured a great depth of information was collected across urban areas of different sizes. However, the overall sample (N = 177) remained relatively small, with data only collected in Northern England. The results may not be generalisable to urban areas in other countries, or for individuals aged under 55. It highlights key barriers faced when travelling across urban environments, and that the same barriers may be experienced within, and when travelling to, green space.

2.3.1.5 Personal preference and the social environment

In a study conducted in Vancouver with women aged 72-97 living in retirement apartments, 'the woman herself' was defined as a barrier to physical activity (Bjornsdottir, Arnadottir and Halldorsdottir, 2012). The phrase 'the woman herself' referred to individual-level factors that act as a barrier to physical activity, such as having a former physically passive lifestyle, low motivation and self-efficacy, declining health, and sociophobia (a fear of socialising). A key reason for using green space is physical activity, therefore if 'the woman herself' is a barrier to physical activity, then this may limit one of the key reasons to use green space and thus act as a barrier. The social environment was also found to be a barrier to physical activity. Social factors included having care responsibilities and no encouragement from staff. These findings suggest that both individual-level factors, as well as the social environment, influence physical activity levels and capabilities. However, this study was conducted on a small sample (N = 10) of older women, with differences by gender and age likely to exist. For example, adolescents have previously reported social activities as motivators for visiting green space, rather than barriers (Bloemsma *et al.*, 2018). This emphasises that more research is required that explores further how physical, social, and individual factors influencing physical activity interconnect across the wider and various levels of the socio-determinants of health.

One study explored determinants of green space use amongst low-income multi-ethnic families in the North of England, with parents (N=30) of young (0-3-year-old) children interviewed. Social and community influences were found to both positively encourage use of green space, for example through positive social interactions and practical support, and to act as a barrier to use of green space, by experiencing antisocial or inappropriate behaviours in green space (Cronin-de-Chavez, Islam and McEachan, 2019). The majority of interviewees were female parents/carers not in employment, which reflected the demographic of parents caring for young children in the study area, and a population group that is often excluded from academic research. However, the findings may not reflect the barriers to green space use experienced by working parents and by male parents/carers. Both of the studies discussed in this section emphasise the influence that personal preference and the social environment has on green space use, as both a barrier and a potential facilitator.

2.3.2 Barriers to green space use for individuals with chronic health conditions

The literature in this section will focus on barriers to green space use for those with general health conditions (or poor health), as well as more specific chronic health conditions, including mobility limitations and physical disabilities, vascular conditions, progressive illnesses, mental health conditions and cognitive impairments, arthritis, and other conditions (stroke, brain injury, and chronic obstructive pulmonary disease (COPD)).

2.3.2.1 General health conditions

Multiple studies have discussed the impact of having a chronic health condition on walking, being mobile, and using green space (Dawson *et al.*, 2007; Clarke, 2014; Hand, 2016; Keskinen *et al.*, 2020; Portegijs *et al.*, 2020). For example, one study selected 28 parks from 6 urban Montreal neighbourhoods of differing health status, with poor health areas being defined by life expectancy for men at birth, lung cancer incidence rate, and ischemic heart disease mortality rate, and the poor health areas having rankings lower than the regional average for these three factors. They found that neighbourhood parks located in poor health areas were of poorer quality, including limited provision of facilities for physical exercise, adjacency to industrial sites and multi-lane roads, and a concentration of physical incivilities (Coen and Ross, 2006). It was reported that the poor quality of the parks was likely to have serious implications for the utility of these spaces and the promotion of health behaviours. Although this study was based in Canada, and may not be generalisable to other countries, the influence of poor quality green space on use and health has been found to be similar in other settings, including Australia and the Netherlands (Dillen *et al.*, 2012; Feng and Astell-Burt, 2017).

Further studies were found through the literature search that focused on barriers to walking in urban environments. The general walking barriers can be linked to green space barriers, with moving around urban areas also likely to be relevant to walking within green spaces, but caution being necessary when comparing natural and urban environments. It was reported that having chronic health conditions was associated with greater difficulties walking 500m, with one chronic health condition that has large debilitating effects on mobility

perhaps being more meaningful than overall chronic disease burden (Keskinen *et al.*, 2020; Portegijs *et al.*, 2020). On the other hand, a US study of adults aged 65+ (N = 6,578), found that a greater number of chronic health conditions was associated with greater difficulty going outside (Clarke, 2014). This study had a large, nationally representative sample; however, recall bias may have been present, with the older adults asked to recall their trips from the last month. The sample was also predominantly white (80.5%), and therefore may not reflect the experiences of Black, Asian, or minority ethnic individuals.

The urban environment and infrastructure have been reported as the greatest barriers to physical activity for individuals with poor health. Specifically, a lack of benches, traffic problems, steep slopes, neighbourhood safety, and limited provision of facilities for physical exercise (Coen and Ross, 2006; Hand, 2016; Keskinen *et al.*, 2020). Those with physical impairments have been found to lack the confidence to be mobile, particularly when experiencing negative social encounters with other people (Bevan *et al.*, 2016). These findings highlight the higher number of barriers faced navigating urban environments, particularly for individuals with health conditions. It is important to be cautious when comparing the barriers faced in urban and natural environments, with some features likely to be similar (e.g., pavements surfaces) and some very different (e.g., traffic levels). The lack of literature focusing on barriers to green space use for those with poor health emphasises a key gap in the literature.

2.3.2.2 Mobility limitations and physical disabilities

Only two studies from the literature search explored barriers to green space use for individuals with physical disabilities and mobility limitations. Therefore, the scope was cautiously broadened to include studies exploring barriers to physical activity, walking, and use of the built environment for individuals with these health conditions.

A qualitative study in Denmark of individuals with mobility limitations (N = 24, aged 12-68 years) found that a lack of accessibility within the green space (i.e., uneven pavements, no resting places, steps with no ramps) led to feelings of exclusion and outsideness (Corazon *et al.*, 2019). Several interviewees also reported a lack of information about the accessibility within the space as a

barrier. This lack of information, as well as the related fear of encountering difficulties, getting hurt, becoming tired, or not being able to use the toilet meant that most of the interviewees reported using green space with which they were familiar and felt safe. This study had a relatively small sample size, and the interviewees had volunteered to take part in the study which may have caused the sample to be biased towards people with an interest in, and positive attitude towards, using green spaces (Corazon *et al.*, 2019). Another Danish study found that both respondents with (N = 383) and without (N = 10,855) mobility limitations stated that the longer the distance to the nearest green space, the less frequently they used green space (Stigsdotter, Corazon and Ekholm, 2018). Both studies provide further understanding of barriers to green space for individuals with mobility limitations and physical disabilities.

A study conducted in the US found that all perceived barriers to walking, including traffic and crime, were significantly more common among adults with any disability compared to those with no disability, regardless of adjustments (Omura *et al.*, 2020). The way in which the neighbourhood is perceived, as well as the barriers to walking within the neighbourhood, are affected by the type of disability and the degree to which the disability impacts daily life (Tynan, 2021).

Deducing the type of disability can prove challenging, with one of the key difficulties that arises when exploring barriers to green space use for individuals with chronic conditions being the breadth of conditions that are experienced amongst the population, and how these are described and categorised. Within the papers found through the literature search that explored physical disabilities, terms included ‘disabled’, ‘users of mobility devices’, ‘mobility limitations’, ‘people with disabilities’, ‘physical disabilities’, ‘mobility-limited’, ‘groups using assistive mobility technologies’ and ‘wheelchair users’. The wide variety of terms used for physical disabilities adds difficulty when comparing differences in barriers to green space use, with a single term being needed to ensure comparability and a clear definition.

A systematic review of literature from 1990-2015 exploring whether the built environment moderates the relationship between having a disability and lower physical activity levels found that most research to date has been on older adults with physical disabilities (Eisenberg, Vanderbom and Vasudevan, 2017).

Within the systematic review, the most common barriers to physical activity for individuals with disabilities were related to the design of the built environment, particularly the density of people and streets. The results also highlighted the importance of the quality of the built environment, for example, focusing on pavement condition as well as pavement presence (Eisenberg, Vanderbom and Vasudevan, 2017). Most of the papers included in the systematic review had US samples (N = 10 papers), with others based in Canada, Sweden, and Turkey. This suggests that there is a lack of literature on the built environment, disabilities, and physical activity, especially in non-Western countries. From other research not included in the systematic review, the findings are corroborated, with reports that the environment should be accessible and aesthetically pleasing, with good signage, well-kept pavements, good public transport, and resting places/shelter (Brown, Kaplan and Quaderer, 1999; Kirchner, Gerber and Smith, 2008; Ripat and Colatruglio, 2016; Smith *et al.*, 2021).

It has been suggested that individuals with and without disabilities experience the same type of environmental barriers, however, disability exacerbates the experience of these barriers (Visagie *et al.*, 2017). For example, poor access to public transport and difficult terrain in rural areas with poor infrastructure affects all people, but the extent to which it affects people with disabilities may be different due to increasing exclusion. Visagie *et al.* (2017) found that other barriers, such as access to assistive technology and feelings of stigmatisation and discrimination, are specifically related to disability. These examples were found in a study conducted across sub-Saharan Africa (in South Africa, Sudan, Malawi, and Namibia), providing unique data for this region. The samples were not representative of the four countries' populations and involved self-reporting of environmental barriers which likely introduced bias into the data. Despite these limitations, the same pattern was reflected in mitigating barriers in a Canadian study; features that help users with disabilities that require mobility devices are also likely to help many others, including people with pushchairs (Gan *et al.*, 2022).

Four domains associated with likelihood of physical activity for people with disabilities were highlighted by Rimmer *et al.* (2016): access, usability, adherence, and health and function. Physical access (to get to the location, e.g., a park or tennis courts) is typically the first obstacle to physical activity for

individuals with limited mobility. Usability goes beyond physical access and addresses user-design principles that are associated with the individual having an efficient, effective, and satisfying experience; how they feel about performing the exercise. Adherence includes motivation to sustain the behaviour once both access and usability are satisfied. Health and function as a domain are related to how the type of health condition someone has may influence their experience differently to someone with another condition. For example, what may be effective for people with lower-level spinal cord injury may have a different physiological effect on people with multiple sclerosis or higher-level spinal cord injury (Rimmer, Lai and Young, 2016). Further understanding of the health and function domain is particularly missing in existing literature and will be the main focus of this thesis.

Finally, a systematic review of literature focusing on exercise, leisure, and well-being for people with disabilities stated that the degree of participation among people with disabilities is affected by a multitude of factors that include a specific individual's personal attributes and their environment (Rowland, 2013). This emphasises the need to remember that an individual is more than their disability, and this should be reflected in research. These studies all highlight the place itself, especially accessibility within and design of the green space, as key barriers for individuals with physical disabilities.

2.3.2.3 Vascular conditions

Three studies focusing on vascular-related health conditions, which affect the circulatory system, were found through the literature search. These studies explored cardiovascular diseases, blood pressure, peripheral artery disease (PAD; a circulatory problem in which narrowed arteries reduce blood flow to limbs), and hypertension (Forechi *et al.*, 2018; Arya *et al.*, 2020; Aliyas, 2021). Two of the studies focused on older adults (65+), with the third study including 34-74-year-olds. This could be explained by those aged 60+ in the UK having the highest prevalence of cardiovascular disease and hypertension (Bhatnagar *et al.*, 2016; Tapela *et al.*, 2021).

One of the studies explored green space use of older adults aged 65+ in Iran (N = 912), it was found that the length of stay in green space was negatively

associated with blood pressure and cardiovascular diseases, but individuals with cardiovascular diseases were more likely to use green space more frequently, whilst those with hypertension used them less frequently (Aliyas, 2021). The data were collecting using surveys, which resulted in a relatively large sample, however the results were also susceptible to social desirability bias.

The other two studies explored physical activity and life-space mobility. Life-space mobility measures community mobility and social participation by quantifying the distance, frequency, and independence obtained as an individual moves through their environment (Arya *et al.*, 2020). Exploring reasons for a lack of physical activity, a Brazilian study of civil servants (N = 15,105, aged 35-74) focused on individuals with hypertension, the reasons for a lack of physical activity were found to be associated with a lack of opportunity and conditions to practice physical activity (Forechi *et al.*, 2018). Using the life-space mobility measure, a longitudinal study in the US focused on older adults with peripheral artery disease (PAD) (N = 981) and found that these individuals had more rapidly declining life-space mobility compared to those without PAD (Arya *et al.*, 2020). However, this association was no longer present when adjusting for demographic variables, chronic comorbid condition, Geriatric Depression Score, and Mini-Mental State Examination scores. The findings from the three studies emphasise the difference in use of green space/physical activity levels and related barriers for individuals with different health conditions.

Two further studies were found through snowballing of literature that focused on physical activity for individuals with cardiovascular conditions (Klompstra, Jaarsma and Strömberg, 2015; Abaraogu *et al.*, 2018). Abaraogu et al. (2018) conducted a systematic review of 18 studies (N = 4,376) focusing on the barriers and enablers for engaging in walking for patients with intermittent claudication (IC; most commonly pain affecting the calf) and PAD. They found that the most frequently reported barriers to engaging in walking among the patients were multiple health concerns, walking induced pain, lack of knowledge (e.g., about the disease pathology; recommendations for green space visits from friends and professionals, for example; and knowledge of the space and facilities), and poor walking capacity. The most frequently reported enablers were cognitive coping strategies, good support systems, and receiving specific instructions to walk. Similarly, Klompstra et al. (2015) conducted research on physical activity

barriers for patients who had suffered heart failure in Sweden (N = 154), using a cross-sectional survey design. The most commonly reported barrier was "suffering from minor injuries" (85%), followed by "need to spend time on other things" (83%), "need to spend time on family responsibilities" (82%), "feeling physically tired" (82%), and "working long hours" (80%). These findings suggest that health/mobility is a key barrier to physical activity for individuals with heart conditions, however time constraints are also a key reason for a lack of physical activity.

2.3.2.4 Progressive illnesses

From the literature search results, five studies focused on individuals with a form of progressive illness. Three studies explored use of green space by dementia patients, and two studies explored physical activity in individuals who had been diagnosed with cancer or were cancer survivors (Van Schaik *et al.*, 2008; Bossen, 2010; Olsson *et al.*, 2013; DeGuzman, Chu and Keim-Malpass, 2019; Figuracion, 2020).

In two studies, the key barriers to green space use reported by people with dementia included difficulty with access (e.g., locked or heavy doors, distant location), lack of accessible designs (e.g., no handrails, poor surface materials), lack of safety features and resting spaces, untrained staff, lack of weather protection (e.g., canopies, screened or glassed-in enclosures), weather-related problems (e.g., excessive heat, cold, sun, rain), and lack of easy access to facilities such as toilets and drinking fountains (Van Schaik *et al.*, 2008; Bossen, 2010). Staff knowledge and concerns for safety were reported as crucial parts of access to, and use of, green spaces for those with dementia. A study conducted in Sweden explored individuals with early-stage dementia (N = 11) and their reflections on being in green space using repeated interviews (Olsson *et al.*, 2013). This was a small sample, however the repeated interviews allowed for prolonged engagement and provided greater depth to the findings. They found that two sub-themes emerged, with a shift between 'still being a part of it all' and a sense of grief/loss, as well as striving to keep using green space despite the perceived barriers. The barriers mentioned were physical impairment, problems with orientation (in time and space), and mental aspects of living with dementia (Olsson *et al.*, 2013).

In the literature, the barriers to physical activity for cancer patients and survivors were varied, including fatigue, impaired mobility, depressed mood, and limited time to devote to exercise. In a qualitative study of cancer survivors (N = 7) based in central Virginia, US, concerns for safety were found to be exacerbated by cancer-related physical limitations (Deguzman, Chu and Keim-Malpass, 2019). Cost has also been reported as a key barrier to physical activity for patients with cancer, with financial toxicity highlighted as a barrier. Financial toxicity is defined as financial problems resulting from medical care that leads to debt and bankruptcy, affecting patients' quality of life and access to care (Figuracion, 2020). These expenses can also influence an individual's ability to undertake physical activity and use green space; especially when costs are incurred for transport, entry to a site, and suitable clothing. Financial toxicity is likely to be a larger issue in countries with private healthcare, such as the US.

The results of the literature search highlighted the lack of studies that explore green space use or physical activity levels in individuals with cancer, particularly younger adults. The highlighted literature only included small US samples and qualitative research methods, which provide depth rather than breadth. More research is required to further understand the barriers to green space use for individuals with progressive illnesses, including those with other health conditions, such as Parkinson's disease and Huntington's disease.

2.3.2.5 Mental health conditions and cognitive impairments

Most studies exploring mental health and green space have focused on the impact of green space use on an individual's mental health. There are few studies that instead focus on the impact of mental health on green space use, and fewer exploring barriers to green space use for individuals with mental health conditions or cognitive impairments.

From the literature search results, two studies explored depression and physical activity, one focused on loneliness and walking, and one focused on mild to moderate cognitive impairment and life-space mobility (Hybels *et al.*, 2010; Rantakokko, Iwarsson, Hirvensalo, *et al.*, 2010; Rantakokko *et al.*, 2014; Ullrich *et al.*, 2019). All four studies use older age samples, aged 60+ years. This

emphasises a research gap in the existing literature, with a lack of research focusing on the influence of mental health conditions on green space use and barriers for individuals aged <60 years. This is particularly important, with the increasing prevalence of poor mental health among young people in the UK. A study in England reported an 81% increase in referrals for children and young people's mental health services between April and September 2021 (337,135 young people referred), compared with the same time period in 2019 (186,496 referred). The increase for adults (19 years and over) in the same period was 11% (Iacobucci, 2022; Morris and Fisher, 2022).

A Finnish study on loneliness in 75-90-year-olds (N = 848) found that respondents who reported loneliness had greater difficulty walking 2km, restricted autonomy in participation outdoors, and more environmental barriers to outdoor mobility than people not experiencing loneliness (Rantakokko *et al.*, 2014). Even after adjusting for walking difficulties and number of chronic conditions, the association between environmental barriers and loneliness remained significant. This suggests that other resources, such as psychological characteristics, and in particular self-efficacy, may explain the association.

In the studies exploring depression and physical activity, questions of cause and effect arose. Depressive symptoms were observed simultaneously with unmet physical activity need, making it possible that depressive symptoms were a consequence rather than a cause of unmet physical activity need (Rantakokko, Iwarsson, Hirvensalo, *et al.*, 2010). One study of older adults with major depression in North Carolina (N=248) found that there was not a single trajectory between depression and functional status for all patients in their sample; with some patients having no mobility limitations, some patients having improved mobility over time, and others reporting worsening mobility (Hybels *et al.*, 2010). Similarly, no significant association was found between depressive symptoms and life-space mobility in older adults with cognitive impairments (N=118) (Ullrich *et al.*, 2019). These findings further emphasise the challenges that can occur when exploring the associations between mental health and green space use, with one barrier or pattern of usage not being applicable to all individuals with the same health condition.

2.3.2.6 Arthritis

Two studies from the literature search explored physical activity and mobility in individuals with arthritis, based in North Carolina, US and North Staffordshire, UK (Martin *et al.*, 2007; Rantakokko and Wilkie, 2017).

A major theme that emerged from the literature on arthritis and physical activity was the importance of environmental barriers. In adults with GP-diagnosed osteoarthritis based in North Staffordshire (N = 1,802), the association between osteoarthritis and the onset of restricted mobility was greater when environmental barriers were present. Environmental barriers included living in an area with hills and steep slopes, inaccessible public buildings, poor pavement condition, lack of access to public parks or sport facilities, heavy traffic or speeding cars, and adverse weather. The most commonly reported environmental barriers were hills, steep slopes, and adverse weather (Rantakokko and Wilkie, 2017). The generalisability of the study findings may be limited because the area covered by this study is more deprived in terms of health, education, and employment, but has fewer barriers to housing and services than England as a whole.

The results of the US study (N = 2,479) showed similar community-level reasons for physical inactivity (e.g., rural environment, heavy traffic, and lack of sidewalks) despite arthritis status. A primary barrier to physical activity for those with arthritis was walking surfaces, with sub-analyses by arthritis status revealing that quality of walking surfaces was the only theme unique to individuals with arthritis (Martin *et al.*, 2007). The study concluded that individuals with arthritis encounter similar barriers to physical activity as those without arthritis, however they also navigate their environment with additional physical limitations. A goal was set to prevent the burden of arthritis on physical activity and general quality of life, which can also be reflected when exploring barriers to green space use for those with arthritis.

2.3.2.7 Other health conditions

There were a number of health conditions, namely stroke, brain injury, and chronic obstructive pulmonary disease (COPD), for which only one study was found.

A study exploring stroke survivors' (N = 20) personal experiences in green space in Michigan highlighted three themes that emerged from the stroke survivors' description of their personal experiences, with a combination of facilitators and barriers (Twardzik *et al.*, 2022). These themes included feelings of vigilance (e.g., heightened awareness, familiarity with the environment decreasing vigilance), employing adaptation strategies (e.g., altering an environment to meet needs, continuous modification within environments), and management of dynamic relations between the self and context (e.g., changing perceptions of environment over time, fluctuating function). They also found that some individuals viewed barriers as opportunities to improve individual function, and therefore embraced adaptations. The study only included stroke survivors who could walk safely outdoors, therefore the experiences of individuals with severe limitations were not collected. Motivation bias may have been introduced by participants being recruited from an existing registry of potential research subjects at a large academic medical centre. This is a bias that is introduced when the characteristics of the self-selected participants differ from people who do not select into the study (e.g., an interest in the research topic or a wish to express their point of view).

Stroke survivors reported accompaniment as a factor leading to an increased willingness to engage in green space use, however, for those with traumatic brain injuries, needing support from others was associated with reporting more environmental barriers (Whiteneck, Gerhart and Cusick, 2004; Twardzik *et al.*, 2022). This was also found to differ by the type of assistance needed; people requiring physical assistance reported more barriers relating to work or school, and people requiring cognitive assistance reported more overall and policy barriers (Whiteneck, Gerhart and Cusick, 2004). Similarly, a study exploring life-space mobility in older adults with COPD found that reporting decreased independence was a key barrier to engaging in outdoor activities, leading to greater loneliness (Garcia *et al.*, 2017). The influence of this barrier and results relating to life-space mobility limitation may have been under-estimated, with the sample containing a low number of patients with severe and very severe COPD. These findings suggest that barriers are not likely to be reported alone, and most barriers to green space use are likely to synergistically influence each other, as well as influence health.

2.3.3 Facilitators of green space use

Ten studies reported facilitators of green space use or physical activity. Facilitators are factors that allow for, or encourage, green space use. The studies reported multiple facilitators, including good quality green space, use of phone applications, green space within walking distance, availability of facilities, well-maintained walking routes, familiar and appealing surroundings, good lighting, cleanliness, and variation in the natural landscape (Seaman, Jones and Ellaway, 2010; Satariano *et al.*, 2012; Tsai *et al.*, 2013; Eronen *et al.*, 2014; Rantakokko *et al.*, 2015; Portegijs, Keskinen, *et al.*, 2017; Keskinen *et al.*, 2018; Noone and Jenkins, 2018; Hinrichs *et al.*, 2019; Shams and Barker, 2019).

The presence of green space itself has been highlighted as a strong facilitator of physical activity, particularly walking. A study of older adults in Finland (N=848 75-90-year-olds) found that, for individuals with difficulties in walking, perceiving green space as a facilitator for outdoor mobility resulted in two to three-times higher odds of reporting moderate physical activity (Keskinen *et al.*, 2018). This was corroborated by a separate study that found that those who reported perceiving a green space in their neighbourhood as facilitating their mobility had ten-times higher odds of walking compared to their counterparts (Hinrichs *et al.*, 2019). However, both studies were conducted in Finland with older adults, therefore these findings may not be generalisable to other age groups and those residing outside of Finland.

A study exploring dementia patients' (N = 6) involvement with a gardening project in Glasgow found that the patients reported gardening as a facilitator to their use of the local green space through the development of new social bonds based upon shared interests, rather than through a shared diagnosis (Noone and Jenkins, 2018). This supports the idea of nature as a facilitator. Despite a small sample, the use of qualitative methods (interviews and observations) guided by phenomenological principles facilitated deeper understanding of the meaning of community gardening from the perspectives of people with dementia.

Green space quality and accessibility have also been reported as key facilitators. Living in areas where there were local services and attractive walking destinations near home was found to promote physical activity and green space

use (Tsai *et al.*, 2013; Eronen *et al.*, 2014; Portegijs, Rantakokko, *et al.*, 2017). In a study of 150 visitors to four green spaces in the UK (two in Leeds and two in Manchester), the highest rated characteristics of local parks were cleanliness, variation in the natural landscape, safety, accessibility, and size (Shams and Barker, 2019). Accessibility was associated with evenness of the landscape and the availability of wide pathways. Toilets, walking or cycling paths, availability of parking areas, and benches for sitting were the most preferred facilities. Walking or cycling paths were linked to accessibility and safety and were reported as important factors for people with pushchairs or mobility scooters. Facilitators and perceptions of green space are likely to differ by the individual park, city, and country which means that the results may not be generalisable to park users outside of the two UK cities. However, these facilitators were also corroborated by other studies in Finland and the US (Satariano *et al.*, 2012; Rantakokko *et al.*, 2015; Portegijs, Keskinen, *et al.*, 2017).

2.4 Summary of gaps in existing literature

The existing literature shows that there are differences in the use of green space and barriers to using green space by socio-demographic characteristics. They also suggest a difference in the barriers to green space use by type of health condition. However, much of the existing literature focuses on one specific health condition and does not explore if, and how, differences in barriers exist between individuals with different types of health condition. One of the key messages highlighted by the literature was that the same issues – an individual's physical condition/mobility, the quality of the green space, and the accessibility within and to the green space – are barriers to using green space for all. However, these barriers exacerbate low or non-use for those with a chronic health condition. Improvements to green space which allow use for those with particular health conditions, such as mobility issues, also act as facilitators of use in the wider population, such as people travelling with pushchairs (Shams and Barker, 2019).

The existing data and literature on green space use and non-use shows that poor health is one of the top reported reasons for infrequent use (TNS, 2014; Boyd *et al.*, 2018; Wilson and Seddon, 2018). However, these data do not contain any categories within 'poor health'. Researchers have emphasised the need to

understand and promote more inclusive nature experiences that cater for people with diverse health conditions (Boyd *et al.*, 2018). Despite this, current research has focused on singular or small groups of health conditions (e.g., cardiovascular and mental health conditions), rather than exploring differences in green space use between multiple health conditions (Stigsdotter, Corazon and Ekholm, 2018; Bell, 2019; Corazon *et al.*, 2019; Astell-Burt *et al.*, 2023). There has also been a focus on barriers to physical activity or leisure activities, rather than barriers to green space use (Gebhard and Mir, 2021). Therefore, there is a need to fill this gap by exploring whether people with specific health conditions should be targeted in new and existing interventions, as well as the facilitators and barriers to green space use affecting people with different health conditions (e.g., physical disabilities, diabetes, and mental health conditions).

The literature search and review have highlighted gaps in the literature that need to be filled to further understand use of green space and barriers to use, particularly if and how barriers to green space use differ by type of chronic health condition, with results informing future policy and practice. These findings could be used when planning new green space in hospital and care settings, prescribing nature, or designing a new community garden, for example. Comparing the current findings that focus on people with one particular health condition suggests that the barriers to green space use vary between individuals with different health conditions. However, these studies have been conducted in different countries and for different population groups, from university students to older women living in retirement apartments (Bjornsdottir, Arnadottir and Halldorsdottir, 2012; Úbeda-Colomer, Devís-Devís and Sit, 2019). To strengthen understanding of how green space use and barriers differ by type of health condition, it is important to explore these differences for one sample using a variety of analytical approaches.

Another key research gap includes an exploration of barriers to green space use for all age groups, with the majority of the existing literature having older age samples. Despite older adults being more likely to be diagnosed with chronic health conditions, including cancer and dementia, it was reported that common mental disorders were more common in working age adults than in those aged 65+ in England (Stansfield *et al.*, 2014; Cancer Research UK, 2021). This emphasises the importance of collecting data on barriers to green space use and

exploring associations by health condition across age groups to explore differences in green space use by age and health, as well as other socio-demographic characteristics.

An additional gap in existing research is to undertake research with a focus on green space use, rather than physical activity. A majority of the studies measured physical activity levels, walkability, and other urban environment features, rather than use of green space, which meant that the scope of the literature review had to be broadened. To better understand the influence of green space itself, actual use of green space must be explored.

Chapter 3 General barriers to green space use: the People and Nature Survey

3.1 Research questions

This chapter describes the data collection and analysis used to explore general barriers to green space use and investigate how these differ by health condition and socio-demographic characteristics. General barriers are defined here as the reasons for infrequent (or non-) use of green spaces, such as bad weather, cost, and being too busy at home. This third chapter focuses on the general barriers to green space use, with the physical health-related barriers (such as mobility and tiredness) being explored further in Chapter 4. Despite this, both poor physical health and poor mental health are included as general barriers to green space use. The key aim of the data collection, preparation, and analysis was to answer the research questions 1 and 2 (Section 1.4):

- RQ1: How does the type of chronic health condition reported differ by socio-demographic characteristics?
- RQ2: How does the reporting of general barriers to green space use differ by type of chronic health condition and socio-demographic variables (sex, age, income, and ethnicity)?

This chapter will outline the data used to answer these research questions, as well as present descriptive statistics. Following this, the methodology used to explore the differences between health conditions and socio-demographic variables in reporting general barriers to green space use will be discussed, as well as differences in reporting health conditions by socio-demographic characteristics. Finally, the results and interpretations of the results will be presented and explored, concluding with a summary of the key findings.

3.2 Data choice and preparation

There are a variety of methods available to measure green space use. These include self-reporting of green space use collected through surveys (both online and in person), interviews and diaries, accelerometers, and Global Positioning System (GPS) devices (Rappe, Kivela and Rita, 2006; Grilli, Mohan and Curtis, 2020; Gough *et al.*, 2021). Each of these methods have benefits and limitations,

with surveys and interviews involving self-reporting of green space use, which can invoke social desirability bias and/or response bias. Surveys allow for large, representative populations to be sampled and can be easily repeated across different geographical areas and population groups (Jones, Baxter and Khanduja, 2013). For example, the Scottish Household Survey provides a large nationally representative sample (annual N=10,000) and allows linkage to individual level information (including census data) (Martin *et al.*, 2022). However, a survey is often unable to collect more detailed information, such as the exact green space respondents are using and time of day that they use the green space. Interviews allow for a greater depth of information to be gathered, but these are time consuming and often costly. GPS devices are more objective measures of green space use, with higher accuracy and the ability to spatially join information to the user' tracks such as measures of green space quality or amenities. However, the GPS is often not entirely accurate, for example, the device can have a median location error of 2.5m (Olsen *et al.*, 2019). They can also be seen as intrusive, which means smaller sample sizes and selection bias, which both affect the generalisability of findings. These limitations emphasise the importance of deciding which method to use to measure green space use, and the biases/errors that can influence the results of each data collection method.

Large online surveys were chosen to measure green space use throughout the thesis, due to the benefits listed above, the challenges caused by the Covid-19 pandemic, and the ability to collect information on green space use, as well as perceptions of green space, barriers to green space use, and reporting of health conditions at an individual level. To answer the research questions, comparison was required between age groups, across a wide geographical area, and by health status/condition. Therefore, spatial precision, for example knowing which park the respondent used, was sacrificed in order to generate the data that answered the research questions and aims.

After deciding that I required a large representative sample that included individuals across a broad age and geographical range, as well as including health questions, I decided to use Natural England's People and Nature Survey (PANS) for the part of my thesis which explored the barriers to green space use and how these differ by type of chronic health condition and socio-demographic characteristics. This was a result of an online search of potential surveys being

undertaken (Search dates: December 2019-March 2020), looking for surveys of UK residents focusing on use of, or visits to, green space and health. Surveys were considered if they collected data on at least two of the following: green space use/visits, health status, type of health condition, barriers to green space use, and socio-demographic characteristics. The following surveys met these criteria:

- Monitor of Engagement with the Natural Environment (MENE) survey & People and Nature Survey (PANS)
- Woods In and Around Towns (WIAT) survey
- Great British (GB) Day Visits survey
- Scotland's People and Nature Survey (SPANS)
- Greenspace Use and Attitudes Survey
- Scottish Household Survey
- Scottish Health Survey

When exploring the questions included in each of the above surveys, none included questions on all of the following: green space use/visits, health status, types of health conditions, *and* reasons for infrequent (or non-) use of green space (Table 3-1).

Table 3-1: Existing survey question check-list results.

Survey	Location (Annual sample)	Green space use/visits	Health status	Types of health condition	Barriers to green space use	Socio-demographic data
MENE 2018-19 / PANS 2020	England (MENE: 47,580 PANS: 25,000)	✓	✓		✓	✓
WIAT 2007 (Baseline survey)	Glasgow and Aberdeen, Scotland (333)	✓			✓	✓
Great British (GB) Day Visits survey 2019	Great Britain (35,746)	✓				✓
SPANS 2013/14, 2017/18, 2019/20	Scotland (2013/14: 12,104 2017/18: 12,502 2019/20: 11,187)	✓	✓		✓ (2013/14 only – not 2017/18 or 2019/20)	✓
Greenspace Use and Attitudes Survey 2017	Scotland (1,000)	✓	✓			✓
Scottish Household Survey 2019	Scotland (10,557 households 9,776 individuals)	✓	✓	✓		✓
Scottish Health Survey 2019	Scotland (12,089)		✓	✓		✓

All of the surveys that included questions on green space use, health status/condition, barriers to green space use, and socio-demographic data were reviewed. None of the surveys in Table 3-1 included all of the key questions/criteria. Therefore, the surveys that included the majority of the topics, particularly barriers to green space use, and the potential to add questions on health conditions were explored further.

The People and Nature Survey (PANS), created by Natural England, was explored further because it included the largest sample and satisfied the majority of requirements, with the most in-depth and recent data collected on use of green space, health status, barriers to green space use, and socio-demographic data which were required to answer the research questions. However, PANS was missing data on the type of health condition/s that a respondent reporting poor health had. I therefore explored whether I could add a bespoke question to PANS to collect data on types of health conditions, specifically in order to answer my research questions. The survey already included questions on visits to green

space and reasons for infrequent use of green space, as well as data on the respondents' health status (including whether they had a health condition lasting 12 months or more) and their socio-demographic characteristics. In March 2020, the People and Nature team at Natural England were contacted, and enquiries were made into adding a new question to the survey on the types of health condition that the respondents who had a chronic health condition reported. The People and Nature team agreed that the new question could be added to the survey for a set fee. Therefore, as this key question could be added and it satisfied all of the other requirements, I selected PANS as my main source of data collection to explore barriers to green space use for individuals with chronic health conditions. PANS is described in more detail in the following subsection (3.2.1).

3.2.1 The People and Nature Survey (PANS)

The People and Nature Survey (PANS) was created in 2020 to gather data through an online survey focusing on enjoyment, access, and attitudes towards the natural environment in England. The survey is a follow-up of the Monitor of Engagement with the Natural Environment (MENE) survey created by Natural England, which ran from 2009 to 2019 and collected survey data from 500,000 respondents though face-to-face interviews (Natural England, 2020, 2021a).

The PANS survey is ongoing with data collected monthly through Kantar, a data and evidence-based agency which runs multiple online survey panels. An English subset of Kantar's Profiles online panel are invited to participate in PANS (Natural England, 2021a). The Kantar panel uses a diverse set of recruitment sources and methods, including opt-in email, co-registration, and e-newsletter campaigns. The desired sample size of PANS is 25,000 respondents per year, 2,080 per month via the continuous monthly data collection, with respondents aged 16 and over. The survey is run on a continuous basis, with data provided and released quarterly. Weights are included in the dataset to ensure that the sample can be nationally representative of England's population. The PANS weighting is based on the latest available population estimate data from the Office for National Statistics, as well as the weighting developed for MENE (Natural England, 2021a).

PANS has a set of modules which are asked every month, with certain modules asked of a randomly selected sub-sample of individuals. The module asking questions about general experience of green and natural places in the last month is asked of all respondents (N = 25,000 per year) (Natural England, 2020). In this module, the questions include:

- Frequency of green space visits in the last 12 months
- Types of green/natural spaces visited during the last month
- Change in quality of local green spaces in the last 5 years
- What the respondents think these places should be like in general (e.g., within easy walking distance), and what their local spaces are actually like
- Their connection to nature
- The impact of Covid-19 on use and experiences of green space

The module focusing on reasons for not visiting green/natural space in the last fourteen days is asked of a subset (N = 9,000 per year) (Natural England, 2020). Some sample sizes differ due to the routing of the question (e.g., reasons for not spending free time outdoors in last 14 days asked only to those who did not use green space in the last month/14 days). The questions in this module include:

- Whether the participant would have liked to have spent more free time outside in green/natural spaces over the last 14 days
- Reasons for not spending free time outdoors in the last 14 days
- Importance of physical health-related reasons in stopping them from visiting green spaces in the last 14 days
- Concerns or worries about visiting green space (e.g., fear of dogs)
- Reasons for lack of green space use caused by Covid-19
- The impact of transport on visits to green space

The questions/responses used to answer the research questions from these modules are presented in Table 3-2.

Table 3-2: Table of People and Nature Survey questions and responses used in the analyses.

Questions asked in PANS	Response in survey	Re-categorised response (if applicable; discussed further in Section 3.3)	Total N of respondents that answered (unweighted)
Do you have any physical or mental health conditions or illnesses lasting or expected to last for 12 months or more?	1. Yes 2. No 3. Prefer not to say		10,415
You previously said that you have one or more physical or mental health conditions or illnesses lasting or expecting to last for 12 months or more... **Which, if any, of the following best describes your underlying health condition(s)?**	1. Arthritis or joint-related conditions 2. Respiratory or breathing problems e.g., asthma 3. Diabetes 4. Heart, blood pressure or circulation problems 5. Mental health conditions 6. Another physical disability (i.e., that limits your mobility) 7. Severe skin condition or allergy 8. Another progressive disability, illness, or health problem (i.e., that can get worse over time) 9. Other (specify) 10. Prefer not to say 11. Don't know	Arthritis Respiratory Diabetes Heart, blood pressure or circulation problems Mental health conditions Physical disability Progressive disability/illness	2,861
Which one of the following best describes your ethnic group or background?	1. White 2. Mixed 3. Asian or Asian British 4. Black or Black British 5. Chinese 6. Arab 7. Any other ethnic group or background 8. Don't know 9. Prefer not to say	White (1) Black, Asian, Minority Ethnic (BAME) (2-7)	10,094
Which of the following best describes your total annual household income before tax?	1. £0–14,999 2. £15,000–19,999 3. £20,000–29,999 4. £30,000–39,999 5. £40,000–49,999 6. £50,000–59,999 7. £60,000–79,999	£0-19,999 (1-2) £20,000-39,999 (3-4)	10,415

	8. £80,000–99,999 9. £100,000-£149,999 10. £150,000 + 11. Don't know 12. Prefer not to say	£40,000-59,999 (5-6) £60,000-99,999 (7-8) £100,000+ (9-10)	
What was your age last birthday?	**Open text box (allow answers between 16-99)** Don't know Prefer not to say	Age bands (created by Natural England): 16-24 25-39 40-54 55-64 65+	10,415
What gender do you identify as?	1. Male 2. Female 3. In another way (specify) 4. Don't know 5. Prefer not to say	Male Female	10,415
In the last 12 months, how often, on average have you spent free time outside in green and natural spaces?	1. Every day 2. More than twice a week, but not every day 3. Twice a week 4. Once a week 5. Once or twice a month 6. Once every 2-3 months 7. Less often 8. Never 9. Don't know 10. Prefer not to say		10,415
Which of the following type(s) of green and natural spaces have you visited <u>during the last month</u>? *Select all of the types of places visited*	1. Urban green space (such as a park, field, or playground) 2. Grounds of a historic property or country park 3. Allotment or community garden 4. Woodland or forest 5. River, lake, or canal		9,909

	6. Hill, mountain, or moorland 7. Beach / other coastline / sea 8. Nature / wildlife reserve 9. Fields / farmland / countryside 10. Another green and natural space (specify) 11. No visits in the last month 12. Don't know 13. Prefer not to say		
How many times, if at all, did you make this type of visit to green and natural spaces in the last 14 days? *Please type in a number*	Minimum value: 0 Maximum value: 100 Don't know Prefer not to say		9,360
What was the main reason or reasons for not spending free time outdoors in the last 14 days? *Please select up to three answers*	1. Bad / poor weather 2. Poor physical health (or illness) 3. Poor mental health or well being 4. Lack of facilities and access points for those with disabilities 5. Too busy at home 6. Too busy at work / with family commitments 7. Not interested 8. Prefer to do other leisure activities 9. Fear / worry about crime or anti-social behaviour 10. Fear / worry about getting hurt or injured 11. Nowhere near me is nice enough to spend my free time in 12. Cost / too expensive 13. Stayed at home to stop coronavirus spreading / Government restrictions 14. Other (specify)		3,521

	15. No particular reason 16. Don't know 17. Prefer not to say		
How important were the following health related reasons in stopping you from visiting green and natural spaces in the last 14 days?	1. My mobility 2. Concerns that I will become ill during this visit 3. Lack of disabled facilities 4. Unsuitable / poorly maintained sites 5. No one to go with me / help me 6. Tiredness / fatigue 1 – Not at all important 2 3 4 5 – Very important Not applicable Don't know Prefer not to say		424

Although PANS already included a question asking whether the respondent had any physical or mental health conditions/illnesses lasting or expected to last for 12 months or more, there were no questions focusing on the specific type of health condition that the respondent had. Following the discussion with the People and Nature team at Natural England, an additional question was included in the survey to ask for the specific type of chronic health condition that the respondent had (development of this question is described in subsequent subsection 3.2.1.3 and shown in Table 3-2). This question was funded by the Places and Health programme at the MRC/CSO Social and Public Health Sciences Unit, University of Glasgow. The additional question relating to health conditions was added to PANS for the purpose of this research and collected over five months, from November 2020 to March 2021.

3.2.1.1 The green space use questions in PANS

The question asking respondents about their use of green space was an existing question in PANS. Respondents were asked about the number of visits to green space within the last 14 days (with a number of visits given in response) and how often on average they had spent free time outside in green space within the last 12 months (with set response categories). These data already being collected through PANS was beneficial, with the question and responses having been

tested previously. However, the question collecting data on green space use in the last 12 months only asked about 'free time' in green space, which would mean that any utilitarian use of the space was missed. This limitation is mitigated by there being two questions on green space use, within the last 14 days and 12 months, which meant that more recent and longer-term green space use patterns could be explored. The wording of the question asking about the last 12 months was also used in Scotland's People and Nature Survey 2013/14 and 2017/18, asking about frequency of visits to green space in Scotland for leisure and recreation in the last 12 months (TNS, 2014; Wilson and Seddon, 2018).

