# Determining the economic value of interventions for urban green spaces

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January 2026

**Abstract**

Background: Urban Green Spaces (UGS) are broadly associated with improvements in population health and wellbeing, including improvements in mental health, physical activity and educational attainment. However, there is limited evidence around specific interventions to change UGS and their impact on health or education outcomes.

Aims: To explore and evaluate the economic and health impact of UGS interventions.

Methods: The literature on effectiveness and cost-effectiveness of interventions for urban green spaces was systematically identified and reviewed. The data on costs and effectiveness were then consolidated in a model to look at the cost-effectiveness of UGS interventions, and the results were presented in a user-friendly toolkit. The impact of an urban green space intervention on mental health in Bradford was assessed through a difference-in-differences design, using the Born in Bradford dataset, and linked prescription records.

Results: The majority of studies included in the systematic review reported that UGS interventions may have contributed to improvements in physical activity, especially in more deprived settings. Consolidating the data revealed that the three main types of interventions reviewed, namely improving (1) walkways, (2) outdoor fitness equipment, and (3) play areas, were likely to yield cost-effective improvements in physical activity. The difference-in-differences evaluation showed that improvement of UGS in the three most deprived wards of Bradford was associated with a reduction in prescription costs for mental health medications after the intervention. However, no statistically significant effect was observed on the likelihood of receiving a prescription once the model was expanded to adjust for ethnicity.

Conclusions: Improving mental health, physical activity, and reducing health inequalities and inequities are key priorities for the United Kingdom government. The findings of this thesis provide support for the implementation of UGS interventions as a public health strategy to enhance physical activity, improve mental health outcomes, and contribute to overall population health and wellbeing. Further research on additional outcomes, such as educational attainment, and distributional benefits of interventions for UGS can expand on the findings from this thesis.

## Table of Contents


**ABSTRACT** **2**

**CHAPTER 1: BACKGROUND** **9**

About the background 9
Part 1: Urban Green Spaces and Health Promotion in the United Kingdom 10
1.1 Health Promotion in the United Kingdom 10
1.1.1 Interventions for urban green spaces 11
1.2 UGS and human development 12
1.2.1 UGS and Health 12
1.2.2 UGS and Education outcomes 13
1.2.3 UGS and Equity 14
1.2.4 UGS and other outcomes 15
1.4 Logic Model: UGS interventions and its impact on health and education 16
Part 2: Economics and decision-making in UGS 18
1.5 Economics, and environmental economics 18
1.6 Economic frameworks 18
1.6.1 Cost-benefit analysis 19
1.6.2 Cost-effectiveness analysis 20
1.6.2.1 Cost-utility analysis 21
1.6.2.2 Cost-consequence analysis 21
1.6.3 Social Return on Investment 22
1.7 Decision-making on UGS: Different approaches to the same problem 22
1.8 Challenges in evaluating UGS interventions 24
1.9 Estimating the cost-effectiveness of UGS interventions: Addressing gaps in the literature 26

**CHAPTER 2: A SYSTEMATIC REVIEW OF THE IMPACT OF CHANGES TO URBAN GREEN SPACES ON HEALTH AND EDUCATION OUTCOMES, AND A CRITIQUE OF THEIR APPLICABILITY TO INFORM ECONOMIC EVALUATION** **28**

Preface 28
2.1 Abstract 29
2.2 Introduction 30
2.2.1 Aims and Objectives 31
2.3. Methods 32
2.3.1 Protocol registration: 32
2.3.2 Eligibility criteria: 32
2.3.3 Search Methods: 34
2.3.4 Information Sources: 34
2.3.5 Selection Process: 34
2.3.6 Data items and collection 35
2.3.7 Risk of bias: 35
2.3.8 Synthesis methods: 35
2.4. Results 36
2.4.1 Study characteristics 36
2.4.2 Risk of bias 37
2.4.4 Synthesis of findings 39
2.4.4.1 Functional improvements to pathways/walkways 39
2.4.4.2 Improving/installing play or fitness equipment 45
2.4.4.3 Improving the greenery or aesthetics of the space 50
2.4.4.5 A combination of different interventions for urban green spaces 54
2.4.4.6 Quantitative synthesis of findings 58
2.4.5 Economic evaluations 58
2.4.6 Critical review 62

**CHAPTER 3: TOOLKIT FOR THE HEALTH ECONOMIC ASSESSMENT OF URBAN GREEN SPACE INTERVENTIONS (THEAGS)** **65**

Preface 65
Abstract 66
3.1 Introduction 67
3.1.1 Type of interventions 68
3.2 Methodology 69
3.2.1 Outcomes of interest 69
3.2.2 Decision Model 70
3.2.3 Obtaining data to inform model 71
3.2.3.1 Baseline distribution 71
3.2.4 Effectiveness 72
3.2.5 Evidence synthesis on effectiveness 75
3.2.6 Calculation of quality-adjusted life years (QALYs) 76
3.2.7 Cost and resource use 77
3.2.8 Net Monetary Benefit 78
3.2.9 Sensitivity analysis 78
3.2.10 Scenario Analysis 78
3.3 Results 79
3.3.1 Building/Improving a green walkway/pathway 79
3.3.2 Installing/improving fitness equipment 80
3.3.3 Installing/Improving play areas in a public green space 81
3.3.4 Comparing across interventions 83
3.4 Discussion 84

**CHAPTER 4: CAN IMPROVEMENTS TO PARKS AND PLAYGROUNDS IN A DEPRIVED SETTING EFFECT PRESCRIPTIONS FOR ANXIETY AND DEPRESSION? A CASE STUDY FROM BRADFORD, UNITED KINGDOM 87**

Preface 87
4.1 Introduction 93
4.2 Methodology 95
4.2.1 Study setting 95
4.2.1.1 The Better Place intervention 95
4.2.2 The Born in Bradford cohort 96
4.2.3 Mental health prescriptions 97
4.2.4 Cost of prescriptions 97
4.2.5 Cost of intervention 97
4.2.6 Intervention v control group 98
4.2.7 Analysis 98
4.2.7.1 Two-part model using a difference-in-differences approach 98
4.2.7.2 Long term savings from the intervention 100
4.3. Results 100
4.3.1 Descriptive statistics 100
4.3.2 Trends in prescription data for depression and anxiety 101
4.3.3.1 Unadjusted analysis 104
4.3.3.2 Adjusted analysis 105
4.3.4 Cost of interventions per capita 107
4.3.5 Long-term implications of intervention 108

**CHAPTER 5: DISCUSSION 112**

5.1 Importance of findings 112
5.2 Cost-effectiveness of UGS interventions 114
5.2.1 Impacts of UGS interventions on physical activity 114
5.2.2 UGS interventions and mental health 115
5.3 Beyond the results: Unique contributions of this thesis 116
5.3.1 Logic Model 116
5.3.2 A toolkit to support decision-making in UGS for local authorities 117
5.3.3 The use of prescription data for an environmental health evaluation 118
5.4 Limitations and areas for future research 118

5.5 Policy recommendations 120
5.6 Conclusion 122

**CHAPTER 2 – APPENDICES 141**

Appendix 1: Search Strategies 141
Appendix 2 – Risk of Bias 172

**CHAPTER 3 – APPENDICES 179**

Appendix 1 – Screenshots of the toolkit 179
Appendix 2 – User manual for the toolkit 181

**CHAPTER 4 – APPENDICES 188**

Appendix 2: Frequency of prescription by medicine 189
Appendix 3 – Trends in prescription of common mental health medicines 197
Appendix 4 – STATA code for cleaning and merging medicine database 199

**ADDITIONAL FILE 1: ESTIMATING THE IMPACT OF A GREEN SPACE INTERVENTION ON GENERALISED ANXIETY DISORDER (GAD), AND THE PATIENT HEALTH QUESTIONNAIRE (PHQ), AND THE EXPECTED NET MONETARY BENEFIT FROM THE INTERVENTION 236**

**ADDITIONAL FILE 2: ESTIMATING THE IMPACT OF URBAN GREEN SPACES ON MENTAL HEALTH PRESCRIPTIONS IN BRADFORD UK 240**

**ADDITIONAL FILE 3: EXPLORATORY ANALYSIS OF BORN IN BRADFORD GROWING UP 242**

**Acknowledgements**

First, I want to thank my supervisors, Laura Bojke, Peter Coventry and Piran White, who were always generous with their time and provided thoughtful and constructive feedback. Beyond their academic support, I am also grateful to my supervisors, and Laura in particular, for the personal support through this PhD journey which included a pregnancy and subsequently, a baby! The supportive environment that they created, was a great source of motivation for me throughout this PhD.

I would also like to thank my thesis advisors Karen Bloor, Sebastian Hinde and Rosie Maceachan for all their thoughtful comments on each of the chapters presented here. Throughout this PhD, I've also benefited from feedback from numerous researchers and public health professionals, including co-authors below, and members of the Born in Bradford teams including Mikel Subiza-Perez, Ellena Badrick and Adele Adams.

I'm so grateful to my parents for teaching me to be ambitious and resilient, even when the community around us set different expectations for women. And for my family and friends in York, and across Europe including Shabi, Shayan, Chelsea, Hafsa, Chaudhry, Zohair, Mariya, Alex, James, Rafael, Steffi, Seb and Charley for lending their ear, shoulders, and their couch whenenever I needed! I'm also grateful for my PhD cohort, Kristina, Pete, Wei, Refaya and Fei for the all the support throughout the ups and downs of this period.

Lastly, I'd like to thank Ahmed and our son Idris for brightening up every day. I love you, and I couldn't have done this without you.

**Declaration**

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for a degree or other qualification at this University or elsewhere. All sources are acknowledged as references.

**Thesis Outline**

This thesis has been organised as a journal-style thesis and includes three distinct chapters written for publication. One out of the three is already published in a peer-reviewed journal, and two will be submitted for publication. The thesis also includes an introduction at the beginning and concludes with a discussion chapter.

The introduction in Chapter 1 provides the context for the research question and is organised into two parts. The first part of the introduction explores the relationship between interventions for UGS and health and education. The second part of the introduction provides details of health economic frameworks that can be used to evaluate a public health intervention such as interventions for UGS, and provides details of the framework used in this thesis.

Chapter 2/Paper 1 is a systematic review of the literature on the interventions for UGS and health and education outcomes. This paper consolidates the existing literature on how specific changes to UGS, such as installing walkways, can impact health and education outcomes. The review also includes a critique of the literature and the limitations of its use in informing an economic evaluation.

Chapter 3/Paper 2 presents a toolkit to conduct health economic evaluation of interventions for urban green spaces, that was developed as part of this thesis. This toolkit consolidates the findings from paper 1, to present the expected net monetary benefit and the probability of cost-effectiveness for three different types of investments in UGS. Paper 2 describes the methodology used by the toolkit, the results of the health economic assessment, and describes their applicability to inform prioritisation decisions around UGS interventions.

Chapter 4/ Paper 3 is a longitudinal difference-in-differences study, which assesses the impact of a UGS intervention on mental health prescriptions for residents in three deprived wards in Bradford. The results describe the differential effect of the probability of requiring a prescription, and the cost of the prescription for the populations that live in the wards with the improved UGS.

The discussion in chapter 5 summarises the findings, and how the results from these three papers relate to the broader literature around impact of UGS interventions. The discussion also places findings in the context of public health in the United Kingdom, and signals policies that are supported by the findings in this thesis. Lastly, the discussion section outlines the limitations in this thesis, and areas for future research.

# Chapter 1: Background

## About the background

This thesis explores methods to determine the effectiveness and value for money of urban green space (UGS) interventions. The methods used in the thesis draw on disciplines including health economics, environmental health, and the broader health sciences.

This background chapter is organised into two sections, each addressing a core component of this research. Part 1 examines the impact of urban green space interventions on human development, with an emphasis on their impacts on health and educational attainment. It provides an overview of the pathways through which green spaces may affect physical and mental well-being, cognitive development, and educational performance. Part 2 introduces the health economic frameworks that underpin the evaluation of such interventions. It reviews relevant concepts such as cost-effectiveness analysis, cost–benefit analysis, and broader evaluative approaches suited to multisectoral interventions, highlighting methodological considerations when assessing complex, cross-sectoral policies like UGS investments.

Together, these two parts help to establish the conceptual and methodological foundation for the thesis, bridging the evidence on urban green spaces with appropriate economic evaluation methods to inform public health policies.

# Part 1: Urban Green Spaces and Health Promotion in the United Kingdom

## 1.1 Health Promotion in the United Kingdom

Health promotion, as defined by the World Health Organization, refers to programmes that enable communities to improve their health through preventative and lifestyle measures (WHO.int). In the United Kingdom, the importance of health promotion programmes has been emphasised by recent policy discussions, particularly in response to the challenges faced by the National Health Service. In 2024, an independent report on the state of the National Health Service in England declared that the National Health Service was in a "critical condition", partly due to an under-investment in public health (Department of Health and Social Care, 2024). In light of the report's findings, the Prime Minister and the United Kingdom government have committed to invest in more preventive care by promoting a "healthy lifestyle" and reduce the burden of curative care on the National Health Service (Courea, 2024).

One key aspect of promoting health and a healthy lifestyle is *physical activity*. An analysis of physical inactivity and non-communicable diseases found that physical inactivity was linked to "almost one in ten premature deaths from coronary heart disease and one in six deaths from any cause" (Lee et al., 2012). In the United Kingdom, physical activity has decreased by 20% since the 1960s, and approximately 42% of women and 34% of men do not meet the current recommendation of 150 minutes of moderate intensity activity per week (GOV.UK, 2022). The consequences of inactivity are substantial, contributing to conditions such as cardiovascular disease, type 2 diabetes, and certain cancers (Lee et al., 2012; National Institute for Health and Care Excellence, 2018). An analysis from 2011 found that physical inactivity costs the United Kingdom government £1 billion every year, which increases to £7.4 billion a year when considering wider societal costs of inactivity, outside the National Health Service (Scarborough et al., 2011).

Another key focus of health promotion for the United Kingdom government is improving *mental health*. The Adult Psychiatric Morbidity 2023/24 survey, a national survey on mental health, found that the prevalence of symptoms for common mental health problems has been increasing since 1993, with the most recent survey from 2023/24 finding that 1 in 5 people aged 16+ had experienced symptoms of a common mental health problem (Morris, 2025). Recent surveys amongst young people and children found stark increases in the prevalence of mental health conditions as 23% of young people aged 17 to 19, and 20% of children aged 8 to 16 had a probable mental disorder in 2023, up from 10% and 12% respectively in 2017 (Baker, 2024). Improving mental health may also be important for the United Kingdom government due its impact on productivity (Grimani, Aboagye and Kwak, 2019; Huo et al., 2022). Labour productivity in the United Kingdom has been relatively

stagnant in the last 20 years, with productivity in the United Kingdom trailing behind major economies such as the United States of America, Germany and (Harari, 2024). The challenges with the decline in mental health were also highlighted as a key issue in the report on the state of the National Health Service (Department of Health and Social Care, 2024).

One of the key priorities outlined in the more recent National Health Service 10 year-plan is to move "from sickness to prevention: power to make the healthy choice" (Department of Health and Social Care et al., 2025). This policy paper stresses the important role of preventative healthcare in improving population health and reducing the burden on curative services (Fernandes et al., 2023; Department of Health and Social Care et al., 2025). An example of a health promotion intervention in line with the National Health Service strategy that has shown benefits for mental health and physical activity is changes to *urban green spaces* (Callaghan et al., 2021; Hunter et al., 2015; Richardson et al., 2013).

### 1.1.1 Interventions for urban green spaces

Urban green spaces (UGS) refer to publicly accessible areas within urban environments that are primarily intended for recreational use and contact with nature (WHO Regional Office for Europe, 2016). These include parks, playgrounds, urban forests, greenways, and other spaces that serve as communal areas for relaxation, physical activity, and social interaction. UGS are distinct from private green areas, such as residential gardens or privately owned urban farms, which are not generally open to the public and therefore not classified as UGS for the purpose of this thesis.

Interventions for UGS can be defined as modifications or improvements to the space. There are a range of different interventions for UGS, typically either designed to encourage more use of the green space, or to improve the user experience for those already using the UGS. Some examples include installing or improving playgrounds to encourage increased physical activity amongst young children or installing outdoor fitness equipment to promote exercise amongst adults. Examples of implemented interventions include building a skate park in a playground to encourage children to use the playground (Cohen et al., 2012), and paving a pathway in a park or UGS to encourage more users to use the UGS for walking, jogging or riding a bicycle (Frank, Hong and Ngo, 2019; Ward Thompson et al., 2019b). Other less targeted examples include improving the aesthetics of the space by improving the greenery (South et al., 2018a) or improving the amenities by adding better signage (Ryan, Hardwicke and Hill, 2023). There is also considerable heterogeneity in the type and range of the modifications, which also affect the impact on health outcomes. For instance, the impact of a change to play areas may have a differential impact compared to improving the greenery. Within categories, the impact of the intervention will also likely depend on the nature

Other researchers have also considered physical activity programmes, such as group fitness exercises as interventions for UGS (Hunter et al., 2019), but for this thesis, the definition of an intervention is limited to capital investments in UGS. This is because the analysis in this thesis is directed towards local authority and local government institutions that may be interested in evaluating UGS interventions or planning for UGS interventions. The majority of spending on public health in England is mediated through budgets allocated to local authorities, but local authorities do not always have the appropriate evidence related to the opportunity cost of these investments (Howdon et al., 2022a). This thesis addresses this gap by generating evidence on the costs, health effects, and cost-effectiveness of capital investments in UGS, to help local authority decision-makers weigh these investments against their opportunity cost. Short-term and personnel-intensive physical activity programmes are resource intensive, and often organised by private providers; therefore, the effectiveness and cost-effectiveness of these programmes was considered a separate research question, beyond the scope of this thesis.

## 1.2 UGS and human development

### 1.2.1 UGS and Health

UGS are considered important *public health investments* as they are associated with numerous benefits for mental and physical wellbeing. A meta-analysis of UGS and health found that for every 0.1 increase in the Normalized Difference Vegetation Index (NDVI), a measure of greenness within 500 metres of a person's residence, there was a 4% reduction in the risk of death from all causes (Rojas-Rueda et al., 2019). "The pathways that may lead to this reduction in mortality are complex, and may include gains through physical activity (Warburton, 2006; Li and Siegrist, 2012; Pearce et al., 2022), improvements in mental health and wellbeing (Liu et al., 2023; Chen et al., 2021), or improvements in environmental factors that can contribute to improved health (Markevych et al., 2017). These pathways have been synthesised in a framework linking greenspace to health through reducing harm, restoring capacities, and building capacities (Markevych et al., 2017).

Much of the research reviewing the association between UGS and health focuses on improvements in physical activity. Green spaces have been associated with improvements in physical activity, through increased walking, cycling, and running. Improvements in physical activity have important health benefits, as they are linked with positive effects on numerous non-communicable diseases, including cardiovascular diseases, cancer, depression and hypertension (Warburton, 2006). A meta-analysis of the impact of physical activity on cardiovascular diseases found that participants with high leisure-time physical activity were likely to benefit from between a 10% to 30% reduction in the risk of coronary heart disease

(Li and Siegrist, 2012). Additionally, a meta-analysis of physical activity and depression found that adults meeting the recommended guidelines for physical activity had on average a 25% reduction in the risk of depression (Li and Siegrist, 2012; Pearce et al., 2022).

A key health outcome linked to UGS is their impact on mental health. A meta-analysis of the effect of living near UGS on depression and anxiety found that a 10% increase in the proportion of green spaces was linked to a 3.7% reduction in the odds of depression and a 6.2% reduction in the odds of anxiety, though the latter was not statistically significant (Liu et al., 2023). Another review on the pathways for the impact of UGS on mental health reported that UGS can improve mental health through (1) environmental factors, (2) social cohesion, (3) physical activity, and (4) the aesthetic appeal of green spaces (Chen et al., 2021).

### 1.2.2 UGS and Education outcomes

Another important but less researched benefit of UGS, is its association with education, as measured through cognitive skills, test scores, and school attendance amongst other metrics. For children, studies have found links between UGS and intelligence, test scores and school attendance. For instance, a recent study in Belgium of students between 7 to 15 years old found that a one quartile increment in residential greenness was associated with on average 2.6-point increase in intelligence quotient scores amongst the children (Bijnens et al., 2020). These findings are similar to another study from Barcelona, Spain, which found a positive association between residential greenness and cognitive function measured by attentiveness and memory amongst 7- to 10-year-old children (Dadvand et al., 2015). However, there is also some uncertainty about the evidence, as a systematic review of the association between UGS and academic performance found mixed results, with most studies (64%) showing a non-significant association with academic performance (Browning and Rigolon, 2019).

UGS may also be linked to cognitive function in adults. A systematic review of urban green and blue spaces found that living near parks was linked to a positive association with cognitive function in adults in 77% of studies (Glover et al., 2024). The authors also reviewed the impact of adults spending time walking or exercising in green spaces and reported positive outcomes for cognitive function in 57.4% of studies (Glover et al., 2024). The authors of the review also contend that no effect may reflect insufficient exposure to nature to produce a measurable impact on cognitive function, instead of reflecting a lack of association between UGS and cognitive function, however, more research is required to determine the minimum dose required for cognitive benefits (Glover et al., 2024).

Researchers have also explored the potential pathways through which UGS influence education. A report by the United Nations Children Fund suggests that there may (Sugar, 2024). Other pathways include enhanced physical development, as green spaces are linked to improved balance and motor coordination, and more physical activity as discussed earlier. Additionally, green spaces are also associated with improved social cohesion and reduced parental stress (Sugar, 2024; Browning and Rigolon, 2019). These pathways have also been reiterated by the authors of a systematic review, with the addition of protective environmental links such as through the impact of reduced air pollution, temperatures and improved biodiversity (Browning and Rigolon, 2019).

### 1.2.3 UGS and Equity

Disparities in health were raised as a major issue in the review of the National Health Service in 2024 (Department of Health and Social Care, 2024) and the potential impact of UGS may be unevenly distributed across populations. Vulnerable and disadvantaged populations often experience poorer health and education outcomes, evidenced by the fact that men from a higher socioeconomic group in the United Kingdom live on average nine years longer compared with men in an unclassified socioeconomic group (ONS.GOV.UK, 2022). Ensuring an equitable distribution of resources is a key criterion for public policy decisions to bridge this divide, and as a result, disadvantaged populations are often prioritised in resource allocation decisions.

A report by Public Health England recommended that the United Kingdom government should “prioritise improving access to greenspace and creating greener communities especially in areas of deprivation” (Public Health England, 2020). This is especially important, given the stark inequities in the current distribution of access to green spaces in the United Kingdom; for instance, a recent report by a non-government organisation, Groundwork, finds that “almost 40% of people from ethnic minority backgrounds live in the most greenspace deprived areas, compared to 14% of White people” (Holland, 2021). This disparity in access to green spaces may further exacerbate existing inequities in health and education outcomes for vulnerable populations.

There is also evidence to suggest that improving access to green spaces for disadvantaged populations leads to higher health benefits, compared with interventions improving access for more privileged populations. A systematic review on green spaces and equity found that even if the green space is of a poorer quality, it provides more benefits to groups of lower socioeconomic-status, compared with higher quality green spaces accessible to higher-socioeconomic status groups (Rigolon et al., 2021). This may be as higher-socioeconomic status groups have better access to substitutes for UGS, especially for physical activity, such as private gym memberships.

### 1.2.4 UGS and other outcomes

Whilst this thesis will primarily focus on the health and education outcomes related to interventions for UGS, there are also broader environmental and socio-economic benefits associated with UGS, such as reduced temperatures, reduced air pollution, changes in crime, improved labour productivity, increased tourism, or improved aesthetics.

With global warming and rising temperatures, environmental outcomes are arguably the most important additional outcome of investing in UGS. Green spaces can help mitigate the impact of global warming by acting as a 'carbon sink' and *sequestering* carbon dioxide from the atmosphere. However, the net carbon impact varies greatly based on factors such as the type of green space and the lifespan of the trees planted, as decomposing trees and the maintenance of the space can also lead to carbon emissions (University of Leeds, 2015). Another important environmental benefit of green spaces is their role in regulating temperatures in urban areas. The 'urban heat island effect' is a phenomenon whereby urban areas with a high population density experience higher temperatures compared to more rural areas. Green spaces can help reduce these temperatures, contributing to further follow-on benefits through reduced energy usage for air conditioners (Aram et al., 2019). For instance, a study in Singapore found that green spaces can reduce temperatures by up to 4 degrees $^{O}$C. (Wong and Yu, 2005).

To a lesser extent, the literature on UGS also examines their broader economic and societal impacts, including effects on employment, productivity, crime reduction, tourism, and energy consumption. For instance, a feasibility study from Lisbon included an economic value for aesthetics and increased employments in its valuation of greening rail stations (Matos Silva et al., 2019). Other evaluations have also included tourism and changes to energy consumptions in their evaluations of investing in UGS (Grosset al., 1981; Hunter et al., 2022; Jones & McDermott, 2018). Studies have also reviewed the links between UGS and crime with more mixed findings (Bogar and Beyer, 2016; Burley, 2018).

Investing in UGS is a complex multi-sectoral intervention with effects across multiple different sectors. The complexity of adequately measuring and attributing the true impact across multiple sectors is a fundamental challenge faced by researchers and policy makers interested in UGS interventions (Bojke et al., 2018; Hunter et al., 2023). This thesis addresses the gaps in the existing literature on UGS using a human development framework centred around health and education outcomes – an approach that is also consistent with other United Kingdom and European government evaluations of green space interventions (HM Treasury United Kingdom, 2020; Institute for European Environmental Policy, 2022; Public Health England, 2020). However, the discussion in chapter 5 elaborates on the scope for future research to extend the findings from this thesis by incorporating other outcomes for a more holistic, policy tailored evaluation.

## 1.3 Interventions for UGS and its impact on health and education

Section 1.2 describes some of the associational evidence of the links between UGS and health, education and wider socio-economic outcomes. The review and empirical research presented in this thesis adds to this evidence base by analysing the impact of *specific interventions* for UGS, such as building playgrounds or improving the greenery, and the impact of each intervention on health and education outcomes. The evidence on specific interventions is more limited, which can make difficult for decision-makers to prioritise between interventions to improve existing UGS or other capital investments.

Studies have shown that interventions such as the development of walkways, improvement of playgrounds, and installation of outdoor fitness equipment can increase physical activity levels, both within the targeted green space and among nearby residents (Sami, Smith and Ogunseitan, 2018; Cohen et al., 2012; Veitch et al., 2018; Panken and Holaly-Zembo, 2015) . In contrast, the relationship between UGS and mental health remains less conclusive. Although greater access to green spaces is generally associated with improved mental well-being, evaluations of specific interventions has found mixed results, as the construction of walkways (Ward Thompson et al., 2019a) found an increase in stress, while a study the greening of vacant lots (South et al., 2018a) reported a reduction in depression.

There is limited literature examining the relationship between UGS interventions and educational attainment. However, some studies have evaluated interventions aimed at greening school environments, which are generally excluded from the definition of UGS, as they are considered private spaces (Fernandes et al., 2023). A review of greening interventions in schools found that improving access to greenery in schools can improve focus and attention to tasks amongst students (Fernandes et al., 2023). The link between greening interventions in school and student attention, the positive associational links described in section 1.2.2, or the positive links with UGS interventions and physical activity could suggest that improving UGS could have follow-on consequences for improving academic performance, but more research is required to test this hypothesis.

## 1.4 Logic Model: UGS interventions and its impact on health and education

Interventions for UGS are complex, with multiple interconnected medium and long-term outcomes. To serve as a foundational conceptual map of these connections between intervention components, pathways, outcomes and impacts, an initial logic model was developed based on the literature examining the impacts of UGS on health and education outcomes, as shown in Figure 1.1 below (Akpinar, 2016; Fitzhugh, Bassett and Evans, 2010; Lee and Maheswaran, 2011; University of Leeds, 2015; van den Berg et al., 2015; Vieira et

al., 2018; World Health Organization Regional Office for Europe, 2016). This prototype logic model was then updated using the results of the systematic review reported in Chapter Two (Raza et al., 2024).

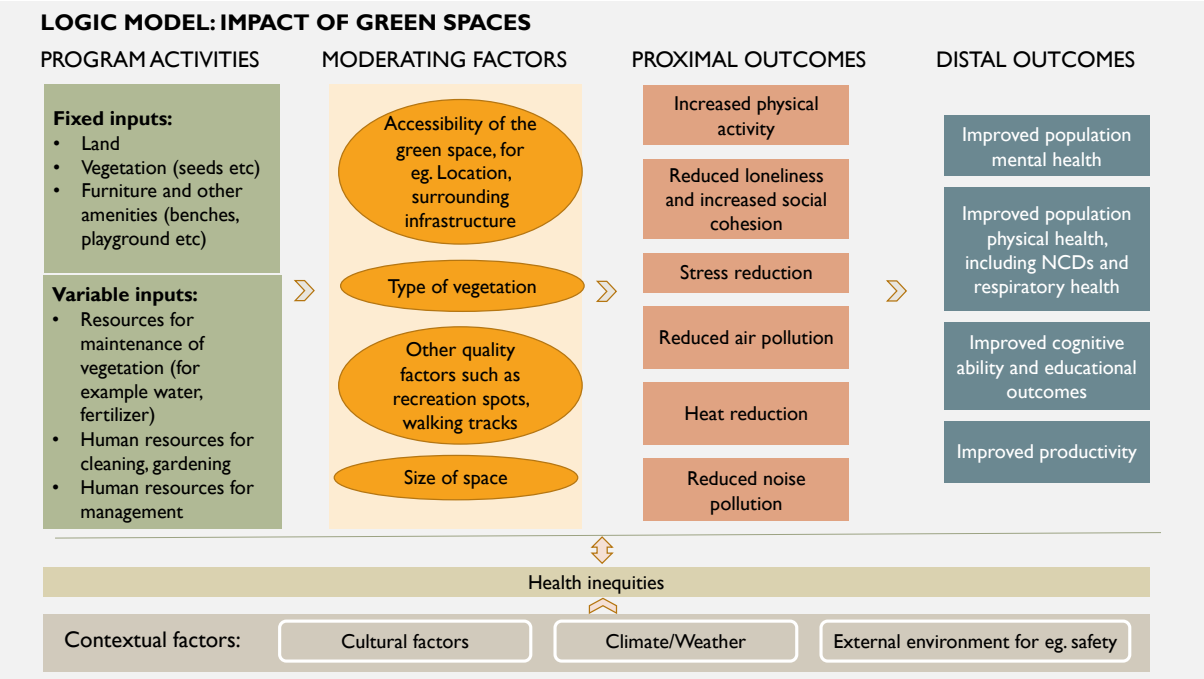



Figure 1.1: Logic Model on the Impact of UGS interventions

The programme activities or interventions in the logic model have been divided into fixed and variable inputs. Fixed inputs include changes to land, vegetation or other amenities in the space, whereas variable inputs include resources used to maintain the quality of the space. There may be a number of moderating factors that can influence the impact of the changes, including the type of green spaces, existing features of the space, and even the size of the space as small pocket parks may be less appealing than large public parks with more room for physical activity. The interventions can have a number of benefits for mental and physical health, as well as environmental benefits such as reducing air pollution which can in turn improve population health.

This logic model illustrates the multifaceted impact of UGS interventions, highlighting the pathways between environmental modifications, human behaviour, and broader societal outcomes. By mapping out the programme activities, moderating factors, and longer-term benefits, the logic model provides a guiding framework for understanding and evaluating the value of UGS initiatives.

Part 2: Economics and decision-making in UGS

## 1.5 Economics, and environmental economics

The premise for making decisions on investments in environmental interventions, such as UGS, has its roots in the study of economics. Economics, as defined by Mankiw (2001) is the study of how society manages its scarce resources. Classical economics emphasises the use of market forces to determine resource allocation, for example Adam Smith introduced the concept of the 'invisible hand', suggesting that markets self-correct to distribute resources in the most efficient way (Smith, 1776). Conversely, Malthus predicted that the existing resource constraints, particularly land, would inevitably lead to population decline and economic stagnation (Malthus, 1798). John Stuart Mill later countered this by arguing that technological progress would increase productivity and prevent the population decline predicted by Malthus (1798). Mill also advocated for government intervention to protect public goods, underscoring the importance of equitable resource distribution (Robbins and Mill, 1979).

The evolution of economic thought progressed with the neo-classical era in the 1870s. Economists like Jevons and Carl Menger focused on consumer preferences and utility[1], laying the foundation for welfare economics (Sandmo, 2015). The concept of utility was further developed by Leon Walras introduced, who introduced the general equilibrium theory, while Alfred Marshall developed the concept of externalities, which are critical for understanding the positive impacts of UGS and forming the basis of environmental economics (Mankiw, 2001).

Environmental economics emerged more prominently in the 20th century, with Arthur C. Pigou's work on pollution taxation (Edgeworth and Pigou, 1913). Environmental crises, such as London's Great Smog in 1952 (Tracton, 2012) and Japan's Minamata disease (Harada, 1995) underscored the field's relevance in the past. More recently, the Covid-19 pandemic has further highlighted the interconnectedness of public health, the environment, and the economy (McKibbin and Fernando, 2023).

## 1.6 Economic frameworks

There are various frameworks used by economists to support decision-making on resource allocation. These frameworks fall under a subdivision of economics called ‘welfare economics’, which is the study of economic policy concerning normative judgements about

[1] Utility can be defined as either benefit, advantage, or pleasure, and therefore maximising utility would be maximising pleasure, benefit, pleasure or advantage.

how resources should be allocated across a society (Perman, 2006). This normative judgment is based on individual and societal utility. Each choice made by an individual reveals his or her preference or utility for that choice; therefore, utility maximisation or the greatest welfare is achieved where individuals have the greatest utility over a choice set.

The marginal costs of an intervention and the utility gained can be compared to an appropriate alternative using an economic evaluation methodology. Economic evaluation can help decision makers identify the value gained from a specific health intervention/programme/service shift, and the value forgone or the opportunity cost of choosing an alternative resource allocation (Drummond et al., 2005). These evaluations may also be used to inform the decision about whether more information is required (Sculpher et al., 2006). In their article, Sculpher et al (2006) outline some of the requirements for an appropriate economic evaluation, including a clear objective function, a consistent perspective, an appropriate time horizon, all relevant evidence, and an appropriate characterisation of uncertainty.

There are different frameworks for conducting an economic evaluation, which mainly differ in their methodology to estimate utility. For example, utility can be measured in monetary terms, as in a cost-benefit analysis, or alternative measures of health specific utility such as health outcomes or quality-adjusted life years (Drummond et al., 2005). This approach using health specific utility falls under extra-welfarism principles and is used in cost-effectiveness analysis or cost-utility analysis. These different frameworks for an economic evaluation are described in more detail below.

### 1.6.1 Cost-benefit analysis

Cost-benefit analysis compares the costs and benefits of alternative interventions in monetary terms; this is the most commonly used approach for decision-making in environmental economics (United Kingdom Health Security Agency, 2020a).

The cost typically refers to the cost of the programme, whilst the benefits are estimated in monetary terms using stated or revealed preferences. Stated preference methods can be used to generate estimates of the monetary value of the benefits using direct feedback from users through surveys; individuals are asked to state their willingness to pay for a certain good or service, a method known as contingent valuation, or using discrete choice experiments whereby individuals are asked to rank their preferences, and the ranking is used to estimate the monetary benefit of a good or a service (Hoevenagel, 1994). Revealed preference methods estimate the monetary benefit through alternative methods such as hedonic price valuation, which uses a regression analysis to predict market values, or the travel-cost method which estimates the value of a service as the monetary amount that

users are willing to pay to access the service (Chintantya and Maryono, 2018; Hanley, Mourato and Wright, 2002).

Environmental economists frequently use cost-benefit analysis to estimate the efficiency of investing in UGS. Much of the research using cost-benefit analysis to evaluate UGS has found that the monetary benefits of an UGS outweigh the cost of its investment (García de Jalón et al., 2020; Karunarathne and Gunawardena, 2020; Mwageni and Kassenga, 2022). Some studies that have evaluated specific types of UGS interventions such as building green roofs or bicycle trails reported mixed results that depend on variables such as weather, energy prices, or the type of roof for green roofs (Nurmi et al., 2016; Wang et al., 2004). Cost-benefit analysiss for UGS have used a range of different outcomes of interest, including noise reduction, stormwater management and physical activity amongst others, and a range of methodologies for valuing the benefit including travel-cost, contingent valuations, and hedonic price value (Anderson, 2018; Chintantya and Maryono, 2018; García de Jalón et al., 2020; Karunarathne and Gunawardena, 2020; Tate et al., 2024; Tyrväinen and Väänänen, 1998).

Cost-benefit analysis is also used for healthcare and other disciplines like transport, although it has had more limited traction in health. Economic evaluations in health economics more commonly use cost-effectiveness analysis or cost-utility analysis, which use generic measures of health outcomes, allowing for comparison between interventions which may have different health outcomes.

### 1.6.2 Cost-effectiveness analysis

A cost-effectiveness analysis is a type of economic evaluation that measures consequences as health outcomes, with cost-utility analysis specifically summarising health outcomes as a composite and generic measure (Drummond et al., 2015). This type of analysis is often used to inform reimbursement decisions in Health Technology Assessments, predominantly to compare between pharmacoeconomic investments such as medicines, diagnostics, and treatments. Examples of cost-effectiveness studies for UGS interventions include studies by Lal et al (2019) and Cohen et al. (2012), both of which estimate the cost per metabolic equivalent hours to assess cost-effectiveness of UGS interventions.

Cost-utility analysis and cost consequence analysis are different types of cost-effectiveness analysis and are described below.

#### 1.6.2.1 Cost-utility analysis

A cost-utility analysis is a type of economic evaluation and cost-effectiveness analysis which uses a more generic, composite measure of health; this type of analysis is most commonly used in health economics, including by national bodies such as the National Institute for Health and Care Excellence or Haute Autorite de Sante in France, to support decision-making around which clinical interventions should be funded by the government (Haute Autorité de Santé; Robinson, 1993; United Kingdom Health Security Agency, 2020c).

Some of the generic measures of health include quality-adjusted life years, disability-adjusted and healthy-years equivalent (Drummond et al., 2015). These summary measures for a population combine morbidity, 'health-related quality of life measures' and mortality to generate a single utility metric that can be used to estimate an individuals' health status.

Whilst cost-utility analysis is not as commonly used for green space interventions, there are examples of cost per quality-adjusted life year being used for green spaces such as this study by Thompson et al (2019a), or other areas of environmental health such as air pollution (Public Health England, 2018).