3.2.1.2 The green space barriers questions in PANS

Two questions regarding barriers to green space use were also included in PANS, with one focusing on general barriers to green space use experienced in the last 14 days, and the second focusing on physical health-related barriers to green space use experienced in the last 14 days. The general barriers question included health as a barrier, specifically poor physical health and poor mental health, with physical health as a barrier being explored further in the physical health-related barriers question (Chapter 4).

The general barriers question included a response category relating to the Covid-19 pandemic ('stayed at home to stop coronavirus spreading/Government restrictions'). The focus in this chapter is not the Covid-19 pandemic, which is explored in greater depth in Chapter 5. However, the PANS data analysed in this thesis were collected during the Covid-19 pandemic, which had an influence on individual perceptions and experiences of green space. The restrictions implemented during the pandemic also disproportionately affected the population group of interest (those with chronic health conditions). Individuals with serious underlying health conditions which put them at high risk of severe illness from Covid-19 were advised to follow shielding measures, including staying at home and avoiding any physical contact with others (Ministry of Housing Communities & Local Government, 2020). Therefore, the Covid-19 pandemic was included as a barrier in this Chapter's analysis.

3.2.1.3 Developing the chronic health condition question for PANS

It was a challenge to know how best to word the new question on type of chronic health condition, with no existing surveys collecting data on barriers to green space use *and* type of chronic health condition. To develop the new chronic health conditions question, I explored the questions used in existing surveys outlined in Table 3-1. The benefits of using a similar question to other surveys include being able to compare my findings with other representative samples. From the surveys explored in Table 3-1, the Scottish Household Survey and Scottish Health Survey were the only surveys that included questions that asked respondents to report whether they had a health condition, if yes, the type of health condition, and provided a range of in-depth response categories. The health condition responses included in these surveys differed, with the Scottish Health Survey 2019 having 40 health conditions listed, and the Scottish Household Survey 2019 having 19. I adapted these responses to ensure that the question and responses were succinct and easy to answer for respondents. I also wanted to use the same question and responses in all of the primary data collection for this thesis, which will be discussed in more detail in Chapter 5. To do this, some health conditions were merged into one category. These were selected firstly based on the health condition – e.g., 'problems or disabilities related to arms or hands', 'problems or disabilities related to legs or feet' and 'problems or disabilities related to back or neck' were combined into 'physical disabilities'. More detail of the grouping is provided in Appendix E. These groupings were also based on green space and physical activity literature, which have been introduced in Chapter 2.

3.2.1.4 Data collection and cleaning

The exact wording of the PANS questions and responses included in the analyses are presented in Table 3-2, as well as the number of respondents who were asked each survey question. The new question was included in PANS over five months (November 2020 to March 2021), with the full dataset being collated and received in May 2021. Once the data were received, a quality check was performed, and data were cleaned and merged into one large dataset before analysis started. During the quality check and cleaning, range checks were undertaken. This is a validation technique to check the value of data to ensure

that it is within a certain range, for example, some responses included a range of 1 (Not at all important) to 5 (Very important). As new primary data was collected, the PANS survey data was also sense checked against the English Health Survey 2019, Understanding Society 2019 (Wave 10), Labour Force Survey 2020/2021, and the 2011 Census for England by comparing weighted counts and percentages of sex, age, and prevalence of chronic health conditions, which adequately matched (Table 3-3). No errors were found in the data.

Table 3-3: Sense checking of sex, age, and health condition PANS data by comparing with four existing surveys. All data are in percentages.

		PANS (Weighted %)	English Health Survey (2019) (%)	Understanding Society (Wave 10) (%)	Census England (2011) (%)	Labour Force Survey (Nov 2020-Jan 2021) (%)
Sex	Male	49	49	48	49	48
	Female	51	51	52	51	52
	Total	100	100	100	100	100
New age groups	16-24	13	13	14	14	9
	25-64	64	65	63	66	63
	65+	23	22	23	20	28
	Total	100	100	100	100	100
Chronic health condition	Yes	40	37			42
	No	60	63			58
	Total	100	100			100

The final PANS sample for the five months included 10,415 English adults (aged 16 and over) and was nationally representative of England's population. Respondents were asked the new question if they had reported having a chronic health condition in the previous question. This additional question was included in the further 2020/2021 data collection of PANS, and the results are now publicly available in the PANS dataset.

The variables used for the analyses will be described in more detail in the following sections, as well as in Chapter 4.

3.2.2 Missing data

Responses of 'don't know' or 'prefer not to say' were removed from analysis. In each variable, these missing data accounted for <5%, which conventionally

means that imputation is not regarded as essential. The distribution of missing values across the other characteristics was checked, which added reassurance and furthered understanding as to the implications of missingness. The count of missing data, if any, will be outlined for each variable below (Section 3.3).

3.3 Descriptive statistics (PANS)

3.3.1 Socio-demographic characteristics

Individual-level socio-demographic characteristics – sex, age, ethnicity, and income – were collected for each PANS respondent. The importance of these characteristics was discussed in Chapter 2, with each being strongly associated with green space use, experiences, and barriers to use in existing green space literature. The outcomes explored throughout this specific chapter will be general barriers to green space, such as bad weather and poor mental health. The outcomes will be explored by health condition and socio-demographic characteristics. The results presented in this section will all be weighted, with unweighted counts presented in Appendix F.

In the raw data, there were five age categories: 16-24, 25-39, 40-54, 55-64 and 65+. The sample size for the five categories (Table 3-4) was large enough to be cross-tabulated with the health conditions. Therefore, I chose to use the five categories rather than reduce the number of age bands. The greatest (26%) percentage of respondents were aged 25-39 years, followed by 40-54 (23%) and 65+ (23%) (Table 3-4).

Table 3-4: Socio-demographic characteristics of PANS respondents by sex, age, ethnicity, and income (weighted counts and percentages).

		Weighted N	Weighted %
Sex	**Female**	5301	51
	Male	5095	49
	Total	10396	100
Age	**16-24**	1364	13
	25-39	2717	26
	40-54	2410	23
	55-64	1554	15
	65+	2371	23

	Total	10415	100
Ethnicity	**White**	8702	86
	BAME	1414	14
	Total	10116	100
Income	**£0-19,999**	2716	26
	£20,000-39,999	3703	36
	£40,000-59,999	2111	20
	£60,000+	1826	18
	Total	10356	100

Respondents were categorised into either ‘male’ or ‘female’ sex. There was an even distribution of respondents by sex, with 51% being female (Table 3-4). Respondents who categorised as ‘other’ (weighted N = 19) for sex were not included in further analysis. This was because the weighted count was too small for specific subgroup analysis.

Annual household income was reported in ten categories in the survey, from £0-14,999 to £150,000+. These were reduced due to small counts, particularly for the higher income bands when exploring differences by barrier or type of health condition. This can be seen in Table 3-5, with counts being <50 for some health conditions, particularly those with incomes of £50,000+. This meant that the number of income categories had to be reduced to ensure that the counts were large enough for further analysis. The annual household income categories were reduced to the following four categories: £0-19,999, £20,000-39,999, £40,000-59,999 and £60,000+. These were based on the household income statistics in England, with £30,500 being the median household income in England from April 2019-March 2020. The median income of the richest fifth of people was £62,400, and for the poorest fifth was £13,800 (Office for National Statistics, 2021a). The Office for National Statistics (ONS) explains that median income provides a good indication of the standard of living of the ‘typical’ individual in terms of their income, whereas the mean income can be influenced by a few individuals with very high incomes (Office for National Statistics, 2021a).

Annual household income was fairly evenly distributed across the four categories, with the highest percentage of respondents (36%) being in the

£20,000-39,999 income group (Table 3-4). This was similar to the English median of £30,500 (Office for National Statistics, 2021a). Respondents who chose 'don't know' (weighted N = 3) or 'prefer not to say' (weighted N = 56) were excluded from the analysis. This missing data accounted for <5% of all data.

In the raw data, ethnicity was presented in five ethnic groups: white, mixed, Black or Black British, Asian or Asian British, and any other ethnic group/background. The weighted percentages matched those reported in the 2019 population estimates for England and Wales (Office for National Statistics, 2021d). However, when cross-tabulating ethnic group and health condition, the majority of the counts for the mixed, Black or Black British, Asian or Asian British and any other ethnic group/background categories were <50 (Table 3-5). Ethnicity was therefore categorised into 'white' and 'Black, Asian and Minority Ethnic (BAME)'. The BAME ethnicity group included Asian or Asian British, Black or Black British, Mixed and any other ethnic group or background. BAME is a commonly used term in research and policy, being used to refer to all non-white minority ethnic groups (Aspinall, 2021). A limitation of using these two categories, and BAME in particular, was that in-depth information on green space use, barriers, and differences by ethnicity was lost during the analysis. However, this was required in order for the counts to be large enough to analyse and report on.

The majority of respondents were white (86%), with 14% in the BAME category (Table 3-4). Respondents who did not respond to the ethnicity question (weighted N = 297) or responded 'don't know' (weighted N = 2), were not included in the analysis. This missing data also accounted for <5% of all data.

Table 3-5: Original income band and ethnicity group counts by type of health condition.

	Weighted N (%)	Health condition (Yes) (N)	Arthritis (Yes)	Respiratory (Yes)	Diabetes (Yes)	Heart/blood pressure/circulatory (Yes)	Mental health conditions (Yes)	Physical disability (Yes)	Progressive illness (Yes)
Household income									
£0-14,999	1567 (15%)	810	303	206	122	167	407	210	122
£15,000-19,999	1149 (11%)	538	219	106	92	153	207	114	93
£20,000-29,999	2015 (19%)	898	320	215	146	182	273	173	98
£30,000-39,999	1688 (16%)	665	216	143	131	148	187	111	100
£40,000-49,999	1248 (12%)	426	155	78	78	78	153	82	56
£50,000-59,999	863 (8%)	274	88	50	49	61	107	26	28
£60,000-79,999	815 (8%)	230	75	57	37	39	73	36	24
£80,000-99,999	522 (5%)	152	32	33	30	37	34	10	17
£100,000-149,999	333 (3%)	89	24	15	25	9	18	4	10
£150,000+	156 (2%)	51	15	12	23	23	24	10	10
Ethnicity									
White	8702 (86%)	3634	1329	771	656	805	1284	683	502
Mixed	208 (2%)	96	25	25	25	28	63	18	4
Black or Black British	365 (4%)	116	23	39	13	15	25	23	9
Asian or Asian British	753 (7%)	211	50	63	35	36	71	41	29
Any other ethnic group or background	89 (1%)	30	11	4	5	7	11	7	5

3.3.2 Health conditions

Table 3-6 shows the prevalence of chronic health conditions in the PANS sample, with 40% reporting a chronic physical or mental health condition. This percentage is what would be expected in the population and matches the English Health Survey and Labour Force Survey results presented in Table 3-3.

Table 3-6: Count and percentage of the chronic health condition question.

Do you have any physical or mental health conditions or illnesses lasting or expected to last for 12 months or more?		
	Weighted N	**Weighted %**
Yes	4157	40
No	6255	60
Total	10415	100

The most commonly reported health conditions were mental health conditions (36%) and arthritis (35%) (Table 3-7). 'Prefer not to say' (weighted n=26), 'don't know' (weighted N = 5) and 'other' (weighted N = 300) were removed.

Table 3-7: The types of chronic health conditions included in PANS, with weighted counts and percentages.

Types of health conditions (weighted)	"Yes" (%)	Total (N)
Arthritis	35	4157
Respiratory	22	4157
Diabetes	18	4157
Heart/blood pressure/circulatory	22	4157
Mental health	36	4157
Physical disability	19	4157
Progressive disability/illness	13	4157

3.3.3 Health conditions and socio-demographic characteristics

To begin to answer the first research question – 'How does the type of chronic health condition reported differ by socio-demographic characteristics?' - cross-tabulations with Pearson's chi-square were used. This allowed significant differences in the reporting of health conditions between socio-demographic groups to be explored. The cross-tabulation results for each health condition are presented in Appendix G, with chi-square p-values included.

Figure 3-1 presents the percentage of respondents from each socio-demographic group who reported having a chronic health condition. The proportions are reported by sex (female: 41%; male: 39%), age (16-24: 33%; 25-39: 36%; 40-54: 39%; 55-64: 42%; 65+: 48%), ethnicity (BAME: 32%; White: 42%), and income (£0-19,999: 50%; £20,000-39,999: 42%; £40-59,999: 33%; £60,000+: 29%). These results suggest that there were differences in the reporting of health conditions by socio-demographic characteristics, which will be explored further in the analysis below (section 3.7.1).

3.3.4 Frequency of green space use

About 27% of respondents reported that they spent free time in green spaces more than twice a week but not every day, with 5% reporting never spending time in green space in the last 12 months (Figure 3-2).

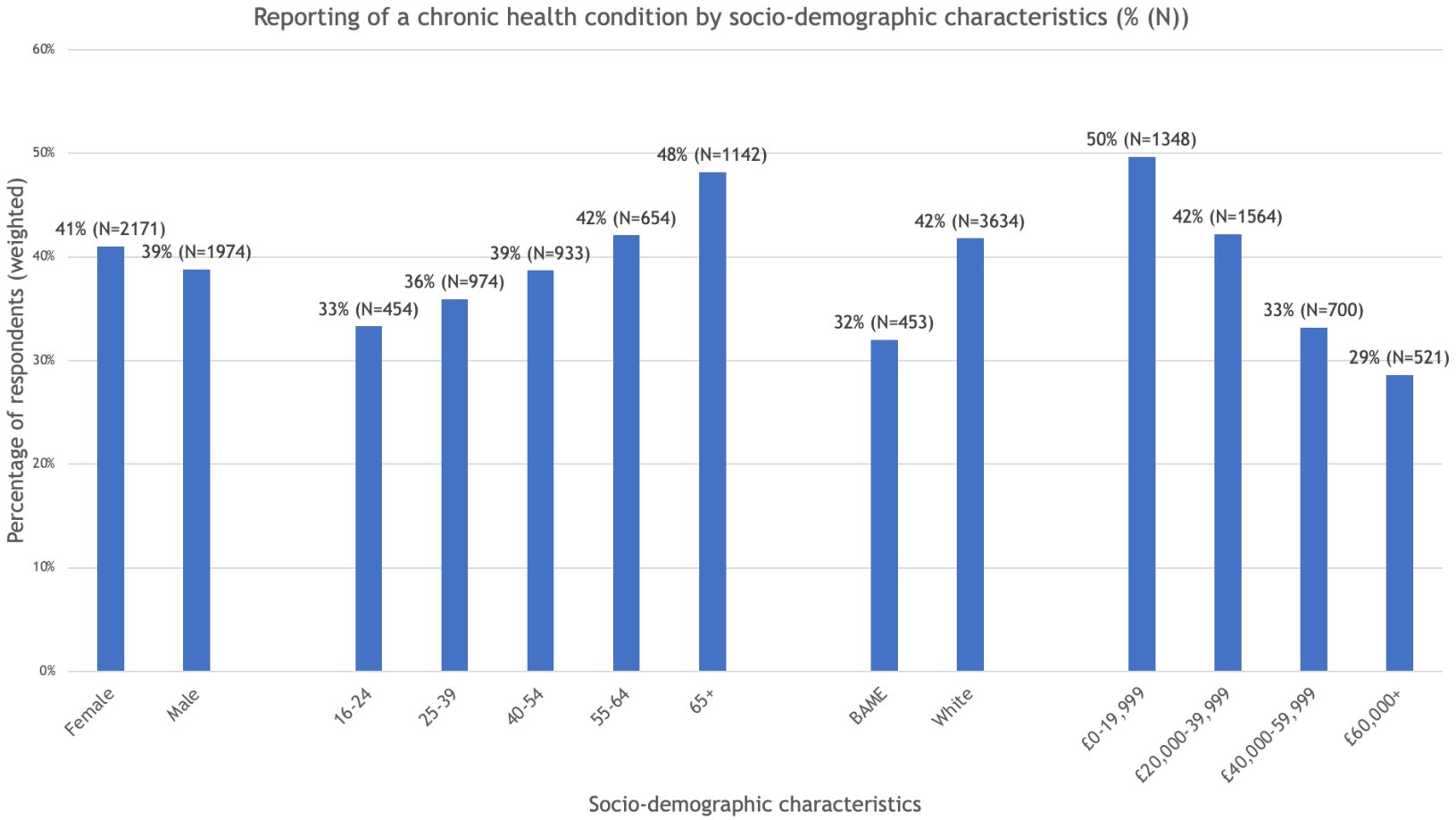


Figure 3-1: Percentage of respondents reporting a chronic health condition by sex, age, ethnicity, and income (all Chi2 p-values <0.05).

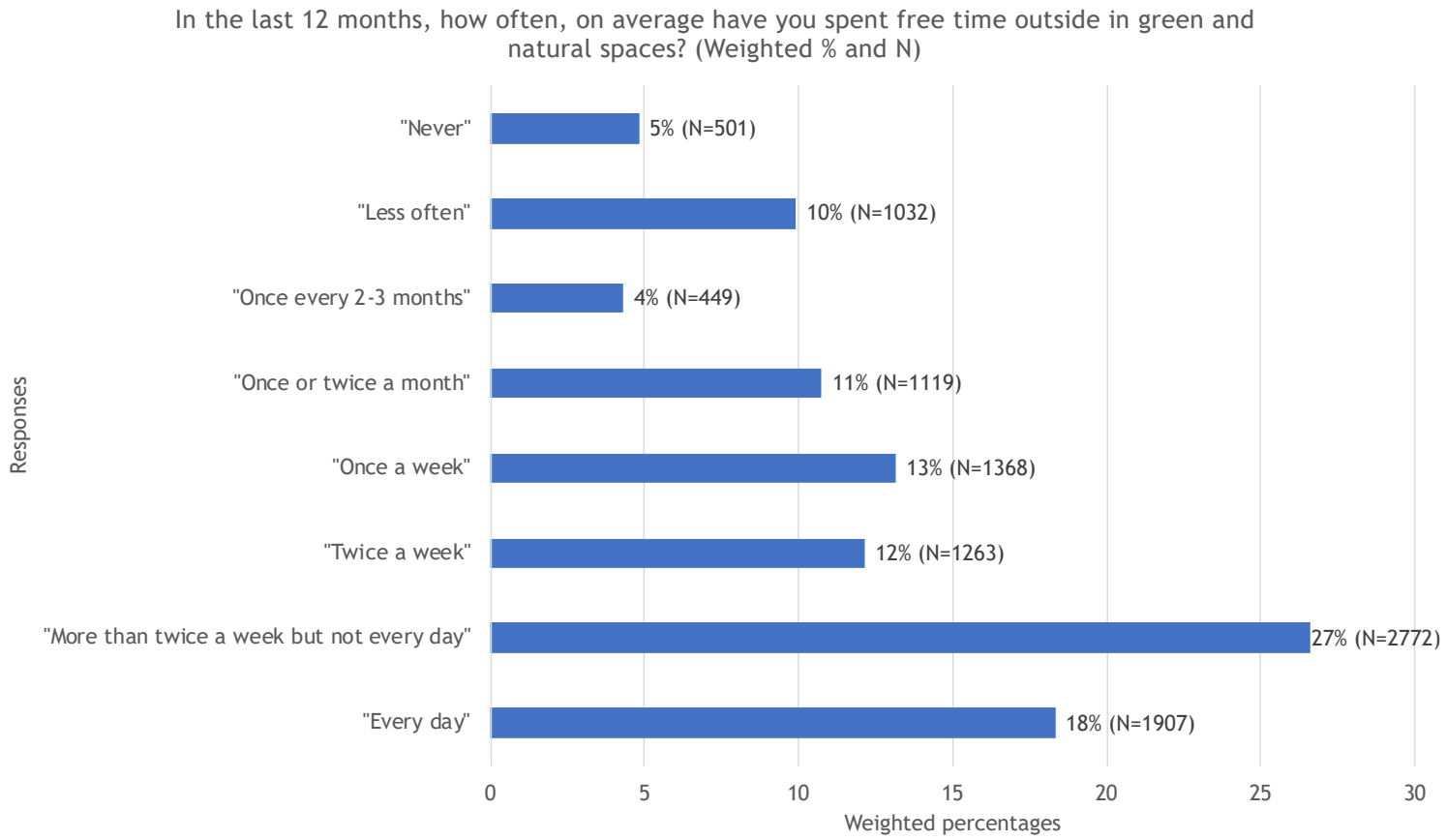


Figure 3-2: Weighted count and percentages of each response to the frequency of green space use question.

3.4 Exploring barriers to green space use

3.4.1 Descriptive statistics

The routing through the survey questions is presented in Figure 3-3. In PANS, only respondents who reported no visits to green space in the last month or no visits in the last 14 days were asked about barriers to green space use. The general barriers question – 'What was the main reason or reasons for not spending free time outdoors in the last 14 days?' – was asked of respondents who had reported no green space visits in the last 14 days, as well as those who responded 'don't know' or 'prefer not to say'. They could select up to three general barriers from the listed responses (Table 3-2).

The physical health-related barriers question – 'How important were the following health related reasons in stopping you from visiting green and natural spaces in the last 14 days?' - was asked if the respondent had chosen 'poor physical health' as a general barrier to green space use (Table 3-2). The respondents were asked to rate each physical health-related barrier by importance. The ranking was from 1 (not at all important) to 5 (very important).

Overall, 3,251 (38%) respondents reported that they had not visited a green space in the last 14 days or responded, 'don't know' or 'prefer not to say'. For those respondents, the most commonly reported general barrier was bad/poor weather (45%), followed by 'stayed at home to stop coronavirus spreading/Government restrictions' (44%) (Table 3-8). Mobility (78%) and tiredness (72%) were the most commonly reported physical health-related barriers, reported only by those who had listed 'poor physical health' as a general barrier (N = 552, 15%) (Table 3-9).

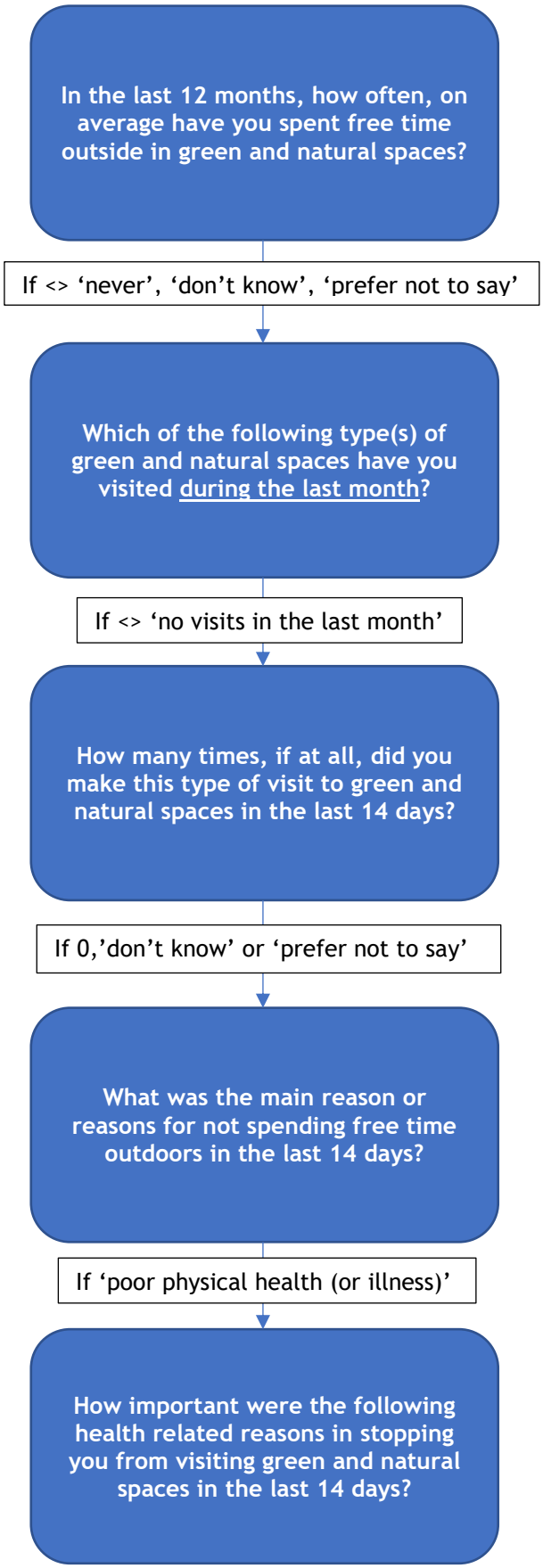


Figure 3-3: Flow chart presenting the survey routing for the barrier questions.

Table 3-8: Weighted counts and percentages for reporting of general barriers to green space use.

		Weighted N	Weighted %
General barriers (Yes)	Bad/poor weather	1636	45
	Poor physical health	552	15
	Poor mental health/well-being	276	8
	Lack of facilities/access points for those with disabilities	116	3
	Too busy at home	433	12
	Too busy at work/with family commitments	446	12
	Not interested	242	7
	Prefer to do other leisure activities	153	4
	Fear/worry about crime or anti-social behaviour	194	5
	Fear/worry about getting hurt or injured	102	3
	Nowhere near me is nice enough to spend free time in	355	10
	Cost/too expensive	112	3
	Stayed at home to stop coronavirus spreading/ Government restrictions	1582	44
	No particular reason	205	6

Table 3-9: Weighted counts and percentages for reporting of physical health-related barriers as 'very important' or 'important'.

		Weighted N	Weighted %
Physical health barriers ('Very important' or 'Important')	Mobility	397	78
	Feeling ill	197	40
	Lack of disabled facilities	189	44
	Unsuitable/ poorly maintained sites	156	39
	No-one to go with/help me	231	51
	Tiredness	366	72

3.4.2 Grouping the general barriers to green space use

This section will outline the exploration of how the outcome variables (i.e., the general barriers) should be treated in the analysis, following the descriptive statistics. Respondents could choose up to three responses to the general barriers question in PANS: 'What was the main reason or reasons for not spending free time outdoors in the last 14 days?' (Table 3-2).

The broad aim of the analysis was to explore associations between general barriers to green space and how these differed by health condition and socio-demographic characteristics. A more specific aim was to investigate whether the general barriers could be grouped into categories, inspired by the leisure constraints model outlined in Chapter 1, and to explore associations between the barrier groupings, health conditions, and socio-demographic variables (Crawford and Godbey, 1987). The outcome of interest was therefore the general barriers to green space use.

To explore whether there were any initial patterns or crossovers between the general barriers, grouped aggregated responses to each barrier were analysed using a summary table, and strings (a sequence of characters) were used to explore which barriers were most commonly reported together, if any. The ability to group the barrier variables would also balance the response sizes, with the general barriers having relatively large differences in the number of responses (e.g., 'Fear/worry about getting hurt or injured' N=102, 'Poor physical health' N=552) (Table 3-8).

Overall, the aim of this analysis was to explore whether there were any initial patterns in the reporting of the general barriers at an individual-level, and to see which barrier responses were commonly reported together by each respondent to explore these patterns and decide if and how to group the barriers. Therefore, the first step of the analysis was to group individual-level barrier responses.

3.4.2.1 Exploring individual-level responses regarding general barriers to green space use

The summary table and strings were created to find which barriers could/should be merged together prior to analysis and whether particular categories arose.

3.4.2.1.1 Grouping general barriers to green space use: String merging

A new strings column was created within the dataset using Excel, which merged the general barrier columns together for each respondent. For example, respondent 1: bad/poor weather; respondent 2: cost/too expensive, nowhere near me is nice enough to spend free time in, fear/worry about crime; respondent 3: too busy at home, prefer to do other leisure activities. The combinations of each barrier were then counted/tallied and explored. As a result of the string merging, the most commonly reported string of barriers included 'bad/poor weather' and 'stayed at home to stop coronavirus spreading/Government restrictions' (N = 295) (Table 3-10). This corroborates with the counts and percentages for these barriers individually, with a large number of respondents reporting 'bad/poor weather' (weighted N = 1,636, 45%) and 'stayed at home to stop coronavirus spreading/Government restrictions' (weighted N = 1,582, 44%) as barriers to green space use (Table 3-8).

As highlighted in Table 3-10, the majority of the strings included 'bad/poor weather' and/or 'stayed at home to stop coronavirus spreading/Government restrictions'. This meant that the strings did not present many new patterns within the barriers. The string with the highest count that did not contain the weather or coronavirus barriers included 'too busy at home' and 'too busy at work/with family commitments' (N = 25). This led to the creation of one general barrier category - 'other priorities'- which initially included 'too busy at home' and 'too busy at work/with family commitments', and then developed further following the summary tables discussed below.

Table 3-10: Results of the column merging in Excel, presenting the most common strings of general barriers (N>20). The barriers '1) Bad/poor weather' and '13) Stayed at home to stop coronavirus spreading/Government restrictions' are highlighted in grey.

String character 1	String character 2	String character 3	Count (>20)
1)Bad/poor weather	13)Stayed at home to stop coronavirus spreading/ Government restrictions		295
1)Bad/poor weather	2)Poor physical health	13)Stayed at home to stop coronavirus spreading/ Government restrictions	97
1)Bad/poor weather	6)Too busy at work/ with family commitments		77
1)Bad/poor weather	11)Nowhere near me is nice enough to spend free time in	13)Stayed at home to stop coronavirus spreading/ Government restrictions	69
1)Bad/poor weather	5)Too busy at home		63
1)Bad/poor weather	2)Poor physical health		63
2)Poor physical health	13)Stayed at home to stop coronavirus spreading/ Government restrictions		62
1)Bad/poor weather	5)Too busy at home	13)Stayed at home to stop coronavirus spreading/ Government restrictions	60
1)Bad/poor weather	6)Too busy at work/ with family commitments	13)Stayed at home to stop coronavirus spreading/ Government restrictions	43
1)Bad/poor weather	5)Too busy at home	6)Too busy at work/ with family commitments	42
6)Too busy at work/ with family commitments	13)Stayed at home to stop coronavirus spreading/ Government restrictions		31
1)Bad/poor weather	11)Nowhere near me is nice enough to spend free time in		29
11)Nowhere near me is nice enough to spend free time in	13)Stayed at home to stop coronavirus spreading/ Government restrictions		27
1)Bad/poor weather	3)Poor mental health/well-being	13)Stayed at home to stop coronavirus spreading/ Government restrictions	27

5)Too busy at home	6)Too busy at work/ with family commitments		25
2)Poor physical health	11)Nowhere near me is nice enough to spend free time in	13)Stayed at home to stop coronavirus spreading/ Government restrictions	25
1)Bad/poor weather	3)Poor mental health/well-being		24
1)Bad/poor weather	7)Not interested		22
3)Poor mental health/well-being	13)Stayed at home to stop coronavirus spreading/ Government restrictions		21
1)Bad/poor weather	9)Fear/worry about crime or anti-social behaviour	13)Stayed at home to stop coronavirus spreading/ Government restrictions	21

3.4.2.1.2 Grouping general barriers to green space use: Summary table

A summary table was created in Excel to explore if any two barriers were commonly reported together, which would show initial patterns in the reporting of the barriers as well as if and how they should be grouped. The summary table provided some guidance for the creation of general barrier categories. The highest counts were explored for each barrier within the table (excluding the weather and coronavirus barriers due to their high counts across all barriers). Figure 3-4 shows the results of the summary table, with each barrier listed on the left, and the barrier on the right that they are connected to by an arrow is the barrier that they have the highest count within the table. The highest count showed which barriers were most commonly reported together and created potential groupings.

The three labels on the far left of Figure 3-4 are the categories created, based on the findings from the table and strings. For example, the outcome of the strings was the creation of ‘other priorities’, with ‘too busy at home’ and ‘too busy at work/with family commitments’ included. The summary table results showed that the barrier ‘prefer to do other leisure activities’ was also connected to ‘too busy at home’ and ‘not interested’.

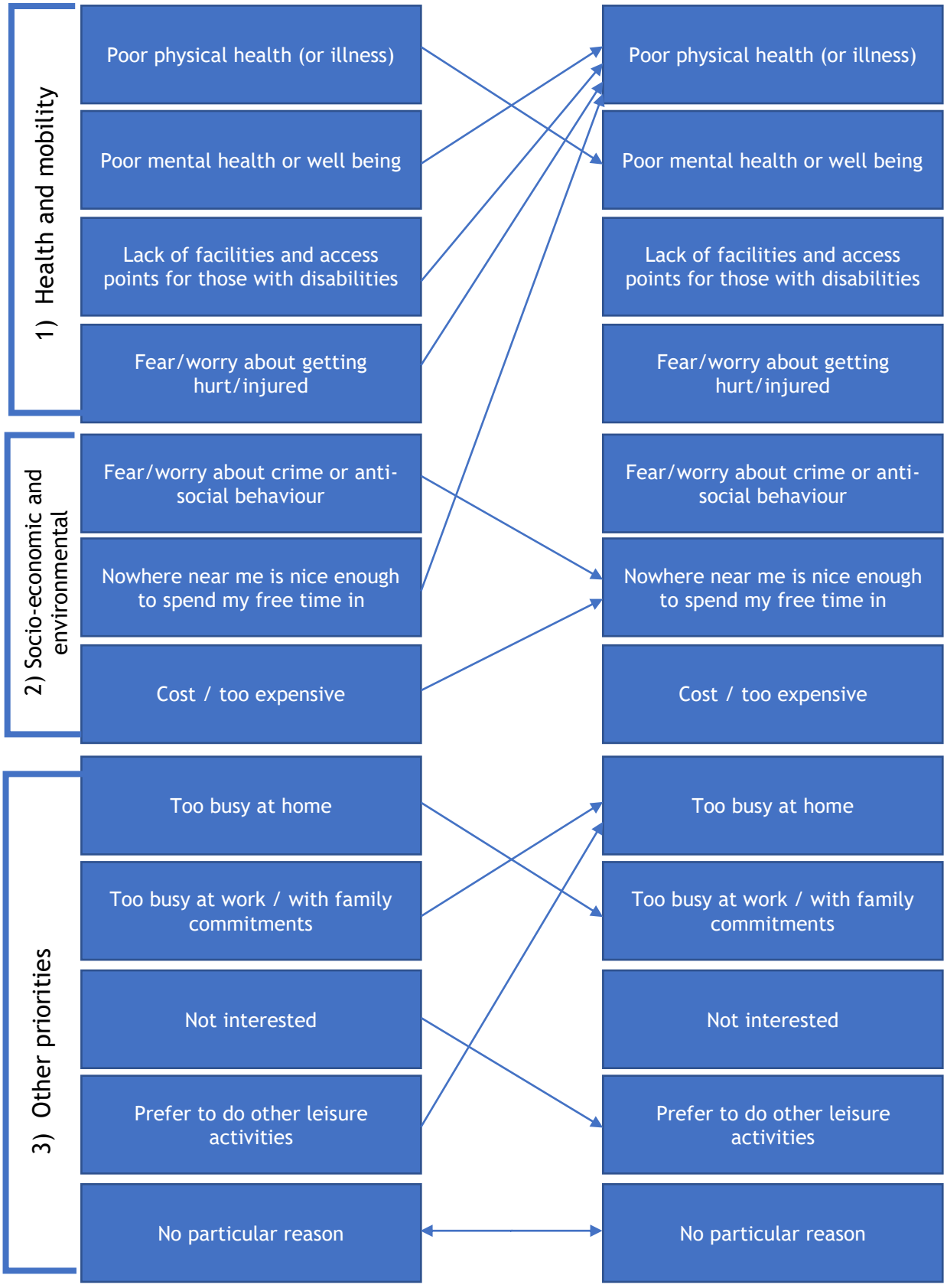


Figure 3-4: The highest counts for each general barrier from the table are presented by the arrows. For example, the most commonly reported barrier with 'poor physical health' was 'poor mental health'.

As a result of the findings produced, as well as the literature review, the following three barrier categories were created:

1. Health and mobility
    - Poor physical health (or illness)
    - Poor mental health or well-being
    - Lack of facilities and access points for those with disabilities
    - Fear/worry about getting hurt or injured
2. Socio-economic and environmental
    - Bad/poor weather
    - Fear/worry about crime or anti-social behaviour
    - Nowhere near me is nice enough to spend my free time in
    - Cost/too expensive
3. Other priorities
    - Too busy at home
    - Too busy at work/with family commitments
    - Not interested
    - Prefer to do other leisure activities
    - Stayed at home to stop coronavirus spreading/Government restrictions
    - No particular reason

3.5 Methods considered for analysis of the general barriers to green space use and health conditions

There were a number of methods available to undertake the analysis to predict which barrier groupings were related to health conditions and socio-demographics characteristics, including factor analysis and multiple regression models. Factor analysis alone was considered, which is based on the creation of latent variables (which are variables that cannot be observed but can be measured by multiple observed variables, such as the barrier category 'other priorities') using existing data, with the aim of simplifying a dataset by representing the variables in terms of a smaller number of variables. There are many different types of factor analysis depending on the data, with Principal Components Analysis (PCA) used for continuous variables, and Multiple Correspondence Analysis (MCA) for categorical data (Tam, 2012). Multiple logistic regression was also considered, with the general barriers as the outcome variables. However, this would not have allowed the three categories to have been analysed. Instead, each individual barrier would have been a separate outcome. To be able to explore both the barrier categories (as latent variables) and any difference in the reporting of the general barriers to green space use by

health condition and socio-demographic characteristics, the factor analysis and logistic regression methods had to be combined using Structural Equation Modelling.

3.5.1 Structural Equation Modelling (SEM)

To be able to analyse how barriers in the three categories (health and mobility, socio-economic and environmental, and other priorities) relate to the health conditions and socio-demographic characteristics, Structural Equation Modelling (SEM) was used. SEM allows latent variables to be created, which allowed me to measure the fit of the observed barrier variables into the three categories (creating latent variables). The outcome variables of the model were the three barrier categories: health and mobility, socio-economic and environmental, and other priorities. The questions being answered by SEM were whether the variables really did lie in the groups created, and whether they could be treated as latent variables that are capturing these groupings.

SEM is the main analytical method used in the subsequent chapter and will be described in full there. However, to provide justification for its use here, I will provide a short summary. SEM was chosen over the alternative methods discussed because it is comprised of two parts that combine factor analysis with regression analysis:

- The structural model, which consists of regression-like relationships among variables.

- The latent variable model, or measurement model, which forms the latent variables used in the structural model. (Weston and Gore, 2006; Wagner, Thatcher Kantor and Piasta, 2010; Beaujean, 2014).

The measurement models of the SEM were run in R, to explore the factor loadings (or fit) of the three categories. A separate measurement model was run for each latent variable. The packages lavaan (v0.6-9), semptools (v0.2.9.3), and lavaan.survey (v1.1.3.1) were used.

3.5.1.1 Running the Structural Equation Model

The measurement models were run in R, with the three barrier categories created from the initial grouping in subsection 3.4.2:

1. Health and mobility
    - Poor physical health (or illness)
    - Poor mental health or well-being
    - Lack of facilities and access points for those with disabilities
    - Fear/worry about getting hurt or injured
2. Socio-economic and environmental
    - Bad/poor weather
    - Fear/worry about crime or anti-social behaviour
    - Nowhere near me is nice enough to spend my free time in
    - Cost/too expensive
3. Other priorities
    - Too busy at home
    - Too busy at work/with family commitments
    - Not interested
    - Prefer to do other leisure activities
    - Stayed at home to stop coronavirus spreading/Government restrictions
    - No particular reason

The results of the measurement models showed that that the 14 barrier responses were not suitable for grouping into the three barrier categories. This was reflected in the general barriers not loading into latent variables based on these three barrier categories (Table 3-11). Factors within the measurement models should have $p<0.05$, and the standardised estimates are suggested to be at least 0.3, with general guidance for best factor loadings being recommended as 0.6 and above (Kim *et al.*, 2016; Dash and Paul, 2021). The loadings presented show that there was not a good fit for any of the categories/latent variables, with the majority of the standardised estimates being <0.6 with $p>0.05$ (Table 3-11).

The barrier ‘stayed at home to stop coronavirus spreading/Government restrictions’ had to be removed from the ‘other priorities’ measurement model due to high correlation with the other barriers included, which is corroborated in the string merging in section 3.4.2.1.1. The fit was also explored when certain barriers were removed from categories (e.g., ‘bad/poor weather’ removed from the ‘socio-economic and environmental’ model), however there continued to be

poor fit. This suggested that the general barriers did not fit into the categories and should be viewed as individual variables.

Table 3-11: Results from the full SEM measurement models.

Category/latent variable	Observed variable	Estimate	Standardised estimate	P-value
Health & mobility	Poor physical health	1	0.648	-
	Poor mental health	0.163	0.106	0.255
	Lack of facilities and access points for those with disabilities	0.739	0.478	0.156
	Fear/worry about getting hurt or injured	0.422	0.273	0.142
Socio-economic & environmental	Fear/worry about crime or anti-social behaviour	1	0.266	-
	Cost/too expensive	2.280	0.607	0.019
	Nowhere near me is nice enough to spend free time in	0.423	0.112	0.137
	Bad/poor weather	-1.687	-0.447	0.049
Other priorities	Too busy at home	1	0.317	-
	Too busy at work/with family commitments	2.286	0.724	0.060
	Not interested	-1.080	-0.342	0.001
	Prefer to do other leisure activities	-0.623	-0.197	0.047

	Stayed at home to stop coronavirus spreading/ Government restrictions	-	-	-
	No particular reason	-1.212	-0.348	0.101

3.6 Multiple binary logistic regression models

The results in the previous section showed that the individual-level reported general barriers to green space use were not able to be grouped. This meant that SEM was no longer a possible method of analysis, with the measurement model not having adequate model fit. Instead, only the structural model (i.e., regression model) could be undertaken. This would allow exploration into any significant differences in reporting of the individual general barriers to green space use by health condition and socio-demographic variables.

To explore the general barriers individually and answer the research questions, multiple binary logistic regression models were undertaken. Logistic regression was selected for this data because it was designed for binary outcome variables, such as the general barrier variables (answered 'yes' or 'no'). Logistic regression works similarly to linear regression, but with a dichotomous outcome (or dependent) variable. In multiple logistic regression, the predictor (or independent) variables may be of any data level (categorical, ordinal, or continuous) (Brunner and Giannini, 2011).

To enable better interpretation and visualisation of the results, odds ratios were calculated. Odds are the ratio between probabilities – the probability of an event favourable to an outcome and the probability of an event against the outcome. They are constrained between zero and infinity (Sperandei, 2014).

3.6.1 Answering the research question: How does the reporting of general barriers to green space use differ by type of chronic health condition and socio-demographic characteristics?