#### 1.6.2.2 Cost-consequence analysis

A cost-consequence analysis lists costs and outcomes separately, to provide more information across sectors to decision-makers in their evaluation (United Kingdom Health Security Agency, 2020b). Cost-consequence analysis differs from cost-utility analysis and cost-benefit analysis in that it does not summarise the benefits in a single metric but presents all the outcomes to decision-makers to use in deliberation and decision-making (United Kingdom Health Security Agency, 2020b). These characteristics are especially relevant for cross-sectoral interventions such as green space improvements, where a local authority may fund the investment while the benefits are across the health, education, and environment sectors. Reflecting this, while National Institute for Health and Care Excellence specifies cost-utility analysis as its reference case, it also recognises cost-consequence analysis (alongside cost-benefit analysis) as an appropriate approach for evaluating public health interventions whose impacts span multiple sectors and are not fully captured by quality-adjusted life years alone (National Institute for Health and Care Excellence, 2012)

Despite these advantages, there is still relatively limited use of this methodology so far. An example of a cost-consequence analysis for a UGS intervention is the analysis by Ward Thompson et al (2019) which provides a table of the measured impacts of investing in green spaces including social cohesion, physical activity and stress.

### 1.6.3 Social Return on Investment

Social Return on Investment is another economic framework used to evaluate public health interventions, including green space interventions. An Social Return on Investment approach quantifies the benefits across multiple sectors including social, environmental, and economic benefits using a participatory stakeholder process. It differs from a cost-consequence analysis in that it quantifies each benefit, and from a cost-benefit analysis by incoporating stakeholder valuations to estimate the monetary value of additional impacts such as social benefits.

There is still limited application of an Social Return on Investment for an UGS interventions, but an example by Hunter et al (2022b) to evaluate an urban greenway in Belfast estimated the impact on land and property values; flood alleviation; tourism; labour employment and productivity; quality of place; climate change; and health (Hunter et al., 2022b). The authors monetised the effects on each parameter to find that benefit-cost ratio ranged from 2.88 to 5.81 (Hunter et al., 2022b).

## 1.7 Decision-making on UGS: Different approaches to the same problem

The multi-sectoral impacts of interventions for UGS means that these interventions are relevant for urban planning, health care, biodiversity and environmental management, labour productivity, disaster management, sports, and education.

Urban planners, environmental economists, and local authorities typically use either a cost-benefit or a Social Return on Investment approach to evaluate interventions like UGS. For cost-benefit analyses and Social Return on Investment analyses the impact of UGS is typically measured using monetary values of their health and environmental benefits. A limitation of Social Return on Investment and cost-benefit analysis for UGS evaluations is the challenges in comparability and generalisability due to (i) the heterogeneity in the methods used to monetise outcomes, for example the travel-cost method (Parsons, 2003) versus contingent valuation (Springer Berlin Heidelberg) and (ii) different researchers may consider different outcomes of interest, for example leisure value vs environmental value as seen in table 1 below (Chen and Jim, 2008; Heidari, Schmidt and Minsker, 2022). Social Return on Investment, in particular can also be resource and time intensive as it requires stakeholder engagement to quantify the benefits.

Cost-utility analysis may be better suited for comparability as it uses a single summary indicator for health, most commonly quality-adjusted life years or disability-adjusted life

years[2] . The ease of comparability is a key reason why this methodology is recommended by decision-making bodies like National Institute for Health and Care Excellence in the United Kingdom, or Haute Autorite de Sante in France to compare between interventions, with a goal of maximising health consequences of each outcome separately, but there is limited guidance on how to use this information for prioritisation and decision-making (United Kingdom Health Security Agency, 2020b). A table of each methodology and its strengths and limitations can be found in Table 1.1 below.

Table 1.1: A comparison of features between CEA, SROI, CBA, and CCA (Banke-Thomas et al., 2015; UK Health Security Agency, 2020b, 2020a, 2020c)

| **Criteria** | **Cost-Effectiveness Analysis (CEA)** | **Social Return on Investment (SROI)** | **Cost-Benefit Analysis (CBA)** | **Cost-Consequence Analysis (CCA)** |
|---|---|---|---|---|
| Scope | Only evaluates a single outcome | Evaluates multiple outcomes, but can be complex and time-consuming | Focuses on the monetary benefits | Presents impacts across outcomes, making it difficult to rank or compare interventions. |
| Comparability Across Interventions | Easy to compare with other interventions using CUA | Highly context-dependent, meaning results vary between locations and stakeholders. | Results are highly sensitive to monetisation techniques. | Since multiple outcomes are presented separately, decision-makers must weigh trade-offs subjectively. |
| Equity Consideration | Typically, does not incorporate equity considerations, however distributional CEA does explicitly include equity considerations | Can focus on equity, but subjective in determining stakeholder weightings. | Focuses on net benefits, without explicitly considering equity considerations | Can highlight distributional effects but does not provide an explicit comparison method. |

[2] DALYs are disability adjusted life years, which combines years lost due to premature mortality with years lost due to disability. DALYs are more commonly used in lower and lower-middle income countries – more information can be found here: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158#:~:text=DALYs%20for%20a%20disease%20or,health%20condition%20in%20a%20population.

A cost-effectiveness analysis approach was considered the most appropriate economic framework for this thesis for several reasons. A cost-effectiveness analysis approach has been recommended by National Institute for Health and Care Excellence for Health Technology Assessment processes and public health interventions where appropriate, and this air pollution (NG70) (National Institute for Health and Care Excellence, 2017, 2018). A cost-effectiveness analysis is considered appropriate by National Institute for Health and Care Excellence (NICE) as it meets their objectives for maximising health gains from a specific national health services budget (National Institute for Health and Care Excellence, 2022). The choice of framework is not prescribed by any single authority; rather, it is determined by the decision problem and the objective of the decision-maker the analysis is intended to inform. Where the aim is to establish whether an intervention is cost-effective and to rank it against alternatives under a fixed budget, a cost-effectiveness analysis is appropriate, as it provides a decision rule that a cost-consequence analysis does not. This thesis adopts a cost-effectiveness analysis on that basis, reflecting both its research question and the health-maximisation objective of the bodies, such as National Institute for Health and Care Excellence and local authorities, that its findings are intended to inform. A cost-consequence analysis approach was also considered, but ultimately not used as a cost-consequence analysis lists the consequences without a decision rule on how to use or weigh the different evidence bases. Therefore, it was considered more descision-friendly to use Cost-effectiveness analysis, which has already been used by National Institute for Health and Care Excellence for other public health interventions

Local decision makers may be interested in the financial and budgetary impact of the investments for UGS (Howdon et al., 2022a). To address this gap, chapter 3 and chapter 4 include additional calculations for net monetary benefit and budgetary impact. Chapter 3 consolidates the evidence from the systematic review to estimate the net monetary benefit of different investments in UGS, which is an approach that combines the cost, effect and the opportunity cost of health to estimate the expected monetary benefit or the cost-effectiveness of each intervention. Chapter 4 estimates the impact of the intervention on mental health prescriptions, and this analysis is used to predict budget impact or savings from changes in prescriptions.

## 1.8 Challenges in evaluating UGS interventions

Bojke et al. (2018) highlight several key challenges in conducting an economic evaluation of environmental interventions, which are equally relevant to UGS initiatives. These challenges include the cross-sectoral nature of costs and effects, establishing causality, measuring and valuing long-term outcomes, and addressing equity concerns with limited data, as illustrated in Figure 2.

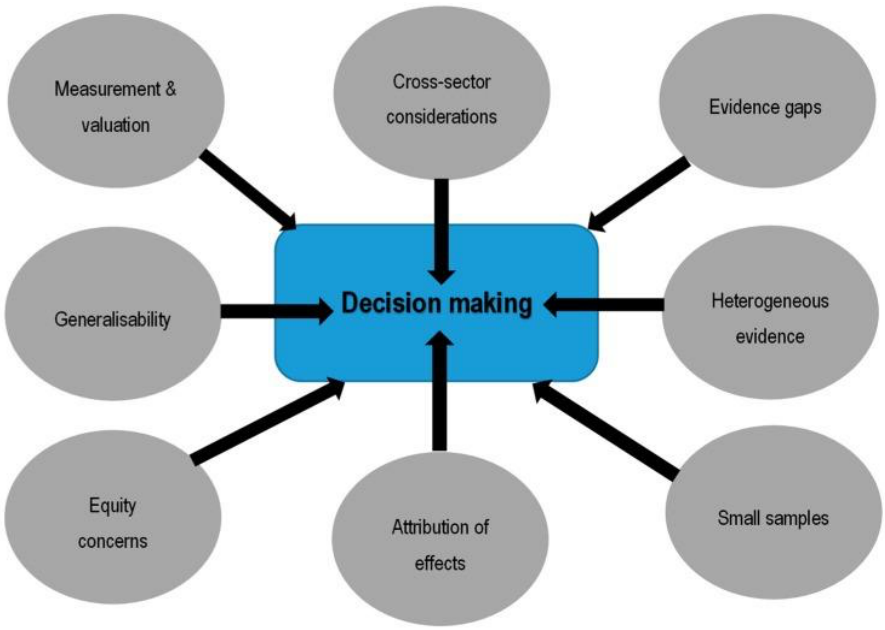



Figure 1.2: Challenges in public health evaluation, developed by (Bojke et al., 2018)

Multi-sectoral Impacts: Interventions targeting UGS have multi-sectoral impacts that extend to health, education, and the environment. Quantifying these impacts is complex because benefits span multiple sectors, for example, a new park might improve physical health through increased physical activity, enhance mental well-being, and offer educational opportunities through environmental awareness programmes (Kruize et al., 2019).

Measurement and Valuation Challenges: Quantifying the benefits of UGS interventions is challenging. Physical activity can be measured using various tools such as self-reported surveys, observation, or accelerometers (Tudor-Locke and Myers, 2001). While accelerometers provide more accurate data than self-reported measures or other observational methods, they may be cost-prohibitive for large-scale, long-term studies (Lee and Shiroma, 2014). Mental health and cognitive performance are similarly difficult to measure due to varying definitions, assessment tools, and subjective reporting.

Scale and Time-frame Limitations: UGS interventions often target large populations over extended periods (Hunter et al., 2023). Evaluating such interventions in real-time or over their full impact duration is often impractical. Longitudinal studies require substantial resources and time, which may not align with funding cycles or policy decision timelines (Bojke et al., 2018).

Equity and Generalisability: Equity is another significant challenge in evaluating UGS interventions (Agyeman, Bullard and Evans, 2002). Different population groups experience varied benefits from UGS, and it is important to assess the distributional effects of the interventions. However, collecting data to capture these differences can be difficult,

especially in underrepresented populations (Bojke et al., 2018). Generalising results from one context to another is complicated by factors such as local climate, crime rates, transportation infrastructure, demographic characteristics, and cultural attitudes towards green spaces (Battiston and Schifanella, 2023) .

These challenges have been further highlighted in the chapters on public health in the recent National Institute for Health and Care Excellence guidelines (National Institute for Health and Care Excellence, 2024b). The guidelines also highlight concerns with context sensitivity, measurement difficulties and the lack of randomised control trials for public health interventions (National Institute for Health and Care Excellence, 2024b).NICE guidelines and a review by Bojke et al (2018) outline that evaluations of UGS interventions must navigate a complex landscape of multi-sectoral impacts, measurement challenges, and contextual variables. Addressing these challenges requires comprehensive data collection strategies, consideration of equity implications, and methodologies that accommodate the long-term and large-scale nature of UGS projects.

## 1.9 Estimating the cost-effectiveness of UGS interventions: Addressing gaps in the literature

This thesis will attempt to address some of the limitations and the gaps in the literature highlighted above. Whilst there is broad associational evidence of the relationship between UGS with health and education, there is limited information on specific interventions and their impact on human development through health and education. Chapter two addresses this gap in the research through a systematic review of the literature on UGS interventions, and its impact on health and education. Subject to data availability and comparability, this review was intended to include a meta-analysis, forming the bases of effect estimates that could be used to populate an economic evaluation. However, due to the data limitations, this was not possible. Instead, chapter two includes a critique of the literature, a narrative synthesis and conclusions regarding the suitability of the studies reviewed to inform an economic evaluation.

One of the challenges identified in chapter two is that of measuring and evaluating UGS interventions, specifically due to data limitations including heterogeneity of evidence, lack of generalisability, and short time-frames. To address this gap, a toolkit was developed which synthesises all existing evidence on UGS interventions and physical activity, using a long-term time frame and multiple scenarios. The model in the toolkit allows users to calculate the expected net monetary benefit and the probability of cost-effectiveness for specific changes to UGS. Chapter three describes the methodology and results for the United Kingdom for the toolkit, which was developed using evidence from the systematic review in chapter two. The toolkit also allows users to estimate scenarios with a long-term benefit and different waning effects to accommodate uncertainty in the evidence.

The toolkit described in chapter three uses the evidence on physical activity, as there was not sufficient evidence to consolidate on mental health. To address this gap, Chapter four uses a natural experiment to evaluate the effect of an UGS intervention on mental health outcomes, using a case study from Bradford, United Kingdom. This study uses data on mental health prescriptions and a difference-in-differences model to estimate whether changes in urban green spaces may lead to an impact on mental health prescriptions for those living in the intervention area.

These contributions introduce new evidence on the effectiveness and cost-effectiveness of interventions for UGS, moving the discussion beyond the associational benefits of UGS, towards more specific consideration of the value for money of investments in UGS interventions, in comparison with ther potential iunvestment opportunities. This evidence may prove helpful for policy makers in local authorities that are responsible for investing in public health, at a time where healthcare facilities are overburdened and mental health has declined sharply. Further research may expand on the findings from this thesis by investigating the impact of additional outcomes, such as environmental or broader social outcomes, and by exploring the distributional effects of interventions for UGS. Chapter 5 discusses the limitations of the findings from this thesis and identifies areas for further research.

## Chapter 2: A Systematic Review of the Impact of Changes to Urban Green Spaces on Health and Education Outcomes, and a Critique of Their Applicability to Inform Economic Evaluation

Preface

As noted in the background, most of the literature on green spaces is associational and does not specifically review interventions for urban green spaces. There are also various types of interventions for urban green spaces, which made it difficult to find all the studies that may have reviewed more specific changes to UGS. Therefore, a systematic review of all potential studies in the literature was considered appropriate to identify any evidence on the research question for this thesis, which is related to the economic value of interventions for UGS.

The review followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines (Page et al., 2021), and the search strategy was developed with the support of an information specialist. We found that it was not possible to list all the different types of UGS interventions, and therefore the search was not limited by intervention type. This led to a high volume of articles in the initial search but allowed for a more comprehensive search of the database.

The research question for this thesis is also focused on the economic value of the interventions, so one of the questions for the review was around the use of evidence for an economic evaluation. The review therefore includes a section on the critique of the studies using a criteria set out by Sculpher et. Al (2006).

A slightly condensed version of the systematic review has been published in International Journal of Environmental Research and Public Health:

> **Raza, W**., Bojke, L., Coventry, P. A., Murphy, P. J., Fulbright, H., & White, P. C. L. (2024). A Systematic Review of the Impact of Changes to Urban Green Spaces on Health and Education Outcomes, and a Critique of Their Applicability to Inform Economic Evaluation. *International Journal of Environmental Research and Public Health*, *21*(11), 1452. https://doi.org/10.3390/ijerph21111452

Author contributions (CRediT): W. Raza — conceptualisation, methodology, investigation, formal analysis, writing – original draft. L. Bojke, P. A. Coventry, P. C. L. White — conceptualisation, supervision, writing – review & editing. P. J. Murphy — investigation (second-reviewer screening), writing – review & editing. H. Fulbright — methodology (search strategy development).

## 2.1 Abstract

Several reviews have consolidated the evidence on the impact of living near an urban green space on improving health and education outcomes and reducing mortality. However, there is limited evidence on the effectiveness or cost-effectiveness of specific improvements to these urban green spaces, which would help decision-makers make informed decisions on how to invest in urban green spaces. Therefore, this review synthesises the impact of more specific changes to, or investments in, urban green spaces on health and education outcomes, synthesises the cost-effectiveness of these interventions, and critiques the applicability of the evidence for an economic evaluation. We find that interventions targeted towards improving play areas or fitness equipment tended to have mostly positive impacts on physical activity, while interventions on improving walking paths, or the overall greenery showed a more mixed impact on physical activity. There were only two studies on the impact of changes to urban green spaces on mental health, with only one finding a positive association of the intervention with depression, and there were no studies measuring the impact of changes to urban green spaces and educational outcomes. From a cost-effectiveness perspective, we find that typically very small improvements are required to make the interventions a cost-effective policy choice; however, we found several limitations with using the existing evidence to estimate the cost-effectiveness of the intervention. Overall, we found that most of the evidence does suggest that improvements to urban green spaces can lead to improvements in physical activity, but further research is needed on the impact on mental health and educational outcomes. Furthermore, additional evidence with longer time horizons, multi-sectoral benefits, distributional outcomes, and more consistent outcome measures would assist in informing cost-effectiveness and may ultimately lead to improved decision-making around investments for UGS in specific contexts.

Keywords: urban green spaces; mental health; physical activity; education; economic evaluation

## 2.2 Introduction

Evidence on cost-effectiveness is used to support decision-makers to make informed choices about how to allocate scarce resources. For many high-income countries like the United Kingdom, cost-effectiveness studies are used in formal decision-making processes before approving any new treatments for funding, and only treatments that provide sufficient value for money are included in the services provided by the National Health Service (National Institute for Health and Care Excellence, 2012; Haute Autorité de Santé).

More recently, economic evaluations have also been used to compare cross-sectoral public health investments such as building cycling trails or implementing health taxes (Kriit et al., 2019; Rissel et al., 2013; Mulcahy et al., 2022; Andreyeva et al., 2022). While clinical economic evaluations typically use evidence from randomised controlled trials to isolate the health impact of the specific treatment, conducting a randomised controlled trial is not typically possible for public health interventions. Additionally, public health interventions can have impacts on multiple sectors, making it far more challenging to estimate their full impact (Bojke et al., 2018; Weatherly et al., 2009). Moreover, public health interventions are likely to incur benefits over the longer term, and it may not be feasible to collect data for the timeframe required (Bojke et al., 2018). These challenges in conducting cost-effectiveness analysis, especially around the lack of data, may lead to suboptimal resource decisions including under or over-funding of public health interventions.

One type of public health intervention that may incur some of the complexities described above are interventions to change or improve urban green spaces. These interventions can include making improvements to greenery by planting more trees, paving pathways for walking or cycling, or installing and improving amenities like streetlights, benches or public toilets. A recent example from the United Kingdom is the improvements of parks across the country by planting trees, improving the cleanliness of parks, and improving park infrastructure (gov.uk, 2022). While these investments in urban green spaces are often met with public support, there is limited evidence on the impact of specific improvements to green spaces. Part of the popularity of these interventions stems from the overall associational evidence of the benefits of urban green spaces. For example, use of green spaces can decrease overall mortality (Rojas-Rueda et al., 2019)improve mental health (Vanaken and Danckaerts, 2018; Zhou et al., 2022) and improve cognitive abilities or educational outcomes (de Keijzer et al., 2016), but there is limited evidence on the benefits arising from specific improvements to these green spaces. The literature on this subject also typically treats all urban green space the same by using a single variable on green cover or proximity to green spaces, and there are limited studies which measure the impact of specific interventions or changes to the features of urban green spaces. Additionally, studies typically report on outcomes for a single sector, despite evidence that urban green spaces

have impacts on both health and education outcomes (Dadvand et al., 2015; Akpinar, 2016; Kruize et al., 2019; Nguyen et al., 2021a; Bojke et al., 2018).

A meta-narrative synthesis conducted in 2019 consolidated some of the multi-sectoral outcomes of interventions for urban green spaces, finding that individual programmes such as physical activity groups in the park are relatively more effective compared with infrastructural investments (Hunter et al., 2019). However, Hunter et al did not cover evidence on the effectiveness of urban green space interventions for health outcomes, or their impact on educational outcomes. Overall, evidence on the cost-effectiveness of these interventions is sparse and there are no reviews consolidating the economic evidence of interventions for urban green spaces.