To answer the research question, 'how does the reporting of general barriers to green space use differ by type of chronic health condition and socio-

demographic variables?', the predicter variables in the analysis were the types of health condition and socio-demographic characteristics. The socio-demographic characteristics included were:

- Sex – female, male (reference)
- Age – 16-24, 25-39 (reference), 40-54, 55-64 and 65+
- Income - £0-19,999, £20,000-39,999 (reference), £40,000-59,999, £60,000+
- Ethnicity – BAME, white (reference)

For each type of health condition, the reference category was respondents with another type of chronic health condition (e.g., respondents with arthritis vs. respondents with other chronic health conditions). This was required because of the way the survey question was worded and responded to, with only respondents who had reported having a chronic health condition being asked their type of health condition. Therefore, each health condition variable was analysed as 'respondents with specific health condition vs. respondents with all other health conditions'.

The outcome variable in each model was one of the general barriers to green space use (e.g., bad/poor weather), which was collected for respondents who did not use green space in the last 14 days. It is important to understand that the outcome was not green space use, as it was already known that the respondent had not used green space, but each barrier to use (i.e., the reason for non-use). Each general barrier had a dichotomous outcome – 'yes' or 'no' (Table 3-2). A different regression model was run for each general barrier. The predictor variables (health condition, age, sex, income, and ethnicity) were included in each regression model to adjust for each other. Each model was also weighted to ensure that the sample was nationally representative. The analysis was conducted using R (v1.1.456), with figures created using the packages ggplot2 (v3.3.5) and cowplot (v1.1.1).

3.6.2 Answering the research question: How does the type of chronic health condition reported differ by socio-demographic characteristics?

To answer the research question by exploring whether type of health condition differs by socio-demographic characteristics, further logistic regression models

were run in R. In these models, the predictor variables were the socio-demographic characteristics (sex, age, income, and ethnicity), and the outcome variable was the type of health condition (e.g., arthritis). These were run individually for each type of health condition, and the socio-demographic variables were all included in each model.

3.7 Results

This section will outline the findings relating to research questions 1 and 2:

- RQ1: How does the type of chronic health condition reported differ by socio-demographic characteristics?
- RQ2: How does the reporting of general barriers to green space use differ by type of chronic health condition and socio-demographic characteristics (sex, age, income, and ethnicity)?

The significant associations between the health conditions and socio-demographic characteristics will be outlined first, followed by the general barriers to green space use which have been sub-sectioned into the three barrier groups (health and mobility, socio-economic and environmental, and other priorities). When referring to 'barriers' or 'barrier' in this section, this refers to barriers to green space use.

3.7.1 Associations between health conditions and socio-demographic characteristics

Associations between the seven types of health conditions included in these analyses and the socio-demographic characteristics – sex, age, income, and ethnicity – are presented in Figure 3-5 and full tables are available within Appendix H. Each of the socio-demographic variables had a significant association ($p<0.05$) with reporting of different types of health conditions.

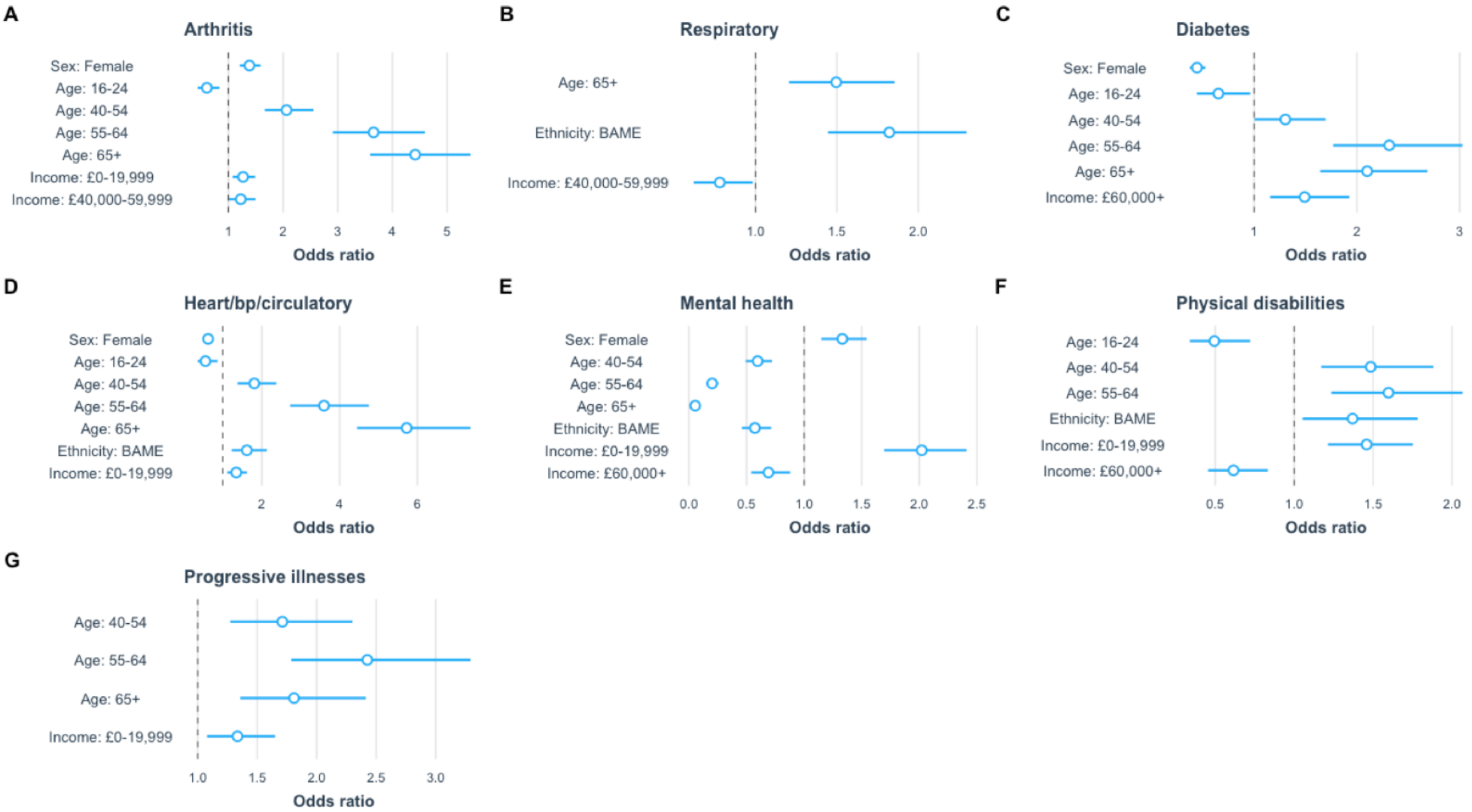


Figure 3-5: Odds ratios (p<0.05) from logistic regression models to explore associations between reporting the types of health conditions and socio-demographic characteristics (adjusted).

3.7.1.1 Sex

Female respondents had higher odds of reporting arthritis (OR 1.38, 95%CI: 1.21-1.59) and mental health conditions (OR 1.33, 95%CI: 1.15-1.54) than male respondents. However, female respondents had lower odds of reporting having diabetes (OR 0.44, 95%CI: 0.37-0.53) and heart/blood pressure/circulatory conditions (OR 0.62, 95%CI: 0.53-0.73).

3.7.1.2 Age

Respondents aged 16-24 years had lower odds of reporting arthritis (OR 0.61, 95%CI: 0.44-0.84), diabetes (OR 0.65, 95%CI: 0.44-0.96), heart/blood pressure/circulatory conditions (OR 0.55, 95%CI: 0.35-0.86), and physical disabilities (OR 0.49, 95%CI: 0.34-0.72) than 25–39-year-old respondents.

Those aged 40-54 had higher odds of reporting arthritis (OR 2.06, 95%CI: 1.67-2.56), heart/blood pressure/circulatory conditions (OR 1.81, 95%CI: 1.38-2.38), physical disabilities (OR 1.48, 95%CI: 1.17-1.88), and progressive illnesses (OR 1.81, 95%CI: 1.36-2.41). However, these respondents had lower odds of reporting mental health conditions (OR 0.60, 95%CI: 0.49-0.72) than 25–39-year-old respondents.

Respondents aged 55-64 had higher odds of reporting arthritis (OR 3.66, 95%CI: 2.91-4.59), diabetes (OR 2.31, 95%CI: 1.77-3.03), heart/blood pressure/circulatory conditions (OR 3.60, 95%CI: 2.73-4.75), physical disabilities (OR 1.60, 95%CI: 1.23-2.07), and progressive illnesses (OR 2.43, 95%CI: 1.79-3.29). They had lower odds of reporting mental health conditions (OR 0.20, 95%CI: 0.16-0.25) compared to those aged 25-39.

Respondents aged 65+ had higher odds of reporting arthritis (OR 4.42, 95%CI: 3.59-5.43), respiratory conditions (OR 1.50, 95%CI: 1.21-1.85), diabetes (OR 2.10, 95%CI: 1.64-2.68), heart/blood pressure/circulatory conditions (OR 5.72, 95%CI: 4.45-7.37), and progressive illnesses (OR 1.81, 95%CI: 1.36-3.41) than 25–39-year-olds, but lower odds of reporting mental health conditions (OR 0.05, 95%CI: 0.04-0.07).

3.7.1.3 Ethnicity

BAME respondents had higher odds of reporting respiratory conditions (OR 1.82, 95%CI: 1.45-2.30), heart/blood pressure/circulatory conditions (OR 1.62, 95%CI: 1.23-2.13), and physical disabilities (OR 1.37, 95%CI: 1.05-1.78), and lower odds of reporting mental health conditions (OR 0.57, 95%CI: 0.46-0.71), compared to white respondents.

3.7.1.4 Income

Respondents in the lower household income category (£0-19,999) had higher odds of reporting arthritis (OR 1.27, 95%CI: 1.08-1.49), heart/blood pressure/circulatory conditions (OR 1.34, 95%CI: 1.12-1.62), mental health conditions (OR 2.02, 95%CI: 1.70-2.41), physical disabilities (OR 1.46, 95%CI: 1.21-1.75), and progressive illnesses (OR 1.33, 95%CI: 1.08-1.65) than those in the £20,000-39,999 income group.

Those in the £40,000-59,999 income group had higher odds of reporting arthritis (OR 1.23, 95%CI: 1.00-1.50), and lower odds of reporting respiratory conditions (OR 0.77, 95%CI: 0.62-0.97) than the £20,000-39,999 income group. Respondents in the highest income group (£60,000+) had higher odds of reporting having diabetes (OR 1.49, 95%CI: 1.16-1.93), and lower odds of mental health conditions (OR 0.69, 95%CI: 0.54-0.88) and physical disabilities (OR 0.62, 95%CI: 0.45-0.83).

3.7.2 General barriers to green space use: Key results

The key results are presented in Table 3-12, which summarises the logistic regression model results for each general barrier. The direction of the odds ratio results ($p<0.1$) is shown by the arrows. Overall, Table 3-12 shows that there was a difference in the reporting of general barriers to green space use by type of chronic health condition. The odds ratio results with p-values <0.05 for each general barrier by type of health condition and socio-demographic variable are then presented below (Figure 3-6, Figure 3-7 and Figure 3-8).

The most commonly reported barrier to green space use for respondents with a chronic health condition was ‘poor physical health’, which was reported for

respondents with all types of health condition except for respondents with diabetes and mental health conditions. Respondents with physical disabilities (OR 2.46, 95%CI: 1.89-3.2) and progressive illnesses (OR 2.17, 95%CI: 1.6-2.96) had the highest odds of reporting this barrier (Table 3-13).

The exact odds ratios, confidence intervals, and p-value results are presented by category (Table 3-13, Table 3-14, and Table 3-15), with the significant associations ($p<0.05$) highlighted in light grey. P-values that were >0.05, but <0.1 are also highlighted in dark grey. The threshold value of $p<0.05$ as significant is arbitrary, and the dichotomous 'significant' and 'non-significant' categories mean that information can be lost (Dahiru, 2008). Therefore, I have included a less stringent threshold of $p<0.1$ to ensure that all possible associations are explored. The results with p-values <0.1 may have a weak association, but one potentially worth exploring further.

Table 3-12: Summary of odds ratio results from the regression models (↑ higher probability of reporting, ↓ lower probability of reporting), adjusted for socio-demographic variables.

↑p<=0.001 ↑p<=0.01 ↑p<0.05 ⇑p<0.1

Health and mobility				
	Poor physical health (Yes)	**Poor mental health (Yes)**	**Lack of facilities/access points for those with disabilities (Yes)**	**Fear/worry about getting hurt or injured (Yes)**
Arthritis (Yes)	↑		↑	
Respiratory (Yes)	↑	↑	↑	
Diabetes (Yes)		↑		
Heart/blood pressure (Yes)	↑			↓
Mental health conditions (Yes)		↑		
Physical disability (Yes)	↑		↑	
Progressive illness (Yes)	↑	↓	↑	↑
Socio-economic and environmental				
	Bad/poor weather (Yes)	**Fear/worry about crime or anti-social behaviour (Yes)**	**Nowhere near me is nice enough to spend free time in (Yes)**	**Cost/too expensive (Yes)**
Arthritis (Yes)				
Respiratory (Yes)		↑		↓
Diabetes (Yes)				↑
Heart/blood pressure (Yes)	⇓			↑
Mental health conditions (Yes)	↑			

Physical disability (Yes)			↑	
Progressive illness (Yes)	↓			

Other priorities						
	Too busy at home (Yes)	**Too busy at work/ with family commitments (Yes)**	**Not interested (Yes)**	**Prefer to do other leisure activities (Yes)**	**Stayed at home to stop coronavirus spreading /Government restrictions (Yes)**	**No particular reason (Yes)**
Arthritis (Yes)			↓		⇑	
Respiratory (Yes)		↓		↓	↑	↓
Diabetes (Yes)	↑					
Heart/blood pressure (Yes)		↑	↓			
Mental health conditions (Yes)				↓		⇓
Physical disability (Yes)		↓				
Progressive illness (Yes)			↓	↓		↑

↑p<=0.001 ↑p<=0.01 ↑p<0.05 ⇑p<0.1

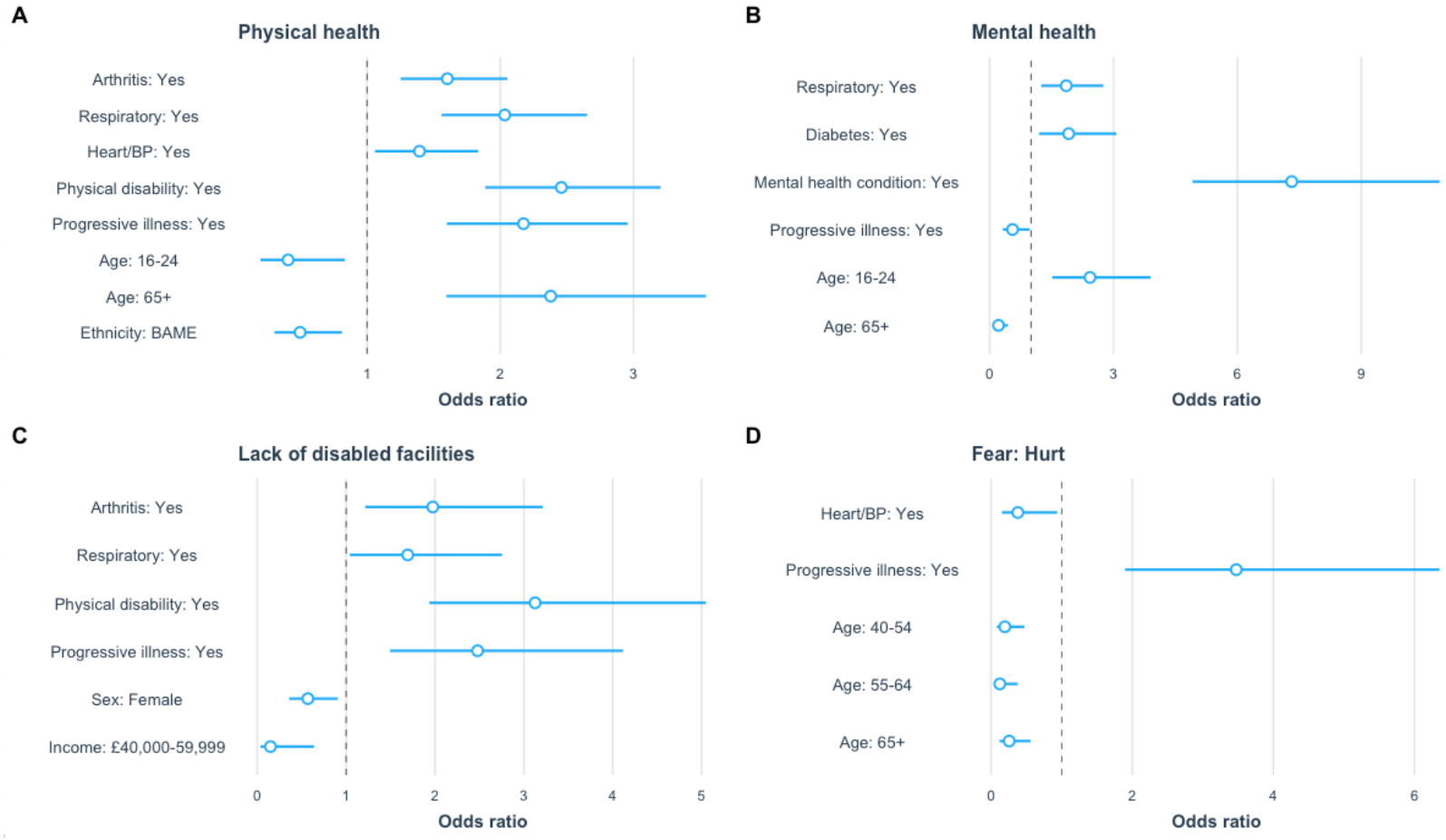


Figure 3-6: Odds ratios (p<0.05) from logistic regression models for health and mobility barriers by health condition and socio-demographic variables (adjusted for each health condition, sex, age, income, and ethnicity).

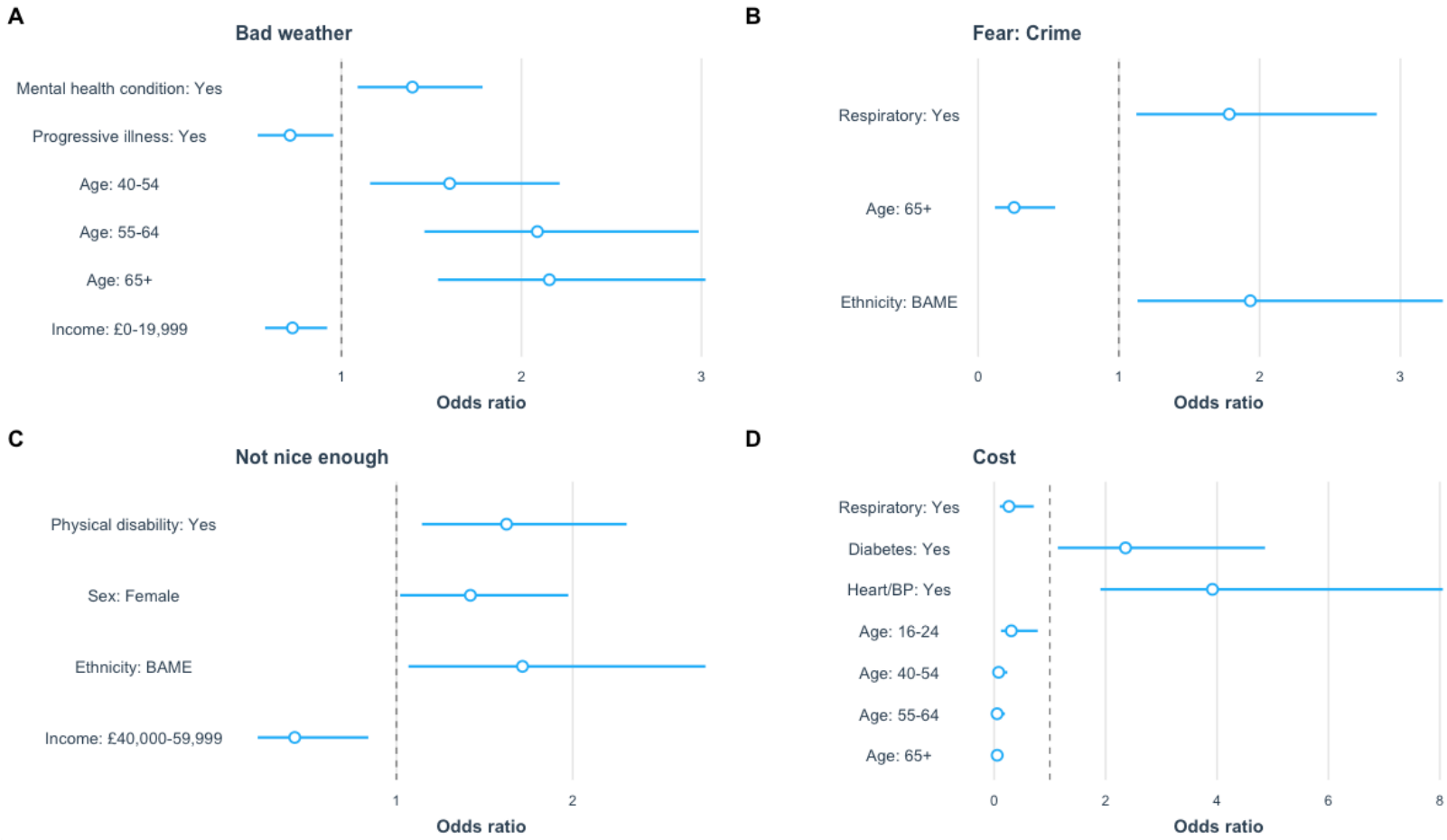


Figure 3-7: Odds ratios (p<0.05) from logistic regression models for socio-economic and environmental barriers by health condition and socio-demographic variables (adjusted for each health condition, sex, age, income, and ethnicity).

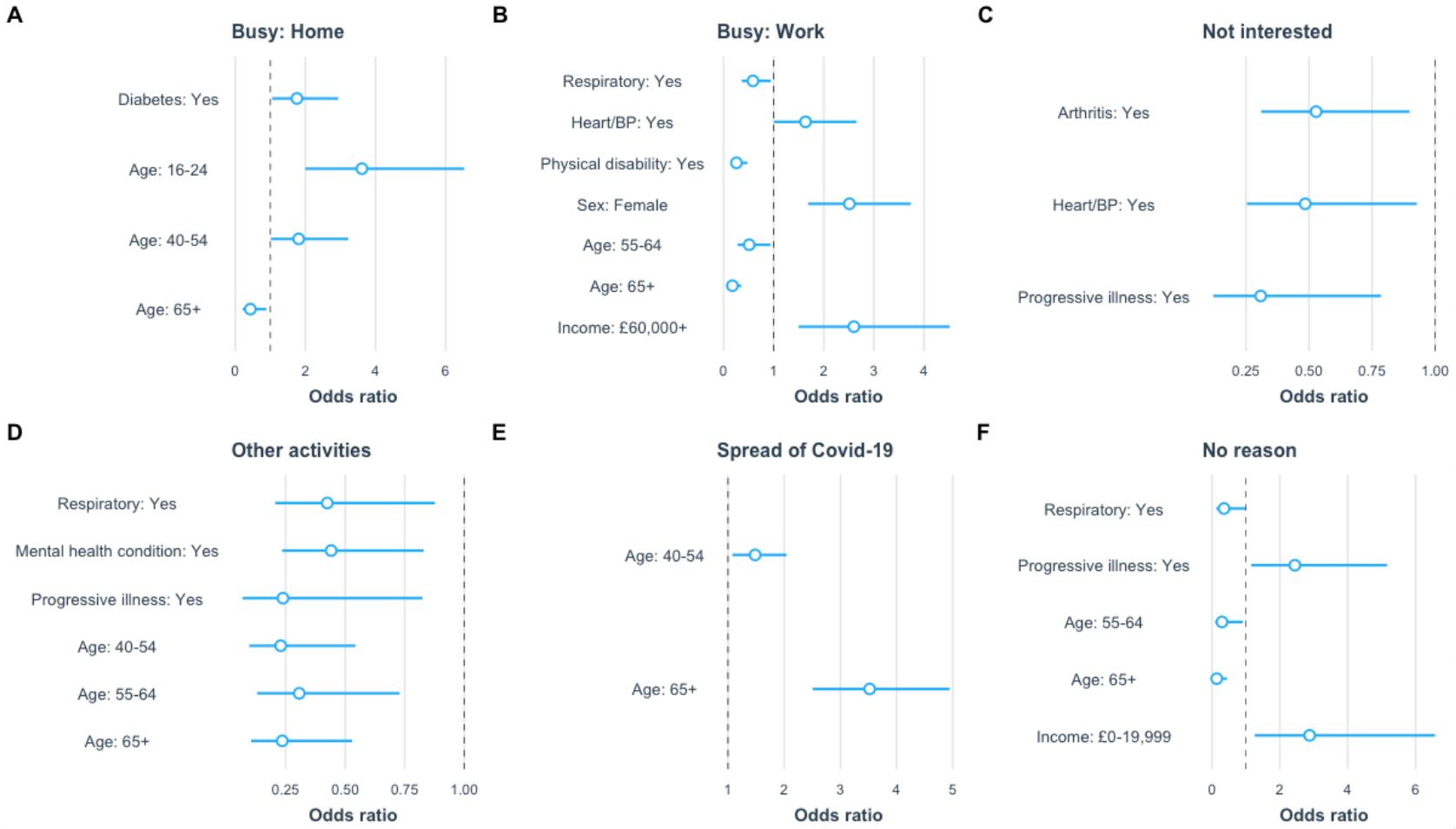


Figure 3-8: Odds ratios (p<0.05) from logistic regression models for other priorities barriers by health condition and socio-demographic variables (adjusted for each health condition, sex, age, income, and ethnicity).

3.7.3 Health and mobility barriers

The odds ratios, confidence intervals, and p-values for these barriers are presented in Table 3-13, with the odds ratios and confidence intervals for each barrier ($p<0.05$) presented visually in Figure 3-6. Overall, there was a relationship between many of the health and mobility barriers, socio-demographic characteristics, and health conditions being reported. Although this varied by health condition and barrier.

In Figure 3-6A, respondents with arthritis (OR 1.60, 95%CI: 1.25-2.05), respiratory conditions (OR 2.03, 95%CI: 1.56-2.65) heart/blood pressure/circulatory conditions (OR 1.39, 95%CI: 1.06-1.83), physical disabilities (OR 2.46, 95%CI: 1.89-3.20), progressive illnesses (OR 2.17, 95%CI: 1.60-2.96), and aged 65+ (OR 2.38, 95%CI: 1.60-3.54) had higher odds of reporting physical health as a barrier, compared to those with other health conditions or aged 25-39. Respondents aged 16-24 (OR 0.41, 95%CI: 0.20-0.83) and BAME respondents (OR 0.50, 95%CI: 0.30-0.81) had lower odds of reporting this barrier.

Respondents with mental health conditions had the highest odds (OR 7.31, 95%CI: 4.91-10.89) of reporting poor mental health/well-being as a barrier, followed by respondents aged 16-24 (OR 2.43, 95%CI: 1.51-3.90), with diabetes (OR 1.91, 95%CI: 1.19-3.06), and with respiratory conditions (OR 1.85, 95%CI: 1.25-2.75). Respondents with progressive illnesses (OR 0.55, 95%CI: 0.32-0.97) and aged 65+ (OR 0.21, 95%CI: 0.10-0.44) had lower odds of reporting this barrier (Figure 3-6B).

For the barrier ‘lack of facilities/access points for those with disabilities’, respondents with arthritis (OR 1.98, 95%CI: 1.21-3.21), respiratory conditions (OR 1.69, 95%CI: 1.04-2.75), physical disabilities (OR 3.13, 95%CI: 1.94-4.12), and progressive illnesses (OR 2.48, 95%CI: 1.49-4.12) had higher odds of reporting. Female respondents (OR 0.57, 95%CI: 0.36-0.91) and those with a household income between £40,000-59,999 (OR 0.15, 95%CI: 0.03-0.64) had lower odds of reporting this as a barrier (Figure 3-6C).

Figure 3-6D shows that respondents with progressive illnesses (OR 3.47, 95%CI: 1.90-6.35) had higher odds of reporting 'fear/worry about getting hurt or injured' as a barrier compared to respondents with other health conditions. However, respondents with heart/blood pressure/circulatory conditions (OR 0.38, 95%CI: 0.15-0.94) had lower odds. Respondents aged 40-54 (OR 0.20, 95%CI: 0.08-0.47), 55-64 (OR 0.12, 95%CI: 0.04-0.38), and 65+ (OR 0.26, 95%CI: 0.12-0.56) had lower odds of reporting this barrier, compared to those aged 25-39.

Table 3-13: Odds ratios and 95% confidence intervals (CI) from logistic regression models for health and mobility barriers by health condition and socio-demographic variables (adjusted for each health condition, sex, age, income and ethnicity; p<0.05, p<0.1.

		Poor physical health		Poor mental health		Lack of facilities/access points for those with disabilities		Fear/worry about getting hurt or injured	
		OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Health conditions	Arthritis	1.6 (1.25-2.05)	<0.001	1.19 (0.81-1.76)	0.384	1.98 (1.21-3.21)	0.006	1.47 (0.81-2.67)	0.204
	Respiratory	2.03 (1.56-2.65)	<0.001	1.85 (1.25-2.75)	0.002	1.69 (1.04-2.75)	0.034	1.28 (0.7-2.35)	0.423
	Diabetes	1.04 (0.76-1.42)	0.791	1.91 (1.19-3.06)	0.007	1.09 (0.61-1.95)	0.778	1.17 (0.53-2.56)	0.697
	Heart/blood pressure/circulatory	1.39 (1.06-1.83)	0.018	0.81 (0.5-1.3)	0.380	1.22 (0.72-2.06)	0.458	0.38 (0.15-0.94)	0.035
	Mental health conditions	0.94 (0.7-1.27)	0.700	7.31 (4.91-10.89)	<0.001	0.85 (0.48-1.5)	0.577	0.73 (0.39-1.34)	0.307
	Physical disabilities	2.46 (1.89-3.2)	<0.001	1.02 (0.67-1.56)	0.916	3.13 (1.94-5.05)	<0.001	1.13 (0.59-2.14)	0.710
	Progressive illnesses	2.17 (1.6-2.96)	<0.001	0.55 (0.32-0.97)	0.038	2.48 (1.49-4.12)	<0.001	3.47 (1.9-6.35)	<0.001
Sex	Male (Ref)								
	Female	0.92 (0.72-1.17)	0.479	1.28 (0.92-1.79)	0.143	0.57 (0.36-0.91)	0.018	0.95 (0.56-1.61)	0.839
Age	25-39 (Ref)								
	16-24	0.41 (0.2-0.83)	0.014	2.43 (1.51-3.9)	<0.001	0.6 (0.18-1.95)	0.395	0.93 (0.45-1.93)	0.837
	40-54	1.4 (0.93-2.1)	0.103	0.95 (0.61-1.46)	0.800	0.46 (0.21-1.02)	0.057	0.2 (0.08-0.47)	<0.001
	55-64	1.33 (0.86-2.05)	0.194	0.98 (0.58-1.65)	0.939	0.54 (0.25-1.17)	0.120	0.12 (0.04-0.38)	<0.001
	65+	2.38 (1.6-3.54)	<0.001	0.21 (0.1-0.44)	<0.001	0.74 (0.37-1.49)	0.399	0.26 (0.12-0.56)	0.001
Ethnicity	White (Ref)								
	BAME	0.5 (0.3-0.81)	0.005	1.47 (0.93-2.34)	0.103	0.77 (0.32-1.83)	0.549	1.65 (0.83-3.3)	0.154
Income	£20,000-39,999 (Ref)								
	£0-19,999	1.03 (0.78-1.34)	0.858	1 (0.69-1.46)	0.990	0.84 (0.5-1.39)	0.497	1.3 (0.7-2.42)	0.407
	£40,000-59,999	0.91 (0.61-1.36)	0.638	0.87 (0.51-1.49)	0.612	0.15 (0.03-0.64)	0.010	0.75 (0.29-1.9)	0.539
	£60,000+	0.87 (0.53-1.4)	0.557	0.8 (0.4-1.61)	0.531	0.99 (0.44-2.22)	0.972	1.71 (0.73-3.99)	0.213

3.7.4 Socio-economic and environmental barriers

The odds ratios, confidence intervals, and p-values for these barriers are presented in Table 3-14, with the odds ratios and confidence intervals for each barrier presented visually in Figure 3-7.

Respondents with progressive illnesses (OR 0.72, 95%CI: 0.54-0.96) and with an income of £0-19,999 (OR 0.73, 95%CI: 0.58-0.92) had lower odds of reporting bad weather as a barrier. Respondents with mental health conditions (OR 1.39, 95%CI: 1.09-1.78), aged 40-54 (OR 1.60, 95%CI: 1.16-2.21), 55-64 (OR 2.09, 95%CI: 1.46-2.98), and 65+ (OR 2.15, 95%CI: 1.54-3.02) had higher odds of reporting this barrier, compared to those with other health conditions or aged 25-39 (Figure 3-7A).

For the barrier 'fear/worry about crime or anti-social behaviour', respondents with respiratory conditions (OR 1.78, 95%CI: 1.12-2.83) and BAME respondents (OR 1.93, 95%CI: 1.13-3.30) had greater odds than those with other health conditions or white respondents of reporting this as a barrier. Respondents aged 65+ (OR 0.26, 95%CI: 0.12-0.55) had lower odds than 25–39-year-olds of reporting this barrier (Figure 3-7B).

Respondents with physical disabilities (OR 1.62, 95%CI: 1.14-2.31), female (OR 1.42, 95%CI: 1.02-1.97), and BAME (OR 1.72, 95%CI: 1.07-2.75) respondents had higher odds of reporting not having nice enough green space near them as a barrier, compared to their counterparts. Those with an income of £40,000-59,999 (OR 0.42, 95%CI: 0.21-0.84) had lower odds compared to the reference group of £20,000-39,999 (Figure 3-7C).

For the barrier 'cost/too expensive', respondents with heart/blood pressure/circulatory conditions (OR 3.92, 95%CI: 1.91-8.05) and diabetes (OR 2.36, 95%CI: 1.14-4.86) had higher odds of reporting it, compared to respondents with other health conditions. These have large confidence intervals, so should be interpreted with some caution (Table 3-14). Respondents with respiratory conditions (OR 0.27, 95%CI: 0.10-0.71) aged 16-24 (OR 0.31, 95%CI: 0.12-0.78), 40-54 (OR 0.08, 95%CI: 0.03-0.24), 55-64 (OR 0.05, 95%CI: 0.01-0.19), and 65+

(OR 0.05, 95%CI: 0.02-0.16) had lower odds of reporting cost as a barrier (Figure 3-7D).

Table 3-14: Odds ratios and 95% confidence intervals (CI) from logistic regression models for health and socio-economic and environmental barriers by health condition and socio-demographic variables (adjusted for each health condition, sex, age, income and ethnicity); p<0.05, p<0.1.

		Bad weather		Fear/worry about crime or antisocial behaviour		Nowhere near me is nice enough		Cost/too expensive	
		OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Health conditions	Arthritis	1.01 (0.81-1.26)	0.928	1.27 (0.78-2.06)	0.333	1.14 (0.81-1.61)	0.461	0.83 (0.4-1.72)	0.617
	Respiratory	0.85 (0.67-1.08)	0.176	1.78 (1.12-2.83)	0.014	1.13 (0.79-1.62)	0.503	0.27 (0.1-0.71)	0.008
	Diabetes	1 (0.76-1.32)	0.990	1.38 (0.78-2.45)	0.270	1.08 (0.7-1.66)	0.720	2.36 (1.14-4.86)	0.020
	Heart/blood pressure/circulatory	0.8 (0.62-1.03)	0.083	1.13 (0.65-1.97)	0.672	1.27 (0.86-1.86)	0.227	3.92 (1.91-8.05)	<0.001
	Mental health conditions	1.39 (1.09-1.78)	0.008	1.09 (0.68-1.75)	0.726	1.19 (0.82-1.72)	0.355	0.82 (0.41-1.64)	0.581
	Physical disabilities	1.04 (0.82-1.33)	0.743	0.89 (0.52-1.52)	0.671	1.62 (1.14-2.31)	0.007	0.59 (0.26-1.34)	0.206
	Progressive illnesses	0.72 (0.54-0.96)	0.023	0.94 (0.5-1.76)	0.845	1.28 (0.85-1.94)	0.235	1.9 (0.82-4.43)	0.135
Sex	Male (Ref)								
	Female	1.19 (0.96-1.46)	0.105	0.79 (0.52-1.21)	0.283	1.42 (1.02-1.97)	0.037	0.96 (0.53-1.75)	0.894
Age	25-39 (Ref)								
	16-24	0.7 (0.46-1.07)	0.096	1.36 (0.71-2.61)	0.351	0.84 (0.44-1.6)	0.592	0.31 (0.12-0.78)	0.013
	40-54	1.6 (1.16-2.21)	0.004	0.84 (0.46-1.51)	0.554	1.03 (0.62-1.69)	0.919	0.08 (0.03-0.24)	<0.001
	55-64	2.09 (1.46-2.98)	<0.001	0.53 (0.26-1.08)	0.081	1.03 (0.6-1.77)	0.909	0.05 (0.01-0.19)	<0.001
	65+	2.15 (1.54-3.02)	<0.001	0.26 (0.12-0.55)	<0.001	0.92 (0.54-1.56)	0.763	0.05 (0.02-0.16)	<0.001
Ethnicity	White (Ref)								
	BAME	0.79 (0.56-1.12)	0.181	1.93 (1.13-3.3)	0.016	1.72 (1.07-2.75)	0.026	1.31 (0.59-2.92)	0.510
Income	£20,000-39,999 (Ref)								
	£0-19,999	0.73 (0.58-0.92)	0.008	0.83 (0.52-1.34)	0.451	1.19 (0.83-1.69)	0.346	1.34 (0.65-2.75)	0.427
	£40,000-59,999	1.19 (0.86-1.66)	0.288	0.66 (0.33-1.3)	0.228	0.42 (0.21-0.84)	0.014	1.13 (0.44-2.86)	0.804
	£60,000+	0.79 (0.53-1.18)	0.251	0.38 (0.14-1.04)	0.058	0.97 (0.52-1.81)	0.916	1.19 (0.42-3.37)	0.741

3.7.5 Other priorities as a barrier

The odds ratios, confidence intervals, and p-values for these barriers are presented in Table 3-15, with the odds ratios and confidence intervals for each barrier presented visually in Figure 3-8.

Age was associated with being too busy at home, with respondents aged 16-24 (OR 3.61, 95%CI: 2.0-6.53) and 40-54 (OR 1.81, 95%CI: 1.02-3.22) having higher odds of reporting this barrier, and 65+ (OR 0.43, 95%CI: 0.21-0.89) lower odds, compared to those aged 25-39. Respondents with diabetes (OR 1.76, 95%CI: 1.05-2.94) had higher odds than those with other health conditions of reporting this barrier (Figure 3-8A).

Regarding the barrier 'too busy at work/with family commitments', respondents with respiratory conditions (OR 0.59, 95%CI: 0.36-0.94), physical disabilities (OR 0.26, 95%CI: 0.14-0.48), aged 55-64 (OR 0.51, 95% CI: 0.28-0.94), and aged 65+ (OR 0.18, 95%CI: 0.09-0.35) had lower odds of reporting this barrier. Respondents with heart/blood pressure/circulatory conditions (OR 1.64, 95%CI: 1.01-2.65), female respondents (OR 2.51, 95%CI: 1.69-3.74), and those with the highest income level of £60,000+ (OR 2.60, 95%CI: 1.50-4.51) had higher odds than those with other health conditions, male, and middle-income respondents (Figure 3-8B).

Three health conditions were associated with lower odds of reporting 'not interested' as a barrier – arthritis (OR 0.53, 95%CI: 0.31-0.90), heart/blood pressure/circulatory (OR 0.49, 95%CI: 0.25-0.93), and progressive illnesses (OR 0.31, 95%CI: 0.12-0.78). No sociodemographic variables were associated with this barrier (Figure 3-8C).

There were also three health conditions associated with lower odds of reporting 'prefer to do other leisure activities' as a barrier – respiratory conditions (OR 0.42, 95%CI: 0.21-0.88), mental health conditions (OR 0.44, 95%CI: 0.23-0.83), and progressive illnesses (OR 0.24, 95%CI: 0.07-0.82). Respondents aged 40-54 (OR 0.23, 95%CI: 0.10-0.54), 55-64 (OR 0.31, 95%CI: 0.13-0.73), and 65+ (OR 0.24, 95%CI: 0.10-0.53) had lower odds of reporting this barrier compared to those aged 25-39 (Figure 3-8D).

Respondents aged 40-54 (OR 1.48, 95%CI: 1.08-2.04) and 65+ (OR 3.52, 95%CI: 2.51-4.94) had greater odds of reporting the barrier ‘stayed at home to stop coronavirus spreading/Government restrictions’ compared to those aged 25-39 (Figure 3-8E).

Respondents with respiratory conditions (OR 0.36, 95%CI: 0.13-0.99), aged 55-64 (OR 0.30, 95%CI: 0.10-0.91), and aged 65+ (OR 0.14, 95%CI: 0.04-0.44) had lower odds of reporting having no particular reason for not using green space. Respondents with progressive illnesses (OR 2.44, 95%CI: 1.16-5.16) and with an income of £0-19,999 (OR 2.88, 95%CI: 1.26-6.58) had greater odds than those with other health conditions and in the £20,000-39,999 income group (Figure 3-8F).

Table 3-15: Odds ratios (OR) and 95% confidence intervals (CI) from logistic regression models for other priorities barriers by health condition and socio-demographic variables (adjusted for each health condition, sex, age, income and ethnicity); p<0.05, p<0.1.

		Busy at home		Busy at work/family commitments		Not interested	
		OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Health conditions	Arthritis	0.77 (0.49-1.21)	0.260	0.89 (0.58-1.35)	0.570	0.53 (0.31-0.9)	0.019
	Respiratory	1.21 (0.77-1.9)	0.411	0.59 (0.36-0.94)	0.028	0.86 (0.51-1.46)	0.580
	Diabetes	1.76 (1.05-2.94)	0.031	0.64 (0.36-1.14)	0.131	1.44 (0.81-2.54)	0.215
	Heart/blood pressure/circulatory	0.79 (0.46-1.36)	0.398	1.64 (1.01-2.65)	0.046	0.49 (0.25-0.93)	0.029
	Mental health conditions	0.72 (0.47-1.12)	0.150	0.96 (0.64-1.44)	0.843	0.69 (0.41-1.16)	0.159
	Physical disabilities	1.02 (0.63-1.65)	0.933	0.26 (0.14-0.48)	<0.001	0.62 (0.35-1.12)	0.115
	Progressive illnesses	0.79 (0.44-1.44)	0.443	0.7 (0.37-1.33)	0.281	0.31 (0.12-0.78)	0.014
Sex	Male (Ref)						
	Female	1.2 (0.81-1.78)	0.369	2.51 (1.69-3.74)	<0.001	0.97 (0.63-1.49)	0.882
Age	25-39 (Ref)						
	16-24	3.61 (2-6.53)	<0.001	0.57 (0.31-1.04)	0.066	0.75 (0.36-1.57)	0.450
	40-54	1.81 (1.02-3.22)	0.044	1.08 (0.68-1.73)	0.739	1.24 (0.69-2.21)	0.474
	55-64	0.95 (0.47-1.91)	0.886	0.51 (0.28-0.94)	0.030	0.56 (0.25-1.25)	0.156
	65+	0.43 (0.21-0.89)	0.022	0.18 (0.09-0.35)	<0.001	0.68 (0.34-1.35)	0.272
Ethnicity	White (Ref)						
	BAME	1.06 (0.62-1.81)	0.824	1.21 (0.73-1.98)	0.459	1.27 (0.69-2.35)	0.445
Income	£20,000-39,999 (Ref)						
	£0-19,999	0.78 (0.49-1.22)	0.275	0.65 (0.42-1.01)	0.055	1.33 (0.81-2.17)	0.256
	£40,000-59,999	1 (0.56-1.8)	0.992	0.88 (0.51-1.51)	0.632	0.71 (0.33-1.51)	0.372
	£60,000+	1.14 (0.6-2.18)	0.692	2.6 (1.5-4.51)	0.001	1.1 (0.51-2.37)	0.808

		Prefer other leisure activities		Stayed at home to stop spread of Covid-19		No particular reason	
		OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Health conditions	Arthritis	1.05 (0.58-1.87)	0.880	1.24 (0.99-1.55)	0.061	0.7 (0.34-1.46)	0.343
	Respiratory	0.42 (0.21-0.88)	0.021	1.27 (1-1.62)	0.053	0.36 (0.13-0.99)	0.049
	Diabetes	1.23 (0.62-2.42)	0.551	0.8 (0.6-1.06)	0.115	0.85 (0.35-2.06)	0.712
	Heart/blood pressure/circulatory	1.56 (0.84-2.91)	0.159	0.82 (0.63-1.06)	0.134	1.5 (0.67-3.33)	0.323
	Mental health conditions	0.44 (0.23-0.83)	0.011	0.94 (0.74-1.2)	0.643	0.52 (0.26-1.05)	0.068
	Physical disabilities	1.12 (0.61-2.07)	0.708	0.94 (0.74-1.2)	0.641	0.6 (0.27-1.32)	0.203
	Progressive illnesses	0.24 (0.07-0.82)	0.023	1.05 (0.79-1.4)	0.730	2.44 (1.16-5.16)	0.019
Sex	Male (Ref)						
	Female	1.14 (0.68-1.91)	0.608	1.03 (0.84-1.27)	0.780	0.57 (0.3-1.07)	0.078
Age	25-39 (Ref)						
	16-24	0.69 (0.31-1.52)	0.352	0.95 (0.64-1.41)	0.792	0.73 (0.27-1.96)	0.527
	40-54	0.23 (0.1-0.54)	0.001	1.48 (1.08-2.04)	0.015	0.78 (0.35-1.74)	0.548
	55-64	0.31 (0.13-0.73)	0.007	1.28 (0.9-1.83)	0.165	0.3 (0.1-0.91)	0.033
	65+	0.24 (0.1-0.53)	<0.001	3.52 (2.51-4.94)	<0.001	0.14 (0.04-0.44)	0.001
Ethnicity	White (Ref)						
	BAME	1.26 (0.61-2.61)	0.540	0.91 (0.65-1.27)	0.572	0.55 (0.19-1.59)	0.272
Income	£20,000-39,999 (Ref)						
	£0-19,999	1.23 (0.67-2.28)	0.509	0.97 (0.77-1.24)	0.832	2.88 (1.26-6.58)	0.012
	£40,000-59,999	1.94 (0.96-3.93)	0.065	1.22 (0.88-1.7)	0.233	0.99 (0.29-3.35)	0.989
	£60,000+	0.77 (0.28-2.12)	0.618	0.89 (0.6-1.33)	0.575	2.1 (0.67-6.56)	0.200

3.7.6 Sensitivity analysis

Sensitivity analysis was used to assess the appropriateness of a particular model specification and explore the strength of the conclusions being drawn from the model. It allowed confidence to be gained in the results of the primary analysis (Salciccioli *et al.*, 2016). Sensitivity analysis was also used to explore whether aggregating the socio-demographic variable categories impacted upon the results of the regression models.

To explore the robustness of the findings, sensitivity analysis was undertaken on the regression model for 'poor physical health and well-being'. This barrier was chosen because of its high count (N = 552), and its further importance for the physical health-related barriers which will be explored in Chapter 4. Different categories for income, age, and ethnicity were explored in the sensitivity analysis:

- Income:
  - Four categories (£0-19,999, £20,000-39,999 (reference), £40,000-59,999, £60,000+) *vs.*
  - Ten categories (£0-14,999, £15,000-19,999, £20,000–29,999, £30,000-39,999 (reference), £40,000–49,999, £50,000–59,999, £60,000–79,999, £80,000–99,999, £100,000-£149,999, £150,000+)
- Age:
  - Three categories (16-24, 25-64 (reference), 65+) *vs.*
  - Five categories (16-24, 25-39 (reference), 40-54, 55-64, 65+)
- Ethnicity:
  - Two categories (white (reference), BAME) *vs.*
  - Five categories (white (reference), mixed, Black or Black British, Asian or Asian British, any other ethnic group/background)

Logistic regression models were run in R for each of these variables. The difference in the regression estimates and p-values between the two categorisations for each variable were examined using the car package (v3.1.0). For each variable, the direction of the associations and significance of the p-value (i.e., $p<0.05$) did not differ from the main analyses (Appendix I, Appendix J, and Appendix K)

3.8 Discussion: Interpretations of the results

The results provided answers to the two research questions. Overall, the reporting of type of chronic health condition did differ depending on the

respondents' sex, age, income, and ethnicity, and the reporting of general barriers to green space use did differ by the respondent's type of chronic health condition and socio-demographic characteristics.

3.8.1 Associations between health conditions and socio-demographic variables

Key results include differences in the reporting of mental health conditions by sex and ethnicity, with female respondents having higher odds, and BAME respondents having lower odds, of reporting mental health conditions than their male and white counterparts. Income was found to be associated with diabetes, with respondents in the higher income group (£60,000+) having greater odds of reporting diabetes than those in the £20,000-39,999 income group; bringing into question the differences in type 1 and type 2 diabetes and how diabetes was defined in the survey.

The finding that respondents with a household income of £60,000+ had greater odds of reporting diabetes differs from the literature, where individuals with lower income are reported as more likely to have diabetes (Tanaka, Gjona and Gulliford, 2012; Hill-Briggs *et al.*, 2021). This could be related to the reference category used, which was £20,000-39,999 rather than the lowest income group (£0-19,999), with respondents with £60,000+ income having greater odds of reporting diabetes than those with £20,000-39,999 household income group. This could also be due to the definition used for diabetes, with a lack of distinction between type 1 and type 2 diabetes. Previous research has reported that greater affluence, occupation, and education are associated with higher type 1 diabetes risk, whilst lower household earnings has been found to be associated with type 2 diabetes risk (Liese *et al.*, 2012; Cuddapah *et al.*, 2022). It could also relate to the regression model being adjusted for other socio-demographic characteristics, including age and sex. One study found an interaction between income and industry regarding risk of developing diabetes, which was influenced by the individual's sex (Ishihara *et al.*, 2022). In certain industries (such as lifestyle-related, personal services, and entertainment services), men had a higher risk of developing diabetes in the high-income group, and women had a higher risk in the low-income group. They also found that the cumulative incidence rate of developing diabetes was higher in men than women, which corroborates with the

finding in this analysis that female respondents had lower odds of reporting diabetes (Ishihara et al., 2022).

The findings regarding the reporting of mental health conditions are interesting, particularly by sex. Female respondents were more likely than males to report having a mental health condition. This was also found in other research conducted in England in 2014, where one in five women and one in eight men reported having a common mental health problem (McManus *et al.*, 2016). However, despite there being a sex difference in the overall population prevalence of mental health conditions, the reporting of mental health as a barrier to using green space did not differ by sex.

BAME respondents had lower odds of reporting mental health conditions compared to white respondents. The pattern for mental health conditions could be explained in part by the stigma attached to mental disorders. A recent systematic review found that racial minorities reported more stigma than racial majorities for common mental health conditions across the world (Eylem *et al.*, 2020). The presence of stigma could lead to social desirability bias when answering survey questions relating to mental health. Additionally, a UK systematic review focusing on prevalence of mental health disorders by ethnic group found a strong pattern in the prevalence of suicidal thoughts in men (Rees *et al.*, 2016). Prevalence of suicidal thoughts were relatively low for South Asian men and were lower for this ethnic group than for white men. They also found a strong pattern for the prevalence of suicidal thoughts for adults generally, finding that prevalence was low for Black adults, and lower for this group than it was for white adults. These findings corroborate with the regression results regarding ethnicity and mental health.

3.8.2 Mobility and health barriers to green space use

Regarding the reporting of mobility and health barriers to green space use, key results include respondents with progressive illnesses having greater odds of reporting a lack of facilities/access points for those with disabilities and fear/worry about getting hurt/injured, but lower odds of reporting poor mental health as a barrier to using green space. Some of the findings regarding mobility and health barriers were unsurprising, for example, respondents with mental

health conditions having greater odds of reporting poor mental health as a barrier to green space compared to respondents with other health conditions. However, one key finding was that respondents aged 16-24 had greater odds of reporting poor mental health as a barrier to green space use than those aged 25-39.

The finding that younger respondents (aged 16-24) had greater odds of reporting poor mental health as a barrier to green space use compared to 25–39-year-olds emphasises the ongoing mental health crisis that young people are facing in the UK and beyond. A report by NHS Digital (2022) found that in young people aged 17-19 years living in England, rates of probable mental disorder rose from 10% in 2017, to 18% in 2020, and reached 26% in 2022 (Newlove-Delgado *et al.*, 2022). In the United States (US), a report from 2020 found that young adults aged 18-25 had the highest prevalence of any mental illness (31%), compared to adults aged 26-49 (25%) and 50+ (15%). Young adults also had the highest prevalence of serious mental illness (10%), compared to adults aged 26-49 (7%) and 50+ (3%). However, young adults were the least likely to have received mental health treatment (National Institute of Mental Health, 2020).

Adolescence to young adulthood (those aged 14-25) has been reported to be a complex sensitive period for the emergence of mental health conditions (Owens *et al.*, 2022). For example, it has been found that three-quarters of all mental health disorders start by the age of 24 years (Kessler *et al.*, 2005). The finding that the youngest age group had higher odds of reporting 'poor mental health' as a barrier, but there was no difference in reporting of mental health conditions, could be explained by their mental health condition being more acute and therefore creating a barrier to getting outside and using green space in the last 14 days. The wording of questions measuring the prevalence of mental health conditions is also of importance. For example, the National Institute of Mental Health (2020) explored past year prevalence of mental illness, compared to this study measuring chronic health conditions lasting at least 12 months.

Respondents with progressive illnesses and those aged 65+ had lower odds of reporting poor mental health as a barrier. This could be explained by age being positively associated with the chance of developing multiple disorders, which could mean that physical health-related barriers, such as 'poor physical health'

and ‘fear/worry about getting hurt or injured’, influenced their use of green space more than mental health (Royal College of Psychiatrists, 2018). Respondents were only able to select three responses to the barriers question, with poor mental health possibly being a lesser barrier to green space use for this age group.

Respondents with physical disabilities and progressive illnesses had the highest odds of reporting poor physical health and lack of facilities/access points for those with disabilities as barriers to green space use. Only respondents with progressive illnesses had significantly ($p<0.05$) higher odds of reporting fear/worry about getting hurt/injured. This is corroborated by existing research, which have found that individuals with progressive illnesses, such as dementia and Parkinson’s disease, reported fear of falling, mobility issues, and lack of confidence as key barriers to physical activity (Ellis *et al.*, 2013; Natural England, 2016; Gebhard and Mir, 2021).

3.8.3 Socio-economic and environmental barriers

The results showed that BAME respondents were more likely to report fear about crime/anti-social behaviour and ‘nowhere near me is nice enough to spend free time’ as barriers to green space use, compared to white respondents. This suggests that there is a connection between ethnicity and neighbourhood barriers, or that BAME respondents were more likely to live in less desirable neighbourhoods.

This finding is reported in other research on green space and ethnicity, which have focused on green space access and use. People from a mixed BAME population have been found to have significantly more negative perceptions and to be less satisfied with local place characteristics, including urban green space quality (Roe, Aspinall and Ward Thompson, 2016; Public Health England, 2020b). This was particularly prevalent in the Bangladeshi population, who were less satisfied with the neighbourhood environment, safety, and attractiveness of urban green space, and were therefore less likely to visit (Roe, Aspinall and Ward Thompson, 2016). It has also been found that BAME individuals are more likely to live in deprived areas, with people from the White British, White Irish and White Other ethnic groups the least likely out of all ethnic groups to live in

the most income-deprived 10% of neighbourhoods in England, and people from the Pakistani ethnic groups over 3 times as likely as White British people to live in the most overall deprived 10% of neighbourhoods (Communities and Local Government, 2020). This supports the importance of neighbourhood barriers to green space use, as well as the neighbourhood itself, in affecting the BAME population's use of green space.

Female respondents were also more likely to report 'nowhere near me is nice enough to spend free time' as one of their top three barriers to green space use. This association could be explained by sex differences in how the aesthetics and accessibility of an area is valued. It has been found that women see greater aesthetic value in green spaces than men and attribute a higher value to characteristics such as lighting, pleasant views, safety, off-lead dog areas, playgrounds, and recreational areas (Ode Sang *et al.*, 2016; Braçe, Garrido-Cumbrera and Correa-Fernández, 2021). One explanation suggested for this is that women have been found to spend more time in or near their home environment, and therefore see green spaces as an important addition to their local area (de Vries *et al.*, 2003; Ode Sang *et al.*, 2016). This could also be associated with existing literature finding that women are more likely to feel unsafe in green environments (Maas *et al.*, 2009; Braçe, Garrido-Cumbrera and Correa-Fernández, 2021). However, there was no significant difference ($p>0.05$) found by sex when reporting fear about crime/anti-social behaviour as a barrier.

Respondents with physical disabilities were more likely to report that nowhere near them was nice enough to spend time in as a barrier compared to respondents with other health conditions. Corazon et al (2019) found that interviewees with mobility disabilities assigned a hierarchy of values to different green spaces and experiences, with the most 'pristine' spaces being assigned the highest value. Some respondents attributed higher value to local green spaces, linking them to personal safety and social contact, however they also reported fear when going out alone, which caused feelings of nervousness and tension (Corazon *et al.*, 2019). This suggests that the quality of the space (or 'niceness') as a barrier may not be related to crime and disorder, with no significant association found for reporting fear of crime as a barrier for respondents with physical disabilities. These findings highlight the importance of green space

quality for those with physical disabilities, as well as for female respondents more generally.

3.8.4 Other priorities and COVID-19 as a barrier

Key results include older respondents (65+) having greater odds of reporting staying at home to stop coronavirus spreading/Government restrictions as a barrier to green space use compared to the younger age groups, with no differences found by health condition. Only respondents with diabetes had higher odds of reporting being too busy at home as a barrier, and only respondents with progressive illness reported no particular reason for non/infrequent use of green space.

Respondents with diabetes had higher odds than those with other health conditions of reporting being too busy at home as a barrier. This has also been reported in existing research on exercise. For example, a study undertaken in Birmingham, UK exploring barriers and facilitators to exercising in patients with Type 1 diabetes identified a lack of time and motivation as two of the key barriers to exercise (Lascar *et al.*, 2014). Other studies have also found that a key barrier to exercise in individuals with diabetes is a lack of time overall (Alharbi *et al.*, 2017; Gallé *et al.*, 2017; Cartagena, Tort-Nasarre and Arnaldo, 2021). It is interesting that respondents with diabetes were more likely to report being too busy as a barrier to green space use, especially when they were not more likely to report a lack of interest as a barrier. This poses a question about whether the health condition and its management/treatment have a significant burden on time, which influences use of green space.

The results showed that respondents aged 65+ had the highest odds of reporting ‘stayed at home to stop coronavirus spreading/Government restrictions’ as a barrier to green space use, and that there were no significant differences ($p<0.05$) by health condition. This suggests that age, rather than health condition, was the greatest factor determining the influence that Covid-19 restrictions had on green space use. The finding that older people stated Covid-19 as a reason for not using green space is understandable, with this age group being disproportionately affected by the disease, with the highest incidence of severe symptoms and death, as well as being more likely to avoid social contact

(Armitage and Nellums, 2020; Public Health England, 2020a). The PANS data used in this thesis were collected from November 2020 to March 2021 during a Covid-19 wave, as well as during the winter, which likely exacerbated anxiety around catching coronavirus and the related negative health impacts.

It has also been reported in existing research that older age groups (aged 50-69 and 70+) were more likely to follow restrictions relating to social distancing than younger age groups (aged 18-24), who were the least likely to say they always or often maintained social distancing (Office for National Statistics, 2021c, 2022a). This finding was corroborated in the analysis of the YouGov data (in Chapter 5) collected between April 2020-April 2021 during the start of the Covid-19 pandemic, with UK respondents aged 65+ more likely to report fear for their health when outdoors, that they or a member of their household were at risk of severe consequences of COVID-19, and that they were using an outdoor space at home instead as barriers to using green space. These were the strongest associations seen across the models included in the *Land* publication (Burnett, Olsen and Mitchell, 2022). This further supports the finding that older age individuals' use of green space was the most affected by Covid-19. The finding could be explained by many of the health conditions included in this analysis also being included in the shielding list by the UK Government (individuals advised to stay at home to keep themselves safe and avoiding contact with others between March 2020 and September 2021) (Cabinet Office, 2020). This would mean that there were no differences by health condition because the majority of respondents reporting chronic health conditions were staying at home, as advised.

Respondents with progressive illnesses were more likely than those with other health conditions to report 'no particular reason' for not using green space. This could mean that individuals with progressive illnesses were impacted more by physical health-related barriers, such as mobility and tiredness. This will be explored further in Chapter 4.

3.9 Summary

The regression analysis explored how reporting of general barriers to green space use differed by type of health condition, as well as by socio-demographic

characteristics. The results showed that there were significant differences by type of health condition and socio-demographic characteristics when reporting the general barriers. A theme that emerged from the regression models that should be explored further is the difference between individual level health-related barriers (such as poor physical health) and more place-based barriers (such as a lack of facilities). Most of the place-based barriers can be more easily mitigated, for example by adding more benches or accessible toilets. However, the individual level health barriers would be more challenging to change.

An apparent trend between individuals with physical disabilities, females, and BAME respondents included the higher odds of reporting neighbourhood barriers. These findings were corroborated by existing research and emphasise the importance of the quality of local green space in influencing use of these spaces, particularly for these population groups.

The finding that respondents aged 16-24 years had higher odds of reporting poor mental health as a barrier to green space use highlights the mental health crisis that the UK is currently facing, exacerbated by the Covid-19 pandemic. This also emphasises the need for further evidence to support the use of green space for improving mental health in this population group, with a focus on how young people can be encouraged to spend time in green and other natural spaces in order to gain much-needed mental health and well-being benefits.

These findings emphasise that different factors appear to be more important for different population groups in terms of acting as a barrier to green space use, particularly by sex, ethnicity, and health condition. With the general barriers to green space use differing by health condition and socio-demographic characteristics, specific barriers need to be overcome to support individuals with specific health conditions and within certain population groups. Further evidence is required to understand whether reducing/removing those barriers to green space use would change actual use of green space.

Chapter 4 Physical health-related barriers to green space use: Structural Equation Models

4.1 Research question

Previous chapters have discussed general barriers to green space use and how these differ by respondents' socio-demographic characteristics and health conditions. This chapter will now answer the third research question (Section 1.4):

- RQ3: How does the reporting of physical health-related barriers to using green space differ by type of chronic health condition and socio-demographic characteristics?

The chapter will explore further the reporting of health and mobility-related barriers, such as feeling concerned about becoming ill, compared to place-related barriers, such as poor maintenance and quality of the green space. This will involve the use of Structural Equation Modelling (SEM) to create the health and mobility-related barrier variable and explore how the 'predictors' (type of health condition and socio-demographic variables) are associated with the 'outcome' (reporting the physical health-related barrier to green space use).

Within this chapter, I will use the People and Nature Survey (PANS) data that was described in detail in Chapter 3. For this specific project, the outcome of interest is reporting of physical-health related barriers, including mobility and tiredness/fatigue. This outcome will be explored by health condition and socio-demographic characteristics (sex, age, ethnicity, and income).

4.2 Structural Equation Modelling (SEM)

The goal of Structural Equation Modelling (SEM) is to provide a parsimonious summary of the interrelationships among variables, which a simple regression model cannot provide. A key strength of SEM is that it allows the use of multiple measures to represent constructs, which are unobserved hypothetical variables (Weston and Gore, 2006). SEM enables the evaluation of relationships among latent variables, which are variables that cannot be directly observed but can be

derived from other variables, by combining the strengths of factor analysis and multiple regression in a single model that can then be tested statistically (Hays, Revicki and Coyne, 2005).

A latent variable is a variable that cannot be observed, with most constructs in research being latent variables. Latent variables are instead measured by multiple observed variables and provide a means of extracting a relatively 'pure' measure of a construct from the observed variables (Weston and Gore, 2006; Wagner, Thatcher Kantor and Piasta, 2010; Beaujean, 2014). In other words, a latent measure is something that cannot be measured with a single definite variable, because it is an 'idea' rather than something easily quantifiable. For example, in one study, 'social disorder' was analysed as a latent variable/construct. It was measured using five items from a postal survey: "Neighbours are threatening", "Most people in this area can't be trusted", "People would be afraid to walk alone in this area after dark", "Vandalism and graffiti are a big problem in this area", and "This area is always full of litter and rubbish" (Stafford *et al.*, 2008). Social disorder is the perception that minor forms of public disorder lead to serious crime and a downward spiral; it is an idea or concept, rather than one variable (Sampson and Raudenbush, 2004). Each of the items listed above, in combination, gets closer to capturing the idea of 'social disorder' itself.

SEM was chosen over other approaches, such as multiple binary logistic regression modelling, because this method allows for multiple variables to be included and enables exploration of the relationships among the predictors. SEM allows delineation of the direct (i.e., variance not shared with other variables) and indirect (i.e., mediation) effects among latent variables, as well as observed variables (Hays, Revicki and Coyne, 2005). The ability to create latent variables allows the themes that emerged from the regression models in Chapter 3 to be explored further, particularly the difference between health and mobility-related barriers (such as feeling tired and/or ill, having mobility issues) and place-related barriers (lack of facilities, poorly maintained sites).

Another advantage of SEM is that it can visualise data, and connections between variables, in a graphical way – as a path diagram (Fan *et al.*, 2016). Variance and covariance can also be measured and visualised in SEM, which in this analysis

provides interesting insights into the connections between the physical health-related barriers and the socio-demographic variables. Path diagrams use geometric figures to represent variable types and arrows to represent the relationships between variables (Beaujean, 2014). They present direct relationships and non-directional relationships using single and double-headed arrows, with the double-headed arrows representing covariance between variables (Hershberger, Marcoulides and Parramore, 2003). Variance within a single variable is also presented in a path diagram.

One of the major advantages of SEM over regression analysis is that SEM takes into account measurement errors, which are not accounted for in regression analysis (Nunkoo and Ramkissoon, 2012). Measurement error is the difference between the observed value of a variable and the true, but unobserved, value of that variable (European Commission Collaboration in Research and Methodology for Official Statistics, 2019).

Path Analysis (PA) or Confirmatory Factor Analysis (CFA) could have been used independently, instead of combined in SEM. PA (e.g., regression) tests models and relationships among observed variables, and CFA tests models of relationships between latent variables and observed variables (Suhr, 2006). However, SEM combines the two methods to find if a relationship exists between all of the variables, which then provides answers to the research questions.

4.2.1 The process of SEM

A SEM is comprised of two parts:

- The structural model, which consists of regression-like relationships among variables.

- The latent variable model, or measurement model, which forms the latent variables used in the structural model. (Weston and Gore, 2006; Wagner, Thatcher Kantor and Piasta, 2010; Beaujean, 2014).

If a measurement model is analysed without a structural model, then it is a Confirmatory Factor Analysis (CFA). Similarly, if there is not a hypothesized

structure for the latent variable model, then it would be an Exploratory Factor Analysis (EFA) (Beaujean, 2014).

The SEM is undertaken in five stages: model specification, model identification, model estimation, model evaluation, and model modification (Thakkar, 2020).

Stage 1: Model specification involves the development and definition of the model. This includes explaining the rationale of the overall model and explaining the relationships. The first step is specifying the measurement model. A CFA is used to test the measurement properties of the latent variables in the model. In particular, it is used to measure the extent to which the observed indicators capture the underlying construct (or latent variable) (Stafford *et al.*, 2008; Thakkar, 2020).

Stage 2: Model identification is undertaken to check if the model is over-identified, just-identified, or under-identified. A model is identified if it is possible to derive a unique solution for every parameter (Ramlall, 2016c). Parameters are constant, they indicate the nature and size of the relationship between two variables. Model coefficients can only be estimated in a just-identified or over-identified model (Fan *et al.*, 2016). If the degrees of freedom (dfs) are negative, with more estimated parameters than observations, then the model is under-identified. If the dfs are equal to zero, then the model is just-identified. This means that parameters can be estimated, but goodness of fit testing is not possible. If the dfs are above zero, then the model is over-identified, with more than one set of parameter estimates possible. This is beneficial, allowing exploration of which parameter estimates provide the best fit to the data (Stevens, 2009).

Under-identification can occur if variables are highly intercorrelated, or the scales of the variables are not fixed (the path from a latent variable to one of the measured variables must be set as a constant) (Beran and Violato, 2010). In this study, to ensure that the model was not under-identified, the latent variables had at least two indicators (Fan *et al.*, 2016). The dfs for each model were above zero, therefore the models were over-identified.

Stage 3: Model estimation, which refers to the methods used to estimate parameters. Maximum likelihood (ML) is the default estimator in most SEM software, which estimates the extent to which the model predicts the values of the sample covariance matrix (Beran and Violato, 2010). The estimation method used in this study was diagonally weighted least squares (DWLS), which is recommended when categorical data is used (Shi and Maydeu-Olivares, 2019).

Stage 4: Model evaluation, or model testing, is then used to check the model fit. It is necessary to ensure that the chosen observed variables are an actual measure of construct for the latent variable being created (Thakkar, 2020). The model evaluation is based on the fit indices for the test of a single path coefficient (e.g., p-value) and the overall model fit (e.g., Root Mean Square Error of Approximation (RMSEA)). If more fit indices are used to test the model, then it is more likely that a mis-specified model will be rejected. It is suggested that at least two fit indices should be used (Fan *et al.*, 2016). In this analysis four fit indices are used for each model, which will be discussed further in section 4.2.2.3.

Stage 5: Model modification. This is only required if the model fit is weak. The model is adjusted and refined, and then the model fit is re-examined to check for improvement (Fan *et al.*, 2016; Thakkar, 2020).

4.2.2 Performing SEM

In this section I will set out some key considerations for the conduct of SEM and explain how I approached carrying out the process. All SEM analyses were completed in R using the packages lavaan (version 0.6-9), semptools (version 0.2.9.3), and lavaan.survey (version 1.1.3.1).

4.2.2.1 Sample size

A minimum sample size of 100 is recommended for SEM, although this depends upon the complexity of the model (Wolf *et al.*, 2013). For the SEMs undertaken here, the sample included only those who reported having a chronic health condition (weighted N = 4,157) and those that chose ‘poor physical health’ as a general barrier to green space use (weighted N = 552) (see Figure 3-3 for survey question routing). Overall, the final sample size available was 201, which

reflects the number of respondents who reported a chronic health condition (excluding those reporting mental health conditions, discussed in Section 4.2.3), chose 'poor physical health' as a general barrier to green space use, and responded to the physical health-related barrier question (with don't know, prefer not to say, and N/A being excluded).

4.2.2.2 Multicollinearity

Multicollinearity refers to situations where observed variables are so highly related that they are essentially redundant. This is a concern in some analysis because researchers use related measures as indicators of a construct, and often measures are too highly related for some statistical operations to function (Weston and Gore, 2006). This can lead to variables being removed, or the model being restructured. However, when using several observed variables to describe a latent variable, SEM is immune to multicollinearity (Ramlall, 2016a). In these analyses, three observed variables were used to describe the latent variable which meant that there would not be issues of multicollinearity.

4.2.2.3 Model fit

Goodness of fit indices are required to check the model fit. In this analysis, Root Mean Square Error of Approximation (RMSEA), Standardised Root Mean Square Residual (SRMR), Comparative Fit Index (CFI) and the chi-square test were used. These goodness of fit indices are commonly used in existing literature, with RMSEA, SRMR, and CFI being among the most widely reported (Taasoobshirazi and Wang, 2016). Kline (2016) suggested that the chi-square, RMSEA, CFI and SRMR should be reported for each model when it is possible to do so. The Tucker-Lewis Index (TLI) was calculated, but not reported, because the values of CFI and TLI are highly correlated (Kline, 2016). These fit indices are included in the lavaan package in R. The automatic calculation of multiple goodness of fit indices can allow researchers to report the indices that support their model's fit (Stone, 2021). Therefore, each of the four fit indices have been reported for each SEM to show that certain results have not been selectively reported.

Goodness of fit indices and recommended thresholds for each fit statistic are shown in Table 4-1.

Table 4-1: Description of goodness of fit indices, with recommended thresholds (Ramlall, 2016b; Shi, Lee and Maydeu-Olivares, 2018).

Fit statistics	Recommended threshold	Range of value
Chi-square test	Insignificant result at a 0.05 threshold ($p > 0.05$)	Tabled chi-square
Root mean squared Error of Approximation (RMSEA)	<0.06	0 to 1
Standardised root mean square residual (SRMR)	<0.06	0 to 1
Comparative fit index (CFI)	>0.90	0 to 1

4.2.3 Creating the models

The physical health-related barrier questions were asked if the respondent reported 'poor physical health (or illness)' as a general barrier, therefore data for respondents with mental health conditions were removed despite them being able to report both a mental health condition and poor physical health as a general barrier. The respondents who reported 'poor physical health/well-being' (weighted N = 552) were asked to rate how important the following physical health-related barriers were in stopping them from visiting green/natural spaces in the last two weeks. They were rated from 1 (not at all important) to 5 (very important).

The physical health-related barriers included in the survey in response to being asked 'How important were the following health related reasons in stopping you from visiting green and natural spaces in the last 14 days?' were:

- My mobility
- Concerns that I will become ill during this visit
- Lack of disabled facilities
- Unsuitable/poorly maintained sites
- No-one to go with me/help me
- Tiredness/fatigue

The data itself informed the creation of the latent variable. When exploring covariance amongst the general barriers to green space use in Chapter 3, 'health and mobility' presented itself as a key theme. This was because the general barriers that related to health and mobility were commonly reported together, such as 'poor physical health' and 'a fear of getting hurt/injured'. During the

structural model, the results emphasised the difference between barriers that related to personal/physical mobility and health ('what I can do') and those related to the space and accessibility or perceptions of the space ('what I am enabled to do'). Therefore, the data itself informed the creation of the latent variable 'mobility/health' within the wider model focusing on physical health-related barriers, health conditions, and socio-demographic characteristics.

4.2.4 Visualising the results

SEM figures, or path diagrams, use geometric figures to represent variable types and arrows to represent the relationships between variables (Beaujean, 2014). Latent variables are represented by ovals and observed variables by rectangles. Single-headed arrows show direct relationships and double-headed arrows indicate non-directional relationships (Beaujean, 2014; Fan *et al.*, 2016). Therefore, when performing a SEM, two-way arrows are representative of a covariance between the connected variables. These paths are interpreted as correlational, rather than directional (Hershberger, Marcoulides and Parramore, 2003). There are also arrows connecting the same variable, and this represents variance.

Figure 4-1 presents the initial plan for the SEMs in the form of a path diagram. The latent variable 'mobility/health' is presented in an oval. The three observed variables 'my mobility', 'concerns that I become ill during the visit', and 'tiredness/fatigue' are each connected to the oval with single-headed arrows to show that these three observed variables are describing the new latent variable. The three rectangles at the bottom right of the figure, 'lack of disabled facilities', 'unsuitable/poorly maintained sites', and 'no-one to go with me/help me' are three observed variables (physical health-related barriers) that are outcomes, along with the latent variable. The five variables in the rectangles at the top of the figure are the socio-demographic variables and the type of health condition, which are all predictor variables. These each have single-headed arrows leading into each of the outcome/barrier variables, this is because the direct relationship between the predictors and outcomes are being explored in the SEM. The blue double-headed arrows represent covariance being analysed between each of the predictor variables and each of the outcome variables.

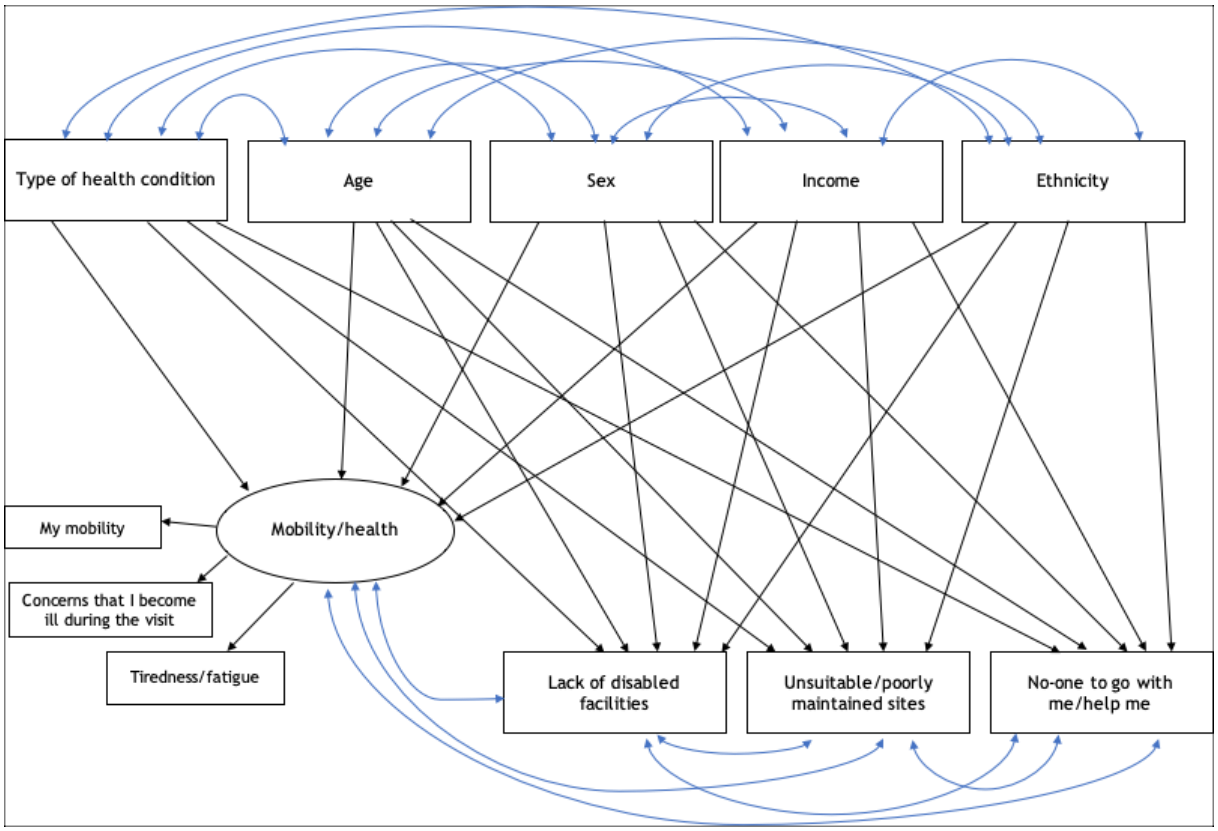


Figure 4-1:The initial plan for the SEMs focusing on physical health-related barriers to green space use.

4.2.5 The data and variables

The variables included in the SEM were categorical, except for age. Therefore, for the model, the binary exogenous categorical variables had to be recoded as dummy (0/1) variables and any ordinal variables were coded to reflect their existing order (e.g., 1, 2, 3 etc.) (Rosseel, 2022). The survey respondents with health conditions were asked to rank each of the physical health-related barriers by importance – from 1 (Not at all important) to 5 (Very important). This scale was kept the same in the SEM. The types of health conditions were categorised as 'Yes' (1) and 'No' (0) as to whether the respondent reported having the type of health condition.

The health conditions included in the SEMs were:

- Arthritis
- Respiratory conditions
- Diabetes
- Heart/blood pressure/circulatory conditions
- Physical disabilities
- Progressive illnesses

The socio-demographic categories included were:

- Sex – Male (0), Female (1)
- Age – exact age of respondents (16+ years)
- Income - £0-19,999 (1), £20,000-39,999 (2), £40,000-59,999 (3), £60,000-99,999 (4), £100,000+ (5)
- Ethnicity – White (0), BAME (1)

SEMs, based on Figure 4-1, were run in R. A SEM was created for each type of health condition to explore associations between the predictor variables (type of health condition and sociodemographic variables) and the outcome variables (physical health-related barriers).

4.2.6 Creating the latent variable

The latent variable 'mobility/health' was created by combining three observed variables: 'my mobility', 'concerns that I become ill during the visit', and 'tiredness/fatigue'. The model was specified, and the measurement model checked before the structural model (or regressions) were added. In existing literature, factor loadings within the measurement model are suggested to be at least 0.3, with general guidance for best factor loadings being recommended as 0.6 and above (Kim *et al.*, 2016; Dash and Paul, 2021). The factor loadings are presented in Table 4-2, all standardised estimates were >=0.6 and the p-values were <0.05. This means that the observed variables adequately measured the latent variable.

Table 4-2: Factor loadings for the 'mobility/health' latent variable (estimates, standardised estimates, and p-values) and the goodness of fit tests.

Observed variable	Estimate	Standardised estimate	P-value	Goodness of fit tests
My mobility	1	0.627	-	RMSEA: <0.001 SRMR: <0.001 CFI: 1.000
Concerns that I become ill during the visit	0.999	0.627	<0.001	
Tiredness/fatigue	1.103	0.692	<0.001	

The results in Table 4-2 were derived from the whole sample of respondents who reported health conditions, rather than per type of health condition. Therefore, the estimates change slightly when loaded for the models by subgroup, created for each health condition (e.g., the SEM for respondents with arthritis). However, all loadings were around the same value for each sub-group, with each standardised estimate being >0.6 and p-values <0.001.

As outlined in Table 4-1, good model fit is defined as Root Mean Squared Error of Approximation (RMSEA) and Standardised Root Mean square Residual (SRMR) having values <0.06, Comparative Fit Indices (CFI) having a value >0.90, and Chi-Square p-values >0.05 (Ramlall, 2016b; Shi, Lee and Maydeu-Olivares, 2018). The model fit for each SEM is presented in Appendix L. The factor loadings were acceptable for each model, with good model fit.

4.2.7 Path diagrams

SEM figures, or path diagrams, were created for each model that had statistically significant results. The covariance results for each SEM are presented in Appendix M.

4.3 Hypotheses

In light of the literature discussed in Chapter 2, I hypothesised that the reporting of physical health-related barriers would differ by type of health condition. The hypotheses are outlined and explained below.

4.3.1 Hypothesis 1: All health conditions would report mobility/health barriers to green space use as important

Existing research has found that disability type, sex, and age do not affect the reporting of barriers to physical activity, such as 'exercise tires me' and 'exercise is hard work for me' (Malone, Barfield and Brasher, 2012). Regardless of disability type, the respondents reported internal barriers (e.g., tiredness) as more constraining, rather than environmental (place-based) and social barriers (e.g., family not encouraging, too few places to exercise). Each health condition included in the analysis has a physical component, which could impact an individual's mobility and their level of fatigue when exercising or using green space. Therefore, I hypothesised that all health conditions would report mobility/health barriers to green space use as important.

4.3.2 Hypothesis 2: Physical health-related barriers focusing on the space/environment itself ('place-based') would be reported as important only by respondents with arthritis, heart/blood pressure/circulatory conditions, physical disabilities, and progressive illnesses

This second hypothesis was determined by a lack of facilities and being limited by the physical environment having previously been reported as barriers to physical activity by adults with arthritis, heart conditions, physical disabilities, and progressive illnesses (Burns, Paterson and Watson, 2008; Petursdottir, Arnadottir and Halldorsdottir, 2010; Morris *et al.*, 2011; Bay *et al.*, 2020). The suitability of a green space site has been defined in existing literature for each of these health conditions by availability of accessible toilets, rest areas, suitable pathways, and clear signage barriers (Mitchell and Burton, 2010; Petursdottir, Arnadottir and Halldorsdottir, 2010; Mapes and Vale, 2012; Saadati Qamsari, Noorizadeh Dehkordi and Dadgoo, 2018; Corazon *et al.*, 2019). Therefore, I hypothesised that a lack of facilities and being limited by the physical environment would be reported by respondents with arthritis, heart/blood pressure/circulatory conditions, physical disabilities, and progressive illnesses.

4.3.3 Hypothesis 3: Reporting of 'having no-one to go with/help me' as a barrier would only be associated with respondents with progressive illnesses, who would have an increased likelihood of reporting this barrier as important

Research exploring individuals with progressive illnesses such as dementia and Parkinson's disease have found that social motivation from family, staff, or volunteers encouraged trips outdoors, and that the availability of support was a key barrier (Mitchell and Burton, 2010; Lamont *et al.*, 2011; Mapes and Vale, 2012). An existing study also found no significant difference between respondents with a mobility disability compared to those with no disability when reporting 'no companions' as a barrier to participating in a favourite outdoor activity (Williams *et al.*, 2004). Additionally, research on students with different disabilities suggested that intrapersonal barriers to physical activity, such as pain and tiredness, were reported more often than interpersonal barriers, such as not having support from friends/family (Úbeda-Colomer, Devís-Devís and Sit, 2019). Therefore, I hypothesised that 'having no-one to go with/help me' as a barrier would be associated with respondents with progressive illnesses.