Sustainable methods for improving health and education are included in the sustainable development goals for 2030 (United Nations, 2015). Furthermore, health and education are investments that can improve productivity and reduce health care utilisation (Chevalier et al., 2004; Lenneman et al., 2011; Andersen, 1995). Therefore, the health and education outcomes pertaining from green space interventions, and the cost-effectiveness of these interventions, will be important for decision makers to support prioritisation decisions between different types of investments in urban green spaces, or in decisions to invest in urban green spaces compared to other capital investments.

This systematic review addresses this gap by consolidating the evidence on the health and educational benefits of urban green space modifications, understanding that any improvements in health and educational outcomes need to be placed into the context of the costs incurred, and assess the applicability of this evidence to inform economic evaluation. This review aims to support decision makers in making choices about capital investments in green spaces. We therefore did not include any programmes such as group fitness activities in our definition of a modification to an UGS.

### 2.2.1 Aims and Objectives

This review is divided into two sections; the first part consists of a systematic review of modifications to urban green spaces to answer the following research questions:

RQ1. How do changes to the features of urban green spaces impact common physical health and mental health outcomes?
RQ2. How do changes to the features of urban green spaces impact common educational outcomes such as test scores, school attendance, or educational attainment?
RQ3. Do the health and education outcomes of urban green space interventions reflect a cost-effective policy choice?

RQ4. What is the aggregated quantitative impact of urban green spaces on health and education outcomes?

The second part of this review is a critical analysis of the strengths and limitations of the existing evidence to inform economic evaluation. This critique uses the criteria set out by Sculpher et al (2006).

## 2.3. Methods

### 2.3.1 Protocol registration:

This review is reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 updated guidelines (Page et al., 2021). This review was registered on PROSPERO (CRD42022352737).

### 2.3.2 Eligibility criteria:

There is no clear consensus on the definition of an urban green space, but the definition of urban green spaces used by the World Health Organization in their report in 2016 (World Health Organization Regional Office for Europe, 2016) has been widely used and was considered appropriate for this review. Their definition focuses on *publicly accessible green spaces in urban areas with a primary recreational purpose*, such as parks, fields, and urban woodlands. It also includes green spaces linked to water bodies, for example, the greenery surrounding rivers and lakes.

*Interventions* for green spaces were defined as any modification to specific features or characteristics of the urban green space such as changing the vegetation in the space, improving access to the space, or improving walking pathways.

As per the definition of intervention, studies that did not specifically address a change in an urban green space or studies outside an urban setting were excluded from the review. We also excluded any individual-level behaviour change interventions aimed at increasing the use of the urban green spaces, as the interventions of interest are limited to population-based modifications. The sources we searched included peer-reviewed literature including reviews, original publications, dissertations, and conference papers. Letters, editorials and opinion pieces were excluded from the search strategy and inclusion criteria.

This review also included *economic evaluations* of interventions or modifications in the features on urban green spaces which focus on health and education outcomes. As

economic evaluations fall within the scope of the review, these were identified and extracted separately. Although there were no specific search terms related to economic evidence, as the overall review is broader than economic evaluations, the economics database EconLit was searched on the Ovid platform. The PICOS (population intervention comparator outcome and study design) for the review is outlined in Table 1 below.

Table 2.1: PICOS inclusion criteria

| | |
|---|---|
| **Population** | All adults and children > 1 year using an urban green space |
| **Intervention** | Modifications or improvements to urban green spaces, for example, installing more trees, refurbishing play areas or installing amenities like benches |
| **Comparator** | Pre-intervention population or control green spaces or a combination |
| **Outcomes** | Summary health indicators, including DALYs, QALYs and HEALYs<br>OR<br>Incidence and prevalence of common mental health outcomes including depression, anxiety and mood disorders.<br>OR<br>Commonly associated physical health outcomes related to green spaces including physical activity.<br>OR<br>Commonly measured educational outcomes including test scores, educational attainment, and cognitive ability.<br>OR<br>Monetary outcomes for e.g. Costs saved from health benefits.<br>OR<br>Cost-effectiveness ratios, including benefit-cost ratios.<br><br>Other multi-sectoral outcomes reported only in combination with at least one of the health and education outcomes listed above, with an explicit acknowledgment of the bias in results. This includes:<br>Environmental outcomes<br>Crime and safety<br>Broader wellbeing indicators<br>Broader economic benefits (real estate pricing, tourism) |
| **Study design** | Cohort studies, or case control studies. |

### 2.3.3 Search Methods:

The searches were designed to systematically identify studies on urban green spaces, with health and education outcomes. An Information Specialist (HF) was consulted to advise on the strategy.

An initial search strategy was developed in Ovid MEDLINE and the PICOS was used to define the concepts of the topic and the structure of the searches. The strategy included terms to represent the various concepts: urban green space, health outcomes and education outcomes. No date, language or geographical limits were applied to the original searches.

Search strategies for all databases were run again in March 2024 to include any new articles from between 2022 (the year of the original searches) and 2024. The same search strategy was used in the update searches, except for the inclusion of date limits from 2022 – Current. Records from both the original and update searches were deduplicated using Endnote.

The search strategies for the original searches in March 2022 can be found in Appendix 1. A breakdown of the PRISMA diagram with the number of articles screened in the original and update searches can be found in Figure A2.1 in Appendix 1.

### 2.3.4 Information Sources:

The following databases were searched in March 2022 and March 2024: Medline (via Ovid), Embase (via Ovid), PsycINFO (via Ovid) EconLit (via Ovid) Social Science Citation Index (via Web of Science), ERIC (via EBSCO), Cochrane CENTRAL (via Wiley), and Cochrane CDSR (via Wiley).

These databases were chosen to obtain literature across multiple disciplines including health, psychology, education, social sciences, and economics. This broad selection of sources was important to understand multi-sectoral outcomes of the interventions.

### 2.3.5 Selection Process

The review was completed using a two-step strategy using the software Rayyan (Ouzzani et al., 2016): (1) title and abstract review and (2) full-text review. The primary reviewer WR screened titles and abstracts for all articles and a secondary reviewer PM reviewed 10% of all the articles. The 10% was chosen for pragmatic reasons given the large search results. Any disagreements were discussed in detail, until there was consensus on the decision.

Additionally, articles that did not clearly meet the inclusion criteria were discussed further with LB, PC and PW to reach agreement on inclusion.

### 2.3.6 Data items and collection

For each study, data were extracted for the following: article title; year published; country; target population; setting; data collection period; study design, data collection methodology; sample size; type of green space; intervention type and details; comparator type and details; primary education outcome and details; primary health outcome; health outcome tool (if applicable); health outcome measure; primary health outcome results; secondary health outcome; secondary health outcome tool (if applicable); secondary health outcome measure; secondary health outcome results; relevant disease area/ risk factor; other outcome measures; other outcome results. For studies that included an economic evaluation, data were also extracted for the fields: type of economic evaluation; perspective for economic evaluation; population, intervention details, comparator details, and limitations as shown in the data extraction form in Appendix 3.

### 2.3.7 Risk of bias:

All included articles were assessed for a risk of bias using the checklist in Appendix 2. This checklist has been adapted using the National Institute for Health and Care Excellence checklist on quantitative intervention studies (National Institute for Health and Care Excellence, 2012), the Newcastle-Ottawa Scale for non-randomised studies, (Wells et al., 2000) and a systematic review of green spaces and cognition (de Keijzer et al., 2016). This checklist includes information for internal and external validity, as well as any risk of bias in the outcomes reported. For economic evaluations, we used the updated CHEERS checklist to evaluate risk of bias as shown in Appendix 2 (Husereau et al., 2022)

### 2.3.8 Synthesis methods:

Following the full text review, the articles were categorised according to the type of green space intervention to support more meaningful inferences on the impact of specific interventions. The categories were developed based on the type of capital investments, and the expected behaviour change from the intervention. For example, investments related to paving pathways or expanding pathway was considered a separate type of intervention that may be targeting increased walking, running or biking on the pathway. Similarly, installing or improving playgrounds was considered a separate type of intervention that would involve capital investments related to equipment, and encourage local physical activity for specific age groups in that specific area. We also planned to synthesise the quantitative evidence on

the effectiveness of green space interventions subject to the availability of data, and sufficient consistency across study outcomes.

A logic model was developed to define the theory of change for modifications to urban green spaces. Given this is a complex intervention with multiple long-term and intermediate outcomes, a logic model can help to understand the pathways to change, and the multiple impacts (Craig et al., 2008). The logic model can also serve as the conceptual basis of an economic evaluation by identifying all potential parameters of interest for the model. An initial version of the logic model was presented in chapter 1 of this thesis (Lee and Maheswaran, 2011; World Health Organization Regional Office for Europe, 2016; The land trust, 2018; University of Leeds, 2015; Akpinar, 2016; Vieira et al., 2018; Nguyen et al., 2021b; Hillsdon et al., 2006). The logic model was then updated after reviewing the articles in this systematic review.

Lastly, this review includes a critical appraisal of the literature on evaluations of interventions for urban green spaces, and the applicability of this evidence to inform an economic evaluation. This critical appraisal was conducted using the criteria set out by Sculpher et al. (2006) to evaluate the extent to which this evidence can be used to inform an assessment of cost-effectiveness. The review by Sculpher et al. (2006) evaluates the use of randomised control trials for conducting an economic evaluation, by presenting what parameters would be included in an ideal economic evaluation. As part of this review, we extend their analysis to critique the existing literature on green space interventions against the ideal economic evaluation standard to highlight the limitations with the existing research, and provide direction for further research. Since economic evaluations include effectiveness evidence, all articles included in this review have been included in the critique; for studies that did not include an economic evaluation, this critique addresses the limitations in using the information on effectiveness for a cost-effectiveness analysis.

## 2.4. Results

### 2.4.1 Study characteristics

Our search identified 9884 results after de-duplication, and 182 articles were included for full-text screening after title and abstract screening. Two articles used the same study, so a total of 29 articles and 28 studies were included in the analysis after full-text screening.

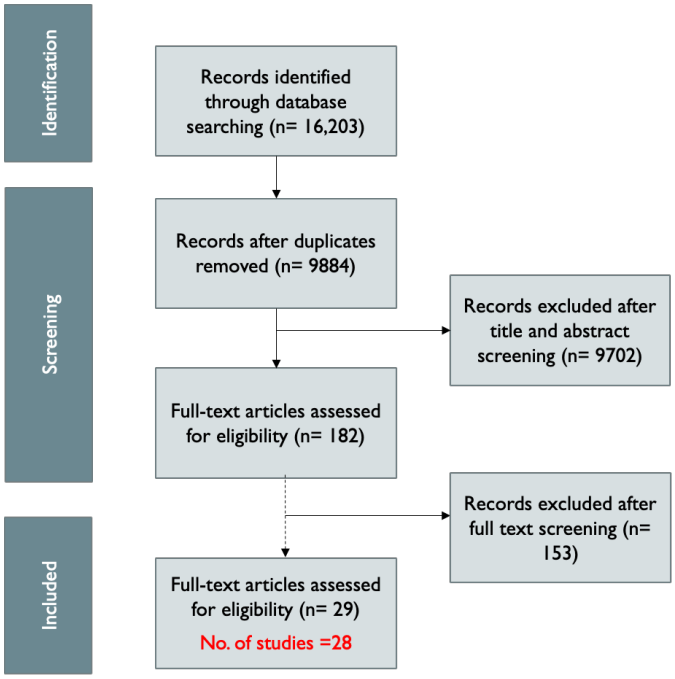



Figure 2.1: Study selection

Of the 28 studies included, 27 were from high-income countries, including United States (11), United Kingdom (6), Australia (5), Netherlands (2), Denmark (2), Canada (1) and Norway (1). There was only one study from an Upper-Middle income country, South Africa. Most studies (18) used a combination of pre-post and case-control study design, while five studies used a case control study design, and six studies used a pre-post study design. Parks and walking/cycling routes were the most common types of green spaces with 14 and 9 studies on each respectively, and one study was based on a walking route inside a park. A further three studies looked at open public green spaces and one measured the impact on an urban woodland. A total of three studies were economic evaluations which considered both the effectiveness and cost-effectiveness of their urban green space interventions.

There were no studies measuring improvements in educational outcomes. Most studies (25) defined physical activity as their primary outcome of interest, followed by self-reported mental health outcomes (2) and overall quality-adjusted life years (1). There was a range of different data collection methodologies, including observation using tools like System for Observing Play and Recreation in Communities, surveys, accelerometers, and manual or digital counters.

### 2.4.2 Risk of bias

All included studies had a moderate risk of bias, as shown in table 1 in Appendix 2. Some of the common limitations included a short follow-up period, a lack of confounders for studies

that used observation as the data collection methodology, or a lack of external generalisability to the overall population, especially for studies using observation.

### 2.4.3 Logic model

Figure 2.2 below is a logic model which outlines the pathways for change from improvements to urban green spaces, including the potential short- and long-term impacts of these changes (Craig et al., 2008). This visual representation of the process of short-term and long-term impact may serve as a first step towards building an economic model.

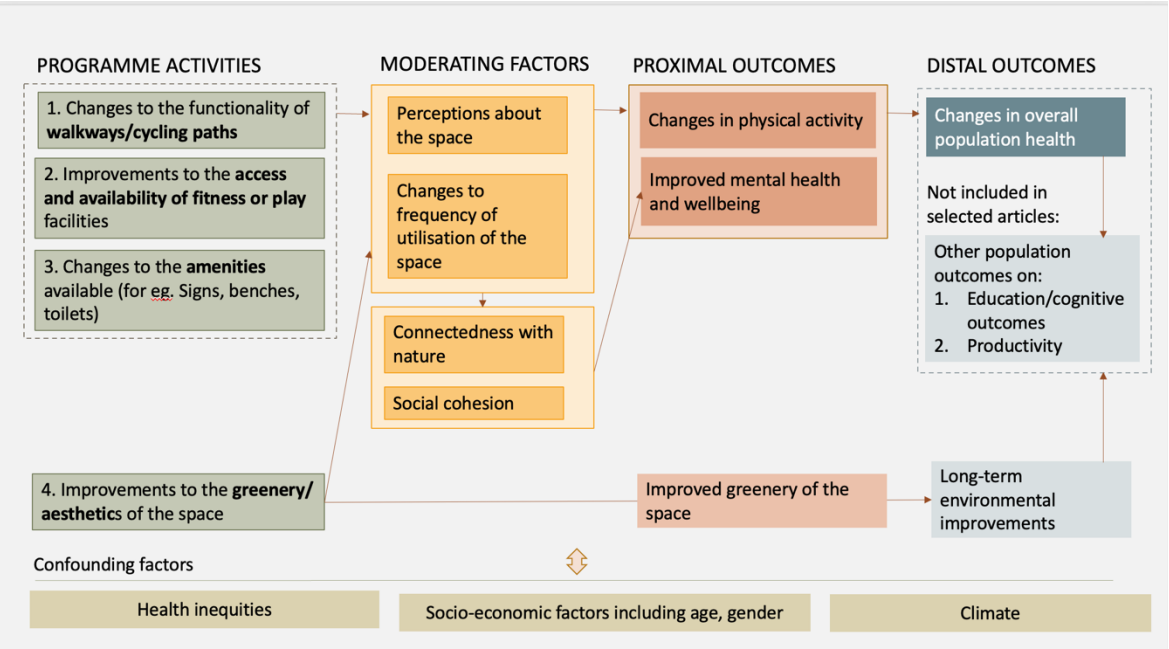



Figure 2.2: Logic model for the impact of modifications to the features of urban green spaces.

Following the review, the programme activities or interventions in the logic model have been divided into the four categories shown in Figure 2.2. Each intervention, for example improvements to the greenery such as planting more trees, may lead to changes in the perception of the space or the frequency of utilisation of the space, which may in turn lead to increased physical activity. An increase in physical activity has longer term benefits for overall health, education attainment, and productivity (Erlichman, Kerbey and James, 2002; Keeley and Fox, 2009). Improvements to urban green spaces may also increase frequency of utilisation, which could lead to improved mental health by improving connectedness with nature and other individuals in the public space. Improved mental health has longer term consequences on physical health, educational attainment, and productivity (Doran and Kinchin, 2019). Improvements to green spaces may also lead to environmental improvements including reduced air pollution, lower temperatures, and increased carbon capture, and some of these improvements such as the reduction of air pollution may have

secondary and more diffuse benefits for public health, with implications for healthcare. However, as this review focuses on the primary impacts of changes to green spaces on the health of the users of these green spaces, rather than any secondary or more diffuse effects that may extend to people not actively using the space, these relationships have not been explored further in this paper.

The four categories of interventions defined in the logic model have been used to synthesise the results in the next section.

### 2.4.4 Synthesis of findings

The findings from the review have been organised in categories to support more meaningful inferences on the impact of interventions. The four categories are as follows; (1) Functional improvements to pathways/walkways, (2) Improving/installing play or fitness equipment (3) improving the greenery or aesthetics of the space and/or (4) Making improvements to the amenities available in the space. Evidence on the impact of modifications to urban green spaces has been synthesised based on these four categories.

#### 2.4.4.1 Functional improvements to pathways/walkways

The search found 13 studies on improving walking and cycling pathways (Table 2.2). Twelve out of the thirteen studies measured the impact of the intervention on physical activity and six found a positive impact (Grunseit et al., 2019; Frank, Hong and Ngo, 2019; Gustat et al., 2012; Benton et al., 2021; Ward Thompson et al., 2019a, 2019b; Fitzhugh, Bassett and Evans, 2010). Some studies reporting positive outcomes include a controlled study in Canada, which found improving a 2 km cycling path increased the odds of achieving 20 minutes of physical activity a day by 100%, and a study from Australia, which found a 200% increase in cyclists over a period of 3 years following improvements to the walking trail in Sydney (Grunseit et al., 2019). Five studies from Europe and North America found that improving walking or cycling pathways did not lead to a statistically significant impact on physical activity (Anthun et al., 2019; Hunter et al., 2021; Richardson et al., 2020; Auchincloss et al., 2019; Ryan, Hardwicke and Hill, 2023), while one study on a greenway in the Netherlands found physical activity increased in the specific green space with the intervention, but not for the green space users overall (Stappers et al., 2021). Other than physical activity, studies also looked at the impact on mental health and overall health status. One study found that residents living near an improved walking trail had an increased level of perceived stress, which the authors contend may be due to other external factors (Ward Thompson et al., 2019a, 2019b), while a second study reported no impact of improving walking trails on EQ-5D amongst adults over 65 years old (Ward Thompson et al., 2014).

Table 2.2 - Studies evaluating the impact of making improvements to walking trails

| Study | Country | Setting | Study design | Intervention | Outcomes | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Ward Thompson et al., 2019a, 2019b | UK (Scotland) | Individuals older than 15 from disadvantaged neighbourhoods in Scotland living 1 km from urban woodlands in Glasgow | Difference-in-differences | Modest-scale physical changes to the woods, consisting largely of footpath surfacing and drainage, improving entrances and clearing rubbish and overgrown vegetation | Perceived stress scale (PSS)<br>Physical activity level (MVPA) | Survey | Increases in perceived stress in intervention area at Wave 2 by 1.52 points (95% CI 0.78 to 2.27) and at Wave 3 of 3.58 (95% CI 2.85 to 4.31);<br>Physical activity (PA) increased in intervention area by 144.7 METs from baseline and decreased in control |
| Frank, Hong and Ngo, 2019 | Canada | Residents in Vancouver living close to a retrofitted urban greenway | Case control study | Improving conditions for bicyclists of all ages and abilities on the Comox Greenway. The two-kilometer route consists of a mix of cycling facilities and other streetscape improvements | MVPA | IPAQ survey | Odds of achieving 20 min daily of MVPA increased by 100% (2.00; 95% CI = 1.00, 3.98) |

| Study | Country | Setting | Study design | Intervention | Outcomes | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Anthun et al., 2019 | Norway | Municipality in Norway with a population of approximately 14,000 | Before-and-after study | Improving a footpath by increasing width and providing places including benches for social interaction, fishing, playing, and barbecuing. | Physical activity | Survey | No impact on PA |
| Stappers et al., 2021 | Netherlands | Residents of Maastricht living near the highway road | Non-randomised natural experiment | Creation of a semi-paved middle section between two one-way streets, prioritised for use by pedestrians, cyclists and for recreation. This middle section was separated from the adjacent streets by wide strips of grass and trees, creating the so-called 'Green Carpet'. The Green Carpet has a length of 2.3 kilometers | Physical activity | Survey | Total and transport-based PA levels did not increase over time.<br>A sub-group analysis found an 8% increase of MVPA on the Green Carpet |
| Hunter et al., 2021 | UK (Northern Ireland) | Residents (aged ≥16 years) who lived ≤1-mile radius of the greenway | Before-and-after evaluation | A major urban regeneration project in Belfast, Northern Ireland including provision of a 9 km urban greenway along the course of 3 rivers; 5 km of remediated water courses;<br>16 km of new or improved foot and cycle paths; 13 ha of upgraded parks | Physical activity | IPAQ survey | No impact on PA |

| Study | Country | Setting | Study design | Intervention | Outcomes | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Auchinclossa et al., 2019 | USA | Residents in a poor, high-crime, predominantly African-American neighbourhood of Philadelphia, Pennsylvania | Before-and after study | A 'greenway' project to retrofit designated sidewalks and street segments into a wide, tree-lined asphalt paved greenway. The greenway plan also included major intersection improvements (sidewalk bump-outs, count-down pedestrian signals, ADA ramps, improved intersection markings/paint), bus stop shelters, street trees, bicycle racks, signage, and enhancement of storm water management | Physical activity level (MVPA) | SOPARC | No significant changes over time between observation and control |
| Gustat et al., 2012 | USA | Low-income, primarily African American neighbourhood in New Orleans | Repeated cross-sectional study | PACE and the city of New Orleans built an 8-foot-wide path of 6 blocks on a grassy, tree-filled median of a wide neighbourhood boulevard. | Physical activity | Survey | 41% were MVPA in the intervention neighbourhood compared with 24% and 38% in the comparison neighbourhoods |
| Richardson et al., 2020 | USA | Publicly accessible parks in Pittsburgh's Hill District and Homewood neighbourhoods, | Difference-in-differences | Creation and renovation of current greenspace, including multiple parks, six outdoor stairwells, and three trails connecting parks. | Physical activity level (MVPA) | SOPARC | No significant impact on MVPA |

| Study | Country | Setting | Study design | Intervention | Outcomes | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Grunseit et al., 2019 | Australia | Suburbs of Sydney, Australia | pre and post-completion | Building new bridges, 2 km of new boardwalk, toilet facility upgrades, park furniture, rest stops, vantage outlook points, heritage restoration, environmental protection and substantial planting of local vegetation | Physical activity | Digital counter | Encounter data recorded 200–300% increases in cyclists |
| Benton et al., 2021 | UK (England) | Residents of Boothstown and Ellensbrook (population = 9532), which is the 2nd least deprived ward in Salford. Salford is the 22nd most deprived local authority in England | Diff-in-diff | New walking infrastructure and green space improvements along an urban canal in the UK | Physical activity | MOHAWk (observation) | Vigorous activity increased at 7 months ($p = .009$) and 24 months ($p = .002$), but not at 12 months ($p = .96$) post-baseline |
| Thompson et al., 2014 | UK (England, Wales and Scotland) | Participants aged 65+ living in intervention streets. | Repeated cross-sectional surveys | urban and landscape design to make streets safer and more attractive, for example, by inserting planters | EQ-5D | Survey | No impact on EQ-5D |

| Study | Country | Setting | Study design | Intervention | Outcomes | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Fitzhugh et al., 2010 | USA | Residents of a neighbourhood in Knoxville Tenesee with access to the developed trail. At baseline, the intervention neighbourhood was characterised by a population density of 2590 people per square mile | Quasi-experimental research design; case-control + before-after | An urban greenway/trail was retrofitted in a neighbourhood that lacked connectivity of the residential pedestrian infrastructure to nonresidential destinations. | Physical activity | Observation | The 2-hour physical activity counts increased between pre- and post-intervention (p=0.000), with a median increase of 8 counts. |
| Ryan, Hardwicke and Hill, 2023 | UK | All residents living near selected parks in Northampton, UK | Natural experiment study; case-control plus before-after | Installation of signage along several existing paths within an urban park to create a signposted 3 km circular route, which would take users through key park amenities (i.e. woodland, lake, heritage Abbey building, and historic battlefield). | Physical activity | Observation | No significant change in PA |

#### 2.4.4.2 Improving/installing play or fitness equipment

There were nine studies focused on improving on installing new play areas or fitness equipment in urban green spaces (Table 2.3). The interventions included improvements for playgrounds, play areas, skate parks, and installation or refurbishment of outdoor fitness equipment. Overall, eight of the nine studies reported some positive impact on physical activity and three of these studies also reported a mix of positive and neutral or negative findings depending on the park or population. There were two studies from Australia measuring the impact of a new playscape in a park in Melbourne, and both found positive impacts for physical activity amongst both adults and children (Lal et al., 2019; Veitch et al., 2018). Two studies on installing outdoor gyms in the United States found positive impacts; one reported an increased odds ratio for physical activity (Sami, Smith and Ogunseitan, 2018) and the second reported an increased number of exercise sessions in the first follow-up but not the second, (Cohen et al., 2012). An additional two studies in the United States found improved playground equipment (Panken and Holaly-Zembo, 2015) and improvements to a skate park increased physical activity amongst children (Cohen et al., 2009), although the same study reported no impact of a refurbished fitness centre on older adults (Cohen et al., 2009). Lastly, a study in South Africa found upgrades to play areas led to increased physical activity in the regional parks, but not the large park (Bartels et al., 2023).

Table 2.3 - Studies on improvements to fitness/play areas, including equipment.

| Study | Country | Setting | Study design | Intervention | Outcome | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Lal et al., 2019 | Australia | Residents living near the intervention park in Melbourne | Natural experiment study (intervention vs control) | Refurbishment involved the installation of a new play-scape including a large 360 degree swing, traditional swing set, maze, rockers, sandpit, nature play area, climbing equipment, landscaping, and various sculptures | Physical activity | Survey | Large overall increase in MET-h at T3 was observed at the intervention park, resulting in a net gain of 114,114 MET-h (95%CI =80,476 − 146,096) relative to the control park. |
| Pawlowski et al., 2019 | Denmark | Local fifth-grade children (10–11 years old) from a deprived neighbourhood in Copenhagen | pre- (baseline) and post-intervention phase (follow-up) evaluation | Five playable installations were designed and built: 1) a boxing pavilion, 2) a 7-metre-high tower, 3) big nets, 4) a piano, and 5) stepping stones | Physical activity level (MVPA) | Accelerometer | PA and MVPA decreased by almost 17% and 47%, respectively from baseline to follow-up and SB increased by more than 63%. |

| Study | Country | Setting | Study design | Intervention | Outcomes | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Sami, Smith and Ogunseitan, 2018 | USA | Residents living close to Eastgate Park in Garden Grove, California | Before-and after study | The fitness zone in Eastgate Park was installed in a previously open space. The city's parks and recreation department worked with Greenfields Outdoor Fitness Equipment, Inc to install 8 pieces of equipment | Physical activity level | SOPARC | Odds ratio for a higher activity level was 1.41 (95% CI, 1.21-1.63; P < .001), and the mean period-average MET score was 0.34 |
| Cohen et al., 2009 | USA | Users of a skate park and community center in Los Angeles | Before-and-after + Case control study | Skate park: Improvements to the skate surfaces themselves<br>The senior center: improvements were made to its entrance, courtyard areas, and gymnasium. | Physical activity level (MVPA) | SOPARC | Increase of skate park use was dramatically higher in the intervention skate park (p < .001), representing a 510% versus 77% increase in the comparison park.<br>There were no changes in PA in the senior center |
| Panken and Holaly-Zembo, 2015 | USA | Residents living close to community parks in Flint, Michigan | Case control study | Improvements such as new pavilions, benches, and playground equipment and human capital invested in local park | Physical activity level (MVPA) | PPSDO (Observation) | 59% of users in intervention parks were moderately active, but only 37% of users in the control park were moderately active |

| Study | Country | Setting | Study design | Intervention | Outcomes | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Ng et al., 2020 | Australia | Preschoolers aged 2–5 years and their parents across metropolitan city of Perth Australia | pre-post-test design with intervention and matched control centers | Improvements to fixed play portable play equipment' from the including total size of playing area, outdoor play spaces and natural elements | Physical activity level (MVPA) | Accelerometer | Intervention preschoolers were more active than control at follow-up 30.46 vs. 19.16 min/day increase in MVPA (all $p < 0.001$)) |
| Veitch et al., 2018 | Australia | Residents living near large metropolitan park in Melbourne, Australia | Natural experiment study (intervention vs control) | Installing a play-scape (a play area designed with the intent of bringing children and accompanying adults back to nature) in a large metropolitan park | Physical activity | SOPARC | Significant increases in engagement in MVPA at the intervention park, relative to the control park, among children (IRR = 5.15, $p = 0.002$) and adults (IRR = 1.81, $p = 0.030$) |
| Cohen et al., 2012 | USA | Diverse park users across 12 parks in LA, USA | Natural experiment study with control, plus pre and post evaluation | Installing ''Fitness Zones'', easy-to-use outdoor gyms for strength training and aerobic exercise. | Physical activity | SOPARC | Average number of reported exercise sessions (2.76 vs. 2.49; p¼0.03) was significantly higher at the first follow-up but not the second follow-up |
| Bartels et al., 2023 | South Africa | All residents living near selected 10 parks in Cape Town South Africa | Case control study | Seperate play areas for different age groups, shaded and seated picnic area, a skate park, outdoor gym, amphitheatre and fencing | Physical activity | SOPARC | No change in physical acitivity in the large park<br>Regional parks: The proportion of park visitors who were sedentary (62%) and engaged in vigorous |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | around the perimeter to increase safety | | | physical activity (18%) was slightly higher in the intervention parks (p = 0.001) |

#### 2.4.4.3 Improving the greenery or aesthetics of the space

Only one study focussed solely on improving the greenery or aesthetics of the space, finding that the intervention reduced self-reported depression, but had no statistically significant impact on self-reported mental health (Table 2.4) (South et al., 2018b).

Table 2.4: Study on the impact of improvements to greenery or aesthetics of the area

| Study | Country | Setting | Study design | Intervention | Outcome | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| South et al., 2018b | USA | Community-dwelling adults living in Philadelphia, Pennsylvania | Case control study | The greening intervention involved removing trash, grading the land, planting new grass and a small number of trees, installing a low wooden perimeter fence, and performing regular monthly maintenance. | Short-form Kessler-6 Psychological Distress Scale (K6) | Surveys | Intention-to-treat analyses of the greening intervention compared with no intervention demonstrated a significant decrease in feeling depressed (−41.5%; 95% CI, −63.6% to −5.9%; P = .03) and feeling worthless (−50.9%; 95% CI, −74.7% to −4.7%; P = .04). Analysis also demonstrated a nonsignificant reduction in overall self-reported poor mental health (−62.8%; 95% CI, −86.2% to 0.4%; P = .051) |

#### 2.4.4.4 Improving the amenities available in the space

There was one study that only reviewed the impact of improving amenities, in this case improving signage, and found no impact on physical activity as seen in Table 2.5 (Ryan, Hardwicke and Hill, 2023). Nine other studies included improvements to the amenities in combination with other interventions, and included amenities such as improved lighting, more bicycle racks, more picnic benches, or improved toilets (Auchincloss et al., 2019; Ward Thompson et al., 2019a; Panken and Holaly-Zembo, 2015; Anthun et al., 2019; Hunter et al., 2021; Grunseit et al., 2019; Benton et al., 2021; Kelly, Clennin and Hughey, 2022; Bartels et al., 2023). However, these improvements were all delivered in combination with other interventions and can therefore not be separated out to estimate impact.

Table 2.5: Studies on the impact of only changing amenities for the area

| Study | Country | Setting | Study design | Intervention | Outcome | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Ryan, Hardwicke and Hill, 2023 | England | Residents living near the Delapre Park in Northampshire | A natural experiment with pre-post at intervention and control parks | Installing signage along existing paths to create a signposted 3 km circular route, which would take users through key park amenities (i.e. woodland, lake, heritage Abbey building, and historic battlefield). | Physical activity level | SOPARC | No impact |

#### 2.4.4.5 A combination of different interventions for urban green spaces

Of the five studies that incorporated a combination of interventions (Table 2.6), three studies found no statistically significant impact of the improvements on physical activity (Droomers et al., 2016; Kelly, Clennin and Hughey, 2022; Acciai et al., 2023), while two studies found an increase in both light and moderate-to-vigorous physical activity (Andersen et al., 2017; Duncan, Bell and Austin, 2022).

Table 2.6: Studies on the impact of a combination of interventions

| Study | Country | Setting | Study design | Intervention | Outcome | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Droomers et al., 2015 | Netherlands | 40 most deprived neighbourhoods of the Netherlands | Difference-in-differences | Nine of these neighbourhoods invested in new public parks replacing vacant land, thereby adding new green space<br>The other nine neighbourhoods redeveloped and refurbished existing parks by adding more open areas for playing and recreation | Physical activity level | SOPARC | No impact |
| Andersen et al., 2017 | Denmark | Adolescents aged 11–16 years spending a minimum of 10 minutes daily within a 400-m buffer of the renewal district, which is a disadvantaged neighbourhood with 72% immigrants or children of immigrants | A natural experiment with a pre- and post-design | The urban renewal was a multicomponent strategy including, for example, renovation of public housing and courtyards; adding streetlights; renovation or establishment of new urban green spaces, playgrounds, and sport facilities | Physical activity level (MVPA) | Accelerometer, GPS and GIS | In 2012, adolescents spent 24.6 minutes more per day (p=0.017) in the buffered district (excluding time at home or at school) Of this additional time in the district, 7.8 minutes was spent in light activity, and 4.5 minutes in MVPA. |

| Study | Country | Setting | Study design | Intervention | Outcome | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Duncan, Bell and Austin, 2022 | Australia | Residents living near a park in Bundaberg, Queensland, which is a regional community with has high levels of socio-economic disadvantage | Before-and-after study | The redevelopment included landscaping, reducing the size of the monorail to half the original size, refurbishing some of the existing play equipment, installing additional children's play equipment and amenities (i.e., water fountains, barbeques, tables, dog watering bowls;); installation of an informal sports court and two multi-use seniors' strength and balance stations | Physical activity | SOPARC | The average daily number of park users engaged in moderate-intensity physical activity increased from baseline 2.61 to follow-up 26.23 ($p < 0.001$) and vigorous activity increased from baseline 0.91 to follow-up10.56 ($p < 0.001$). |
| Kelly, Clennin and Hughey, 2022 | USA | Residents of a suburban community outside Denver, Colorado | Before-and-after study | Park A: interventions include an expanded trail, a natural pavilion/boulder seating, fitness equipment, benches, and a picnic shelter.<br>Park B: Interventions include an expanded trail, fitness equipment, a dog park, a picnic shelter, benches, new trees, and improved lighting. | Physical activity | Household survey | No statistically significant change was found; While the proportion of visitors observed being very physically active after park improvements were made at Park A increased from 20% to 24%, the change was not significantly different<br>At Park B, the proportion of visitors observed being very active decreased from 21% to 15% (not significant), |

| Study | Country | Setting | Study design | Intervention | Outcome | Data collection tool | Results |
|---|---|---|---|---|---|---|---|
| Acciai et al., 2023 | USA | Two cohorts of 3- to 15-year-old children (n = 599) living in 4 low-income New Jersey cities | Case control study | Installed a new basketball court, soccer field, fitness nodes, spray ground, pool, walking path, playground equipment, volleyball courts, artificial turf, Renovations: walking path, resurfaced basketball court, reset of basketball backboard, water access feature (kayak/ canoe launch), refurbished playground equipment, resurfaced tennis courts Amenity Trash bins, benches, directional assistance, signage, bike rack, landscaping/gardens, tables and chairs, restrooms, safety services at fitness nodes, outdoor lighting, fencing, picnic area, outdoor shelter, new boathouse, performance space, curbs, field striping, open shade structure, new parking lot, game table | Physical activity | Household survey | Renovated opportunities in parks were not associated with children's PA. |

#### 2.4.4.6 Quantitative synthesis of findings

An initial plan for the review included an attempt to synthesise some of the results described above. A quantitative synthesis of findings such a meta-analysis is an important starting point to inform estimates of cost-effectiveness. However, after reviewing and discussing the results, it was found that it would not be feasible to use these results for a meta-analysis. One of the major challenges was that the studies used different measures for physical activity such as an odds ratio of moderate to vigorous activity or counts of people that were physically active. The two studies that measured the impact of green space interventions on mental health used different outcomes (stress and depression) to measure the impact on mental health. Given the range of measurement tools and data analysis methods used, it was not considered feasible to consolidate the findings reported in this review. Secondly, 12 of the 25 studies measuring physical activity used observation as their data collection tool and reported counts of individuals engaged in physical activity. These studies did not report the proportion of people engaged in physical activity, and as such it may be impractical to consolidate the evidence using data on counts alone. Lastly, there were also concerns about consolidating outcomes given the heterogeneity of the studies, such as the range of the type of interventions, type of green spaces, data collection methods, study designs, and the study populations.

### 2.4.5 Economic evaluations

Three studies estimated the efficiency of the intervention along with effectiveness by including a cost-effectiveness analysis in their paper (Ward Thompson et al., 2019a, 2019b; Lal et al., 2019; Cohen et al., 2012). A cost-effectiveness analysis in this context would estimate the ratio of the per capita cost per health unit gained, to determine the value for money from an urban green space intervention; this analysis can then be used to compare the green space intervention with other investment options. All three studies used a cost effectiveness approach, whilst one study also provided a cost-consequence analysis (Ward Thompson et al., 2019a, 2019b). Two studies by Lal et al (Lal et al., 2019) and Cohen et al (Cohen et al., 2012) reported on a cost per metabolic equivalent ratio by converting observed physical activity to metabolic equivalent scores; Lal et al (2019) measured the impact of a new playscape in Australia and reported a cost-effectiveness ratio of AU$0.58 per MET-h gained, while Cohen et al (Cohen et al., 2012) measured the impact of fitness zones reported a similar effect of $0.105 per MET-h gained. A third study from Scotland. United Kingdom, found no health gains from improving trails in an urban woodland, but the authors used an illustrative example to estimate the cost per quality-adjusted life year gained and found that the cost-effectiveness could be between £662 to £935 per quality-adjusted life years gained (Ward Thompson et al., 2019a, 2019b).

Cost-effectiveness analysis can also be used to independently assess whether an intervention is good value for money by comparing the results against a pre-determined threshold. Lal et al. (2019) concluded that the intervention was cost-effective according to a threshold for metabolic equivalent gained, which was calculated by the authors based on Australia's spending on physical activity. Cohen et al (2012) also suggested that the intervention is cost-effective but did not qualify the threshold used to determine cost-effectiveness. The study in Scotland by Ward-Thompson et al (2019a, 2019b) used a threshold of £20,000 per quality-adjusted life year gained, but the study did not find any improvements in health, and as a result the interventions were not found to be cost-effectiveness using a timeframe of 6 months after the intervention. All three studies found a low cost per individual, suggesting that even small positive changes in health outcomes may lead to the intervention being regarded as cost-effective (Table 2.7).