4.3.4 Hypothesis 4: The likelihood of reporting each physical health-related barrier would increase with age, and decrease with income, with no significant differences by sex and ethnicity

There is little available evidence on how health-related barriers to green space use differ by socio-demographic characteristics, with most research focusing on the associations between poor health and socio-demographic variables. One study from the United States (US) found that with each additional year of age, the odds of reporting poor health as a reason for not visiting National Forests increased by a factor of 1.05 (Burns and Graefe, 2007). A study using Natural England's Monitor of Engagement with the Natural Environment (MENE) survey found that poor health was more likely to be reported by those in the lowest socio-economic group and those in part-time employment or not working (Boyd *et al.*, 2018). These findings informed the hypotheses that there would be differences in physical health-related barriers to green space use by age and income.

Regarding sex, in a study focusing on woodland use, no significant differences were found between sex profiles of visitors and non-visitors, with unclear conclusions whether barriers to woodland use were linked to their sex (Morris *et al.*, 2011). As discussed in Chapter 3, differences in barriers to green space use by ethnicity have been reported to be associated with experiences of racism and anxiety, a lack of time and resources, and issues of exclusion that act as barriers for Black and Minority Ethnic groups (CABE Space, 2010). These findings informed the hypotheses that there would not be differences in the reporting of physical health-related barriers by sex and ethnicity.

Therefore, I hypothesised that the likelihood of reporting each physical health-related barrier would increase with age, and decrease with income, with no significant differences by sex and ethnicity.

4.4 Results

In this section, the main findings from the SEMs will be outlined, with path diagrams used to explore the inter-relationships between the variables. One example path diagram will be included in this section, and all of the other path diagrams can be found in the Appendices (Appendix N, Appendix O, Appendix P, Appendix Q, and Appendix R).

Each model explores whether an association exists between the type of health condition (e.g., arthritis) and reporting the physical health-related barrier (e.g., having no-one to go with/help me) as an important barrier to using green space, as well as the strength of the association using p-values. These were adjusted by socio-demographic characteristics to explore differences in the reporting of the physical health-related barriers by the respondent's age, sex, income, and ethnicity.

The results for the sociodemographic characteristics are presented in Appendix S. These show that there were no differences in the reporting of physical health-related barriers by sex, age, income, and ethnicity, when adjusted for each type of health condition. The only p-value <0.1 was for the age variable in the SEM for respiratory conditions (p=0.052), with a 22% lower likelihood of reporting mobility/health as important as age increased.

4.4.1 Path diagrams

The results are extracted from SEM path diagrams, an example of one of the path diagrams created from a SEM is presented in Figure 4-2. To fit the variable names into the rectangle/oval shapes, some names had to be shortened, a key is available in Table 4-3. Path diagrams for each type of health condition are presented in Appendix N (arthritis), Appendix O (respiratory conditions), Appendix P (diabetes), Appendix Q (heart conditions), and Appendix R (progressive illnesses).

Table 4-3: Table key of variable names from SEM path diagrams.

Shortened variable name in path diagram	Full variable name
Health	Mobility/health
Lack fac	Lack of disabled facilities
Maint	Unsuitable/poorly maintained sites
Noone	No-one to go with me/help me
Mobility	My mobility
Ill	Concerns that I become ill during the visit
Tired	Tiredness/fatigue
Arthritis	Arthritis
Resp	Respiratory conditions
Diabetes	Diabetes
Heart	Heart/blood pressure/circulatory conditions
Phys	Physical disabilities
Prog	Progressive illnesses

The path diagram in Figure 4-2 presents the standardised estimates for respondents with physical disabilities. The colour of the line represents the direction of the standardised estimate, with green showing a positive direction and red showing a negative direction.

The most important data that are presented in this figure are in the single-headed arrows between the type of health condition and socio-demographic variables, and the physical health-related barriers. From Figure 4-2, these show that respondents with physical disabilities had an increased likelihood of reporting mobility/health (28%), a lack of disabled facilities (32%), unsuitable/poorly maintained sites (17%) and no-one to go with (17%) as important barriers.

The rest of this chapter will highlight the results for each SEM, with path diagrams for each type of health condition presented in the appendices.

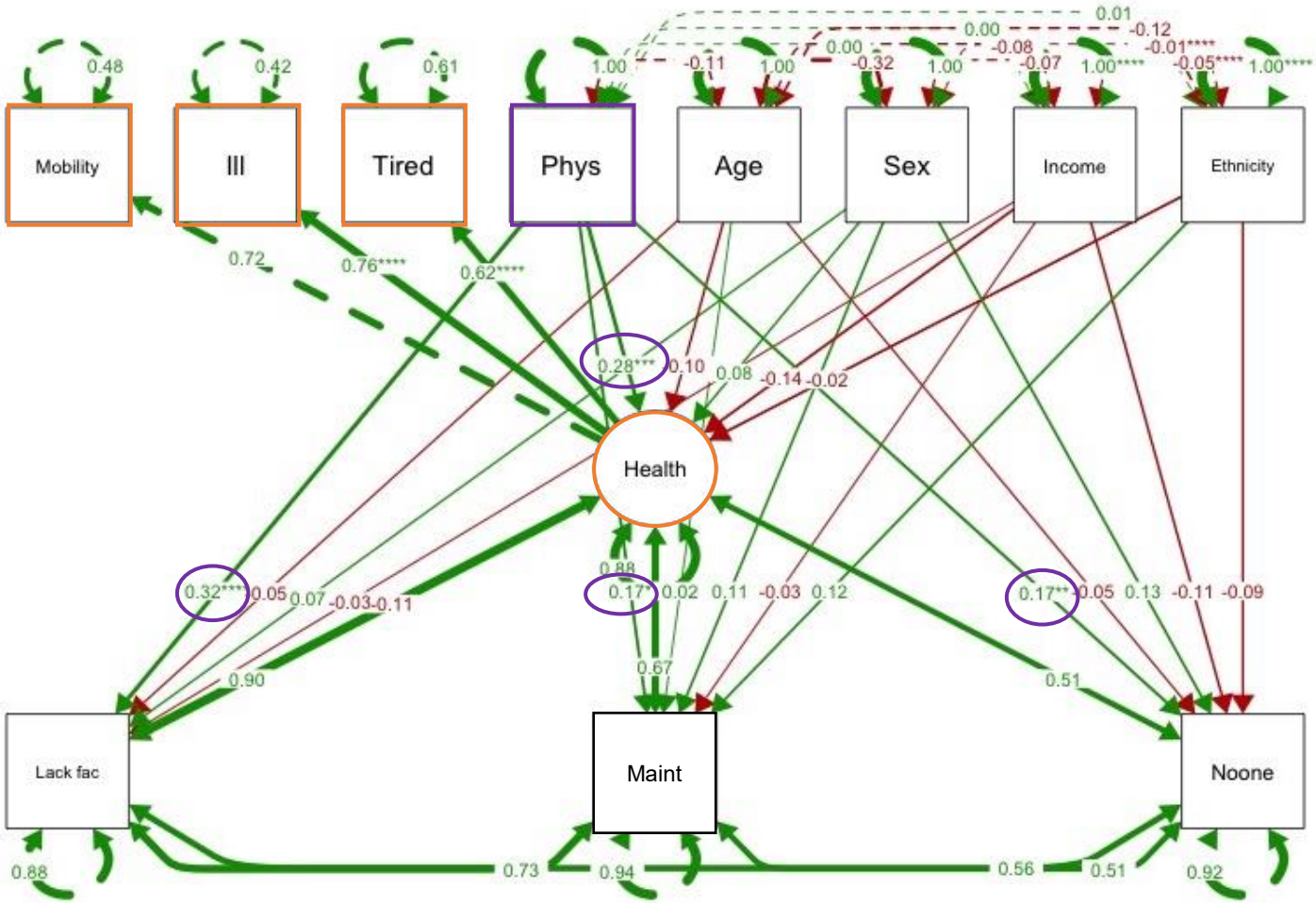


Figure 4-2: SEM for physical disabilities, socio-demographic variables, and health barriers – showing standardised estimates, *p<0.1 **P<0.05 ***p<0.01, ****p<0.001. The orange squares and circle represent the creation of the latent variable ('Health'), the purple square represents the health condition 'physical disabilities' as a predictor, and the results circled in purple are key standardised estimates.

4.4.2 Presenting and interpreting the results

Each SEM was conducted individually for each type of chronic health condition to better understand how the barrier, health condition, and socio-demographic variables interacted in the model, as well as the model fit. The results from the SEMs (where $p<0.1$) are presented in Table 4-4. The statistical strength of the p-value is represented by the size of the arrow. These results show that there were differences in the reporting of physical health-related barriers to green space use depending on the type of health condition reported. For example, respondents with progressive illnesses were the most likely to report all of the physical health-related barriers as important, compared to respondents without progressive illnesses. In contrast, respondents with arthritis were not statistically significantly more likely to report any of the barriers as important.

The p-values and standardised estimates are presented in Table 4-5, with the significant associations ($p<0.05$) highlighted in light grey. P-values that were >0.05, but <0.1 are also highlighted in dark grey. I included a less stringent threshold of $p<0.1$ to ensure that all possible associations were explored. This is also to account for a relatively small sample size (N = 201).

Table 4-4: Summary of significant regression estimates from the SEM results (↑ higher probability of reporting, ↓ lower probability of reporting).

	Mobility/health	Lack of disabled facilities	Unsuitable / poorly maintained sites	No-one to go with/help me
Arthritis				
Respiratory	↑			
Diabetes		↑		
Heart/blood pressure/circulatory	↑	↑	↑	
Physical disability	↑	↑	↑	↑
Progressive illness	↑	↑	↑	↑

↑p<=0.001 ↑p<=0.01 ↑p<=0.05 ↑p<0.1

Table 4-5: SEM regression results for the types of health condition, p<0.05, p<0.1.

	Mobility/health		Lack of disabled facilities		Unsuitable / poorly maintained sites		No-one to go with/help me	
	P-value	Std Estimate	P-value	Std Estimate	P-value	Std Estimate	P-value	Std Estimate
Arthritis	0.307	0.11	0.211	0.12	0.975	-0.00	0.353	0.09
Respiratory	*0.026*	0.28	0.224	0.12	0.45	0.08	0.139	0.15
Diabetes	0.253	0.13	*0.075*	0.19	0.547	0.06	0.314	0.10
Heart/blood pressure/circulatory	*0.002*	0.34	*0.007*	0.28	*0.057*	0.20	0.367	0.09
Physical disability	*0.01*	0.28	*0.001*	0.32	*0.053*	0.18	*0.047*	0.17
Progressive illness	*0.013*	0.27	*0.008*	0.24	*<0.001*	0.31	*0.001*	0.30

4.4.3 Mobility/health

The majority of health conditions were associated with reporting of the latent variable, 'mobility/health', with p-values <0.05. The standardised estimates show that respondents with respiratory condition (28%), heart/blood pressure/circulatory conditions (34%), physical disabilities (28%) and progressive illnesses (27%) all had an increased likelihood of reporting this as an important barrier to green space use.

4.4.4 Lack of disabled facilities

Three types of health conditions had p-values <0.01, with the standardised estimates showing that respondents with heart/blood pressure/circulatory conditions (28%), physical disabilities (32%) and progressive illnesses (24%) all had increased likelihood of reporting a lack of disabled facilities as an important barrier to using green space. Respondents with diabetes had a 19% increased likelihood of reporting this barrier, with a p-value <0.1.

4.4.5 Unsuitable/poorly maintained sites

Respondents with progressive illnesses had a strong association with reporting unsuitable/poorly maintained sites as an important barrier (p<0.001) to using green space. These respondents had 31% increased likelihood of reporting this barrier as important.

Respondents with physical disabilities (18%) and heart/blood pressure/circulatory conditions (20%) had weaker increased likelihoods of reporting unsuitable/poorly maintained sites as an important barrier, with p-values around 0.05.

4.4.6 No-one to go with/help me

For this physical health-related barrier, there were associations for respondents with two types of health conditions, with p-values <0.05. Respondents with physical disabilities (17%) and progressive illnesses (30%) had higher likelihoods of reporting having no-one to go with/help as an important barrier to using green space.

4.5 Discussion: Interpretation of the results

The literature review (Chapter 2) highlighted the lack of literature focusing on the reporting of physical health-related barriers to green space use for individuals with chronic health conditions, with a greater amount of research available which explores barriers to physical activity, including walking. Therefore, I have used the literature exploring barriers to physical activity, as well as barriers to green space use, within this discussion section to provide context to the chapter results.

4.5.1 Hypothesis 1: All health conditions would report mobility/health barriers to green space use as important

Respondents with respiratory conditions (28%), heart/blood pressure/circulatory conditions (34%), physical disabilities (28%) and progressive illnesses (27%) had increased probability of reporting the latent variable ‘mobility/health’ as an important barrier to using green space. There were no significant associations for respondents with arthritis and diabetes, which means that my hypothesis was only partially supported by the results because only four of the health conditions were associated with reporting mobility/health barriers to green space use as important, not all six.

Respondents with heart/blood pressure/circulatory conditions had the highest likelihood of reporting mobility/health barriers to green space use as important

than those with other types of health condition. This could be because individuals with circulatory conditions have been found to feel pain when engaging in walking, as well as feeling physically tired (Klompstra, Jaarsma and Strömberg, 2015; Abaraogu *et al.*, 2018). This finding is corroborated by a systematic review of 18 studies (N = 4,376) focusing on the barriers and enablers for engaging in walking for patients with intermittent claudication (IC; most commonly pain affecting the calf) and peripheral arterial disease (PAD; a circulatory problem in which narrowed arteries reduce blood flow to limbs). They found that the most frequently reported barriers to engaging in walking among the patients were comorbid health concerns, walking induced pain, lack of knowledge (e.g., about the disease pathology and walking recommendations), and poor walking capacity (Abaraogu *et al.*, 2018).

Respondents with arthritis had no significant association with reporting mobility/health as an important barrier to green space use, or any of the other physical health-related barriers. This could be attributed to exercise being utilised to manage the disease, with positive benefits for joint tissues (Hunter and Eckstein, 2009). For example, individuals with rheumatoid arthritis are encouraged to include aerobic and resistance exercise as part of routine care (Cooney *et al.*, 2011). This may explain why these respondents did not find the physical health-related barriers important, despite being more likely to report poor physical health as a general barrier to green space use in Chapter 3.

Similarly, exercise is seen as a way to manage some symptoms of diabetes (both type 1 and type 2). For example, Diabetes UK encourages diabetic individuals to take part in physical activity because this can help the body use insulin better, help maintain blood pressure and flexibility, improve cholesterol and energy-levels, reduce stress levels, and can improve average long-term blood sugar levels (HbA1c) for those with type 2 diabetes (Diabetes UK, 2022). This could explain the lack of significant association between respondents with diabetes and reporting mobility/health barriers.

4.5.2 Hypothesis 2: Physical health-related barriers focusing on the space/environment itself ('place-based') would be reported as important only by respondents with arthritis, heart/blood pressure/circulatory conditions, physical disabilities, and progressive illnesses

This hypothesis was only partially supported by the results, with no significant association found between respondents with arthritis and reporting the 'unsuitable/poorly maintained sites' and 'lack of disabled facilities' barriers as important. Respondents with progressive illnesses (31% higher likelihood of reporting) were the only group with $p<0.001$ that reported unsuitable/poorly maintained sites as an important barrier to green space use. Respondents with physical disabilities (18% higher likelihood) and heart/blood pressure/circulatory conditions (20% higher likelihood) also reported this barrier as important, but with weaker associations ($p<0.06$).

Respondents with heart/blood pressure/circulatory conditions (27.5%), physical disabilities (32%) and progressive illnesses (24%) all had significantly higher likelihoods of reporting 'lack of disabled facilities' as an important barrier to using green space. The reasons for reporting a lack of disabled facilities as a barrier by these three types of health conditions are reportedly similar according to the existing literature.

Respondents with these three types of health condition having increased likelihood of reporting both lack of disabled facilities and poorly maintained sites as important is not surprising, as these are both considered place-based barriers to green space use. The suitability of a site is defined in existing literature for each of these health conditions by availability of accessible toilets, rest areas, suitable pathways, and clear signage barriers (Mitchell and Burton, 2010; Petursdottir, Arnadottir and Halldorsdottir, 2010; Mapes and Vale, 2012; Saadati Qamsari, Noorizadeh Dehkordi and Dadgoo, 2018; Corazon *et al.*, 2019).

Additionally, existing research has explored the key barriers to physical activity and green space use for respondents with heart/blood pressure/circulatory conditions, physical disabilities, and progressive illnesses. For individuals with heart conditions, the key barriers to walking and physical activity in general were a lack of seating, the presence of stairs, and a lack of local facilities

(Abaraogu *et al.*, 2018; Bay *et al.*, 2020). For individuals with physical disabilities, a lack of facilities was reported as a key barrier to using green space, as well as a lack of detailed information about access and facilities, and provision of appropriate services such as accessible toilets (Burns, Paterson and Watson, 2008; Morris *et al.*, 2011; Corazon *et al.*, 2019).

For individuals with progressive illnesses, 'facilities' were the most commonly reported factor determining accessibility to, and engagement with, green spaces in a Natural England survey for individuals with dementia (Natural England, 2016). Clarity of use and function has been highlighted as more important for individuals with dementia than style or aesthetics. People with dementia often struggle to interpret cues that signal a building's use and entrance locations, therefore ensuring that places have obvious cues about their uses is important for a suitable and welcoming environment (Mitchell and Burton, 2010). This explains why the maintenance of a site was reported as especially important for respondents with progressive illnesses.

4.5.3 Hypothesis 3: Reporting of 'having no-one to go with/help me' as a barrier would only be associated with respondents with progressive illnesses, who would have increased likelihood of reporting this barrier as important

The hypothesis was partially supported by the results, with the hypothesis only including those with progressive illnesses. Respondents with physical disabilities (17%) and progressive illnesses (30%) had higher likelihoods of reporting no-one to go with/help me as an important physical health-related barrier to using green space. The likelihood of respondents with progressive illness reporting this barrier as important is almost double that for respondents with physical disabilities. This is likely connected to the explanations behind my hypothesis outlined in Section 4.3.3, with research finding that individuals with dementia and Parkinson's disease found social motivation as a key facilitator to green space use (Mitchell and Burton, 2010; Lamont *et al.*, 2011; Mapes and Vale, 2012).

The association with physical disabilities could be explained by feelings of not belonging being mitigated by having a companion (Morris *et al.*, 2011). For example, individuals with disabilities have previously reported feeling 'awkward'

in outdoor spaces and unwilling to go into rural locations without support from people without disabilities (Burns, Paterson and Watson, 2008; Morris *et al.*, 2011). However, this is not always the case, with some individuals not feeling a need for someone without disabilities to be there for support, which could explain the lower likelihood of reporting the barrier as important compared to respondents with progressive illnesses (Burns, Paterson and Watson, 2008).

4.5.4 Hypothesis 4: The likelihood of reporting each physical health-related barrier would increase with age, and decrease with income, with no significant differences by sex and ethnicity

There were no statistically significant differences in the reporting of physical health-related barriers by socio-demographic variables. The only p-value <0.1 was for the age variable in the SEM for respiratory conditions, with a 22% lower likelihood of reporting mobility/health as an important barrier as age increased (Appendix S). Within the analysis, the results were adjusted for the respondent having respiratory conditions. Therefore, the respondent's mobility/health may not have been viewed as an important barrier to using green space when their health condition was already adjusted for. Instead, the risk of contracting coronavirus or the poor weather may have been seen as greater barriers to green space use for older respondents, as seen in Chapter 3.

In existing literature, there is variation in use of green space by socio-demographic variables, as outlined in Chapter 2. However, the results from this analysis show that this pattern is not found in physical health-related barriers to green space use. Despite this, differences in the reporting of health conditions by socio-demographic variables were found in Section 3.7.1. For example, respondents in the lowest income group had higher odds of reporting arthritis, heart/blood pressure/circulatory conditions, mental health conditions, physical disabilities, and progressive illnesses than those in the £20,000-39,999 income group. The focus on health conditions may remove the variance by socio-demographic characteristics.

4.6 Summary

The SEM analysis undertaken explored which physical health-related barriers were reported for respondents with chronic health conditions and how these differed by type of chronic health condition. The aim of answering the third research question, 'how do physical health-related barriers to using green space differ between different types of chronic health conditions and by socio-demographic characteristics?', was also to explore how the physical health-related barriers may explain reasons for low/non-use of green space among the population group with poor health, as well as by sex, age, ethnicity, and income.

The SEM results showed that there were differences in the reporting of physical health-related barriers by type of health condition, with none of the barriers being reported as important by all six health conditions included in the analysis. The results suggest that both mobility-based and place-based barriers are important barriers to green space use, particularly for respondents with physical disabilities, progressive illnesses, and heart/blood pressure/circulatory conditions. These findings also corroborate the Chapter 3 conclusions that a 'one size fits all' approach will not work in mitigating barriers to green space use for those with chronic health conditions. Instead, specific barriers need to be overcome to support individuals with specific health conditions.

When exploring the literature to understand the reasons behind the reporting of specific physical health-related barriers, it appears that there are also differences *within* these types of health conditions. For example, within the progressive illnesses group differences between those with dementia, Parkinson's disease, and Multiple Sclerosis (MS). Therefore, further research is needed to investigate the influence of individual differences on using green space for those with health conditions, and to explore differences within the types of health condition.

The finding that there was only one association ($p<0.1$) between socio-demographic characteristics and physical health-related barriers is important. This result suggests that the health conditions are the key drivers behind these physical-health related barriers. However, there was variation in the reporting of health conditions by socio-demographic variables, including income, which

could explain the variation in green space use. For example, some of the relationship between income and no/low use of green space could be mediated through poor health. Alternatively, lower income could be associated with infrequent use of green space for other reasons, but also associated with poor health, which is in turn also associated with barriers to green space use. Removing the physical health-related barriers to green space use could have the potential to reduce wider inequalities in green space use, with the biggest proportional impact for the lower income group who have a higher proportion of respondents reporting a chronic health condition.

Chapter 5 Green space use and barriers to use during the Covid-19 pandemic

The content of this chapter is published as two research papers in BMJ Open and *Land*:

- ***Burnett, H.**, Olsen, J. R., Nicholls, N. and Mitchell, R. (2021) Change in time spent visiting and experiences of green space following restrictions on movement during the COVID-19 pandemic: a nationally representative cross-sectional study of UK adults. BMJ Open, 11(3), e044067. (doi: 10.1136/bmjopen-2020-044067)*

- ***Burnett, H.**, Olsen, J. R. and Mitchell, R. (2022) Green space visits and barriers to visiting during the Covid-19 pandemic: a three-wave nationally representative cross-sectional study of UK adults. Land, 11(4), 503. (doi: 10.3390/land11040503)*

5.1 Research questions

This chapter describes the data collection and analysis used to investigate the influence of the novel coronavirus disease 2019 (Covid-19) pandemic on green space use and barriers to using green space. As previously stated, due to the COVID-19 pandemic the main research questions of the thesis were revised due to the importance of understanding the immediate and on-going impact of the pandemic on green space use and barriers (Section 1.3). With all of the data collection for the thesis being undertaken during the pandemic, it was important to provide further context and explore how the pandemic influenced green space use. The key aims of the data collection and analysis in this chapter were to answer research questions 4, 5, and 6 (Section 1.4):

- RQ4: How did green space visits change during the Covid-19 pandemic?
- RQ5: Which barriers to green space visits were reported during the Covid-19 pandemic?
- RQ6: How did green space visits and barriers change over time and by sex, age, and socio-economic position?

The chapter will start with an overview of the Covid-19 pandemic and how the UK Government restrictions on movement would likely impact green space

access, use, and barriers to use. The chapter will focus particularly on change in use of green space and the barriers caused or exacerbated by the pandemic, such as fearing for health when outdoors and being worried about social distancing.

5.2 The Covid-19 pandemic

)Due to the restrictions implemented during the Covid-19 pandemic, there were a number of factors that could create, exacerbate, or remove barriers to accessing and using green space that required exploration. For example, the reduction in time allowed outdoors, the removal of commuting for those working from home, home schooling commitments, and worries about transmission of Covid-19, particularly for those with a health condition (Kouroupa *et al.*, 2022; Office for National Statistics, 2022b). Some of the restrictions, such as shielding, were targeted at certain population groups, such as older individuals and those with chronic health conditions.

In March 2020, shielding measures were implemented for individuals with serious underlying health conditions which put them at very high risk of severe illness from Covid-19 (Ministry of Housing Communities & Local Government, 2020). These measures included staying at home at all times and avoiding face-to-face contact with others. The restrictive and novel nature of these measures created new questions regarding how this change affected green space use for individuals with chronic health conditions, as well as the older generation, who were more likely to be shielding at this time.

Additionally, throughout the lockdowns and restrictions, those who were able to were asked to work from home to reduce the risk of catching and spreading coronavirus. However, the ability to work from home was not possible for certain groups/workers. Findings from the Office for National Statistics (2020) suggest that those in lower income groups were more likely to have to be in the workplace, with 30.5% of employees in the bottom three income deciles (monthly earnings of up to £1,450) considered as ‘key workers’ in March/April 2020, compared to 26.4% in the top three income deciles (monthly earnings of up to £3,250) (Office for National Statistics, 2020). Key workers included those working in health and social care, education and childcare, key public services

(e.g., justice system, charities), food and other necessary goods, transport, and utilities (Cabinet Office, 2022). In June 2020, it was reported that 58% of UK key workers were female, compared to a workforce average of 48%, and 15% of key workers were BAME, compared to a workforce average of 12% (Francis-Devine, 2020). Skilled workers in the knowledge economy could more easily shift to online and distance working, with lower income workers less likely to have this choice. Predictions were made at the start of the pandemic that higher income workers would use green spaces more, being more likely to be working from home, whereas lower income workers would have a decrease in green space use (Honey-Rosés *et al.*, 2020). This therefore created new questions regarding the inequalities in green space use by socio-demographic characteristics including income and sex.

5.3 Data collection

In 2020, everyday life changed drastically. This had an impact on the research questions being answered in the thesis, as well as the available methods. There was a need to collect and analyse novel data on how the pandemic was changing the UK population's use of green spaces and potentially exacerbating the barriers to use. Therefore, primary data collection for the thesis was designed to collect these data.

5.3.1 Data collection methods considered

The rapid ongoing changes to restrictions meant that quick data collection was required. Surveys were chosen to collect a range of data on use and barriers to using green space from a large, representative sample. Multiple data collection methods were considered. With the restrictions in place, in-person survey distribution would not have been possible. If it had been possible, in-person surveys would have allowed for complex questions to be asked and visual aids to be used, however they have been reported as more expensive and time consuming than alternative survey methods (Jones, Baxter and Khanduja, 2013).

Postal surveys allow for a large sample to be reached, with opportunity to use visual aids. However, the nature of postal surveys means that non-response rates are high, with a potentially long wait for responses and often lower response

rates than alternative survey methods. Rapid data collection was required to capture data on green space use at the start of the lockdown/restrictions being implemented.

Online surveys allow collection of large amounts of data from participants in a short time frame, and are also efficient (i.e., with fewer errors due to transferring hand-written data to computers) and economical (i.e., low human resource efforts whilst collecting a large amount of data on varied populations) (Regmi *et al.*, 2016). Non-response can be an issue when using online surveys, with respondents being more likely to skip a question or not answer with as much detail compared to in-person or telephone surveys. Also, some respondents may not be accessible due to the nature of online surveys – for example, certain groups are less likely to have access to the internet or a computer/mobile phone, such as older people and more vulnerable communities (e.g., homeless) (Jones, Baxter and Khanduja, 2013). Despite these limitations, due to the nature of the restrictions, and with rapid data collection required, online surveys were used to collect the data on patterns of green space use and barriers during the pandemic.

5.3.2 YouGov surveys

Online survey companies based in the UK, YouGov and Prolific, were explored; both companies could provide a nationally representative sample in a short time frame. YouGov was chosen to administer the survey, being a more established provider having been founded in 2000 with 22 million panel members globally, compared to Prolific being founded in 2014 with 130,000 panel members globally (Prolific, 2022; YouGov, 2022). YouGov could provide survey results within 24 hours, with an internal review system and nationally representative sample. This allowed me to collect data rapidly and at a relatively large scale.

The design of the study, in terms of the specific questions included and their terminology, evolved with the pandemic. This evolution will be explained in sections below. Three waves of a repeat cross-sectional survey were administered by YouGov between April 2020 and April 2021. Each wave was drawn from YouGov's UK/GB Omnibus of 800,000 panellists who specifically opted in to participate in online research activities (YouGov, 2020a).

Respondents were selected at random from this panel by YouGov and then sent a survey link to complete. All three waves were nationally representative of the UK population when weightings were applied. Sample weights were calculated and provided by YouGov (YouGov, 2020b). YouGov statistically weight the data to the national profile of adults (18+) by age, gender, social class, region, and education level. Targets for the weighted data are derived from the census, Office for National Statistics (ONS) population estimates, and large-scale random probability surveys such as the Labour Force Survey (YouGov, 2020b). Active sampling was also used alongside weights to ensure that the right proportions for each population were used and that the results were representative of the country as a whole. The weighting ensured that the results were representative of the UK population, and reduced bias in sample groups (e.g., fewer Black respondents in the final sample than white, or fewer people aged 18-24 than aged 50+).

5.3.3 Survey content & development

Three waves of data were collected over the first year of the Covid-19 pandemic: April 2020, November 2020, and April 2021. The three survey waves are described in Table 5-1.

Table 5-1: YouGov survey waves with the date the survey was administered, sample size, and restrictions implemented at that time.

Wave	Date collected	Sample size	Restrictions at that time
1	30th April-1st May 2020	2,252	From 23rd March 2020, the UK was in the 'first lockdown' ('stay at home' phase), the population were only permitted to leave home for limited purposes (collect medicines, essential shopping, one form of exercise per day). The same lockdown restrictions were implemented across constituent nations of the UK
2	26th November 2020	2,246	Covid-19 policies and restrictions differed among the constituent nations of the UK: • England was in a winter lockdown, with the population asked to stay at home and only leave for limited reasons such as education, essential shopping, exercise, health care, or to care for vulnerable people (Prime Minister's Office, 2020).

			• Wales was just out of a strict lockdown, with gyms, schools, and restaurants being reopened (Drakeford, 2020). • Scotland was operating localized lockdowns with almost half of its population under strict restrictions, including a ban on indoor household socialising and only essential shops being open (Sturgeon, 2020).
3	29th–30th April 2021	2,215	Covid-19 policies were starting to be relaxed across the UK. Non-essential shops had reopened, outdoor gatherings for up to six people were allowed, and the population was able to travel outside of their local area (The Institute for Government, 2021).

Wave 1 was initially designed and implemented as a one-off cross-sectional survey in April 2020. As the Covid-19 pandemic persisted and evolved, and the further restrictions were implemented across the UK, this led to the two subsequent surveys being commissioned in November 2020 and April 2021. This meant that some question wording differed very slightly between wave 1, and waves 2 and 3 (Table 5-2). During the creation of each survey wave, YouGov checked the wording of each question to ensure it was clear and followed their guidance, such as having a maximum of 10 response categories per question.

To design the survey questions, I drew inspiriation from the existing Monitoring Engagement with the Natural Environment (MENE) survey created by Natural England, particularly for the use of green space and barriers to green space questions and responses. With the first wave of the survey being created in early 2020, at the start of the Covid-19 pandemic, there were no existing surveys to review that asked about the impact of the pandemic on green space use. Therefore, the Covid-related barriers to green space use were derived from the restrictions on movement (i.e., being asked to stay at home), personal experience, recent news articles on changes in policy and restrictions, and feedback from colleagues in the Places and Health programme at the University of Glasgow. The question focusing on type of health condition was based on the Scottish Household Survey and Scottish Health Survey, which will be discussed in greater detail below (Section 5.3.3.4). The survey was reviewed by my supervisors, as well as colleagues in the Places and Health programme, and then sent to YouGov for final review.

5.3.3.1 Use of green space

The survey questions were based on existing instruments that collected data on green space use. Natural England's Monitor of Engagement with the Natural Environment (MENE) survey was used to formulate the question on frequency of green space use, as well as experience of, and barriers to, green space use. The MENE survey ran from 2009-2019 with a focus of capturing time spent in the natural environment, including use of green spaces, volunteering, and pro-environmental behaviours such as recycling (Natural England, 2022a).

In this data collection, use of green space was measured in the form of actual visits to green space. For every survey wave, respondents were asked about their green space visitation frequency (Table 5-2). Green spaces were defined as 'places where you can see and experience plants, trees, and nature outside of the household (e.g., public parks, sports fields, agricultural land, woodlands, coastal paths, and nature reserves)' (Taylor and Hochuli, 2017).

Table 5-2: The survey themes, question wording (by wave), and response categories.

Themes	Wave 1 Questions	Waves 2 and 3 Questions	Response Categories
Visitation frequency	Have you visited a green space since the movement restrictions have been enforced in the UK? (i.e., since 23rd March 2020).	Have you visited ANY green spaces in the last 4 weeks	'Yes, I have' 'No, I have not'
	"How much, if at all, has the amount of time that you have spent visiting green spaces changed since the 'lock down' movement restrictions began (i.e., 23rd March 2020) compared to before?"		'Increased' (increased a lot and increased a little vs. no difference, decreased a little and decreased a lot) 'Decreased' (decreased a lot and decreased a little vs. no difference, increased a little and increased a lot)
		"On average, how often have you visited ANY green spaces in the last 4 weeks (i.e., since mid-September 2020)? (Please select the option that best applies)"	'Frequently' (once a day, 2 to 3 times a week, or once a week) 'Infrequently' (once every 2 weeks, or once in the last 4 weeks)
Barriers to visiting (included in the analysis)	*[If the respondent had not visited green space since lockdown was implemented]* Which, if any, of the following are reasons for you not visiting green spaces since the restrictions were introduced (i.e., 23rd March 2020)? (Please select all that apply) 1. I am worried that I will not be able to socially distance from others in these spaces (i.e., remain 2 metres away)	*[If the respondent had not visited green space or had visited 'infrequently' in the last 4 weeks]* You previously said you have not regularly visited a green space in the last 4 weeks... Which, if any, of the following are your reasons for this? (Please select all that apply) 1. I am worried that I will not be able to socially distance from others in these spaces (i.e., remain 2 metres away)	'Yes' 'No'

	2. Green spaces are much busier now 3. I fear for my health when I go outdoors (i.e., contracting Coronavirus (COVID-19) 4. I/ a member of my household is at higher risk of being severely affected by Coronavirus (COVID-19) 5. I am using an outside space at my home (e.g., garden) instead 6. I am not interested in visiting green spaces	2. Green spaces are too busy for me (e.g., I can't enjoy them when they are crowded, they aren't peaceful enough, I feel uncomfortable surrounded by that many people etc.) 3. I fear for my health when I go outdoors (i.e., contracting Coronavirus (COVID-19)) 4. I/ a member of my household is at higher risk of being severely affected by Coronavirus (COVID-19) 5. I am using an outside space at my home (e.g., garden etc.) instead 6. I am not interested in visiting green spaces	

5.3.3.2 Barriers to green space use

Those that had not visited green spaces (waves 1, 2, and 3) or had visited infrequently (once every 2 weeks or once in the last 4 weeks in waves 2 and 3) were asked about the barriers to visiting green spaces and reasons for their non- or low frequency visitations (Table 5-2). This measure of infrequent visits was based on Natural England's People and Nature Survey (PANS) 2020, which is discussed in more detail in Chapter 3, and Scotland's People and Nature Survey (SPANS) 2013-14, created by NatureScot. In PANS, they asked the barriers to green space use question to respondents who had not visited green space in the last 2 weeks (Natural England, 2020). In SPANS 2013-14, the barriers to green space use question was asked of respondents who had visited less than once or twice a month, with the next most frequent response being once a week (TNS, 2014).

5.3.3.3 Covid-19 barriers to green space use

The survey waves covered a range of reported barriers to the use of green spaces, with 12 barriers included in wave 1 and 15 barriers in waves 2 and 3. For this chapter, and a thesis focused on health-related barriers to use, the attention is on those particularly relevant to Covid-19 and the lockdown restrictions. These were: 'worried about social distancing in green space', 'green spaces are too busy', 'fear for health when outdoors (i.e., contracting Covid-19)', 'member of household/individual at risk of being severely affected by Covid-19′, 'using an outdoor space at home instead', and 'not interested'.

5.3.3.4 Health conditions

As explained in Section 3.2.1.3, both the Scottish Household Survey 2019 and the Scottish Health Survey 2019 were used to formulate the question on type of health condition. The health condition responses included in those two surveys differed, with the Scottish Health Survey 2019 having 40 health conditions listed, and the Scottish Household Survey 2019 having 19. I decided to adapt these responses, but I was limited by YouGov's survey creation restrictions to a maximum of 10 response categories. This meant that the health conditions had to be merged and the response categories matched those used in the People and Nature Survey as described in Chapter 3.

5.3.3.5 Socio-demographic characteristics

Individual demographic and socio-economic (socio-demographic) characteristics, known to be associated with green space use, were also captured. These were: sex (male, female); age group (18–24 years, 25–64 years, 65+ years); and social grade (higher social grade, lower social grade) categorised by YouGov using combined occupational social grade categories. Higher social grades included non-manual workers, such as senior managers, whilst lower social grades included all manual workers, such as labourers (The Market Research Society (MRS), 2020). The socio-demographic variables were consistent across all survey waves, with consistency in the question wording and response categories checked.

5.3.4 Data preparation

Following the datasets being provided by YouGov in spreadsheets, the data underwent a quality check by YouGov and myself. I cleaned the data by checking for input or spelling errors, any incomplete columns, and labelling errors which required changing by YouGov. The three survey waves were combined for the analysis, with a new variable/column created that indicated the survey wave number (i.e., Wave 1, Wave 2, or Wave 3). This allowed change in green space use and barriers over the three waves to be analysed, as well as interaction effects between the waves, green space barriers, and socio-demographic variables. With the data being repeated cross-sections, any change over time represented a population shift rather than an individual level one. No errors were found in the final datasets. Responses of ‘don’t know’ or ‘prefer not to say’ were removed from analysis. In each variable, these missing data accounted for <5%, which conventionally means that imputation is not regarded as essential. This was to be expected because the population drawn upon were self-nominated as panellists for YouGov who are compensated for completing the surveys.

5.4 Results

5.4.1 Descriptive statistics

The weighted percentage for each socio-demographic characteristic was the same for each wave, with 51.5% of respondents being female and 48.5% male (Table 5-3). The greatest (66%) percentage of respondents were aged 25-64, followed by 65+ (23%) and 18-24 (11%). By social grade, 57% of respondents were in the higher social grade group and 43% in the lower social grade group (Table 5-3). Unweighted counts are available in Appendix T.

Table 5-3: Socio-demographic characteristics of the YouGov respondents by survey wave (weighted counts and percentages). The percentages were the same across the three waves due to the weighting.

		Wave 1	Wave 2	Wave 3	Weighted %
Wave	**N**	2252	2246	2215	-
Sex	**Female**	1160	1157	1141	51.5
	Male	1092	1089	1074	48.5
Age	**18-24**	250	249	246	11
	25-64	1482	1478	1457	66
	65+	520	519	512	23
Social grade	**Higher**	1284	1280	1263	57
	Lower	968	966	952	43

5.4.1.1 Green space visits

5.4.1.1.1 Green space visits in wave 1

In wave 1 (April 2020), 93% of all respondents had visited green space in the year before the Covid-19 restrictions on movement were enforced. In contrast, 49% of respondents reported that they had visited green spaces in the 4 weeks prior to the survey (Table 5-4, Figure 5-1). Additionally, 63% of respondents reported that the amount of time they spent in green space had decreased since the restrictions on movement compared to before, with 15% reporting an increase, and 22% reporting no difference in visitation frequency.

Table 5-4: Proportion of respondents visiting green spaces or reporting barriers to doing so.

		Those Who Visited Green Space in the Previous 4 Weeks	Those Who Either Did Not Visit Green Space in the Previous 4 Weeks or Did So Infrequently ^						
		% (n)	% (n)	Worried about Social Distancing in Green Spaces	Green Spaces Are Too Busy	Fear for Health When Outdoors (i.e., Contracting Covid-19)	Member of Household/Individual at Risk of Being Severely Affected by Covid-19	Using an Outdoor Space at Home Instead	Not Interested in Visiting Green Spaces
Wave									
1 April 20	%	49% (1086)	50% (1123)	25%	9%	27%	26%	47%	8%
2 Nov 20	%	65% (1421)	45% (1020)	14%	9%	14%	15%	26%	9%
3 April 21	%	68% (1479)	45% (987)	14%	18%	10%	8%	32%	10%
Sex *									
Male	%	61% (1934)	45% (1476)	17%	10%	16%	16%	30%	12%
Female	%	61% (2052)	48% (1654)	19%	13%	19%	18%	39%	7%
Age group *									
18–24	%	60% (411)	46% (340)	19%	14%	15%	12%	22%	14%
25–64	%	62% (2685)	46% (2031)	18%	12%	16%	14%	30%	8%
65+	%	58% (890)	49% (758)	18%	10%	23%	27%	54%	9%
Social grade*									
Higher social grade	%	66% (2492)	41% (1578)	20%	12%	18%	16%	36%	9%
Lower social grade	%	53% (1494)	54% (1552)	16%	11%	17%	18%	33%	10%

* Responses by demographic variables combined for all three waves, Chi^2 p-values < 0.05. All Ns were weighted to account for survey response bias.
^ Infrequently defined as once every 2 weeks or once in the previous 4 weeks.