Table 2.7: Economic evaluation findings

| Study | Country | Setting | Study design | Intervention (details) | Type of economic evaluation | Measures of effectiveness | Cost/resource use | Cost-effectiveness results |
|---|---|---|---|---|---|---|---|---|
| Thompson et al., 2019a, 2019b | UK (Scotland) | Individuals older than 15 from disadvantaged neighbourhoods in Scotland living 1 km from urban woodlands in Glasgow | Difference-in-differences | Modest-scale physical changes to the woods to improve their attractiveness for use, consisting largely of footpath surfacing and drainage, improving entrances and clearing rubbish and overgrown vegetation | Cost-utility analysis, Cost-consequence analysis | Stress | The cost per individual was calculated based on the eligible population (n = 20,472) of the intervention communities. This resulted in the average cost per person of £7.68, (95% CI £7.67–£7.69) for the physical intervention in Wave 2 and £11.80, (95% CI £11.79–£11.82) for both physical and social interventions in Wave 3. | 1 The CUA was not possible as there was no observed change in PA and stress had increased in intervention group. 2. The CCA compares the cost per person (£7.68) with outcomes listed above, as well as other outcomes (social connectedness, connectedness with nature) |
| Lal et al., 2019 | Australia | Residents living near the intervention park in Melbourne | Natural experiment study (intervention vs control) | Refurbishment involved the installation of a new play-scape including a large 360 degree swing, traditional swing set, maze, rockers, sandpit, | Cost-effectiveness analysis | Physical activity, measured in metabolic equivalent hours | Assuming 20 years' amortization, the incremental annual costs of the installation and maintenance of the play-scape were $64,155. | The average cost per MET-h gained per person was $0.58 (95% UI $0.44–$0.80) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | nature play area, climbing equipment, landscaping, and various sculptures | | | | |
| Cohen et al., 2012 | USA | Diverse park users across 12 parks in LA, USA | Natural experiment study with control, plus pre and post evaluation | Installing ‘‘Fitness Zones’’, easy-to-use outdoor gyms consisting of durable, weather-, and vandal-resistant exercise equipment for strength training and aerobic exercise. | Cost-effectiveness analysis | a net gain of 1,909 METs in the 12 parks or 159 METs per park. This is equivalent to 52,311 additional METs/yea | the total cost for each Fitness Zone averaged $45,000, which covered the cost of 8 pieces of equipment, installation, and staff time for coordinating the installations. e amortized the cost of the equipment over 15 years, the duration of the equipment’s limited warranty, and then added $2,000 per year for the cost of maintenance | Their installation appears to have increased the level of moderate to vigorous physical activity in the park at a very favourable cost-effective ratio, (10.5 cents/MET).. |

### 2.4.6 Critical review

After analysing the evidence from all included articles in the systematic review, several limitations to using the studies to inform an economic evaluation were identified. This critique includes all 28 studies, including those that were not economic evaluations, since the intention was to ascertain if the studies could be used to inform an assessment of cost-effectiveness. As noted by Sculpher et al, (2006) an economic evaluation must be able to answer the following two questions: the first is whether the intervention is a cost-effective strategy based on the existing evidence, and the second is whether demanding additional evidence is a cost-effective strategy (Sculpher et al., 2006). This critique uses the framework used by Sculpher et al. (2006) to outline the limitations of the evidence on the effectiveness and efficiency of urban green space interventions.

- Short time horizons: An economic evaluation must use an appropriate time horizon to capture the totality of any differences in costs and outcomes. All included studies used less than six years as their time horizon, with only two studies using a follow-up period that was longer than two years (Bartels et al., 2023; Cohen et al., 2009). As seen in the logic model in figure 2, the impact of an urban green space intervention requires behaviour change or environmental changes - both of which can have long term implications for health and well-being. Currently, the studies used to evaluate the intervention do not account for these longer-term impacts. Another limitation of short-time horizons is that the evaluation will fail to account for any changes in utilisation of the space, or physical activity, over longer periods of time. Interventions to promote physical activity have demonstrated limitations with long-term adherence, and by using short time horizons we may fail to understand the true 'stickiness' of these interventions (Malina, 2001; Jennings, 2010).
- Difficulty in capturing all multi-sectoral outcomes: Urban green spaces may have multi-sectoral effects on population health and wellbeing, education and productivity, and environmental outcomes (Karunarathne and Gunawardena, 2020; Kruize et al., 2019; University of Leeds, 2015; Strohbach, Arnold and Haase, 2012; de Keijzer et al., 2016). None of the studies provided detailed values for each potential impact, and on their own, the studies provide insufficient evidence to support decision-makers concerned with impacts across multiple sectors. Most studies reported on single outcomes, however seven of the included 28 studies measured and reported on multiple outcomes including a combination of physical and mental health, and/or environmental improvements.
- Inconsistencies in outcome measures: Studies on this topic have used both a range of data collection tools and indicators to report on physical activity and mental health. The range of indicators will likely make it difficult for decision makers to compare and assess the existing evidence in a meaningful way. For physical activity for example, studies have used counts of individuals engaged in physical activity, or

the odds of spending 20 minutes doing moderate to vigorous physical activity, or simple changes in the number of people observed to be engaged in physical activity. One option for standardising the outcome measure could be to focus on measurable outcomes that can be linked to existing guidelines where they exist. For example, many countries, including the United Kingdom, have guidelines on time spent in moderate to vigorous physical activity, and therefore evidence which shows changes in time spent in moderate to vigorous physical activity may be most useful for policy makers in this context.

- Limited understanding of the distribution of outcomes across a population: There are several existing disparities in access to green spaces between high- and low-income neighbourhoods in many European cities (Institute for European Environmental Policy, 2022) and even more stark discrepancies between high- and low-income countries (Chen et al., 2022). This inequity in access may further exacerbate existing health inequities. Some of the included studies did report on outcomes for age groups but only one specifically measured outcomes for more disadvantaged populations and found a more positive impact of the intervention for lower income groups (South et al., 2018b).

## 2.5. Discussion

This systematic review provides an overview of the existing literature on the impact of changes to urban green spaces on the health outcomes of users of those spaces. Overall, we found that improvements to urban green spaces have a predominantly positive effect on physical activity, and a mixed impact on mental health outcomes. Interventions targeted towards play or fitness equipment tended to have a more positive impact on physical activity compared to the other interventions included in this review. This may be because interventions for fitness or play equipment are relatively more targeted towards increasing physical activity, compared to, for example, interventions related to improving the greenery or aesthetics of the space. There were two studies evaluating the impact on mental health outcomes; one study reported an increase in stress (which the authors suggest is likely from other causes), and a second reported a decrease in depression following the green space intervention. From a cost-effectiveness perspective, there were three studies that included an economic evaluation of the interventions, and all three studies found that very small improvements in physical activity or health outcomes were required to make improvements to green spaces a cost-effective strategy.

This is the first systematic review on the cost-effectiveness of specific interventions for urban green spaces. As part of this review, we produced a logic model which outlines the four types of interventions for urban green spaces, and their short-term and long-term implications for population health and education. Furthermore, this review consolidates the evidence on interventions for urban green spaces and their impacts on health and education

outcomes and highlights how it may be used to conduct a cost-effectiveness study of an intervention for an urban green space.

This review has a few limitations. For instance, we were not able to synthesise the quantitative evidence on the impact of interventions for urban green spaces. While this review was initially set up to include a meta-analysis where feasible, we found it would not be possible to consolidate the evidence in a meaningful way due to the range of different outcome measures, and missing information on important parameters like sample size. Secondly, this review does not include reports or other grey literature to maintain a higher quality of evidence, and this quality criterion may have resulted in the exclusion of relevant evidence not published in the peer-reviewed literature.

This review highlights several areas for future research. As noted above in section 2.4.6, further research is required to consolidate the evidence on effectiveness and estimate the cost-effectiveness of interventions for urban green spaces. There are several challenges in using the existing studies for an economic evaluation including (i) short term horizons, (ii) difficulty in capturing all multi-sectoral outcomes, (iii) inconsistencies in outcome measures and (iv) limited results on equity.

Additionally, further research on the impact of interventions for urban green spaces on educational outcomes, and mental health outcomes could also be helpful for decision makers. Whilst there is a vast body of literature which finds positive associational links between green spaces and mental health outcomes, including for specific outcomes such as depression and anxiety (Vanaken and Danckaerts, 2018; South et al., 2018b; McEachan et al., 2018a; Gascon et al., 2018), we only found two out of 28 studies measured the impact of changes to urban green spaces on mental health. Most of the studies focused only on changes to physical activity. There was also associational evidence of the link between green spaces, cognitive performance, and educational outcomes (KARI et al., 2017; de Keijzer et al., 2016), but there were no studies measuring changes to green spaces and their impacts on educational outcomes.

Overall, the studies included in our review demonstrate that improvements in urban green spaces may lead to improved outcomes for mental health and physical activity. As described above, further evidence may help consolidate these results, with a view to supporting a cost-effectiveness analysis, which will ultimately help decision makers determine how best to invest in urban green spaces, given the specificities of their context.

## Chapter 3: Toolkit for the Health Economic Assessment of urban Green Space interventions (THEAGS)

Preface

The review in chapter 2 found that there were only three studies that had included an economic evaluation of interventions for urban green spaces. Chapter 2 also found large heterogeneity in the available evidence, including types of intervention and outcome measures, which would make it difficult for decision-makers to meaningfully engage with the economic evidence for policy decisions around interventions for UGS.

This chapter presents a toolkit that may be used to estimate the economic value of a UGS intervention. This toolkit uses the findings from the review in chapter 2 and considers the longer-term costs and consequences of any benefits of UGS, using an economic evaluation approach, specified as a Markov model.

The toolkit was presented to the Born in Bradford study group, and the Better Start project team in charge of implementing a green space intervention in Bradford. Their comments and feedback have been incorporated in the final toolkit.

You can download the toolkit from the dropbox link here:
https://www.dropbox.com/scl/fo/bbtyi9qchifduvgvsktal/AJ7n0OKTuQjknHiiPDrURTU?rlkey=m39tljpqrrt2y9r5tlt0dcski&st=mn3ralgv&dl=0

This toolkit is also currently used as part of a course on the 'Health Impact Evaluation' taught by Dr Lukas Kauer at the University of Luzern.

This chapter was presented at the EUHEA PhD conference in 2024.

Chapter 3 will be submitted as a research article to the International Journal of Environmental Research and Public Health

Abstract

Background: Green space interventions can have long-term and wide-ranging benefits for health and wellbeing, often making it difficult to fully estimate their effect. This lack of evidence on impact can make it difficult for policy makers to prioritise upgrading green space investments compared with other infrastructural developments. This paper addresses this by presenting a model to estimate the impact of green space interventions on physical activity. This model is presented through a toolkit named the Toolkit for the Health Economic Assessment of urban Green Space interventions (THEAGS)

Methodology: THEAGS uses the results from a systematic review of UGS interventions to model the expected health impacts for three types of interventions: (i) building or improving walkways, (ii) installing or upgrading outdoor fitness equipment, and (iii) improving children's play areas. The effects of the intervention were modelled as changes in moderate-to-vigorous physical activity, with outcomes converted into quality-adjusted life years. Intervention costs were derived from published sources and local case studies. Cost-effectiveness was assessed over a 10-year horizon using net monetary benefit, under varying values for the opportunity cost of health (£500–£50,000 per quality-adjusted life year). Both deterministic and probabilistic analyses were conducted, including sensitivity analyses with waning effects (20% and 50%).

Results: Across interventions, the probability of cost-effectiveness was generally high at National Institute for Health and Care Excellence thresholds (£20,000–£30,000 per quality-adjusted life year), although the estimates of net monetary benefit showed considerable uncertainty. Improvements to outdoor fitness equipment had the highest probability of cost-effectiveness, while play area improvements generated the largest average net monetary benefit per capita (£64), albeit with greater variability influenced by quality and maintenance. Walkway interventions showed relatively modest gains and higher uncertainty. The toolkit enables comparison across interventions and thresholds, allowing decision-makers to tailor results to local contexts.

Conclusion: THEAGS provides a transparent, adaptable tool for assessing the cost-effectiveness of UGS interventions. It highlights the likely value-for-money of investments in fitness equipment and play areas, while also considering uncertainties arising from study heterogeneity, intervention quality, and maintenance. Future iterations should incorporate evidence on additional outcomes (for e.g., mental health, education, environmental benefits) and explore distributional impacts across population subgroups.

## 3.1 Introduction

Urban green spaces, including parks, playgrounds and green pathways are essential features of a healthy and sustainable city (City Better Life and Assessment, 2010; World Health Organization Regional Office for Europe, 2016). With increasing urbanisation, investing in urban green spaces has become an increasingly important policy objective for local governments. This is further emphasised by the sustainable development goal 11.7, in which member nations have committed to improving access to urban green spaces, especially for more vulnerable populations (United Nations).

Urban green spaces are linked to improved physical activity, improved mental health, and lower overall mortality (Astell-Burt et al., 2022a; Rojas-Rueda et al., 2019; Schipperijn et al., 2013). A valuation of urban green spaces in England by Public Health England found that urban green spaces can save £2.1 billion in health every year through improvements in physical activity alone (Public Health England, 2020). This potential improvement in physical activity is increasingly important as physical activity has decreased in the United Kingdom since the 1960s, and approximately 42% of women and 34% of men do not meet the current guidelines for physical activity (GOV.UK, 2022). Improvements to urban green spaces may be a cost-effective approach to address the declining physical activity in the United Kingdom. A review by Zhang et al. (2022) found that park renovations, adding fitness equipment, introducing pockets parks, and improvements to walking and cycling environments leads to an increase in physical activity. Similarly, Hunter et al., (2015) and Raza et al. (2024) also found that improvements to across a range of interventions for urban green spaces will lead to improvements in physical activity and mental health. Hunter et al. (2019) also reported that physical activity programmes such as group fitness activities were effective in improving physical activity of the residents.

Whilst there is evidence that investments in UGS improve physical activity, there is limited evidence on the cost-effectiveness of specific investments, making it difficult for decision-makers to make evidence-based decisions for investing in green spaces (Raza et al., 2024). To address this gap, a toolkit called the “Toolkit for the Health Economic Assessment of urban Green Space interventions” (THEAGS) was developed, which consolidates the existing evidence on costs and effects of urban green spaces to allow users to estimate the net monetary benefit for interventions in urban green spaces, using a range of different scenarios. Toolkits such as THEAGS are commonly used to synthesise and present evidence to decision-makers in a user-friendly way. A similar toolkit called the Health Economic Assessment Tool for walking and Cycling has been developed by the World Health Organization to estimate the benefit of developing additional pathways (World Health Organization, 2021), and has been used widely for urban planning across different countries (Kahlmeier et al., 2023). In the the United Kingdom, similar health economics models, as used by Health Economic Assessment Tools and THEAGS have been used to develop policies

around air quality (National Institute for Health and Care Excellence, 2017), and physical activity (National Institute for Health and Care Excellence, 2018)

THEAGS uses the evidence on costs and effectiveness of UGS interventions to support decision makers make policy choices between capital investments in green spaces, or investments in other public goods. The results from the toolkit may also be used to support cases for investments in urban green spaces. The evidence used to develop the toolkit is based on a systematic review in chapter 2, published elsewhere (Raza et al., 2024). The toolkit may be updated with new evidence on the impact of interventions for urban green spaces, as this becomes available.

### 3.1.1 Type of interventions

There can be a range of different types of investments in urban green spaces. For the purposes of this toolkit, these investments/interventions have been classified into three different categories as defined in the systematic review in chapter 2 (Raza et al., 2024). More details on the categories and their associated impact can be found in the review. The categories are listed below:

1. Building/Improving a green walkway/pathway: This includes any improvements to pathways in an urban green space. Improvements include paving pathways, expanding trails, or other developments that can improve a user's experience in using the path for walking, running or biking.
2. Installing/Improving fitness equipment in a public green space: This includes any outdoor gym equipment installed to support individuals exercise outdoors. Some examples of outdoor fitness equipment include pull up bars, or cross trainers.
3. Installing/Improving play areas in a public green space: Play areas include playgrounds, sand pits, or other spaces designed for play for young children. Improvements include the installation of new play equipment, or the improvements or repairs to existing play spaces.

A fourth category of intervention "Improving the greenery of the area" was not included in the model due to a lack of evidence on effectiveness.

For the same type and scale of intervention, upgrading existing infrastructure is generally cheaper than installing it from new, as an upgrade builds on infrastructure that is already in place. The categories used here combine both actions, so the estimates for both costs (Section 3.2.7) and effects reflect a mix of installation and upgrade of infrastructure.

## 3.2 Methodology

This section outlines the methods used to estimate the long-term costs and effects for each type of intervention for UGS. The health economic model uses a range of different data sources for each analysis outlined in more detail below.

### 3.2.1 Outcomes of interest

Physical activity can be measured in several ways. This toolkit uses moderate to vigorous physical activity as its main outcome of interest, for three reasons. First, United Kingdom physical activity guidelines are set in terms of minutes of moderate-to-vigorous physical activity. Second, existing work maps moderate-to-vigorous physical activity to quality-adjusted life years, allowing net monetary benefit to be assessed. Third, moderate-to-vigorous physical activity is widely reported in physical activity surveys, including those of the United Kingdom Office for National Statistics, so the data are readily available..

The impact of physical activity has been summarised separately for adults and children. Adults and children are defined in line with the United Kingdom Chief Medical Officers' physical activity guidelines, which set separate recommendations for each group: children and young people (aged 5–18 years), for whom an average of 60 minutes of moderate-to-vigorous physical activity per day is recommended, and adults (aged 19 years and over), for whom 150 minutes of moderate-to-vigorous physical activity per week is recommended (Department of Health and Social Care United Kingdom).This separation followed the evidence from the systematic review, and because of different guidelines for moderate-to-vigorous physical activity between adults and children. The use of physical activity as the main outcome of interest is consistent with previous economic evaluations of urban green spaces, including an evaluation conducted by Public Health England (Public Health England, 2020)

This toolkit estimates the impact of specific changes to urban green spaces on physical activity over a 10-year period. 10 years is relatively conservative compared to urban planning studies, for example a health economic assessment of urban green spaces by Birmingham uses a time-period of 25 years (Hölzinger and Grayson, 2019). However, a review of the long-term effects of physical activity interventions found that most studies (including the ones used in this analysis) use a relatively short follow-up period, mostly under 48 months, which makes extrapolation over long time periods highly uncertain (Ominyi, Clifton and Cushen-Brewster, 2024; Gasana et al., 2023) . To account for this uncertainty, the analysis uses a starting point for a 10-year period but also allows scenarios with waning effects such that the time-period is effectively reduced to 4 years and 2 years respectively.

### 3.2.2 Decision Model

This toolkit broadly uses two different approaches to specify a decision model, depending on the methodology of data analysis for each included study. The details of the approach, and the studies utilised are provided below:

Approach 1: Markov model

A Markov model[3] was used to estimate expected effect using studies that used an odds ratio, or a percentage change in physical activity. For these studies, a percentage change in physical activity was used to estimate the changes in the transitioning between states of physical activity.

The states of physical activity in the model were developed based on United Kingdom guidelines for physical activity for adults and children (Department of Health and Social Care United Kingdom)

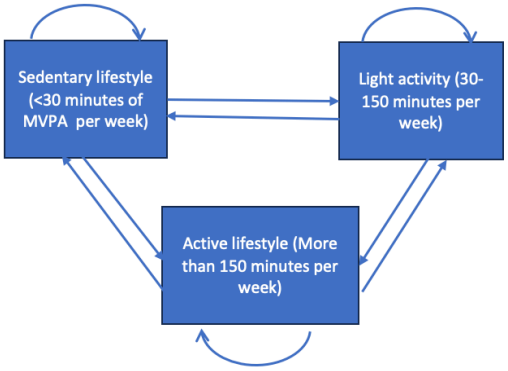



Figure 3.1: Markov Model for physical activity in adults

[3] Markov models can be used to track costs and health-related quality of life by representing health as a set of discrete states, and using transition probabilities to describe movement between states over time (Briggs and Sculpher, 1998). In this model, it's assumed that people move between health states (defined by levels of physical activity) over fixed time periods, with the proability of moving depending only on their current state, not their past. Each state has its own costs and quality-of-life values, which are added up over time (Briggs and Sculpher, 1998).

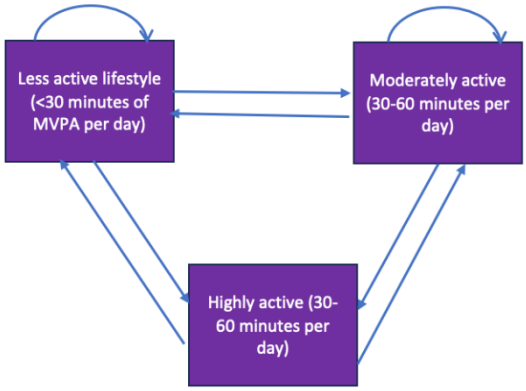



Figure 3.2: Markov Model for physical activity in children

Approach 2: Direct calculation

The model applies the estimated percentage change in physical activity to move individuals between the moderate-to-vigorous physical activity states shown in Figures 3.1 and 3.2. The model assumes that intervention is resulting in a sustained change in the distribution of physical activity, which is carried across a cycle length of 10 years matching the time horizon of the analysis. Health benefits accrue over this period, with waning scenarios (Section 3.2.1) reducing the effective duration of the effect to 4 or 2 years. Costs and effects are discounted at an annual rate of 3%

Several studies have reported the expected impact of the intervention for UGS on time spent doing physical activity, measured in minutes as opposed to proportions. For these studies, this toolkit uses the additional minutes of moderate-to-vigorous physical activity to calculate the expected change in quality-adjusted life years.

### 3.2.3 Obtaining data to inform model

The model described above uses data from multiple studies to predict the costs and effectiveness of each intervention, and ultimately estimate the incremental net monetary benefit for these interventions. This section outlines how data from the studies in the review have been used to inform the costs and effects used in this toolkit.

#### 3.2.3.1 Baseline distribution

As a default, the toolkit currently uses United Kingdom data on physical activity from 2022/23 as reported by the United Kingdom Office for Health Improvement and Disparities (Office for Health Improvements and Disparities, 2023). The model also uses the proportion

of adults who “Utilise outdoor space for exercise or health reasons” and the proportion of children who “Spending time in a green space everyday” from 2015/16 to estimate the proportion of the population that would receive the “treatment effect”, which in the case of this model is the estimated change in physical activity. Table 3.1 below includes the values used for the default baseline distribution.

Table 3.1: Baseline distribution of values used in the Toolkit

| **Indicator** | | **Value (%)** |
|---|---|---|
| Distribution of MVPA/ week (adults aged 19 and over) | Less than 30 mins | 22.6 |
| | 30 to 150 mins | 11.3 |
| | More than 150 minutes | 66.1 |
| Distribution of MVPA/ day (children aged 5 to 19) | Less than 30 mins | 30.2 |
| | 30-59 minutes | 22.8 |
| | More than 60 mins | 47.0 |
| Utilisation of outdoor space for health reasons | Adults | 17.9 |
| Spending time in a green space everyday | Children | 85.0 |

For city-specific cases or non-United Kingdom users, wherever the distribution of physical activity for their area of interest is known, users can add customised values for the baseline distribution. The model will then calculate the effect based on the values entered. As a default, the toolkit uses United Kingdom baseline data as shown in Table 3.1 above.

The default baseline values are drawn from nationally representative surveys of England (the Active Lives Survey and the Monitor of Engagement with the Natural Environment) and therefore include both urban and rural residents. As engagement with green space tends to be higher among rural populations, these national figures may not exactly reflect the baseline distribution of an urban population, which is the target of this toolkit. To address this, the toolkit allows users to replace the default values with area-specific baseline data where these are available (as described above)

### 3.2.4 Effectiveness

This toolkit builds on the studies identified in the systematic review (Chapter 2) to estimate the effect of each intervention on physical activity. The studies have been divided by the type of intervention, and the population of interest. Studies that measured the impact of a combination of interventions were not used in this toolkit, as it was not possible to isolate the impact of a single type of intervention.

Details of each study used in the toolkit can be found in tables 2, 3 and 4 below.

Table 3.2: Included articles and values estimating the impact of improving walkways

| Articles | Age group | Effect size | Lower CI | Upper CI | Outcome |
|---|---|---|---|---|---|
| Auchinclossa et al., 2019 | All | 1.37 | 0.74 | 2.56 | Odds ratio of engaging in MVPA |
| Frank, Hong and Ngo, 2019 | Adults | 2 | 1 | 3.98 | Odds ratio of engaging in MVPA |
| Stappers et al., 2021 | Adults | 8.8 | 1.18 | 16.41 | Change in % of time in MVPA |
| Hunter et al., 2021 | All | -6.1 | -11.5 | -0.7 | Change in mins of total PA |
| Gustat et al., 2012 | Adults | 3.30% | | | Change in the percentage of people in MVPA |

Table 3.3: Included article and value estimating the impact of installing or improving fitness equipment

| Articles | Age group | Effect size | Lower CI | Upper CI | Outcome |
|---|---|---|---|---|---|
| Sami, Smith and Ogunseitan, 2018 | All | 1.58 | 1.14 | 2.18 | Odds ratio of being physically active |

Table 3.4: Included articles and values estimating the impact of improving playgrounds or play areas

| Articles | Age group | Effect size | Lower CI | Upper CI | Outcome |
|---|---|---|---|---|---|
| Ng et al., 2020 | preschoolers aged 2–5 years | 33.9 | | | Diff in mean moderate PA mins/day |
| Andersen et al., 2017 | Adolescents aged 11–16 years | 13.5 | 5.4 | 21.6 | Diff in mean time in MVPA per day |
| Pawlowski et al., 2019 | Children (10-11) | -22.9 | | | Average time spent in MVPA after the intervention |
| Panken and Holaly-Zembo, 2015 | All | 10.60 | | | Change in the % of users engaged in MVPA in the intervention v comparison park |

The effectiveness of the intervention was calculated using two different approaches, based on the type of outcomes reported by the selected study. For studies that reported impact in terms of percentage change or the odds ratio of being engaged in moderate-to-vigorous physical activity, we used a Markov model to estimate effectiveness. For studies that reported the odds ratio, we converted the odds ratio to the percentage of people engaged in moderate-to-vigorous physical activity in each state using the three-step formula below:

Step 1: Calculate the odds pre-intervention:

$$Odds.pre = \frac{Prop.pre}{1 - prop.pre}$$

Step 2: Use the odds ratio to calculate the odds post-intervention:

$$Odds.post = OR \times Odds.pre$$

Step 3: Convert the post-intervention odds back into a probability (proportion):

$$Prop.post = \frac{Odds.post}{1 + Odds.post}$$

In the formula above, prop.pre refers to the proportion of individuals engaged in the recommended moderate-to-vigorous physical activity before the intervention, and the prop.post is the expected proportion of people engaged in the recommended amount of moderate-to-vigorous physical activity after the intervention.

Once the expected proportion of people engaged in physical activity was estimated, the transitional probability of each intervention is calculated using the formulas below:

$$Transitional\ probability\ for\ adults = Change\ in\ proportion\ of\ adults\ engaged\ in\ a\ higher\ MVPA\ state * Proportion\ of\ adults\ that\ use\ green\ space\ for\ exercise$$

$$Transitional\ probability\ for\ children = Change\ in\ proportion\ of\ children\ engaged\ in\ a\ higher\ MVPA\ state * Proportion\ of\ children\ that\ use\ a\ green\ space\ everyday$$

The second approach uses the reported value of change in minutes of moderate-to-vigorous physical activity directly. This value is converted to a population level change using the formula below:

$$Expected\ change\ in\ MVPA\ in\ adults = Reported\ change\ in\ MVPA \times Proportion\ of\ adults\ that\ use\ green\ space\ for\ exercise$$

$$Expected\ change\ in\ MVPA\ in\ children = Reported\ change\ in\ MVPA \times Proportion\ of\ children\ that\ use\ green\ space\ everyday$$

### 3.2.5 Evidence synthesis on effectiveness

Evidence on impact for each intervention type is integrated into the model using a two-step process. The first step is that for each included article, the model calculates 10,000 iterations of the expected impact. The next step is that the model selects between the articles at random for each of the 10,000 iterations. This provides a final result of 10,000 iterations of impact for each intervention, for adults and children, selected randomly between the chosen articles.

Ideally, the model would have used a meta-analysis of the selected articles to estimate impact, as recommended by the National Institute for Health and Care Excellence reference case. However, this was not possible for a number of reasons. Firstly, the data reported by the articles often used observation as their data collection methodology and did not have a defined study sample. The sample sizes from these observational do not represent standardised population samples but rather the number of individuals present in the park at the time of observation. Unlike surveys, which use defined sampling frames, observational studies are context-specific and time-specific, with sample sizes reflecting patterns of use, instead of population denominators. As a result, the study samples are not comparable

across studies and cannot be pooled to estimate a single effect size Secondly, different articles have used different methods of assessing the impact on physical activity, and it was therefore not possible to consolidate the impact of the findings directly between different outcome measures.

### 3.2.6 Calculation of quality-adjusted life years (QALYs)

The toolkit converts the minutes of physical activity to QALYs using the mapping by Beale et al (2012) which estimates that the impact of 30 minutes of physical activity per week is a change in 0.010677 QALYs per year (Beale et al., 2012). This calculation combines the effect of physical activity on breast cancer, colon cancer, diabetes, stroke, and coronary heart disease. Ideally, we would use age-specific QALYs for changes in physical activity, however, to our knowledge this is the only available mapping of the utility to changes in physical activity and has been widely used in the literature for physical activity.

For the Markov model with states defined as a range of physical activity, we used the expected QALY gained for the median of the range of physical activity. The values of QALYgained for each state can be found in Table 3.5. For studies that reported a change in the minutes of physical activity, the expected QALY gained through 30 minutes of physical activity was divided by 30 to estimate a change in QALY per minute. This value of QALY gained per minute of physical activity was then multiplied by the reported change in minutes of physical activity per week to obtain an expected change in QALYs, due to the reported change in physical activity. The toolkit currently assumes a linear increase in QALYs for the default scenarios. Section 3.2.10 describes other scenarios with waning effects to incorporate the possibility of a non-linear response to changes in urban green spaces.

Table 3.5: Expected quality-adjusted life year gained in each state of physical activity

| **Expected QALYs gained in each state** | |
|---|---|
| *Adults* | |
| Less than 30 mins per week | 0.010677 |
| 30 to 150 mins per week | 0.021354 |
| More than 150 minutes per week | 0.042708 |
| *Children* | |
| Less than 30 mins/day | 0.074739 |
| Avg 30-59 minutes a day | 0.112109 |
| More than 60 mins a day | 0.149478 |

### 3.2.7 Cost and resource use

The expected cost per capita for each intervention was calculated using evidence from the systematic review, or using the capital costs from Better Place Bradford (Better Start Bradford). The values for these costs can be found in table 6 below.

Table 3.6: Expected costs of interventions for urban green spaces

| **Type of intervention** | **Expected cost pp (in £)** | **SE** | **Source** |
|---|---|---|---|
| **Building/Improving a green walkway/pathway** | 8.65 | 0.005 | Thompson et al. (2019) |
| **Installing/Improving fitness equipment in a public green space** | 5.30 | 2.43 | Author calculation using Cohen 2012 for total cost |
| **Installing/Improving play areas in a public green space** | 5.94 | 2.43 | Author calculations from Better Place Bradford |

The cost of "Building/Improving a green walkway/pathway" was extracted from the study by Thompson et. al and converted to 2022 values by adjusting for inflation (Ward Thompson et al., 2019a). The standard error is based on the confidence interval reported by the authors.

For installing/improving fitness equipment, THEAGS used the total cost of installing outdoor fitness equipment as reported by Cohen et al., (2012) and converted this to 2022 values in British pounds (£) by adjusting for inflation and currency conversion. This was then divided by the estimated adult population of an average ward in Bradford as a suggested catchment population. This analysis only has a single point estimate for the cost per capita, but to account for any potential uncertainty, the standard error for the intervention on improving play areas was used, under the assumption that the level of uncertainty in capital expenses will be similar across the two interventions.
The intervention to improve play areas used the costs of six interventions for improving in parks in Bradford, and divided this by the population of children in the ward where the park is located. The analysis uses the average cost per capita of these interventions. The standard error was also drawn from this sample of costs. Data for the costs was obtained from the Better Place Bradford project team (Better Start Bradford).

This analysis uses the population of a ward as the catchment population of the intervention to estimate the cost per person, as a ward is the smallest geographical subdivision used by the United Kingdom for planning purposes. Green space interventions, such as Better Place Bradford, have also used wards as their target catchment area (Better Start Bradford). Other studies have also used distance from the green space as a proxy for exposure, but there is

currently no consensus on what should be defined as the catchment area of a public green space.

### 3.2.8 Net Monetary Benefit

Net monetary benefit is defined as net monetary benefit = $\lambda \times \Delta E - \Delta C$ where $\Delta E$ is the incremental effect and $\Delta C$ is the cost of the intervention per person and $\lambda$ is the opportunity cost for health. The toolkit measures effect size by a change in quality-adjusted life years (National Institute for Health and Care Excellence). A recent evaluation finds that this may be an overestimate, and the value should be closer to £12,936 per quality-adjusted life year gain (Lomas, Martin and Claxton, 2019). Given the variation in cost-effectiveness thresholds, the toolkit allows users to select from a range of options to calculate the net monetary benefit of interest for their use-case.

### 3.2.9 Sensitivity analysis

The toolkit allows users to choose the probabilistic analysis[4], which accounts for the uncertainty where it is reported by the included studies. For each study, the toolkit calculated 10,000 iterations for the costs and quality-adjusted life years. For each iteration, costs are selected using a gamma distribution, and the values for costs and standard errors described above. Quality-adjusted life years gained are selected by using normal distribution for the effect size based on the uncertainty reported by the study, where applicable. The toolkit will also randomly pick values from each of the included articles in the final iterations, to account for the variation and uncertainty between studies. The final set of results in the probabilistic analysis provides a graph of the range of values for net monetary benefit and allows the model to account for any uncertainty within the studies and across studies.

Users can also choose to run a deterministic analysis, which uses an average estimate of the effect size from the selected studies.

### 3.2.10 Scenario Analysis

The toolkit also provides users with results for additional scenarios, which includes a waning effect as there is some evidence that interventions for physical activity may have decreasing returns over time (Jennings, 2010). To account for this variation, users are able to

[4] Hatswell AJ, Bullement A, Briggs A, Paulden M, Stevenson MD. Probabilistic Sensitivity Analysis in Cost-Effectiveness Models: Determining Model Convergence in Cohort Models. Pharmacoeconomics. 2018 Dec;36(12):1421-1426. doi: 10.1007/s40273-018-0697-3. PMID: 30051268.

incorporate a 20% or 50% waning effect into the estimations for net monetary benefit. Incorporating the 20% waning effect will reduce the intervention effect each year by an amount that is an 20% of the original effect, such that the intervention effect is 0 by year 6. The 50% waning effect will reduce the intervention effect each year by an amount that is 50% of the original effect, such that the intervention effect is 0 by year 4.

## 3.3 Results

The toolkit allows users to estimate the expected net monetary benefit of their chosen investment across a range of different values for the opportunity cost of health and waning scenarios. The results section provides details of the probabilistic results using baseline data from the United Kingdom. This section has been organised by the expected impact for each type of intervention. and displays the results for some selected scenarios but users can use the toolkit to generate deterministic results, or results for other scenarios not listed here.

### 3.3.1 Building/Improving a green walkway/pathway

Figures 3.3 and 3.4 reveal the expected net monetary benefit, and the probability of cost-effectiveness from investing in improving a green pathway that can support people using the space for walking, running or cycling. Figure 3.3 is a histogram of the net monetary benefit values calculated across 10,000 iterations using a single scenario with cost-effectiveness analysis threshold of £20,000 and no waning effect. The results from this scenario find that the net monetary benefit can range from a maximum gain of £20 to a loss of £90 per person, with an average net monetary benefit gain of £0.68 and a median net monetary benefit per capita of £5.90 per person. The selected example uses a scenario where the opportunity cost of a quality-adjusted life year is £20,000, as value recommended by National Institute for Health and Care Excellence for England and Wales is between £20,000-£30,000, but users of the toolkit can select between a range of thresholds from £500 to £50,000. Figure 3.4 displays the range of average net monetary benefit and the probability of cost-effectiveness across different cost-effectiveness analysis thresholds. The values for the average net monetary benefit range from a loss of £0.75 per person to a gain of £3.5 per person using the thresholds £500 to £50,000, while the cost-effectiveness acceptability curve shows that the probability of cost-effectiveness ranges from 0% to 75% for a threshold of £500 to £50,000. The full range of values can be accessed through the toolkit.

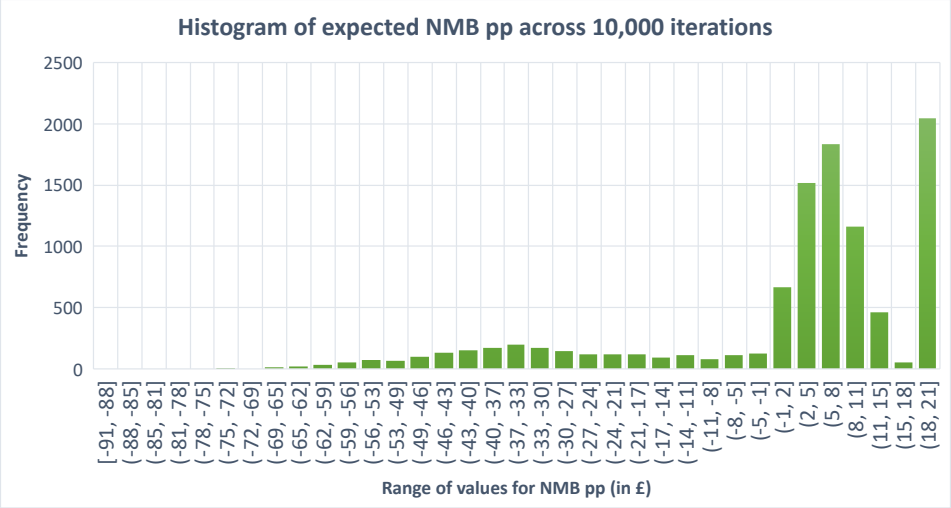



Figure 3.3 – Histogram of expected net monetary benefit per capita across 10,000 iterations for Building/Improving a green walkway/pathway for adults using a cost-effectiveness analysis threshold of £20,000 and no waning effect.