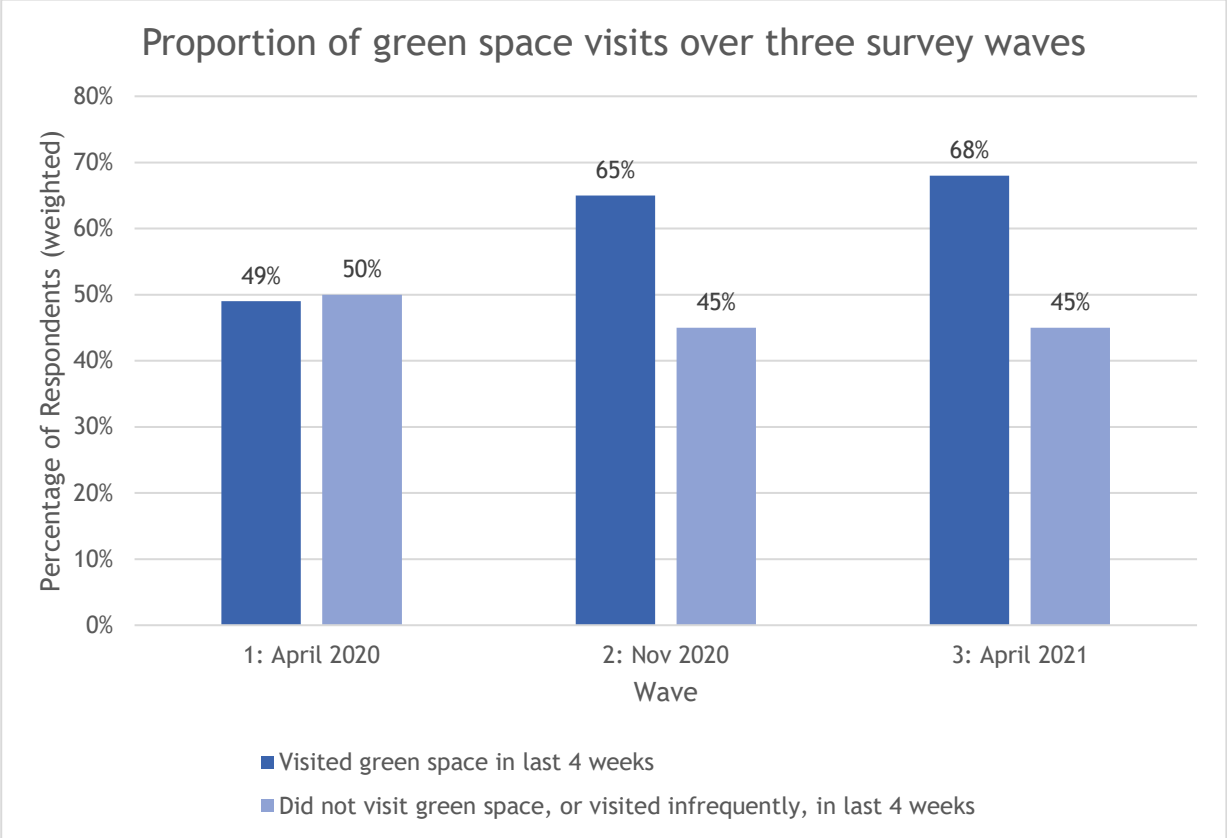


Figure 5-1: The proportion of respondents stating visits or no/infrequent visits to green space over the three survey waves (all significant Chi2, p-values < 0.05). 'Infrequently' defined as once every 2 weeks or once in the previous 4 weeks, which is why percentages do not add up to 100%.

5.4.1.1.2 Green space visits in waves 2 and 3

The proportion of respondents reporting green space visits in the 4 weeks prior increased in wave 2 (November 2020) to 65%, and to 68% in wave 3 (April 2021) (Table 5-4, Figure 5-1).

5.4.1.1.3 Green space visits by socio-demographic characteristics

The differences in green space visits by socio-demographic characteristics can be found in Table 5-4 and Figure 5-2. There was a higher proportion of respondents reporting visits to green space rather than no/infrequent visits in each of the socio-demographic groups (e.g., males, females, those aged 18-24), except for respondents in the lower social grade group. In the lower social grade group, 53% of the respondents reported visiting green spaces in the first year of the pandemic, compared to 54% who reported not visiting green space or visiting infrequently (Figure 5-2).

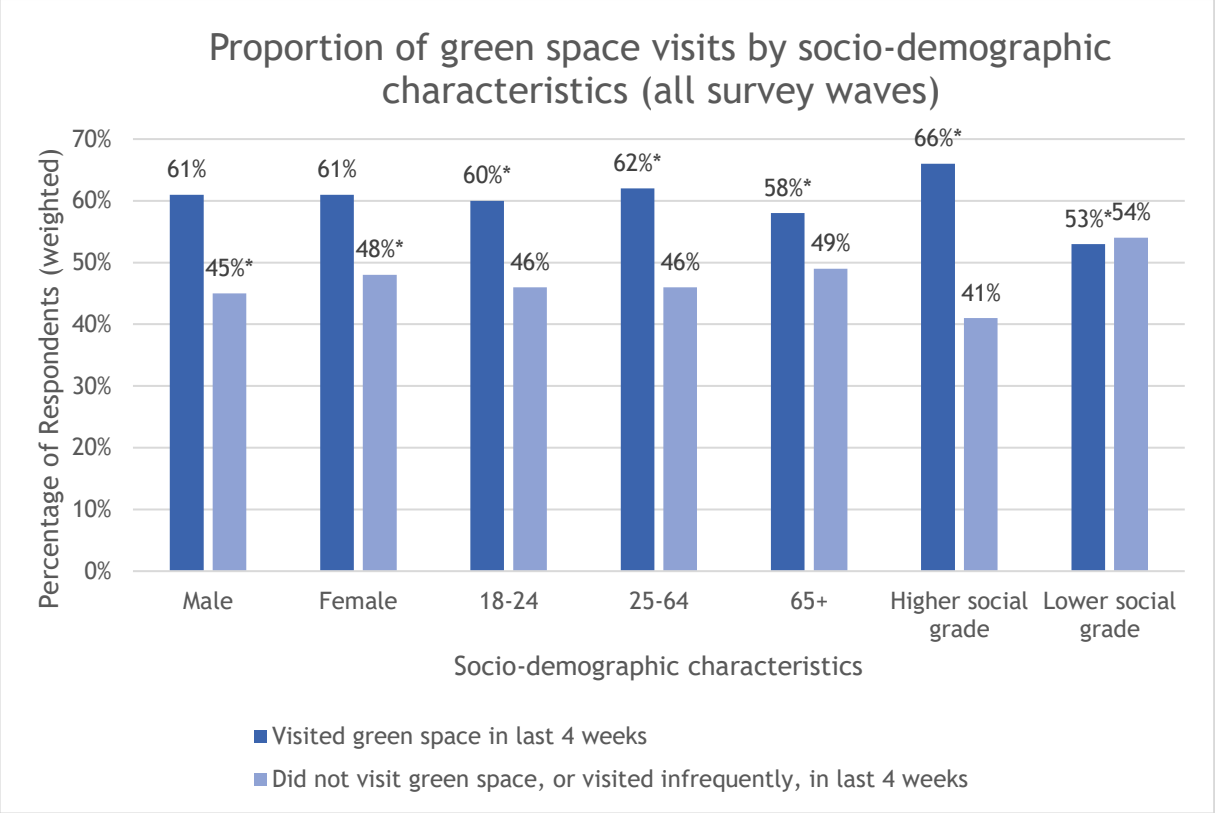


Figure 5-2: The proportion of respondents stating visits or no/infrequent visits to green space by socio-demographic characteristics (* Chi2 p-values < 0.05).

5.4.1.2 Barriers to green space visits

In all survey waves, the most common reason for not visiting green space was "I am using an outside space at my home (e.g., garden) instead" (wave 1: 47%, wave 2: 26%, and wave 3: 32% (Table 5-4)).

In wave 1, the second most commonly reported barrier to visiting green space was, "I fear for my health when I go outdoors (i.e., contracting Coronavirus (COVID-19)" (27%). In wave 2, the second most commonly reported barrier was "I/ a member of my household is at higher risk of being severely affected by Coronavirus (COVID- 19)" (15%). By wave 3, the second most common reason was "green spaces are too busy for me (e.g., I can't enjoy them when they are crowded, they aren't peaceful enough, I feel uncomfortable surrounded by that many people, etc.)" (18%).

5.4.2 Statistical analysis

The descriptive statistics showed evidence that green space visits and barriers to visiting differed by survey wave and socio-demographic characteristics. Therefore, a formal statistical analysis was performed, with multiple binary logistic regression analyses conducted to assess the associations between visiting green space, survey wave, the socio-demographic characteristics, and the reporting of each barrier. Separate models were run for each barrier.

Interaction terms were added to investigate change over time (i.e., between waves) in relationships between the socio-demographic characteristics, survey wave, and green space visits, and between the socio-demographic characteristics, survey wave, and each reported barrier to green space visits. The significance of each interaction was assessed via Wald tests and those which reached a threshold of $p<0.05$ were examined in detail, with $p<0.1$ also highlighted in the results table. Predicted probabilities were derived to ease the interpretation of the significant interaction terms. All statistical analysis was conducted using R (version 3.5.1). Weightings were applied during all analyses to ensure the sample was representative of the UK adult population.

5.4.3 Regression model results

5.4.3.1 Variation in green space visits by survey wave

The regression model results corroborated the descriptive statistics. After adjustment for socio-demographic characteristics, the odds of respondents reporting visiting green spaces since the lockdown restrictions were implemented on 23rd March 2020 (Wave 1) or in the last 4 weeks (Waves 2 and 3) were significantly higher in wave 2 (OR 1.93, 95% CI: 1.71–2.19) and wave 3 (OR 2.25, 95% CI: 1.99–2.55) than in wave 1 (Table 5-5, Figure 5-3A).

Table 5-5: Odds ratios (95% CI) from logistic regression models predicting either visiting green space or reported barriers to visiting; p<0.05, p<0.1.

	Visited Green Space in Previous 4 Weeks	Barriers Reported by Those Who Either Did Not Visit Green Spaces in the Previous 4 Weeks or Did So Infrequently					
		Worried about Social Distancing in Green Spaces	Green Spaces Are Too Busy	Fear for Health When Outdoors	Member of Household/Individual at Risk of Being Severely Affected by Covid-19	Using an Outdoor Space at Home Instead	Not Interested in Visiting Green Spaces
Wave							
1 (ref) (April 20)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2 (Nov 20)	1.93 (1.71-2.19) ***	0.51 (0.41-0.64) ***	1.06 (0.79-1.44)	0.43 (0.34-0.53) ***	0.49 (0.40-0.62) ***	0.39 (0.33-0.47) ***	1.20 (0.88-1.64)
3 (April 21)	2.25 (1.99-2.55) ***	0.50 (0.40-0.62) ***	2.40 (1.84-3.13) ***	0.31 (0.25-0.40) ***	0.25 (0.19-0.32) ***	0.49 (0.40-0.59) ***	1.37 (1.01-1.85) *
Sex							
Male (ref)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.03 (0.93-1.14)	1.26 (1.05-1.52) *	1.31 (1.04-1.63) *	1.18 (0.97-1.43)	1.13 (0.93-1.38)	1.56 (1.34-1.83) ***	0.53 (0.41-0.68) ***
Age group							
18-24	0.90 (0.76-1.06)	1.06 (0.79-1.42)	1.11 (0.78-1.56)	0.95 (0.69-1.31)	0.90 (0.63-1.28)	0.63 (0.48-0.83) ***	1.76 (1.24-2.51) **
25-64 (ref)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
65+	0.82 (0.73-0.93) **	0.94 (0.76-1.18)	0.77 (0.58-1.02)	1.48 (1.20-1.84) ***	2.25 (1.83-2.78) ***	2.70 (2.27-3.22) ***	1.12 (0.83-1.51)
Social grade							
Higher social grade (ref)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Lower social grade	0.57 (0.52-0.63) ***	0.72 (0.60-0.87) ***	0.91 (0.73-1.14)	0.92 (0.76-1.12)	1.14 (0.94-1.38)	0.83 (0.71-0.97) *	1.22 (0.95-1.56)

*** = $p < 0.001$, ** = $p < 0.01$, * $p < 0.05$

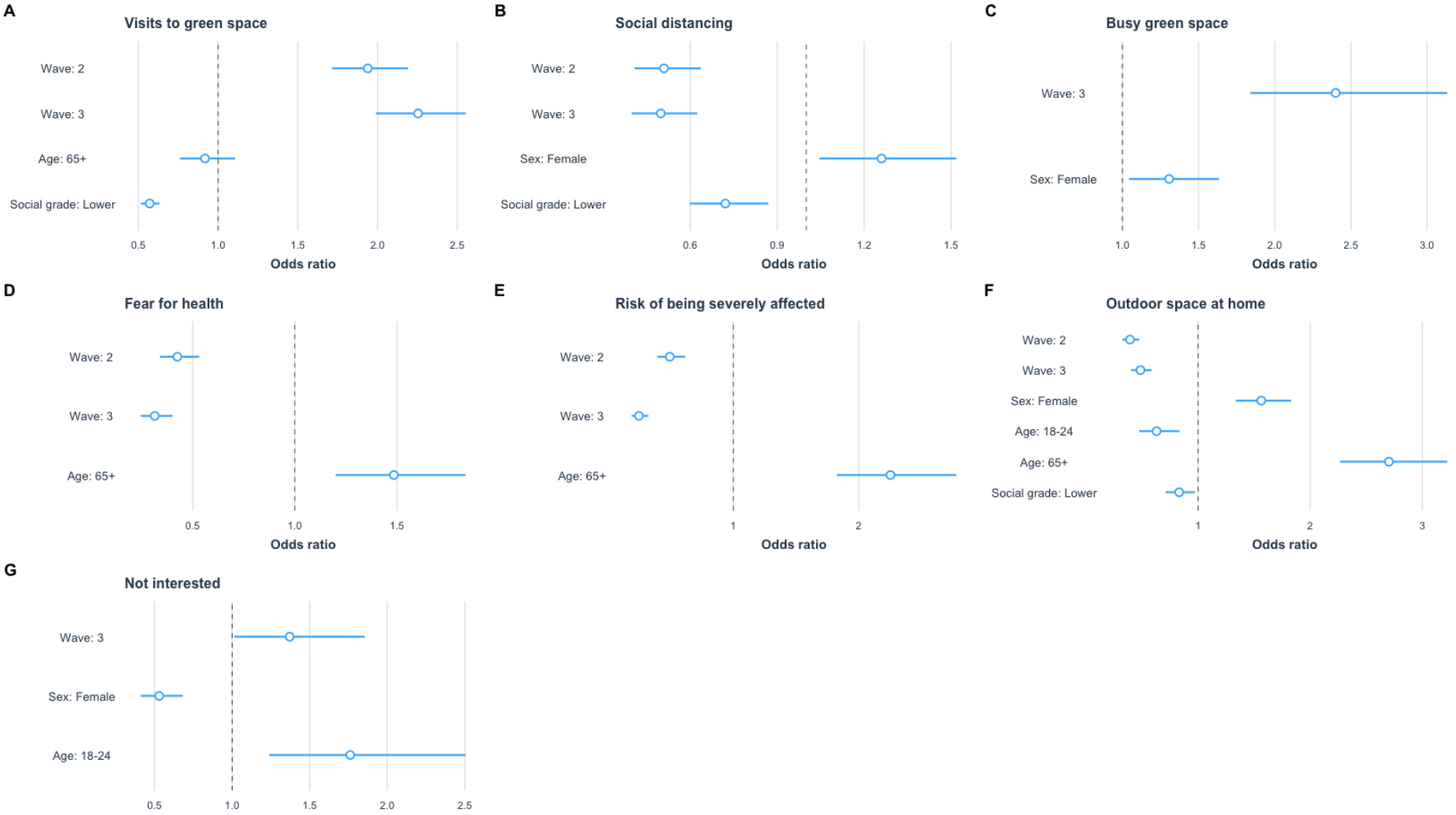


Figure 5-3: Odds ratios (p<0.05) from logistic regression models for visits and barriers by wave and socio-demographic variables (adjusted for each wave, sex, age, and social grade).

5.4.3.2 Variation in green space barriers by survey wave

In general, by waves 2 and 3, respondents were less likely than in wave 1 to report worrying about social distancing in green spaces, fear for health when outdoors, a member of their household (or themselves) being at risk of severe consequences of Covid-19, or using an outdoor space at home as barriers to using green spaces (Table 5-5, Figure 5-3B & Figure 5-3D-F). This may be expected with change in restrictions and initial worries perhaps waning as the pandemic continued. In contrast, by wave 3 respondents were more likely than in wave 1 to report busy green spaces and/or a lack of interest in using green spaces as barriers to visiting green space (Table 5-5, Figure 5-3C & Figure 5-3G). The odds of reporting busy green spaces as a barrier were substantially increased (OR 2.40, 95% CI: 1.84–3.13).

5.4.3.3 Variations in green space visits and barriers by socio-demographic characteristics

These results show the differences in green space visits and barriers to visiting by socio-demographic characteristics, with the data from the three survey waves combined.

5.4.3.3.1 Differences in green space visits and barriers by sex

There were no significant differences between male and female respondents in the likelihood of reporting visits to green spaces across the three waves. However, female respondents were more likely than males to report three barriers to green space visits: being worried about social distancing in green space (OR 1.26, 95% CI: 1.05-1.52), green spaces being too busy (OR 1.31, 95% CI: 1.04-1.63), and using an outdoor space at home (OR 1.56, 95% CI: 1.34-1.83) (Table 5-5, Figure 5-3). Female respondents were less likely than males to report a lack of interest as a barrier to visiting (OR 0.53, 95% CI: 0.41–0.68).

5.4.3.3.2 Differences in green space visits and barriers by age

Respondents aged 65+ were somewhat less likely to have visited green spaces in the last 4 weeks than those aged 25–64 (OR 0.82, 95% CI: 0.73–0.93) (Table 5-5, Figure 5-3A). This older group was also more likely to report fear for their health

when outdoors (OR 1.48, 95% CI: 1.20-1.84), that they or a member of their household were at risk of severe consequences of Covid-19 (OR 2.25, 95% CI: 1.83-2.78), and that they were using an outdoor space at home instead as barriers to visiting (OR 2.70, 95% CI: 2.27-3.22). These were the strongest associations seen in the models regarding socio-demographic characteristics. In contrast, younger respondents were less likely to report using an outdoor space at home as a reason for not visiting green spaces than the middle age group (OR 0.63, 95% CI: 0.48–0.83). This younger age group was also more likely to report not being interested in visiting green spaces, with a relatively large odds ratio of 1.76 (95% CI: 1.24–2.51).

5.4.3.3.3 Differences in green space visits and barriers by social grade

Respondents in the lower social grade group were less likely than those in the higher social grade group to have visited green spaces in the last 4 weeks (OR 0.57, 95% CI: 0.52–0.63) (Table 5-5, Figure 5-3A). The lower social grade group were also less likely to report being worried about social distancing in green spaces (OR 0.72, 95% CI: 0.60-0.87) and using an outdoor space at home instead (OR 0.83, 95% CI: 0.71-0.97) as barriers to visiting green spaces. These associations were relatively modest.

5.4.3.4 Interactions: Change over time in associations between the socio-demographic characteristics and the reporting of green space visits and barriers to visiting

Interaction terms were added in order to investigate change over time in relationships between the socio-demographic characteristics, survey wave, and green space visits, and between the socio-demographic characteristics, survey wave, and each reported barrier. The addition of interaction terms to the models suggested several significant shifts over time (i.e., between waves) in the association between the socio-demographic variables and both visits and reporting of barriers. Details of models with significant interactions are provided in Appendix U (odds ratios) and Appendix V (predicted probabilities).

5.4.3.4.1 Significant interactions between survey wave, social grade, and sex in reporting of green space visits and barriers to visiting

The association between visiting green spaces and social grade differed significantly between waves. This was the only socio-demographic variable to show a significant change in association with green space visits between waves. The predicted probability plot (Figure 5-4A) shows that, whilst the likelihood of visiting increased over time for both social grades, the increase was much sharper between wave 1 (April 2020) and wave 2 (Nov 2020) for the higher social grade group, followed by a more modest increase between waves 2 and 3 (April 2021). In contrast, the increase was relatively constant, wave to wave, for those in the lower social grade group. The result of these differences was an increased socio-economic inequality in visits in wave 3 when compared to wave 1.

The association between sex and reporting green spaces as being too busy to visit also differed significantly between waves. Figure 5-4B suggests a reduction in the difference of reporting this barrier between men and women such that, by wave 3, the difference is lost.

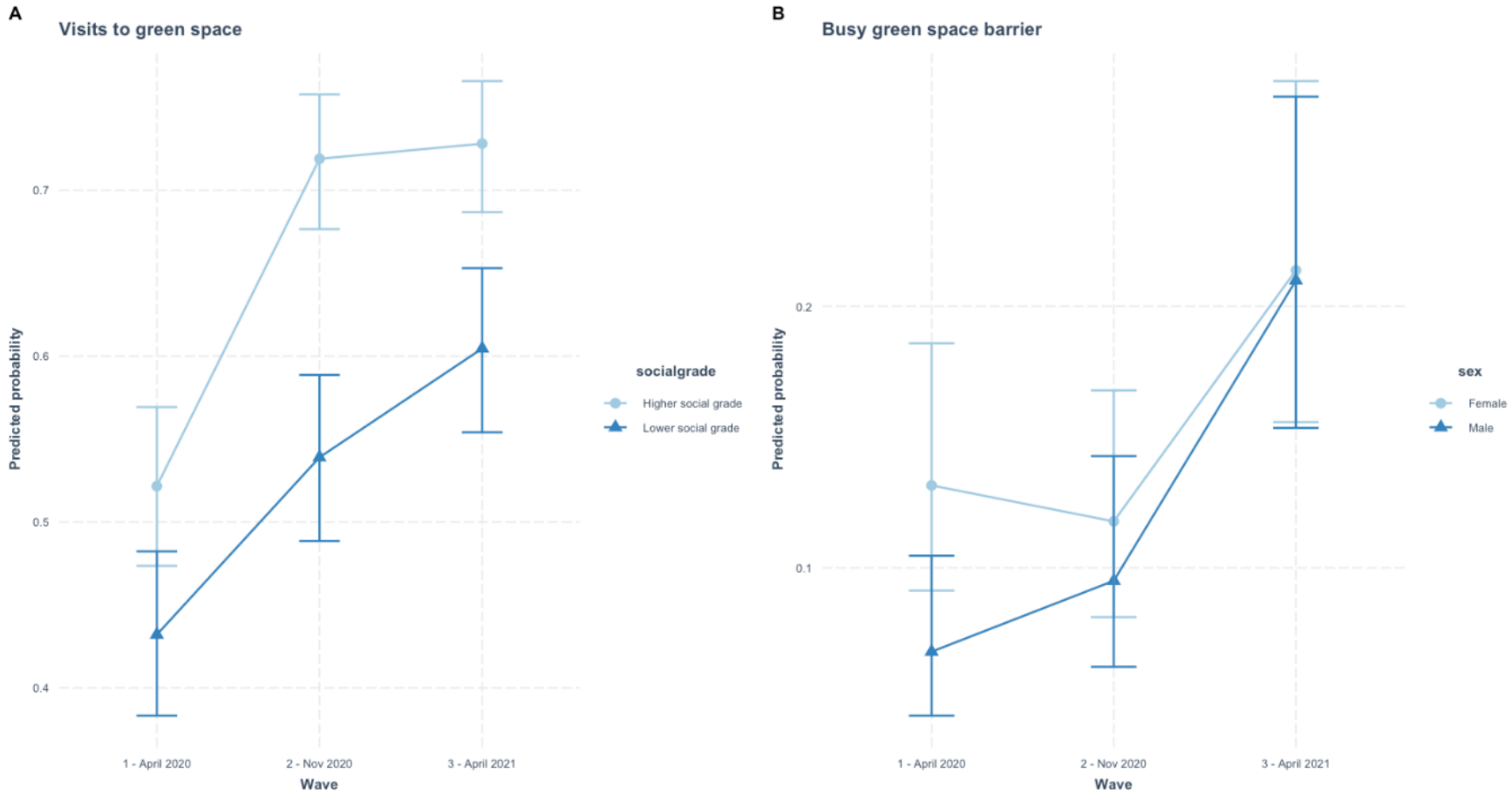


Figure 5-4: Predicted probabilities and confidence intervals from logistic regression models with significant interactions for (A) visits to green space by wave and social grade and (B) the barrier 'green spaces are too busy' by wave and sex.

5.4.3.4.2 Significant interactions between survey wave and age group in reporting of barriers to visiting green space

Whilst those were the only significant interactions involving social grade or sex, there were five significant interactions with age group (Figure 5-5). Figure 5-5A suggests that whilst both 18–24 and 25–64-year-olds became less likely to report difficulty social distancing in green spaces as a barrier to visiting over the year, respondents aged 65+ reporting that barrier remained relatively constant. A dip at wave 2 in reporting busy green spaces as a barrier by the youngest age group, and an overall steeper rise through time by the oldest age group probably explains the significant interaction (Figure 5-5B). There were substantial falls for all age groups in reporting 'fear for my health' as a barrier to green space visits, but the fall was furthest and sharpest for the youngest age group, whilst it reduced between waves 2 and 3 for the older age groups (Figure 5-5C).

Reporting high risk of severe effects from Covid-19 as a barrier fell over time among all age groups, but a substantially higher starting level among those age 65+ and a relatively steeper decline produced a significant interaction (Figure 5-5D). Finally, there were quite complex changes in the relationship between age groups and reporting a lack of interest in visiting green spaces (Figure 5-5E). Perhaps the strongest signal from these was that the lack of interest fell sharply among the youngest age group, in contrast to a rise among the middle age group. However, these results must be treated with caution due to the large confidence intervals which highlight a high level of variability within each age group.

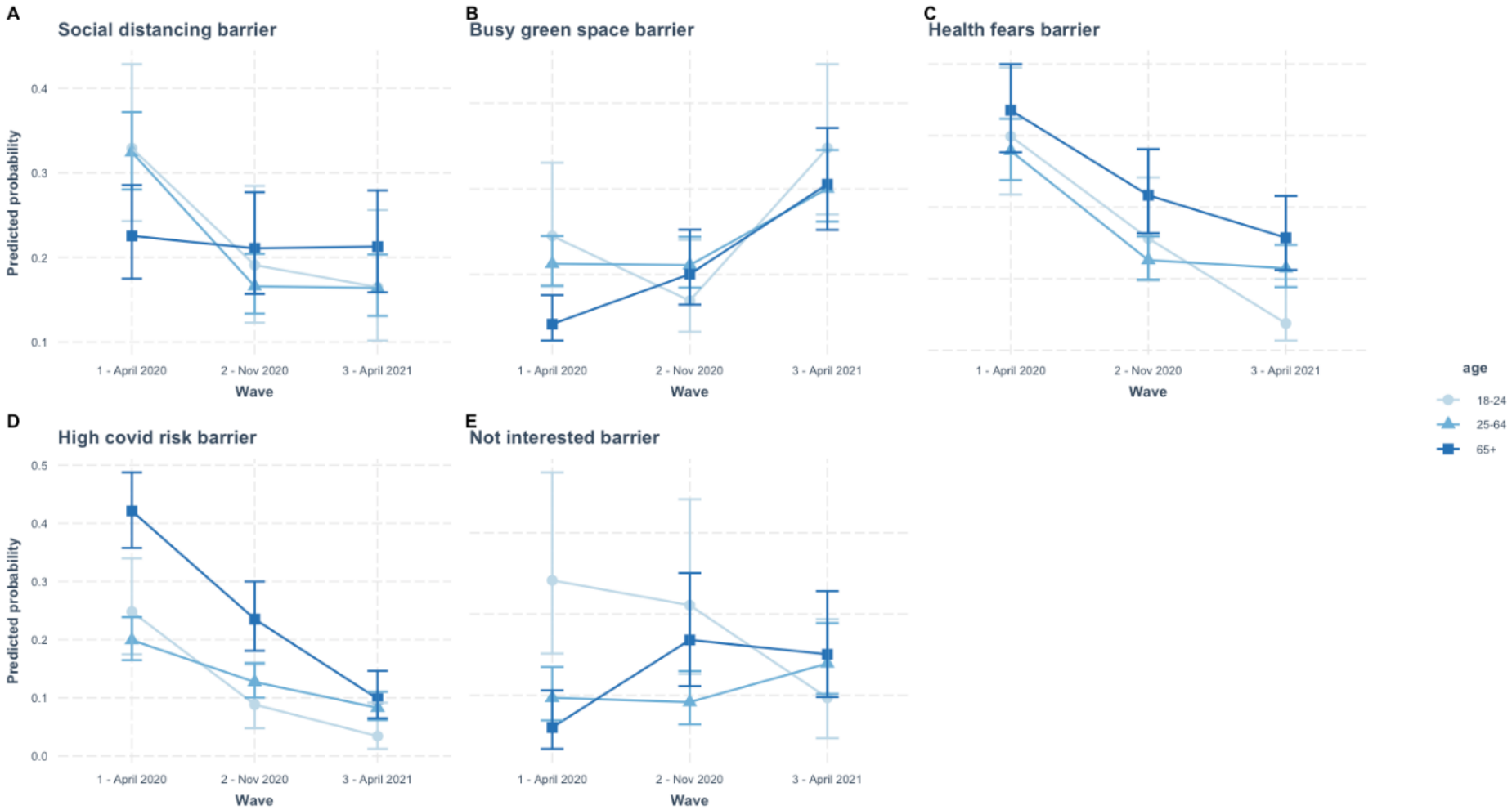


Figure 5-5: Predicted probabilities and confidence intervals from logistic regression models with significant interactions between wave and age group for: (A) the barrier 'I am worried I will not be able to socially distance', (B) the barrier 'green spaces are too busy', (C) the barrier 'I fear for my health when I go outdoors', (D) the barrier 'I/a member of my household is at higher risk of being severely affected by coronavirus', and (E) the barrier 'I am not interested in visiting green spaces'.

5.5 Discussion: Interpretation of the results

5.5.1 Variation in green space visits and barriers by survey wave

The results reported in this chapter present novel findings on how the first year of the Covid-19 pandemic influenced change in green space visits and barriers to visiting in the UK. There were no other directly comparable surveys of green space use covering the UK population at the exact same time points. This was important due to the rapidly changing short-term Covid-19 restrictions that may have influenced behaviours. However, other cohort studies and surveys did take place in England and Scotland at different time points during the Covid-19 pandemic – namely, the People and Nature Survey (PANS) in England and Nature Scot's Enjoying the Outdoors Survey in Scotland (Stewart and Eccleston, 2020; Natural England, 2021b). Nature Scot's survey only asked respondents for frequency of visits to green space between 23rd March-28th May 2020, mid-August to early September 2020, and mid-August to early September 2021. These are different time points to the YouGov surveys, with PANS being the only comparable survey data (albeit only collecting data on the English population), having collected data monthly throughout the pandemic and asking respondents for the number of green space visits taken in the last 2 weeks.

Reported visits to a green space during the 4 weeks prior to respondents completing the survey increased across the three waves, from 49% of respondents in April 2020 to 68% a year later. The PANS results corroborate with my YouGov survey findings on change in green space visits during the pandemic, suggesting substantial increases in visits to green spaces during the first year of the pandemic compared to before (Table 5-6). There is evidence that green space visits fell during the start of the pandemic, compared to the years before. According to data collected from the predecessor of PANS, the Monitor of Engagement with the Natural Environment (MENE) survey, 65% of respondents reported visiting green space at least once a week over the last 12 months in 2018/19 (Natural England, 2019). With the annual MENE data collection, Natural England reported an increase in (at least) weekly visits from 54% in 2009/10 to 65% in 2018/19. This increase in green space visits was stalled by the pandemic, reaching a low of 49% across England (PANS) and the UK (YouGov), however visits increased to above 2018/19 levels by April 2021 (68%).

Table 5-6: Comparing change in visits to green space over time in my YouGov and the People and Nature Surveys (Natural England, 2022c).

	Green space use over time (weighted)		
	April 2020 (Wave 1)	Nov 2020 (Wave 2)	April 2021 (Wave 3)
YouGov – UK (visiting in last 4 weeks)	49%	65%	68%
PANS - England (visited in last 2 weeks)	49%	62%	68%

With nature contact being generally good for health and well-being, this increase in green space visits may have helped mitigate some of the negative mental health impacts of the pandemic. However, it should be acknowledged that the extent of the increase in visits shown in the results was partly driven by the timing of the surveys. Wave 1 was conducted during the strictest lockdown the UK experienced during the pandemic, with outdoor exercise being strongly limited during this time. By waves 2 and 3, restrictions on outdoor exercise were reduced and this probably partly explains the sharp rise in visits to green space (The Institute for Government, 2021).

It is difficult to directly compare countries' changes in green space visits and barriers to visiting green spaces during the Covid-19 pandemic. This is primarily due to international differences in the nature and timing of mobility restrictions at different stages of the pandemic and to the dates of survey data collection in relation to these. Despite limitations to direct comparison, the evidence does suggest that there were substantial changes in green space use in many countries following Covid-19, but the nature of the changes differed. Decreases in use were described in Saudi Arabia, Italy, and Spain (Ugolini *et al.*, 2020; Addas and Maghrabi, 2022), for example, whilst increases were described in Belgium and Norway (Venter *et al.*, 2020; da Schio *et al.*, 2021). At a city level, in New York, equal numbers of respondents reported that they increased (15%) and decreased (14%) their green space visits during the pandemic, which was influenced by Covid-related barriers (N = 1,145). Individuals with greater concerns about crowded green spaces and lack of social distancing visited green spaces less often during the pandemic compared to before, while those who considered green spaces to be more important for their health visited more

frequently (Lopez *et al.*, 2021). The results presented in this thesis chapter may be unique in having assessed changes in green space use at three different time points through the pandemic and in finding that increases in visits were sustained, but Covid-19 specific barriers were not important in the later waves.

In this chapter I focused largely on the barriers to visiting green spaces that could plausibly be created and mitigated by the progress of the pandemic, with the results suggesting a shift in the population's perceptions of risk. Being worried about social distancing, fearing for health, and respondents perceiving a household member or themselves as at risk of being severely affected by Covid-19 were all less likely to be reported by respondents in waves 2 and 3 compared to wave 1. This echoes studies from other countries. Research undertaken in Canada in 2020, for example, reported that some participants noted that seeing more people outside coincided with the easing of restrictions. They also stated that people viewed outdoor activities as permissible because it was occurring outdoors instead of indoors, and there was less risk of spreading coronavirus (McCormack *et al.*, 2022). The relationships between the reported barriers also sheds some light on these changes. For example, by wave 3, respondents were more likely to report green spaces being too busy as a barrier than they had been in wave 1. This corroborates with the finding that visits to green spaces increased over the year; the spaces really were busier. Furthermore, by wave 3, respondents were less likely to report being worried about social distancing as a barrier to using green spaces than in wave 1. This suggests that concerns over crowding/busyness were more connected to accessing the green space and having an enjoyable experience than worries about getting too close to others outdoors. This finding was corroborated by several other studies from around the world (Drakeford, 2020; NHS England, 2020; Dawwas and Dyson, 2021). Research undertaken in Palestine, for example, found that respondents were more likely to visit green spaces alone and less likely to 'relax' or 'socialise' in green spaces after the pandemic occurred compared to before (Dawwas and Dyson, 2021). It is possible that encouraging more people into green spaces had the unintended consequence of putting off others.

Since these are repeat cross-sectional rather than panel data, it was not possible to assess whether/who stopped visiting as a result of these unintended consequences. It is possible, however, to look at more recent data collected on

green space visits and explore whether the trends in green space visits were sustained after April 2021 (Wave 3). As mentioned, PANS data on green space use, experiences, and barriers to use is collected monthly. Figure 5-6 presents data on visits to green space from PANS, MENE and YouGov surveys up to March 2022 (Natural England, 2022b). Overall, the trend in green space visits was sustained from November 2020 onwards, with the proportion of respondents visiting green space in the last 14 days remaining above 60%, except for a decrease to 56% in December 2021. This may be explained by the change in season, with the onset of winter and associated change in weather/temperature making individual preference for green space visits decrease (Zhou *et al.*, 2022). This decrease could also be explained by the spread of the Omicron variant across the UK, which had a high growth rate and led to a rapid increase in Covid-19 cases. This caused the implementation of new restrictions, including face masks becoming compulsory in most public indoor venues and the population being asked to work from home if possible (Johnson, 2021). The new restrictions and spread of Omicron may have caused some people to stay at home and not visit green space as frequently.

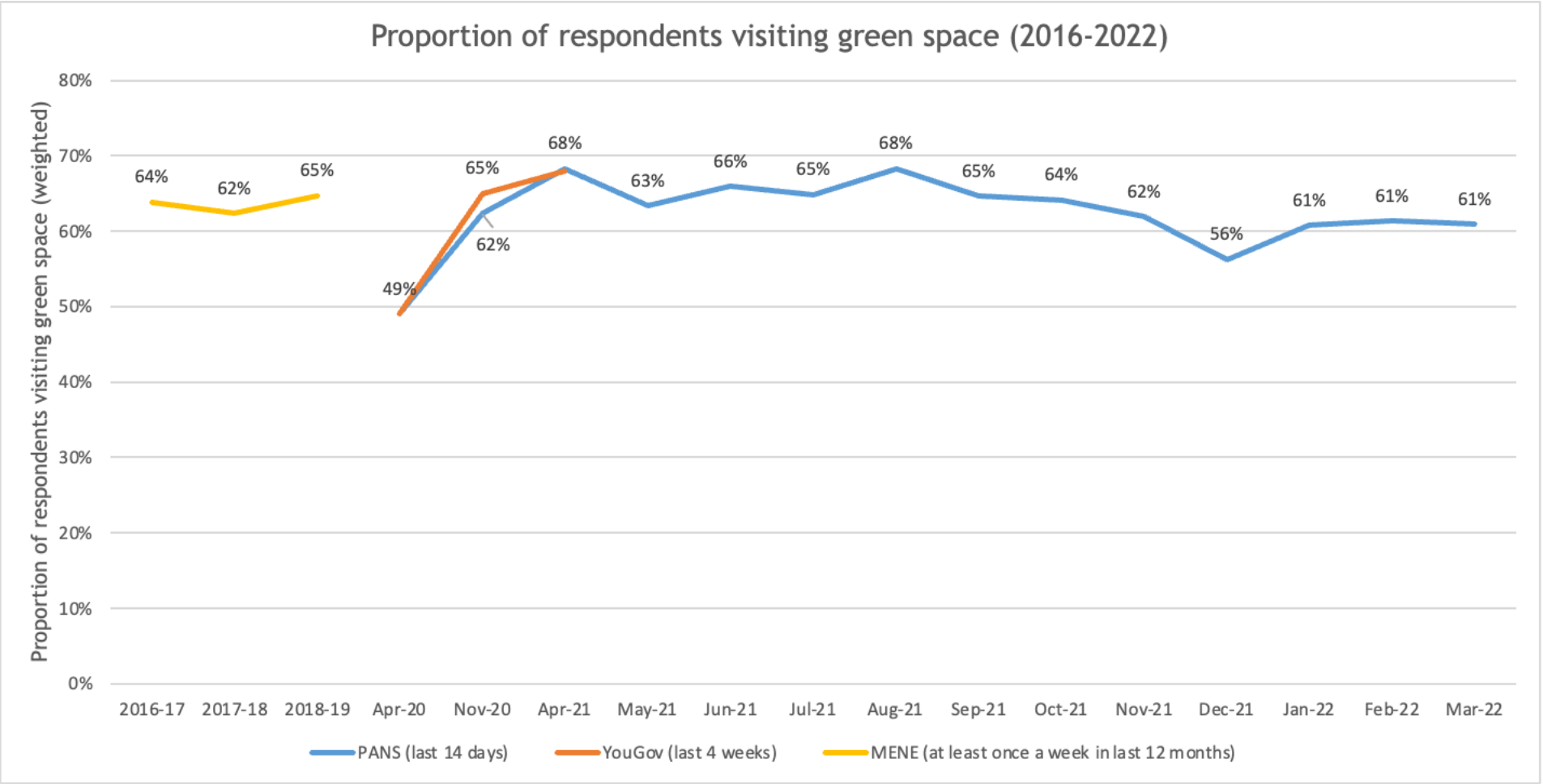


Figure 5-6: Change in the proportion of PANS respondents visiting green space from April 2020-March 2022, to explore whether trends in use of green space were sustained.

5.5.2 Variation in green space visits and barriers by socio-demographic characteristics

Although the proportion of people visiting green spaces increased over time, socio-economic inequality in visits also rose. The environment itself did not alter, but behavioural response to it did. Throughout the study period, higher social grade respondents were more likely to have visited green spaces than the lower social grade respondents. The gap between these groups in terms of the predicted probability of visiting rose by 33% over time. Several other studies have noted socio-economic inequalities in the use of green spaces both pre- and inter-pandemic (Hoffimann, Barros and Ribeiro, 2017; Boyd et al., 2018; Ramblers, 2020; Holland, 2021; Spotswood et al., 2021)(Hoffimann, Barros and Ribeiro, 2017; Boyd et al., 2018; Ramblers, 2020; Holland, 2021; Spotswood et al., 2021). One likely contributor is inequality in access - a classic issue of environmental injustice. For example, a study found that British people with an annual household income lower than £15,000 were less likely to live within a 5-minute walk of green spaces, to live somewhere where the streets are green, and to report good walking routes where they live, compared to households with an annual income of £35,000 or £70,000 (Ramblers, 2020). However, another contributor could be the risk of infection when visiting green spaces. A UK study found that the boroughs in London with a higher risk of infection shared common characteristics. These included the low accessibility of green spaces, high covid case concentration, and high vulnerability to virus transmission (calculated using the Indices of Multiple Deprivation) (Pan, Bardhan and Jin, 2021). Lower social grade respondents may have felt at more risk of contracting coronavirus when visiting neighbourhood green spaces compared to higher social grade respondents.

Overall, the reduction in reporting of green space barriers relating to health and contracting Covid-19 may have been due to both increased understanding of the risk of contracting Covid-19 outdoors and progress with vaccinations from December 2020 in the UK (Jones *et al.*, 2020; NHS England, 2020; The Institute for Government., 2021). In late 2020 and early 2021, for example, studies identified a very low likelihood of Covid-19 transmission outdoors and these

were widely reported in the UK (Jones *et al.*, 2020; Public Health England (PHE) Transmission Group, 2020; BBC News, 2021). However, both this new knowledge and the beginnings of the UK's vaccination programme would have likely only impacted the barriers reported in wave 3 and these were similar to those reported in wave 2. Further evidence that the public understood Covid-19 risks quite well comes from between-group differences in reporting barriers. The oldest group (65+) were most likely to report fearing for their health when outdoors and avoiding green spaces because they or a member of their household were at high risk of being severely affected by Covid-19. Given that those aged 80 years or older were seventy times more likely to die following a positive Covid-19 test compared with those under 40, it seems reasonable that older respondents reported these barriers to a greater extent (Public Health England, 2020a).

Although this analysis focused on barriers plausibly related to Covid-19, the inclusion of 'lack of interest' as a barrier revealed important trends. Across the whole year of study, respondents aged 18–24 years old were more likely than other age groups to report a lack of interest as a barrier to visiting green spaces. This echoes other research, including studies in England before and during the pandemic, which found that younger age groups (16–34 and 16–24 years) were more likely to report a lack of interest than older age groups (Boyd *et al.*, 2018; Natural England and Kantar Public, 2021). However, in the interaction results, there was a sharp reduction during the year in the reporting of a lack of interest as a barrier among young people, and one somewhat in contrast to the older age groups. An apparent increase in interest among young adults could be connected to the relaxing of restrictions from the end of March 2021. The change in restrictions meant outdoor spaces provided the only location for socialising with non-household members (The Institute for Government, 2021). Perhaps this led to younger groups becoming oriented to green spaces as a place to meet and socialise with others (Ramblers, 2021).

5.6 Summary

The findings in this chapter provide novel findings on how the UK population's visits to green spaces, and the barriers to visiting, changed over the first year of the pandemic. Inequalities in green space use by social grade were sustained and

widened over the year from April 2020-2021, which emphasises the exacerbation of environmental injustices during this time. This also highlights the need for further research and action to ensure that good quality green spaces are equally accessible for all demographic groups and communities.

The reporting of Covid-related barriers, such as fear for health and worrying about social distancing, fell over the year in parallel with greater knowledge of the virus, how it spreads, and perceptions of risk. The pandemic seems to have made changes to the perceptions of green spaces. For example, levels of disinterest in visiting green spaces changing for 18–24-year-olds over the year. This finding may emphasise the importance of green spaces as places of socialisation, particularly for younger age groups.

The findings from the data analysis suggest that, despite the positive impact that green spaces can provide for health and well-being, there are still barriers remaining that restrict some of the population from using them and benefitting from them. The findings also indicate that the barriers in place are not experienced equally across socio-demographic groups, particularly by age. The pandemic, and particularly the lockdowns/restrictions, have had both positive and negative impacts on green space use; it will be important for future research to determine whether these have become permanent changes.

Chapter 6 Conclusions

This thesis was the first to explore differences in the reporting of barriers to green space use by health condition in the UK population, making a significant contribution to understanding in the research field. The findings highlight key barriers to green space use that can inform community level interventions, green prescription projects, and wider policy to ensure that the well-being benefits of green spaces are accessible for all.

The thesis included three interlinked stages which address six research questions, focusing on general barriers to green space use, physical health-related barriers to green space use, and the impact of the Covid-19 pandemic on green space use and barriers. The results that explore the impact of the pandemic have also been published in two original research articles (Burnett *et al.*, 2021; Burnett, Olsen and Mitchell, 2022).

The results highlighted key differences in both general and physical health-related barriers to green space use, depending on an individual's health condition and socio-demographic characteristics. For example, those with physical disabilities and progressive illnesses reported each physical health-related barrier (mobility/health, lack of disabled facilities, unsuitable/poorly maintained sites, and having no-one to go with/help them) as important in stopping them from visiting green spaces in the last 14 days. Additionally, regarding general barriers to green space use, respondents with physical disabilities and progressive illnesses had the highest odds of reporting poor physical health and lack of facilities/access points for those with disabilities as barriers to green space use, but only respondents with progressive illnesses had higher odds of reporting fear/worry about getting hurt/injured. These findings emphasise the importance of health-related barriers to green space use for respondents with physical disabilities and progressive illnesses.

A key finding was the higher likelihood of reporting poor mental health as a barrier to green space use for 16–24-year-old respondents (compared to those aged 25-39). With females, young people, more socially disadvantaged groups, and those with pre-existing mental health problems being found to have worse

mental health outcomes during the pandemic, this highlights the need for interventions that improve mental health and well-being (O'Connor *et al.*, 2020)

Existing barriers to green space visits were exacerbated by the Covid-19 pandemic, with new barriers also being created, such as worrying about social distancing in green space. When compared to more recent survey data, it was found that the increased prevalence of green space use was sustained from April 2021, but with a decrease when the Omicron variant spread in December 2021.

6.1 Answering the research questions

With the discussion section in each Chapter outlining the interpretation of the results and how these relate to existing literature and research, this section will outline the key findings for each research question.

6.1.1 Research question 1: How does the type of chronic health condition reported differ by socio-demographic characteristics?

The results of the regression models (Chapter 3) exploring associations between health conditions and socio-demographic characteristics showed that reporting of type of chronic health condition did differ depending on the respondents' sex, age, income, and ethnicity. These differences were expected and corroborated with the existing research on health inequalities by socio-demographic characteristics. For example, a London study (N=1,698) exploring socio-demographics and health inequalities found that socioeconomically disadvantaged individuals had poorer health than those more socioeconomically advantaged, and that physical health worsened as age increased (Hatch *et al.*, 2011). They also found ethnic differences in health, with those in the Black African group having reduced odds of having a chronic mental health condition compared to those in the White British group.

The differences by sex and ethnicity regarding reporting of mental health conditions were highlighted, with female respondents having higher odds and BAME respondents having lower odds of reporting mental health conditions than male and white respondents. These findings were corroborated in existing research and the reasons behind these associations explained further. For

example, an increased prevalence and severity of anxiety and stress-related disorders in women compared to men has been well documented in existing research (Li and Graham, 2017). Regarding the ethnic differences in health, racial minorities have been found to report more stigma than racial majorities for common mental health conditions across the world (Eylem *et al.*, 2020).

Differences by age group were generally expected, with respondents aged 55-64 or 65+ having higher odds of reporting arthritis, respiratory conditions, diabetes, heart/blood pressure/circulatory conditions, physical disabilities, and progressive illnesses than those aged 25-39. The only health condition that the older age groups had lower odds of reporting was mental health. This is reflected in existing research, with chronic health conditions being more prevalent in older people, with 58% of those aged 60+ having a chronic condition and 25% of them having two or more of these, compared to 14% of those under 40 having a chronic health condition (Department of Health, 2012). These findings are corroborated further, with young adults aged 18-25 being found to have the highest prevalence of any mental illness (31%), compared to adults aged 26-49 (25%) and 50+ (15%) (National Institute of Mental Health, 2020).

The differences found in reporting of chronic health conditions by socio-demographic characteristics emphasises the importance of including sex, age, income, and ethnicity when exploring differences in green space use and barriers in the general population and by health condition. This also suggests that these variables should be included as key confounders in further statistical models and for health condition-specific interventions.

6.1.2 Research question 2: How does the reporting of general barriers to green space use differ by type of chronic health condition and socio-demographic variables (sex, age, income, and ethnicity)?

The reporting of general barriers to green space use were found to differ by type of chronic health condition and socio-demographic characteristics. Focusing on the socio-demographic groups, the results for 16-24-year-olds were particularly interesting to unpack further; the finding that respondents aged 16-24 years had higher odds of reporting poor mental health as a barrier to green space use reflects the youth mental health crisis that the UK is currently facing,

exacerbated by the Covid-19 pandemic (Ford, John and Gunnell, 2021; Newlove-Delgado *et al.*, 2021).

Individuals with physical disabilities, females, and BAME respondents had higher odds of reporting neighbourhood barriers, such as not having nice enough green space near them. These findings were corroborated by existing research and highlight the importance of the quality of local green space in influencing use of these spaces, particularly for these population groups. For example, female participants and those with physical disabilities have been found to value aesthetic characteristics and feelings of personal safety in green space (Ode Sang *et al.*, 2016; Corazon *et al.*, 2019; Braçe, Garrido-Cumbrera and Correa-Fernández, 2021).

These findings emphasise that different factors seem to be important for different population groups in terms of acting as a barrier to green space use, with variation, for example, by age, ethnicity, and health condition. Therefore, specific barriers need to be overcome to support individuals with specific health conditions and within certain population groups. Mitigating barriers to green space use that are experienced more significantly by a particular population group might also have ripple-out effects. For example, increasing quality of local green space by improving the facilities (e.g., accessible and good quality toilet facilities, seating areas, catering facilities) and better maintenance of the green space might mitigate the barrier 'nowhere near me is nice enough to spend free time in' for BAME and female respondents, but would also improve the green space for all.

6.1.3 Research question 3: How does the reporting of physical health-related barriers to using green space differ by type of chronic health condition and socio-demographic characteristics?

Overall, despite the positive impact that green space can provide for health and well-being, there are barriers that restrict many individuals from using green spaces and the subsequent benefitting of that use. The physical health-related barrier results suggest that both mobility-based (e.g., fatigue) and place-based (e.g., poorly maintained sites) barriers are important, particularly for respondents with physical disabilities, progressive illnesses, and heart/blood

pressure/circulatory conditions. These findings emphasise that a 'one size fits all' approach to increasing green space use is unlikely to be effective due to the variation in reasons for non-use by population and socio-demographic groups.

Respondents with physical disabilities and progressive illnesses reported an increased likelihood of reporting all of the physical health-related barriers as important, whilst respondents with respiratory conditions only had higher likelihood of reporting mobility/health barriers as important. Meanwhile, there were no significant associations for respondents with arthritis. This suggests that those with physical disabilities and progressive illnesses would benefit most from reducing physical-health related barriers, such as unsuitable/poorly maintained sites and a lack of support ('no-one to go with/help me'). The suitability of a green space site is defined in existing literature for these health conditions by availability of accessible toilets, rest areas, suitable pathways, and clear signage barriers (Mitchell and Burton, 2010; Petursdottir, Arnadottir and Halldorsdottir, 2010; Mapes and Vale, 2012; Saadati Qamsari, Noorizadeh Dehkordi and Dadgoo, 2018; Corazon *et al.*, 2019). By improving the suitability of the green space using this evidence, this would improve the quality of the green space for all users. The results show that for those reporting physical health-related barriers, to increase their green space use would require individual-level mobility/health support and infrastructure improvement that provide disabled facilities.

6.1.4 Research questions 4, 5, and 6: How did green space visits and barriers change over time and by sex, age, and socio-economic position during the Covid-19 pandemic?

From April 2020 to April 2021, there was an increase in the proportion of respondents visiting green spaces, with this increase being sustained after April 2021 (the final data collection period conducted for this thesis) (Natural England, 2022b). However, when data were combined for the three COVID-19 survey waves collected for this thesis' work, respondents aged 65+ and in the lower social grade group were less likely to have visited green spaces in the last 4 weeks than those aged 25-64 or in the higher social grade group. This highlights that inequalities in use of green space were present in the year following the initial UK Covid-19 pandemic lockdown in March 2020 (April 2020-April 2021). When focusing on the interaction effects, the findings also highlight

that existing inequalities in green space use by social grade were exacerbated over the first year of the Covid-19 pandemic. In April 2020, the month after the initial Covid-19 lockdown, new barriers to green space use were created and existing barriers exacerbated. The new, and unique to pandemic, barriers included being worried about social distancing, fearing for health, and higher perceived risk of a household member/themselves being severely affected by Covid-19. However, reporting of these barriers fell in November 2020 and April 2021, perhaps due to the increase in vaccinations, greater knowledge on how the Covid-19 virus itself was spread and advice that meeting with others outside was associated with a low likelihood of Covid-19 transmission (McCormack *et al.*, 2022).

The pandemic seems to have made changes to the perceptions of green spaces, particularly for young adults. For example, levels of disinterest in visiting green space changed for 18–24-year-olds over the year, with younger adults becoming more interested in using green spaces by April 2021. This may have been connected to the change in restrictions at this time, which meant that outdoor spaces were the only location for socialising with people not in the same household (The Institute for Government, 2021). This likely led to younger groups using green spaces as a place to meet and socialise (Ramblers, 2021). This finding emphasises the importance of green spaces for socialisation and connection, particularly for younger age groups during a time of unprecedented change.

6.2 Theoretical frameworks and wider mechanisms

Referring back to Chapter 1 (Section 1.5), none of the theoretical frameworks outlined fully encapsulated the aims of this thesis. According to existing research focusing on the pathways linking green space and health, there remains a gap in current green space literature in exploring multiple pathways between green space and health by developing new composite measures of green space to further explore how greenspace may influence a wide range of health outcomes in different settings and populations through multiple pathways (Markevych *et al.*, 2017). This thesis furthers understanding of multiple pathways between green space and health, by focusing on the influence of health on green space use, rather than the most common focus of existing literature on the influence

of green space use and access on health and wellbeing outcomes. The use of Structural Equation Modelling in particular allowed the exploration of these multiple pathways to be undertaken.

Markevych et al. (2017) discuss the domains of pathways linking green space to positive health outcomes, including: reducing harm (mitigation), restoring capacities (restoration), and building capacities (instoration). These domains were explored in a different way in this thesis, focusing on harm reduction, restoration, and capacity building in the form of barriers. For example, the exploration of fear of harm when using green space and the finding individuals with progressive illnesses having higher likelihood of reporting fear of getting hurt/injured when using green space as a barrier. This change in focus on the pathways between green space and health allowed exploration of how different types of chronic health conditions have differing affects related to mechanisms of green space benefits, barriers, and facilitators.

6.3 Thesis strengths

This thesis contributes novel and original findings by answering the six research questions, with a focus on barriers to green space use and how these differ by health condition which, to my knowledge, had not been explored to this extent in a UK context. The thesis provides an important extension of the commonly used term ‘poor health’ being used solely as a response to questions asking about barriers to green space use. By focusing on this specific barrier, I was able to distinguish between multiple types of health conditions, which contributes new data and findings to the research field seeking to understand why people do or do not use green spaces. Additionally, the ability to compare data on general barriers, physical health-related barriers, and Covid-specific barriers allowed each research question to be answered and barriers to green space use to be explored extensively.

Using Structural Equation Modelling (SEM) to explore the physical health-related barriers added depth to the analysis, and exploration of if and how the physical health-related barriers could be categorised. It also furthered understanding regarding the general barriers, with the findings that these barriers should not be categorised further. The visualisations created using SEM added value to the

analysis, presenting the results in an alternative way to standard regression models.

The combination of the People and Nature Survey (N=10,415) and YouGov survey (N=6,713) created a substantial sample size, with nationally representative samples of both England and the UK. With all of the data collected during the Covid-19 pandemic, a key strength of the thesis was the speed at which data collection took place. Focusing on the YouGov survey, the survey had to be created, reviewed, and administered within a short timeframe to ensure that data were collected during the start of the restriction on movement in the UK. The ability to repeat the survey across three survey waves allowed for patterns in green space use to be explored over the first year of the pandemic. This survey, data analysis, and interpretations created novel findings and a baseline to which the influence of the Covid-19 pandemic can be explored and compared to post-pandemic, or post-restriction, green space use. The rapid data collection, with the first wave of the YouGov survey being conducted just over a month after the movement restrictions were introduced in the UK, also supported national policy, providing new and timely insight into the importance of green space during a turbulent time.

6.4 Thesis limitations

A key limitation of cross-sectional data is the lack of causality that can be determined, with only associations being explored. The data collected from the PANS and YouGov surveys were collected during the Covid-19 pandemic, between 2020 and 2021. This means that the results may not be generalisable outside of the pandemic context. Additionally, PANS is only collected from the English population, and is therefore representative of the English population rather than the UK population. The results may not be generalisable to populations outside of the UK, with the Covid-19 restrictions differing across the world which may have impacted green space use differently in each country. The data may also be limited by the aspect of seasonality impacting upon visits to green space, with the PANS data being collected during the winter (November 2020-March 2021) which may have lead to high levels of infrequent and non-use of green space. The results of the YouGov survey waves may also have been

affected by seasonality, with wave 2 of the survey being collected in November 2020.

A limitation of the surveys, particularly the health conditions question, was that respondents were able to choose more than one health condition. The wording of the health condition question allowed for exploration of multimorbidity, however, to answer the research questions, it was important to explore the health conditions separately. It is essential that we focus on multimorbidity in future green space research to explore how this influences the use of green space and reporting of barriers. This is increasingly important, with multimorbidity becoming a growing concern within ageing populations, reducing quality of life, and putting a strain on health systems (Pearson-Stuttard, Ezzati and Gregg, 2019).

The health conditions were self-reported by survey respondents rather than gathered from administrative data, which creates further limitations. For example, a study comparing self-reported and biomedical data on hypertension and diabetes found that self-reported health led to an underestimation of the prevalence of hypertension and diabetes (Ning, Zhang and Yang, 2016). More depth could also be created within the health conditions question and responses. For example, including types of mental health conditions (such as anxiety, depression, post-traumatic stress disorder) and respiratory conditions (such as asthma, chronic obstructive pulmonary disease).

In PANS, the general barriers question was only asked of those who had not used green space in the last 14 days. This restricts data and excludes 'infrequent users' who may have used green space once in the last 14 days. In wave 1 of the YouGov survey, those who had not visited green space since the lockdown restrictions were implemented (in the last 4 weeks) were asked the barriers question. However, in waves 2 and 3, infrequent users (those who had visited once every 2 weeks or once in the last 4 weeks) were also asked the barriers question, which creates inconsistencies across the samples.

Further limitations arose regarding the barriers to green space use, with vague terms used to identify the barriers. Collecting the data using surveys allowed me to find out which barriers the respondents reported, but not why these factors

are regarded as barriers. There is a lack of depth into the reasons why people experience these particular barriers to green space, and further research, particularly qualitative research, is required to explore this gap. This also means that there is no clear sense of what would resolve or alleviate the reported barriers.

There were also limitations in data collection, particularly the sample size of respondents by ethnicity in PANS. The ethnic group 'BAME' had to be included due to the small number of respondents in the mixed, Black or Black British, Asian or Asian British, and any other ethnic group/background categories. A limitation of using only two categories for ethnicity, and BAME in particular, was that in-depth information on differences in green space use and barriers to use by ethnicity were lost during the analysis. In future, differences should be compared across all ethnic groups, which would only be possible with increased targeted sampling.

6.5 Implications for policy and practice

The results for the barriers to green space use by health condition highlighted differences in general and physical health-related barriers by type of health condition, as well as by socio-demographic variables. Existing literature has stated that organisations challenged with both protecting and enabling people to connect with nature and enjoy it – such as conservation charities, urban planners, or landscape architects - need to understand how best to accommodate diverse sensory, physical, and psychological needs within their site management, visitor communications, and community engagement (Bell *et al.*, 2018). The findings highlighted in this thesis provide further understanding as to what needs to change to ensure that those with specific health (and/or social) needs can use green spaces and benefit from them. Understanding the barriers to green space can also lead to greater understanding of the facilitators to green space use.

6.5.1 Mitigating the key barriers to green space use and utilising the research findings in the co-design of green space

The findings present neighbourhood barriers, such as not have good quality local green space, as key barriers for a range of population groups (i.e., females,

BAME individuals, and those with physical disabilities). Public Health England (2020) suggested that local authorities play a vital role in providing good quality green space that is both inclusive and equitable (Public Health England, 2020b). This would require investment in staffing the green space to ensure the quality is maintained (Buck and Gregory, 2013). It is important, however, to ensure that these changes are co-designed with the target groups. For example, the UK charity 'Make Space for Girls' works with teenage girls to find out what they want from their local green spaces (Walker and Clark, 2023). Their findings emphasise that teenage girls want social seating, swings, outdoor gyms, walking loops, more and smaller social areas, and better public toilet facilities. This exercise of co-designing spaces with groups that are less likely to use green spaces should be broadened, with the findings from this thesis being used to start the conversation as to why these barriers are experienced and how they can be mitigated. An example would be if a green space project was being targeted at, and co-designed with, an older age group. The results show that bad weather, poor physical health, and the spread of Covid-19 were key barriers for the 65+ age group. These three barriers could be discussed further with this group and incorporated into the design, for example, with more sheltered areas for when it is cold and raining, as well as resting places and accessible facilities (such as benches, toilets, café) for those with poor health/mobility.

The findings could be applied to designs for new parks, community allotments, and other green spaces to encourage those with specific health conditions or socio-demographics groups (e.g., young adults, low-income groups) to use green space more frequently and ensure accessibility. For example, if a park was running an event aimed at women, they could arrange the event to run outside of normal working hours and at multiple time points in the week for those doing shift work to ensure inclusivity, as being too busy at work was reported as a key barrier for the female respondents in PANS.

6.5.2 Targeting green social prescriptions

The findings could be utilised in the targeting of green social prescriptions. For example, if a green prescribing project was focusing on individuals with a particular health condition, such as mental health or diabetes, the findings would help tailor the project to ensure that key barriers were mitigated and to

increase the likelihood of an individual with that health condition attending the specific prescription project. For example, if a green prescribing project was targeting their intervention at those with physical disabilities (e.g., wheelchair users), the results from this thesis emphasise the importance of physical access and high quality, well-maintained facilities for those with physical disabilities. Therefore, the project team must ensure that there are access points within the green space and other key facilities available for those with disabilities to encourage participation, such as ramps and accessible toilets.

6.5.3 Informing community level interventions

The thesis findings could be used to inform other community level interventions. In the Liverpool City Region (UK) alone there are many small-scale organisations that target particular populations groups with the purpose of improving health and well-being. For example, the Bridge Community Centre is run by volunteers with the aim to engage with elderly people and those facing mental health problems, social isolation, and disability (NHS Liverpool CCG, 2020). They do this by encouraging development of new skills, building confidence, and promoting independence. One service they provide is use of an allotment space, with individuals growing their own vegetables and taking part in gardening workshops. The findings from this thesis relating to barriers to green space use for older age respondents and those with mental health conditions and physical disabilities could be utilised in a community led project such as the Bridge Community Centre, helping to encourage attendance by those experiencing barriers such as poor physical health and fear of spreading coronavirus, as found for the 65+ age group.

6.5.4 Focus on individual differences in future research, policy, and practice

The analysis of the general barriers to green space use highlighted the difficulties faced when trying to group the barriers to green space use into themes, particularly the general barriers. One of the key findings of the thesis is that types of health condition and socio-demographic groups require targeted focus to better understand individual differences in green space use, perceptions, and barriers, and to ensure that green spaces are accessible for all.

For example, individual differences were highlighted in the results for reporting of general barriers to green space use. Individuals with arthritis were more likely to report poor physical health and lack of facilities/access point for those with disabilities as barriers, whilst those with heart/blood pressure/circulatory conditions were more likely to report cost and being too busy at work or with family commitments as barriers. This process emphasises the importance of exploring individual differences, both in terms of health and socio-demographics and experiencing barriers to green space use.

6.6 Recommendation for future research

The results of this thesis create further questions that could be answered in future research, as detailed below.

6.6.1 Have inequalities in green space use and barriers that were exacerbated during the Covid-19 pandemic been sustained?

Future research is required to explore whether the inequalities in green space use and barriers to use that were created or exacerbated by the Covid-19 pandemic have been sustained. For example, analysing data on green space use and barriers to use from before, during, and after the height of the pandemic. The data collected in PANS could be used to answer this question, with the results being important in improving understanding of how the pandemic influenced the population's use of green space in the long-term.

6.6.2 Does removing barriers to green space use change actual use of these spaces?

The results of this thesis show that barriers to green space use differ by health condition and socio-demographic characteristics. This research can be used to inform policy and practice aiming to reduce barriers to green space use and increase use and access for specific population groups. However, there has been little research on what happens next, with further evidence required to understand whether reducing and removing barriers to green space use would change actual use of green space across the population and for the target groups. This could include a focus on the population in general, as well as those

with chronic health conditions. Green prescribing projects could be evaluated when answering this research question.

6.6.3 Exploring differences in green space use and barriers to use further by type of health condition

With barriers to green space use being found to differ significantly between health conditions, greater depth in terms of the types of health conditions and exact reasons for reporting the barrier could be explored in future research. For example, different mental health conditions could be categorised into anxiety, depression, post-traumatic stress disorder and others, and different specific respiratory conditions could be analysed, such as asthma and COPD. This would allow the results to go a step further, from poor health to type of chronic health conditions, and then deeper into more specific types of health conditions. One of the key limitations of the survey data used throughout this thesis is that self-reported health data were used to explore how the barriers to green space use differ by health condition. Exploring these differences by *diagnosed* health conditions in barriers to green space use would be filling another key research gap. This could be explored through administrative health data, such as those collected by the National Health Service (NHS) from General Practitioners (GPs) and hospitals. This would mitigate the limitations connected to self-reported health, such as under-reporting of health conditions, and allow more certainty regarding the accuracy of the health data.

6.6.4 Green space use and barriers for young adults: how is the current mental health crisis influencing green space use?

From the literature review, the majority of studies exploring barriers to green space use and differences by health conditions have focused on older age groups (Hybels *et al.*, 2010; Rantakokko *et al.*, 2012, 2017; Clarke, 2014). Additional research is required that focuses on young adults' green space use and barriers to use. This is particularly important, with the results highlighting that the respondents aged 16-24 years were significantly more likely than adults aged 25+ to report poor mental health as a barrier, but there were no significant differences in reporting mental health conditions. It would be interesting for future research to investigate the current mental health crisis and explore how

this is influencing green space use in young adults, as well as how green space can help to mitigate poor mental health in this group.

6.7 Final reflections on undertaking a PhD during the Covid-19 pandemic

When starting the PhD in September 2019, the original research aim was to understand infrequent and non-use of green space. Through an initial scoping exercise of the existing data and literature, one potential method of data collection was to conduct in-situ audits of individuals to ask if they did or did not frequently use local parks and the reasons why. The aim was to understand the views of non-users, who have been shown to be in lower socio-economic status groups, harder to reach, and could not be accessed through park user surveys, as they do not use parks (Boyd *et al.*, 2018). However, in early 2020, with the start of the COVID-19 pandemic, I had to make a sharp change in research direction. It was surprising to see that parks and other green spaces remained open despite the lockdown restrictions and became a key location for the UK population to use when able to leave their home (Johnson, 2020; Office for National Statistics, 2021b).

The original research plan became unfeasible. Therefore, I decided to explore the use of secondary datasets for collecting information, as discussed in Chapter 3, which then led to a collaboration with Natural England and the addition of the health conditions question to the People and Nature Survey. This also led to the creation of my YouGov surveys, which were then utilised by Public Health Scotland and contributed to multiple publications. The Covid-19 pandemic created challenges throughout the PhD process, but also the opportunity to explore a completely new research area.

6.8 Concluding thoughts

Extensive research has been published on how access, proximity to, and actual use of green space benefits health and well-being. There is also some literature focusing on wider barriers to green space use. However, less is known on how use of green space and barriers to use differ by socio-demographic characteristics and by type of chronic health condition. This thesis has covered a

key research gap in improving understanding of the barriers to green space use for those with chronic health conditions, and how the barriers differ by health and other personal characteristics. This research is especially important for ensuring that green spaces are accessible (and usable) for all, with the health benefits gained from using green space being felt by those most in need of improved health and well-being.

Chapter 7 Appendices

Appendix A: Literature search keywords for Web of Science.

Web of Science Core Collection		
#	**Searches**	**Results**
1	TI= (wilderness OR garden? OR forest? OR tree? or park OR parks OR "greenspace?" OR “green space?*” OR greenery OR greenness OR "wildspace?" OR "public parks" or " municipal parks" OR "botanic parks" OR woodland OR forestry OR "green belt" OR "natural environment" OR "green-blue space?" OR neighbourhood* OR neighborhood*)	142,075
2	TI=(“health barrier*”)	34
3	TI=(“health status”)	10,759
4	TI=(“mobility limitation*”)	318
5	TI=(“mobility issue*”)	12
6	TI=(“barrier*” near/3 (“green space*” OR “greenspace*” OR outdoor* OR “natural environment”))	29
7	TI=(“facilitat*” near/3 (“green space*” OR “greenspace*” OR outdoor* OR “natural environment”))	9
8	#2 OR #3 OR #4 OR #5 or #6 or #7	11,158
9	#8 AND #1	83
10	TS= (wilderness OR garden? OR forest? OR tree? or park OR parks OR "greenspace?" OR “green space?*” OR greenery OR greenness OR "wildspace?" OR "public parks" or " municipal parks" OR "botanic parks" OR woodland OR forestry OR "green belt" OR "natural environment" OR "green-blue space?" OR neighbourhood* OR neighborhood*)	538,459
11	TS=(“health barrier*”)	146
12	TS =(“health status”)	64,535
13	TS=(“mobility limitation*”)	1,534
14	TS=(“mobility issue*”)	219
15	TS=(“barrier*” near/3 (“green space*” OR “greenspace*” OR outdoor* OR “natural environment”))	96
16	TS=(“facilitat*” near/3 (“green space*” OR “greenspace*” OR outdoor* OR “natural environment”))	114
17	#11 or #12 or #13 or #14 or #15 or #16	66,539
18	#17 and #10	1377
19	#10 or #1	538,459
20	#19 and #8 (TI)	184
21	#19 and #17 (TS)	1377
22	#16 or #15 or #5 or #4 or #3 or #2	11,325
23	#22 and #19	268
24	(#22 AND #19) AND Language: (English)	260
25	Re-ran #24 on 15-09-2022, with data refined to 13-03-2020 to 15-09-2022	132

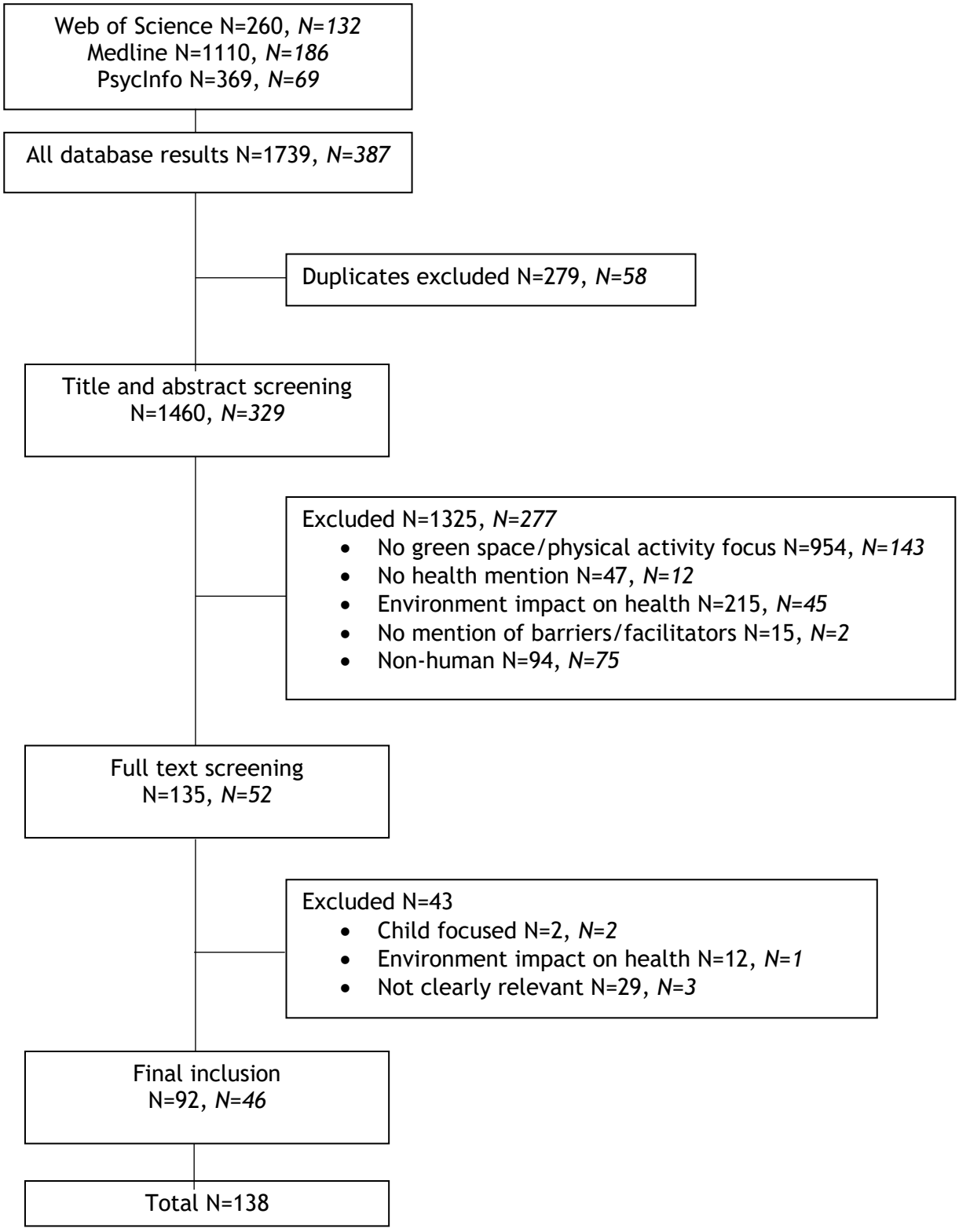
Appendix B: Literature search keywords for Ovid Medline.

Ovid Medline ® 1946+		
#	**Searches**	**Results**
1	Wilderness/	297
2	gardens/	251
3	forests/	8253
4	Parks, Recreational/	1028
5	urban health/	17686
6	trees/	25525
7	environment design/	6219
8	1 or 2 or 3 or 4 or 5 or 6 or 7	56291
9	"green space* ".ab,ti.	830
10	"greenspace*".ab,ti.	138
11	greenery.ab,ti.	123
12	greenness.ab,ti.	534
13	wilderness.ab,ti.	890
14	"wild space*".ab,ti.	1
15	(park or parks).ab,ti.	15535
16	(park land or public park or public parks or municipal park or botanic park or botanic parks or municipal park*).ab,ti.	330
17	"garden*".ab,ti.	9547
18	"woodland*".ab,ti.	2466
19	wooded.ab,ti.	462
20	((nature or green) adj2 (space or area)).ab,ti.	896
21	forestry.ab,ti.	2660
22	“green belt”.ab,ti.	38
23	"green trail*".ab,ti.	0
24	(natural adj2 environment).ab,ti.	6368
25	(neighbourhood* or neighborhood*).ab,ti.	24,205
26	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25	61,955
27	“health barrier*”.ab,ti.	115
28	(health adj2 barrier*).ab,ti.	2192
29	"mobility issue*".ab,ti.	80
30	“health status”.ab,ti.	49,018
31	Mobility Limitation/	4462
32	"mobility limitation*".ab,ti.	769
33	(("green space*" or "greenspace*" or "natural environment" or "outdoor*") adj3 barrier*).ab,ti.	37
34	(("green space*" or "greenspace*" or "natural environment" or "outdoor*") adj3 facilitat*).ab,ti.	35
35	27 or 28 or 29 or 30 or 31 or 32 or 33 or 34	55,872
36	8 or 26	111,987
37	35 and 36	1266
38	exp animals/ not humans.sh.	4,676,556
39	37 not 38	1224
40	Limit 39 to English language	1110
41	Limit 40 to year 2020-2022	186

Appendix C: Literature search keywords for PsycInfo.

PsycInfo (EBSCO Host)		
#	**Searches**	**Results**
1	TI (wilderness/) OR AB (wilderness)	834
2	TI(Parks (Recreational)) OR AB(Parks (Recreational))	62
3	TI(Trees/) OR AB(Trees)	9,962
4	TI(Environment Design/) OR AB (Environment Design)	3,070
5	TI(neighbourhood* or neighbourhood*) OR AB(neighbourhood* or neighborhood*)	20,916
6	TI("green space*") OR AB("green space*")	293
7	TI(greenery) OR AB(greenery)	75
8	TI(greenness) OR AB(greenness)	79
9	TI("wild space*") OR AB(“wild space*)	6
10	TI(park or parks) OR AB(park or parks)	5,810
11	TI(park land or public park or public parks or municipal park or botanic park or botanic parks or municipal park*) OR AB(park land or public park or public parks or municipal park or botanic park or botanic parks or municipal park*)	320
12	TI("garden*") OR AB("garden*")	2,715
13	TI(forest) OR AB(forest)	4,619
14	TI(woodland) OR AB(woodland)	242
15	TI(“natural environment”) OR AB(“natural environment")	2,812
16	TI(forestry) OR AB(forestry)	325
17	TI(“green belt”) OR AB(“green belt”)	5
18	TI("green trail*") OR AB(“green trail*”)	15
19	TI("greenspace*") OR AB(“greenspace*”)	50
20	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19	48,939
21	TI(“mobility issue*”) OR AB(“mobility issue*”)	58
22	TI(“health status”) OR AB(“health status”)	17,468
23	TI(“health barrier*”) OR AB(“health barrier*”)	81
24	TI(“mobility limitation*”) OR AB(“mobility limitation*”)	283
25	21 or 22 or 23 or 24	17,868
26	(“barrier*” N3 (“green space*” OR “greenspace*” OR outdoor* OR “natural environment”))	40
27	(facilitat* N3 ("green space*" or "greenspace*" or "natural environment" or "outdoor*"))	48
28	25 or 26 or 27	17,952
29	20 and 28	369
30	20 and 28: English language	369
31	Rerun 30 with publication year 2020-2022	69

Appendix D: PRISMA flow diagram for the literature review ('N=': number of papers from initial literature search in March 2020, '*N*=': number of papers from follow-up literature search in September 2022).



Appendix E: Groupings of health condition responses.

PANS/YouGov	Scottish Household Survey 2019	Scottish Health Survey 2019
Arthritis or joint-related conditions	Arthritis Problems or disabilities related to back or neck	Arthritis/rheumatism/fibrositis Back problems/slipped disc/spine/neck Other problems of bones/joints/muscles
Respiratory or breathing problems e.g., asthma	Chest or breathing problems (asthma/ bronchitis)	Bronchitis/emphysema Asthma Other respiratory complaints
Diabetes	Diabetes	Diabetes Other endocrine/metabolic
Heart, blood pressure or circulation problems	Heart, blood pressure or circulation problems	Heart attack/angina Hypertension/high blood pressure/blood pressure Stroke/cerebral haemorrhage/cerebral thrombosis Other heart problems
Mental health conditions	Mental health problems	Mental illness/anxiety/depression/nerves
Another physical disability (i.e., that limits your mobility)	Difficulty seeing (even when wearing spectacles/ contact lenses) Difficulty hearing Problems or disabilities related to arms or hands Problems or disabilities related to legs or feet	Varicose veins/phlebitis in lower extremities Other blood vessels/embolic Poor hearing/deafness Meniere's disease/ear complaints causing balance problems
Severe skin condition or allergy	Severe disfigurement, skin condition or allergies	Hay fever Skin complaints

Another progressive disability, illness, or health problem (i.e., that can get worse over time)	Some other progressive disability or illness	Cancer (neoplasm) including lumps, masses, tumours, and growths and benign (non-malignant) lumps and cysts Cataract/poor eyesight/blindness Other eye complaints
Other (specify)	A speech impairment Dyslexia Epilepsy Learning or behavioural problems (e.g., autism, Down's Syndrome) Severe stomach, liver, kidney, or digestive problem Difficulty understanding spoken and/or written word Some other health problem or disability	Mental handicap Epilepsy/fits Migraine/headache Other problems of nervous system Tinnitus/noises in the ear Other ear complaints Piles/haemorrhoids incl. Varicose Veins in anus Stomach ulcer/ulcer/abdominal hernia/rupture Other digestive complaints (stomach, liver, pancreas, bile ducts, small intestine - duodenum, jejunum, and ileum) Complaints of bowel/colon (large intestine, caecum, bowel, colon, rectum) Complaints of teeth/mouth/tongue Kidney complaints Urinary tract infection Other bladder problems/incontinence Reproductive system disorders Infectious and parasitic disease Disorders of blood and blood forming organs and immunity disorders Other complaints *Unclassifiable* *Complaint no longer present* *Not answered/Refusal*

Appendix F: Unweighted counts for the People and Nature Survey (PANS) (socio-demographic characteristics, health conditions, barriers to green space use, and frequency of green space use).

		Unweighted N			Unweighted N
Sex	**Female**	5277	**Ethnicity**	"White"	8768
	Male	5122		"Asian or Asian British"	718
Age	**"16-24"**	1346		"Black or Black British"	310
	"25-39"	2564		"Mixed"	206
	"40-54"	2592		"Any other ethnic group or background"	91
	"55-64"	1564	**Chronic health condition**	Yes	2861
	"65+"	2349		No	7550
Income	**"£0-14999"**	1741	**Type of chronic health condition ("yes")**	Arthritis/joint	1016
	"£15000-19999"	1237		Respiratory/breathing	631
	"£20000-29999"	2110		Diabetes	506
	"£30000-39999"	1730		Heart/bp	602
	"£40000-49999"	1208		Mental health	1070
	"£50000-59999"	782		Another physical disability	598
	"£60000-79999"	723		Skin cond/allergy	159
	"£80000-99999"	431		Another progressive	406
	"£100000-£149999"	271			
	"£150000 +"	128			

Physical health-related barriers		**"1 - Not at all important"**	**"2"**	**"3"**	**"4"**	**"5 - Very important"**
	My mobility	15	6	56	74	245
	Concerns that I will become ill during this visit	86	53	83	53	103
	Lack of disabled facilities	91	34	56	53	101
	Unsuitable / poorly maintained sites	66	49	77	54	73
	No one to go with me / help me	68	35	63	51	123
	Tiredness / fatigue	21	21	65	115	166
General barriers		**"Yes"**	**"No"**			**Unweighted N**
	Bad / poor weather	1624	1897	**Frequency of green space use**	**"Every day"**	1882
	Poor physical health	436	3085		**"More than twice a week but not every day"**	2814
	Poor mental health or well being	231	3290		**"Twice a week"**	1289
	Lack of facilities and access points for those with disabilities	106	3415		**"Once a week"**	1391
	Too busy at home	443	3078		**"Once or twice a month"**	1099
	Too busy at work / with family commitments	423	3098		**"Once every 2-3 months"**	431
	Not interested	247	3274		**"Less often"**	1003
	Prefer to do other leisure activities	150	3371		**"Never"**	503
	Fear / worry about crime or anti-social behaviour	158	3363			
	Fear / worry about getting hurt or injured	83	3438			
	Nowhere near me is nice enough to spend my free time in	341	3180			
	Cost / too expensive	107	3414			

	Stayed at home to stop coronavirus spreading / Government restrictions	1502	2019
	No particular reason	227	3294

Appendix G: Counts, percentages and chi-square p-values for health conditions and socio-demographic characteristics; p<0.05, p<0.1.

		Health condition	Arthritis/joint-related	Respiratory	Diabetes	Heart/bp/circulation	Mental health conditions	Physical disability	Progressive disability/illness
		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Female	N	2171	832	505	265	401	844	398	309
	%	41%	38%	23%	12%	19%	39%	18%	14%
Male	N	1974	621	412	475	503	630	386	251
	%	39%	32%	21%	24%	26%	32%	20%	13%
Chi-Sq p-value		p=0.0214	p<0.0001	p=0.0641	p<0.0001	p<0.0001	p<0.0001	p=0.319	p=0.153
16-24	N	454	59	74	41	28	282	40.00	43
	%	33%	13%	16%	9%	6%	62%	9%	10%
25-39	N	974	188	206	130	104	530	159	87
	%	36%	19%	21%	13%	11%	54%	16%	9%
40-54	N	933	317	196	151	159	429	210	133
	%	39%	34%	21%	16%	17%	46%	23%	14%
55-64	N	654	307	147	159	183	155	155	124
	%	42%	47%	23%	24%	28%	24%	24%	19%
65+	N	1142	583	296	260	429	89	222	173
	%	48%	51%	26%	23%	38%	8%	19%	15%
Chi-Sq p-value		p<0.0001	p<0.0001	p=0.0005	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001
BAME	N	453	109	131	78	86	171	89	47
	%	32%	24%	29%	17%	19%	38%	20%	10%
White	N	3634	1329	771	656	805	1284	683	502
	%	42%	37%	21%	18%	22%	35%	19%	14%
Chi-Sq p-value		p<0.0001	p<0.0001	p=0.0002	p=0.663	p=0.124	p=0.311	p=0.66	p=0.043
£0-19,999	N	1348	522	312	213	320	615	324	215

	%	50%	39%	23%	16%	24%	46%	24%	16%
£20,000-39,999	**N**	1564	536	358	276	331	461	284	198
	%	42%	34%	23%	18%	21%	30%	18%	13%
£40,000-59,999	**N**	700	243	128	127	139	260	108	84
	%	33%	35%	18%	18%	20%	37%	15%	12%
£60,000+	**N**	521	146	116	116	109	150	60	60
	%	29%	28%	22%	22%	21%	29%	12%	12%
Chi-Sq p-value		<0.0001	0.0002	0.0617	0.0124	0.161	<0.0001	<0.0001	0.0119

Appendix H: Logistic regression results of types of health condition and socio-demographic variables; p<0.05, p<0.1.

		Arthritis				Respiratory (Yes)			
		Adjusted				Adjusted			
		p-value	OR	95% CI - LL	95% CI - UL	p-value	OR	95% CI - LL	95% CI - UL
Sex	Male (ref)								
	Female	<0.001	1.38	1.21	1.59	0.077	1.15	0.99	1.33
Age	16-24	0.002	0.61	0.44	0.84	0.066	0.76	0.56	1.02
	25-39 (ref)								
	40-54	<0.001	2.06	1.67	2.56	0.676	1.05	0.84	1.32
	55-64	<0.001	3.66	2.91	4.59	0.164	1.19	0.93	1.53
	65+	<0.001	4.42	3.59	5.43	<0.001	1.50	1.21	1.85
Ethnicity	White (ref)								
	BAME	0.872	0.98	0.77	1.25	<0.001	1.82	1.45	2.30
Income	£0-19,999	0.004	1.27	1.08	1.49	0.757	1.03	0.86	1.23
	£20,000-39,999 (ref)								
	£40,000-59,999	0.046	1.23	1.00	1.50	0.034	0.78	0.62	0.98
	£60,000+	0.976	1.00	0.80	1.27	0.799	0.97	0.76	1.24
		Diabetes (Yes)				Heart/blood pressure (Yes)			
		Adjusted				Adjusted			
		p-value	OR	95% CI - LL	95% CI - UL	p-value	OR	95% CI - LL	95% CI - UL
Sex	Male (ref)								
	Female	<0.001	0.44	0.37	0.53	<0.001	0.62	0.53	0.73
Age	16-24	0.031	0.65	0.44	0.96	0.009	0.55	0.35	0.86
	25-39 (ref)								
	40-54	0.048	1.30	1.00	1.69	<0.001	1.81	1.38	2.38

	55-64	<0.001	2.31	1.77	3.03	<0.001	3.60	2.73	4.75
	65+	<0.001	2.10	1.64	2.68	<0.001	5.72	4.45	7.37
Ethnicity	White (ref)								
	BAME	0.227	1.19	0.90	1.57	0.001	1.62	1.23	2.13
Income	£0-19,999	0.990	1.00	0.81	1.22	0.002	1.34	1.12	1.62
	£20,000-39,999 (ref)								
	£40,000-59,999	0.246	1.15	0.91	1.47	0.284	1.14	0.90	1.44
	£60,000+	0.002	1.49	1.16	1.93	0.180	1.20	0.92	1.56
		Mental health conditions (Yes)				Physical disability (Yes)			
		Adjusted				Adjusted			
		p-value	OR	95% CI - LL	95% CI - UL	p-value	OR	95% CI - LL	95% CI - UL
Sex	Male (ref)								
	Female	<0.001	1.33	1.15	1.54	0.211	0.90	0.77	1.06
Age	16-24	0.103	1.22	0.96	1.55	<0.001	0.49	0.34	0.72
	25-39 (ref)								
	40-54	<0.001	0.60	0.49	0.72	0.001	1.48	1.17	1.88
	55-64	<0.001	0.20	0.16	0.25	<0.001	1.60	1.23	2.07
	65+	<0.001	0.05	0.04	0.07	0.099	1.22	0.96	1.55
Ethnicity	White (ref)								
	BAME	<0.001	0.57	0.46	0.71	0.019	1.37	1.05	1.78
Income	£0-19,999	<0.001	2.02	1.70	2.41	<0.001	1.46	1.21	1.75
	£20,000-39,999 (ref)								
	£40,000-59,999	0.576	1.06	0.86	1.31	0.136	0.83	0.65	1.06

	£60,000+	0.003	0.69	0.54	0.88	0.002	0.62	0.45	0.83
		Progressive illness (Yes							
		Adjusted							
		p-value	OR	95% CI - LL	95% CI - UL				
Sex	Male (ref)								
	Female	0.249	1.11	0.93	1.34				
Age	16-24	0.523	1.14	0.77	1.68				
	25-39 (ref)								
	40-54	<0.001	1.71	1.27	2.30				
	55-64	<0.001	2.43	1.79	3.29				
	65+	<0.001	1.81	1.36	2.41				
Ethnicity	White (ref)								
	BAME	0.610	0.92	0.66	1.28				
Income	£0-19,999	0.008	1.33	1.08	1.65				
	£20,000-39,999 (ref)								
	£40,000-59,999	0.745	0.95	0.72	1.26				
	£60,000+	0.726	1.06	0.77	1.45				

Appendix I: Sensitivity analysis for income, with the 'poor physical health' regression model. SE = Standard Error.

		Income	
		Model 1	Model 2
		Four income groups	Ten income groups
Arthritis	Estimate	0.472	0.481
	SE	0.126	0.127
	P-value	<0.001	<0.001
Respiratory	Estimate	0.71	0.699
	SE	0.135	0.136
	P-value	<0.001	<0.001
Diabetes	Estimate	0.0421	0.0507
	SE	0.1585	0.16
	P-value	0.79056	0.75124
Heart/blood pressure/circulatory	Estimate	0.332	0.345
	SE	0.14	0.141
	P-value	0.01774	0.01445
Mental health conditions	Estimate	-0.0585	-0.0741
	SE	0.1516	0.1528
	P-value	0.69981	0.62784
Physical disabilities	Estimate	0.899	0.891
	SE	0.135	0.136
	P-value	<0.001	<0.001
Progressive illnesses	Estimate	0.776	0.821
	SE	0.157	0.159
	P-value	<0.001	<0.001
Female	Estimate	-0.0875	-0.1109
	SE	0.1236	0.1245
	P-value	0.47905	0.37278
16-24	Estimate	-0.898	-0.906
	SE	0.365	0.366
	P-value	0.01394	0.01341
40-54	Estimate	0.336	0.331
	SE	0.206	0.208
	P-value	0.10287	0.1109
55-64	Estimate	0.286	0.296
	SE	0.22	0.222
	P-value	0.19405	0.18154
65+	Estimate	0.866	0.862
	SE	0.204	0.205
	P-value	<0.001	<0.001

BAME	**Estimate**	-0.699	-0.692
	SE	0.25	0.251
	P-value	0.00515	0.00585
£0-19,999	**Estimate**	0.0248	
	SE	0.1385	
	P-value	0.85766	
£40,000-59,999	**Estimate**	-0.0964	
	SE	0.2049	
	P-value	0.6379	
£60,000+	**Estimate**	-0.145	
	SE	0.246	
	P-value	0.55731	
£0-14,999	**Estimate**		0.213
	SE		0.199
	P-value		0.28553
£15,000-19,999	**Estimate**		-0.0707
	SE		0.2137
	P-value		0.74084
£20,000-29,999	**Estimate**		0.125
	SE		0.206
	P-value		0.54389
£40,000-49,999	**Estimate**		-0.0421
	SE		0.2586
	P-value		0.87055
£50,000-59,999	**Estimate**		0.0305
	SE		0.3785
	P-value		0.93584
£60,000-79,999	**Estimate**		0.173
	SE		0.345
	P-value		0.61559
£80,000-99,999	**Estimate**		0.0147
	SE		0.449
	P-value		0.97383
£100,000-£149,999	**Estimate**		-0.709
	SE		0.683
	P-value		0.29942
£150,000+	**Estimate**		-1.028
	SE		0.936
	P-value		0.27186

Appendix J: Sensitivity analysis for age, with the 'poor physical health' regression model. SE = Standard Error.

		Age	
		Model 1	Model 2
		Three age groups	Five age groups
Arthritis	Estimate	0.502	0.472
	SE	0.125	0.126
	P-value	<0.001	<0.001
Respiratory	Estimate	0.704	0.71
	SE	0.135	0.135
	P-value	<0.001	<0.001
Diabetes	Estimate	0.0515	0.0421
	SE	0.158	0.1585
	P-value	0.74442	0.79056
Heart/blood pressure/circulatory	Estimate	0.353	0.332
	SE	0.139	0.14
	P-value	0.0113	0.01774
Mental health conditions	Estimate	-0.0889	-0.0585
	SE	0.1476	0.1516
	P-value	0.54701	0.69981
Physical disabilities	Estimate	0.914	0.899
	SE	0.135	0.135
	P-value	<0.001	<0.001
Progressive illnesses	Estimate	0.802	0.776
	SE	0.156	0.157
	P-value	<0.001	<0.001
Female	Estimate	-0.0889	-0.0875
	SE	0.1235	0.1236
	P-value	0.47171	0.47905
BAME	Estimate	-0.708	-0.699
	SE	0.247	0.25
	P-value	0.00421	0.00515
£0-19,999	Estimate	0.032	0.0248
	SE	0.1382	0.1385
	P-value	0.8169	0.85766
£40,000-59,999	Estimate	-0.0980	-0.0964
	SE	0.2036	0.2049
	P-value	0.63034	0.6379
£60,000+	Estimate	-0.166	-0.145
	SE	0.245	0.246
	P-value	0.49675	0.55731

16-24	**Estimate**		-0.898
	SE		0.365
	P-value		0.01394
40-54	**Estimate**		0.336
	SE		0.206
	P-value		0.10287
55-64	**Estimate**		0.286
	SE		0.22
	P-value		0.19405
65+	**Estimate**		0.866
	SE		0.204
	P-value		<0.001
16-24	**Estimate**	-1.1	
	SE	0.343	
	P-value	0.00136	
65+	**Estimate**	0.631	
	SE	0.14	
	P-value	<0.001	

Appendix K: Sensitivity analysis for ethnicity, with the 'poor physical health' regression model. SE = Standard Error.

		Ethnicity	
		Model 1	Model 2
		Two ethnicity groups	Five ethnicity groups
Arthritis	Estimate	0.472	0.479
	SE	0.126	0.127
	P-value	<0.001	<0.001
Respiratory	Estimate	0.71	0.708
	SE	0	0.136
	P-value	<0.001	<0.001
Diabetes	Estimate	0.0421	0.0428
	SE	0	0.1588
	P-value	0.79056	0.78734
Heart/blood pressure/circulatory	Estimate	0.332	0.338
	SE	0.14	0.141
	P-value	0.01774	0.01641
Mental health conditions	Estimate	-0.0585	-0.0437
	SE	0.1516	0.1528
	P-value	0.69981	0.77487
Physical disabilities	Estimate	0.899	0.902
	SE	0.135	0.135
	P-value	<0.001	<0.001
Progressive illnesses	Estimate	0.776	0.763
	SE	0.157	0.158
	P-value	<0.001	<0.001
Female	Estimate	-0.0875	-0.0921
	SE	0.1236	0.1238
	P-value	0.47905	0.45711
16-24	Estimate	-0.898	-0.88
	SE	0.365	0.366
	P-value	0.01394	0.01602
40-54	Estimate	0.336	0.358
	SE	0.206	0.207
	P-value	0.10287	0.08349
55-64	Estimate	0.286	0.3
	SE	0.22	0.222
	P-value	0.19405	0.17632
65+	Estimate	0.866	0.883
	SE	0.204	0.205
	P-value	<0.001	<0.001
£0-19,999	Estimate	0.0248	0.0192

	SE	0.1385	0.139
	P-value	0.85766	0.89033
£40,000-59,999	**Estimate**	-0.0964	-0.1145
	SE	0.2049	0.2054
	P-value	0.6379	0.57721
£60,000+	**Estimate**	-0.145	-0.166
	SE	0.246	0.247
	P-value	0.55731	0.502
BAME	**Estimate**	-0.699	
	SE	0.25	
	P-value	0.00515	
Any other ethnic group or background	**Estimate**		-1.62
	SE		1.14
	P-value		0.15247
Asian or Asian British	**Estimate**		-0.328
	SE		0.366
	P-value		0.37084
Black or Black British	**Estimate**		-0.844
	SE		0.45
	P-value		0.06097
Mixed	**Estimate**		-0.909
	SE		0.514
	P-value		0.07674

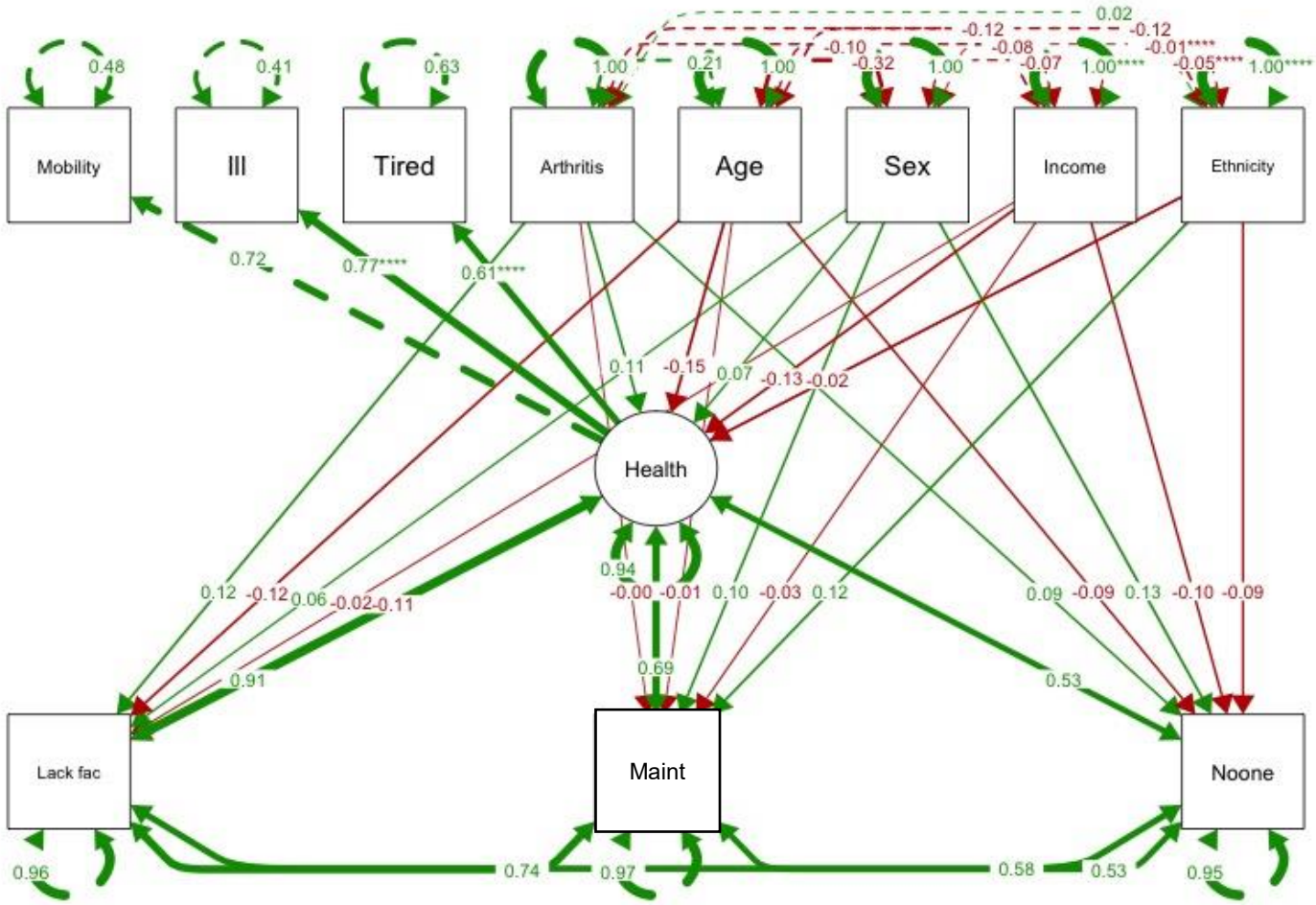
Appendix L: Goodness of fit tests for each SEM.

SEMs by health condition	*RMSEA*	*SRMR*	*CFI*	*P-value (Chi-square)*
Arthritis	<0.001	0.035	1	0.604
Respiratory conditions	<0.001	0.036	1	0.581
Diabetes	<0.001	0.035	1	0.67
Heart/blood pressure/circulatory conditions	<0.001	0.039	1	0.517
Mental health conditions	<0.001	0.035	1	0.616
Physical disabilities	<0.001	0.037	1	0.574
Progressive illnesses	<0.001	0.037	1	0.704

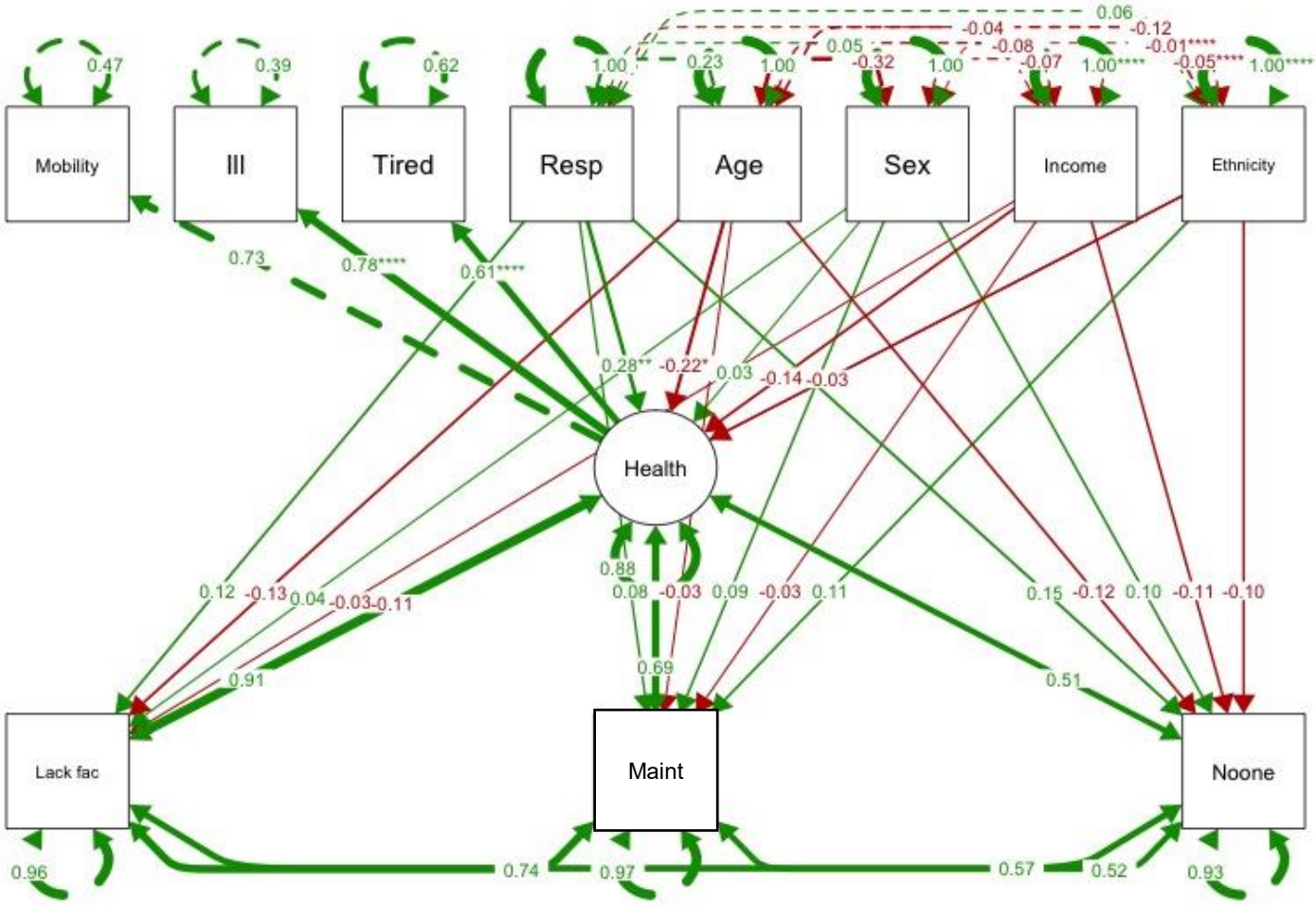
Appendix M: Covariances for each SEM.

		Arthritis		Respiratory		Diabetes		Heart/blood pressure	
		P-value	Std Estimate	P-value	Std Estimate	P-value	Std Estimate	P-value	Std Estimate
Mobility/health									
	Lack of disabled facilities	<0.001	0.912	<0.001	0.915	<0.001	0.917	<0.001	0.915
	Unsuitable / poorly maintained sites	<0.001	0.692	<0.001	0.694	<0.001	0.688	<0.001	0.675
	No-one to go with/help me	<0.001	0.526	<0.001	0.511	<0.001	0.521	<0.001	0.524
Lack of disabled facilities									
	Unsuitable / poorly maintained sites	<0.001	0.744	<0.001	0.736	<0.001	0.739	<0.001	0.724
	No-one to go with/help me	<0.001	0.577	<0.001	0.575	<0.001	0.577	<0.001	0.574
Unsuitable / poorly maintained sites									
	No-one to go with/help me	<0.001	0.529	<0.001	0.525	<0.001	0.525	<0.001	0.521
		Physical disability		Progressive illness					
		P-value	Std Estimate	P-value	Std Estimate				
Mobility/health									
	Lack of disabled facilities	<0.001	0.898	<0.001	0.908				
	Unsuitable / poorly maintained sites	<0.001	0.672	<0.001	0.664				
	No-one to go with/help me	<0.001	0.51	<0.001	0.482				
Lack of disabled facilities									
	Unsuitable / poorly maintained sites	<0.001	0.73	<0.001	0.718				
	No-one to go with/help me	<0.001	0.563	<0.001	0.547				
Unsuitable / poorly maintained sites									
	No-one to go with/help me	<0.001	0.513	<0.001	0.476				

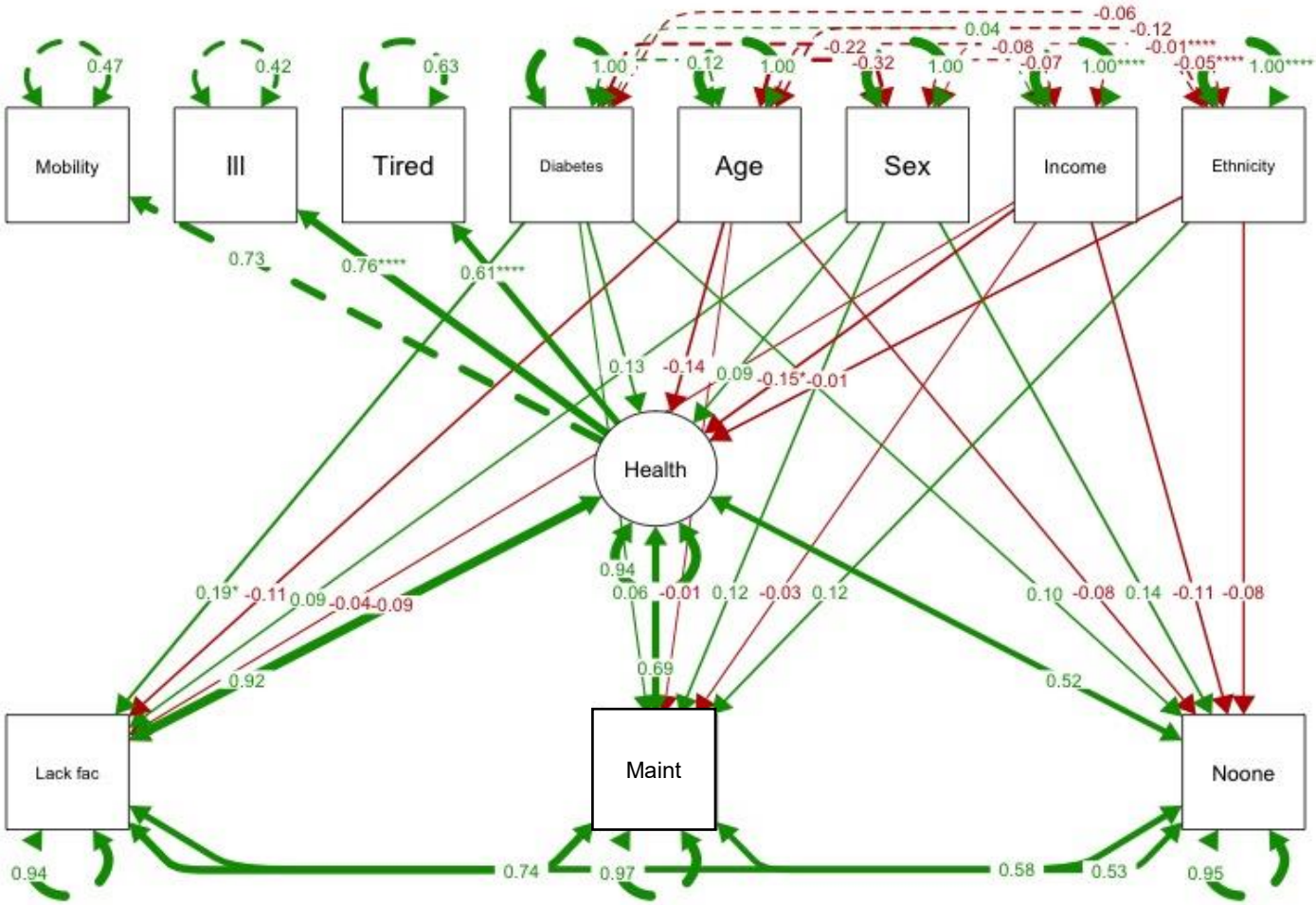
Appendix N: SEM for arthritis, socio-demographic variables, and health barriers – showing standardised estimates, *p<0.1 **P<0.05 ***p<0.01,



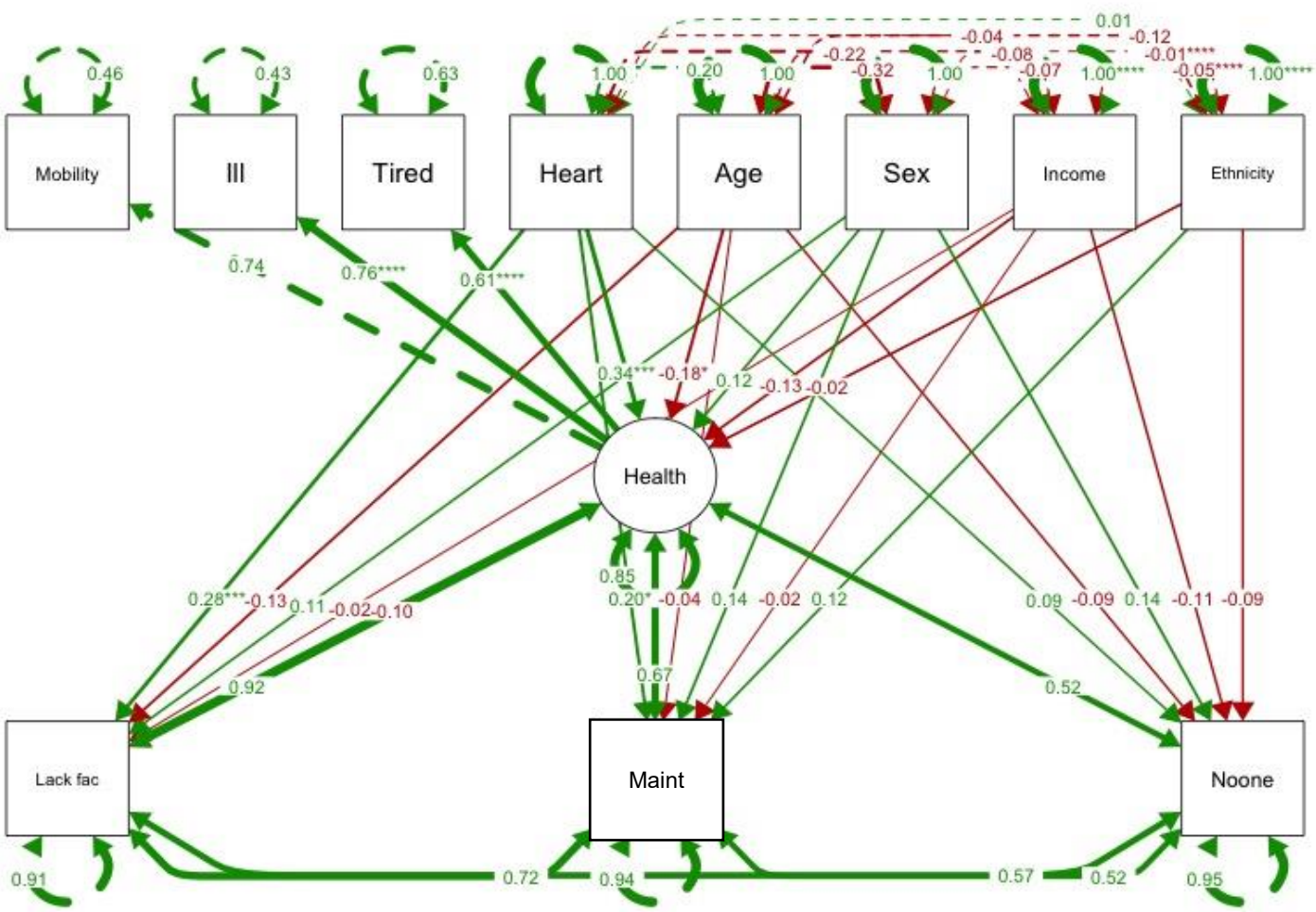
Appendix O: SEM for respiratory conditions, socio-demographic variables, and health barriers – showing standardised estimates, *p<0.1 **P<0.05 ***p<0.01, ****p<0.001.



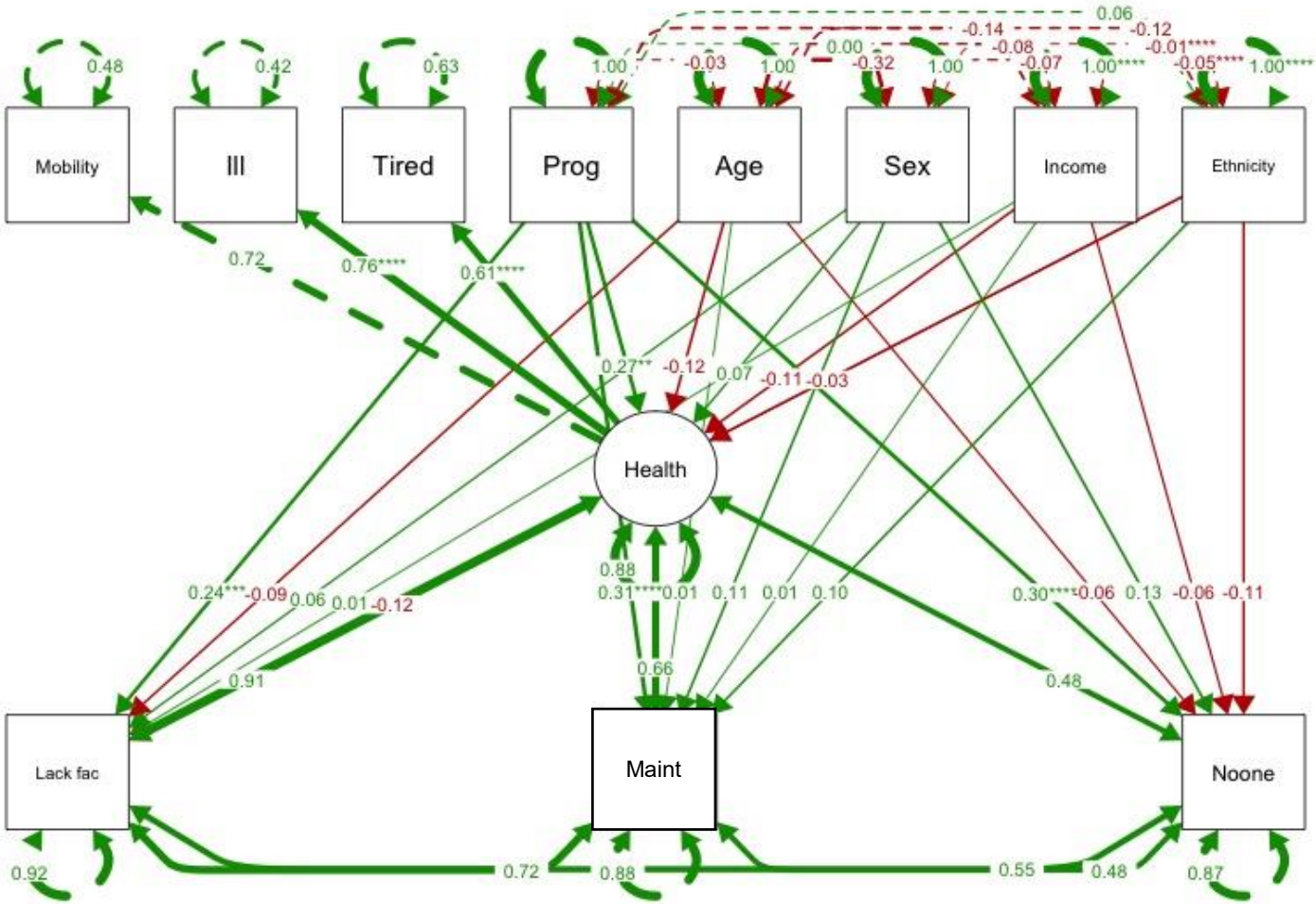
Appendix P: SEM for diabetes, socio-demographic variables, and health barriers – showing standardised estimates, *p<0.1 **P<0.05 ***p<0.01, ****p<0.001.



Appendix Q: SEM for heart/blood pressure/circulatory conditions, socio-demographic variables, and health barriers – showing standardised estimates, *p<0.1 **P<0.05 ***p<0.01, ****p<0.001.



Appendix R: SEM for progressive illnesses, socio-demographic variables, and health barriers – showing standardised estimates, *p<0.1 **P<0.05 ***p<0.01, ****p<0.001.



Appendix S: SEM results for sociodemographic variables by health condition/model.

	Mobility/health		Lack of disabled facilities		Unsuitable / poorly maintained sites		No-one to go with/help me	
	P-value	Std Estimate	P-value	Std Estimate	P-value	Std Estimate	P-value	Std Estimate
Arthritis								
Age	0.204	-0.15	0.221	-0.122	0.937	-0.008	0.363	-0.091
Sex	0.537	0.07	0.576	0.058	0.298	0.104	0.184	0.126
Income	0.138	-0.132	0.831	-0.019	0.712	-0.032	0.249	-0.098
Ethnicity	0.773	-0.023	0.17	-0.108	0.176	0.12	0.297	-0.092
Respiratory								
Age	0.052	-0.215	0.189	-0.133	0.743	-0.033	0.229	-0.12
Sex	0.806	0.029	0.734	0.036	0.373	0.092	0.304	0.101
Income	0.116	-0.137	0.717	-0.033	0.721	-0.032	0.204	-0.11
Ethnicity	0.67	-0.033	0.141	-0.115	0.203	0.112	0.222	-0.103
Diabetes								
Age	0.21	-0.139	0.264	-0.109	0.9	-0.012	0.402	-0.08
Sex	0.444	0.094	0.387	0.093	0.268	0.116	0.143	0.142
Income	0.1	-0.146	0.653	-0.039	0.703	-0.033	0.174	-0.112
Ethnicity	0.935	-0.006	0.228	-0.093	0.158	0.124	0.339	-0.084
Heart/blood pressure/circulatory								
Age	0.093	-0.179	0.167	-0.134	0.692	-0.038	0.399	-0.086
Sex	0.271	0.123	0.303	0.106	0.194	0.137	0.148	0.139
Income	0.134	-0.129	0.781	-0.024	0.795	-0.022	0.205	-0.106
Ethnicity	0.747	-0.023	0.155	-0.104	0.186	0.116	0.3	-0.09
Physical disability								
Age	0.38	-0.096	0.594	-0.05	0.878	0.015	0.584	-0.051
Sex	0.485	0.08	0.49	0.068	0.264	0.113	0.155	0.132
Income	0.101	-0.14	0.772	-0.025	0.751	-0.027	0.187	-0.107
Ethnicity	0.788	-0.022	0.188	-0.106	0.179	0.123	0.299	-0.089
Progressive illness								
Age	0.274	-0.119	0.36	-0.087	0.94	0.007	0.503	-0.058
Sex	0.537	0.071	0.601	0.055	0.268	0.107	0.157	0.132
Income	0.247	-0.105	0.931	0.008	0.868	0.014	0.426	-0.062
Ethnicity	0.751	-0.026	0.117	-0.118	0.198	0.102	0.195	-0.109

Appendix T: Unweighted counts for the YouGov Survey waves (socio-demographic characteristics, frequency of green space visits, and barriers to green space visits).

Unweighted N		Wave 1	Wave 2	Wave 3
Wave	N	2252	2246	2215
Sex	Female	1234	1204	1169
	Male	1018	1042	1046
Age	16-24	165	170	180
	25-64	1497	1492	1430
	65+	590	1430	605
Social grade	Higher	1419	1355	1300
	Lower	833	891	915
Visits to green space	Yes	1086	1421	1479
	No	1123	766	686
Frequency of green space visits	Once a day		354	320
	2 to 3 times a week		478	490
	Once a week		315	350
	Once every 2 weeks		132	152
	Once in the last 4 weeks		122	149
Barriers	Worried about Social Distancing in Green Spaces	279	147	139
	Green Spaces Are Too Busy	95	92	179
	Fear for Health When Outdoors (i.e., Contracting Covid-19)	305	139	103
	Member of Household/Individual at Risk of Being Severely Affected by Covid-19	294	152	81
	Using an Outdoor Space at Home Instead	523	266	296
	Not Interested in Visiting Green Spaces	87	92	102

Appendix U: Significant interaction results by wave and socio-demographic variables, each interaction model was adjusted for wave, sex, age, and social grade; Interaction Odds Ratios (95% Confidence Intervals), *p<0.05*.

		Wave		
		1 (ref)	**2**	**3**
Social grade				
Visits to green space				
	Higher social grade (ref)	-	-	-
	Lower social grade	-	**0.65 (0.51-0.84)**	0.82 (0.64-1.05)
	p-value	-	***<0.001***	0.12
Sex				
Busy green space				
	Male (ref)	-	-	-
	Female	-	0.61 (0.33-1.15)	**0.49 (0.28-0.86)**
	p-value	-	0.12	***0.01***
Age				
Busy green space				
	18-24	-	0.45 (0.16-1.23)	0.98 (0.45-2.15)
	p-value	-	0.12	0.96
	25-64 (ref)	-	-	-
	65+	-	**2.58 (1.11-5.98)**	**2.97 (1.38-6.40)**
	p-value	-	***0.03***	***0.01***
Barriers				
Worried about social distancing				
	18-24	-	1.16 (0.57-2.36)	0.99 (0.47-2.06)
	p-value	-	0.68	0.97
	25-64 (ref)	-	-	-
	65+	-	**2.21 (1.30-3.76)**	**2.27 (1.34-3.87)**
	p-value	-	***0.00***	***0.00***
Higher risk of being severely affected by Covid-19				
	18-24	-	0.50 (0.22-1.14)	0.30 (0.09-0.95)
	p-value	-	0.10	*0.04*
	25-64 (ref)	-	-	-
	65+	-	0.72 (0.45-1.17)	**0.41 (0.23-0.75)**
	p-value	-	0.18	***0.00***
Fear for health				
	18-24	-	1.17 (0.56-2.41)	**0.27 (0.09-0.86)**
	p-value	-	0.68	***0.03***
	25-64 (ref)	-	-	-
	65+	-	1.47 (0.89-2.42)	1.10 (0.64-1.89)
	p-value	-	0.13	0.72
Not interested				
	18-24	-	0.91 (0.40-2.06)	**0.25 (0.10-0.65)**
	p-value	-	0.82	***0.00***
	25-64 (ref)	-	-	-

	65+	-	**3.12 (1.42-6.88)**	1.78 (0.81-3.89)
	p-value	-	***0.00***	0.15

Appendix V: Significant interaction results by wave and socio-demographic variables; Predicted Probabilities (95% Confidence Intervals).

Significant interactions		Wave			
		1	2	3	Anova p-value
Visits to green space					
Social grade	Higher social grade	0.53 (0.50-0.56)	0.73 (0.70-0.75)	0.73 (0.71-0.76)	0.003
	Lower social grade	0.44 (0.41-0.47)	0.55 (0.51-0.58)	0.61 (0.58-0.64)	
Green spaces are too busy					
Sex	Male	0.06 (0.04-0.08)	0.08 (0.06-0.11)	0.18 (0.15-0.21)	0.03
	Female	0.11 (0.09-0.14)	0.10 (0.08-0.12)	0.18 (0.15-0.22)	
Age	18-24	0.13 (0.08-0.20)	0.06 (0.03-0.12)	0.22 (0.15-0.31)	0.009
	25-64	0.10 (0.08-0.12)	0.10 (0.08-0.12)	0.18 (0.15-0.21)	
	65+	0.04 (0.02-0.06)	0.09 (0.06-0.13)	0.18 (0.14-0.24)	
Worried about social distancing					
Age	18-24	0.28 (0.20-0.36)	0.15 (0.10-0.23)	0.13 (0.08-0.21)	0.01
	25-64	0.27 (0.24-0.31)	0.13 (0.11-0.16)	0.13 (0.11-0.16)	
	65+	0.18 (0.14-0.23)	0.17 (0.13-0.23)	0.17 (0.13-0.23)	
Higher risk of being severely affected by Covid-19					
Age	18-24	0.25 (0.18-0.33)	0.09 (0.05-0.16)	0.03 (0.07-0.09)	0.01
	25-64	0.20 (0.17-0.23)	0.13 (0.10-0.15)	0.08 (0.06-0.11)	
	65+	0.42 (0.37-0.48)	0.24 (0.18-0.29)	0.10 (0.07-0.14)	
Fear for health					
Age	18-24	0.28 (0.20-0.36)	0.14 (0.09-0.22)	0.03 (0.01-0.09)	0.04
	25-64	0.26 (0.23-0.29)	0.11 (0.09-0.14)	0.10 (0.08-0.13)	
	65+	0.31 (0.26-0.37)	0.20 (0.15-0.25)	0.14 (0.10-0.19)	
Not interested					
Age	18-24	0.17 (0.11-0.24)	0.15 (0.09-0.22)	0.07 (0.03-0.13)	<0.001
	25-64	0.07 (0.05-0.09)	0.07 (0.05-0.09)	0.10 (0.08-0.12)	
	65+	0.04 (0.03-0.07)	0.12 (0.08-0.17)	0.11 (0.07-0.15)	

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