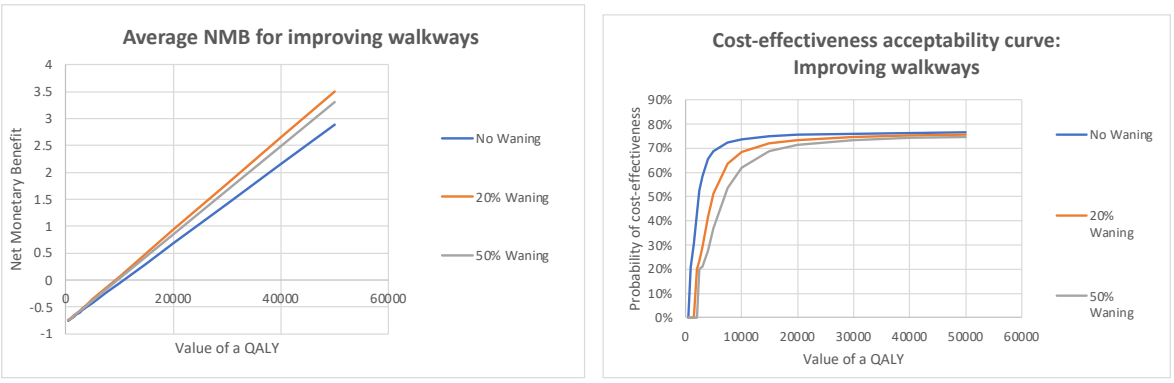



Figure 3.4: Average net monetary benefit per person and cost-effectiveness acceptability curve for investing in pathways

### 3.3.2 Installing/improving fitness equipment

Figure 3.5 displays the variation in net monetary benefit for investing in fitness equipment in an urban green space using a histogram, in a scenario which uses cost-effectiveness analysis threshold of £20,000 with no waning effect over 10 years. In this scenario, the net monetary benefit ranges from a loss of approximately £11 to a gain of £13 per person, with an average net monetary benefit of £6.02. Figure 3.6 shows that investing in fitness equipment appears to have a high probability of cost-effectiveness, with an over 80% probability of cost-effectiveness for all cost-effectiveness analysis thresholds higher than £7500 across all three waning scenarios. For the threshold of £20,000 suggested by National Institute for Health and Care Excellence in England, the probability of cost-effectiveness ranges from 98%-99% based on whether there is a waning effect. For the same cost-

effectiveness analysis threshold, the average net monetary benefit is £6, £2.7 or £1.8 for no waning, 20% waning and 50% waning respectively.

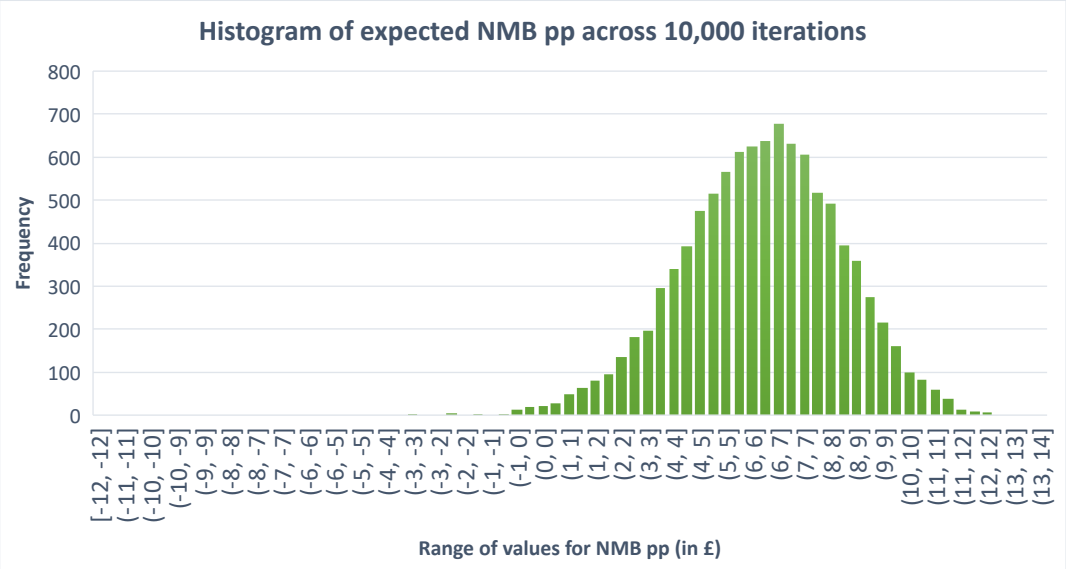



Figure 3.5 – Histogram of expected net monetary benefit pp across 10,000 iterations for installing/improving fitness equipment for adults using a CE threshold of £20,000 and no waning effect.

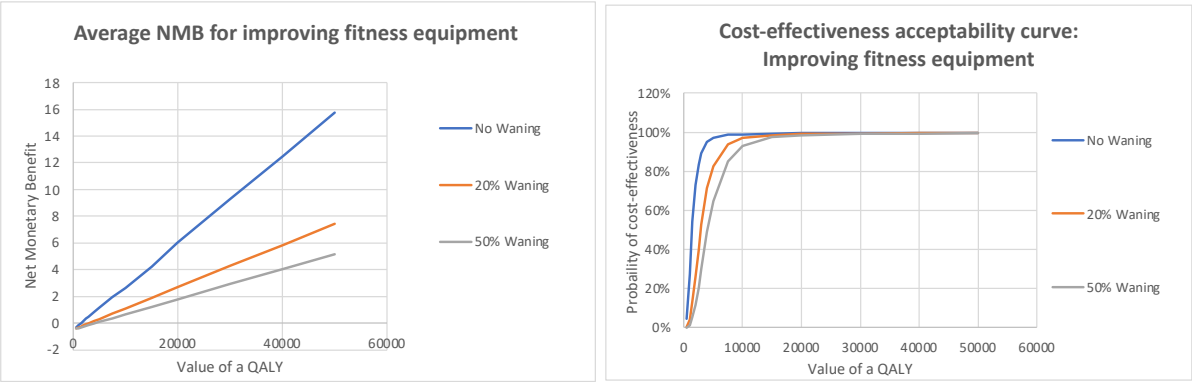



Figure 3.6 – Average net monetary benefit and cost-effectiveness acceptability curve for investing in fitness equipment

### 3.3.3 Installing/Improving play areas in a public green space

A third type of intervention is the improvement of play areas for children between the ages of one and twelve. In a scenario using a cost-effectiveness analysis threshold of £20,000 and no waning for 10 years, figure 8 below displays the range of values for net monetary benefit using a histogram – the values range from a minimum of losing approximately £127 to a

maximum of gaining £403 per person. The average net monetary benefit of this scenario is £64, the median is £105 and the probability of cost-effectiveness is 75%.

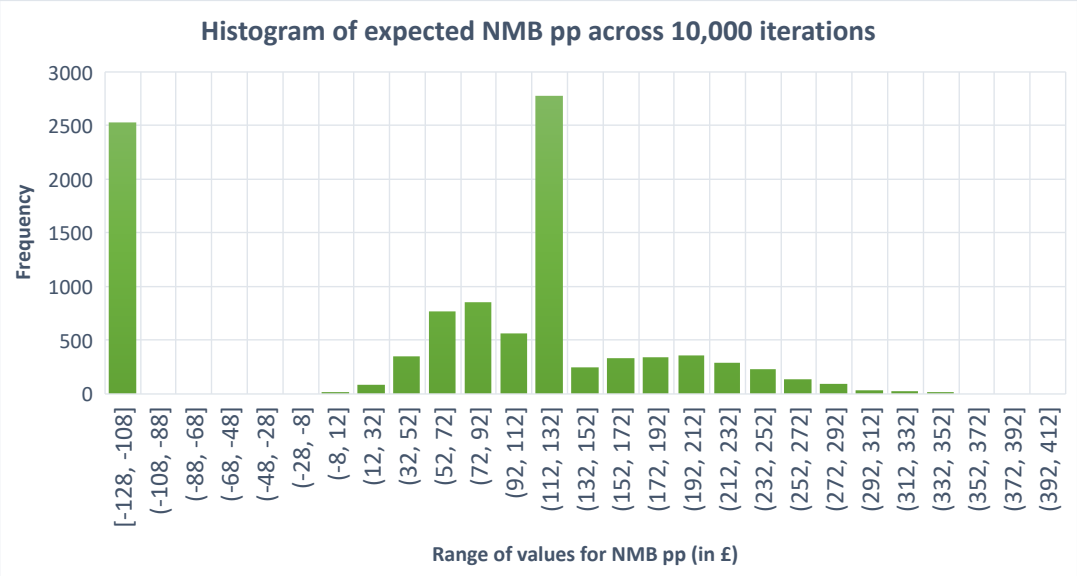



Figure 3.7 – Histogram of expected net monetary benefit pp across 10,000 iterations for installing/Improving play areas in a public green space using a CE threshold of £20,000 and no waning effect

Figure 3.8 shows that the average net monetary benefit is positive for all scenarios with cost-effectiveness analysis thresholds greater than £1000, irrespective of waning effects. The cost-effectiveness acceptability curve threshold plateaus quickly around 75%, which represents the uncertainty in the included studies. Three out of four studies found improvements to physical activity that were found to be largely cost-effective, whereas one study found that external factors such a lack of maintenance and security had led to a decrease in physical activity after the intervention. The existing evidence would suggest that improving play areas and play equipment may be highly cost-effective, but poor maintenance can negatively impact the results.

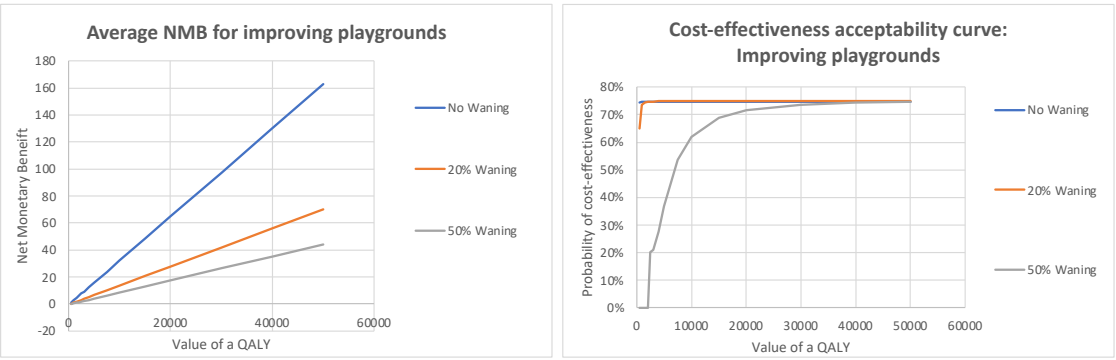



Figure 3.8 - Average net monetary benefit and cost-effectiveness acceptability curve for improving play areas/ play equipment

### 3.3.4 Comparing across interventions

The toolkit also allows users to compare across different types of interventions, and review how the expected net monetary benefit and probability of cost-effectiveness for their selection compares across other scenarios, and different interventions. Figure 3.9 displays an example whereby the user has selected the intervention to improve fitness equipment, a cost-effectiveness threshold of £20,000 and a 20% waning effect. In this example, the green graphs on the left show that the expected net monetary benefit would increase by increasing the threshold for cost-effectiveness, or by removing the waning effect. The probability of cost-effectiveness plateaus at cost-effectiveness analysis threshold of approximately £10,000 but reducing it further would decrease the probability of cost-effectiveness. Based on the evidence in the toolkit, the probability of cost-effectiveness is higher for improving fitness equipment, compared to other interventions for improving playgrounds or walkways. The expected net monetary benefit from investing in fitness equipment was lower compared to improving play areas, but higher than expected net monetary benefit from investing in walkways.

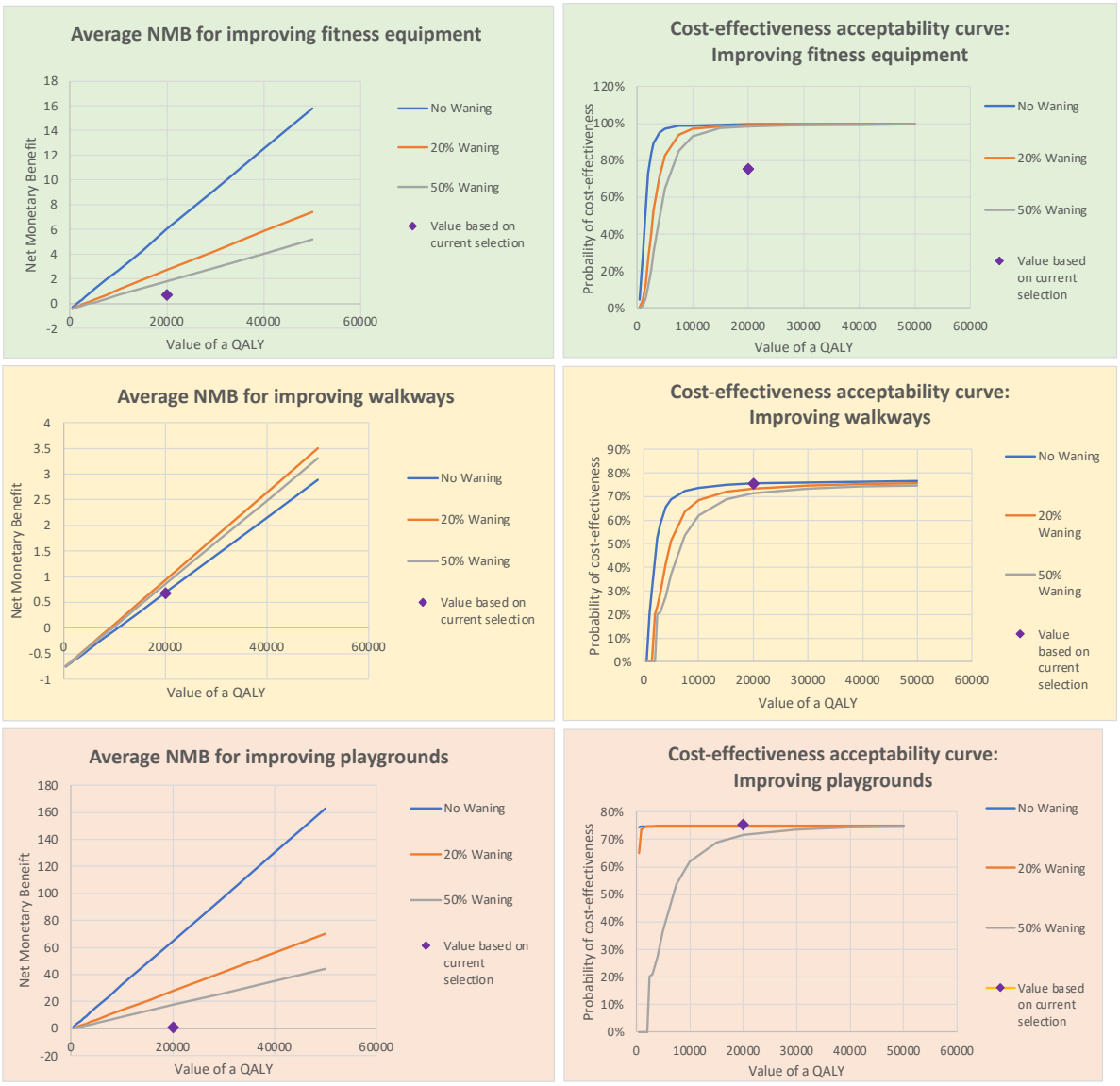



Figure 3.9: Comparing the net monetary benefit and cost-effectiveness acceptability across interventions

## 3.4 Discussion

THEAGS (Toolkit for the Health Economic Assessment of urban Green Space interventions) provides a comprehensive and adaptable tool to support decision makers and researchers advocate for improvements in urban green spaces and make evidence-based choices for investing in urban green spaces. The current evidence used in the toolkit suggests all the three types of investments in UGS, improving walkways, outdoor fitness equipment, and play areas, will likely lead be cost-effective at acceptable thresholds National Institute for Health and Care Excellence), and lead to improvements in physical activity. Cost-effectiveness was likely to be maintained after incorporating waning effects of both 20% and 50%

Whilst the probability of cost-effectiveness is high, there is considerable uncertainty in the results for expected return or the net monetary benefit, which is reflective of the variability in the costs and outcomes in the underlying data. There are a number of sources for the uncertainty, for instance the outcomes may vary by population groups, as studies reporting on more vulnerable populations typically reported a greater impact on physical activity, compared to studies in high income neighbourhoods (Raza et al., 2024). Another source of uncertainty of uncertainty stems from the variation in the maintenance of the interventions, as one study reported a negative effect on physical activity due to poor maintenance of the improvements to a playground (Pawlowski et al., 2019). Lastly, studies have found quality to be an important determinant of satisfaction with green spaces (McEachan et al., 2018b), and the uncertainty in both costs and outcomes may be linked to differences in the quality of the intervention itself.

This toolkit adds to the limited but growing literature around the cost-effectiveness of urban green spaces and provides a user-friendly resource for decision-makers to engage with decisions around the type of green space investments to choose from, and prioritising between green space investments with other local investments. Researchers have pointed to both the lack of economic evidence on green space interventions (Hunter et al., 2023), and the heterogeneity of evidence for environmental interventions like green spaces, and the challenges that this may pose for decision-makers (Bojke et al., 2018). This toolkit addresses this gap by consolidating the evidence on costs and effects, and presenting the evidence in an adaptable, user-friendly excel-based tool.

Previous studies evaluating the cost-effectiveness of interventions in urban green spaces have either found improvements in physical activity that were deemed to be cost-effective, or no change in physical activity leading to the conclusion that improving UGS is not a cost-effective investment (Cohen et al., 2012; Lal et al., 2019; Ward Thompson et al., 2019a, 2019b). This analysis takes the existing evidence one step further by consolidating the findings on improvements in urban green spaces and using probabilistic analysis so that decision can view and account for the uncertainty in the costs and effects of investing in an urban green space. The toolkit also allows users to customise the impact based on their existing baselines, and provides a range of scenarios, to assist decision makers curate the evidence on impact to their local context and needs. For instance, an intervention may be considered cost-effective in England using the proposed National Institute for Health and Care Excellence threshold of £20,000 to £30,000 per quality-adjusted life year, but may not be considered cost-effective in a lower income country with a lower threshold for a quality-adjusted life year. Similarly, interventions have a lower net monetary benefit with a high waning effect and may prove to be less cost-effective relative to competing public health investments.

There are also several limitations to the analysis used by the toolkit, and future iterations of the toolkit can be updated to address some of the existing limitations. For example, it was not possible to consolidate the evidence using a meta-analysis due to the heterogeneity of outcomes and research methodologies. However, once further research with more standardised outcomes becomes available, the toolkit can be easily updated to the results of a meta-analysis. The lack of existing evidence, and heterogeneity in outcome measures also means that the toolkit currently has a limited evidence base, for instance, there was currently no evidence on the impact of improving greenery - this should be expanded once more studies are available. Lastly, the model currently uses the only standard mapping for physical activity and quality-adjusted life years, but if further research provides age-specific mapping, the toolkit should be updated to include these values.

Future research may also consider other dimensions to the analysis, such as additional outcomes or distributional analysis. Interventions for urban green spaces can have a range of multi-sectoral impacts on mental health, education outcomes, and environmental outcomes (Bojke et al., 2018). There is still limited research on the impact of interventions for urban green space, and their effect on multi-sectoral outcomes, but this may be incorporated into the toolkit in the future. Decision-makers may also be interested in the distributional impact of physical activity for more vulnerable populations (Dawkins et al., 2018). There is some existing evidence that vulnerable populations may benefit more from improvements in urban green spaces (Agyeman, Bullard and Evans, 2002; Kruize et al., 2019), but more research would be needed to incorporate this into the existing toolkit.

Overall, THEAGS consolidates the evidence on the effectiveness and cost-effectiveness for interventions in urban green spaces and allows decision makers to generate localised evidence on cost-effectiveness relevant for their context. The current analysis using baseline data from the United Kingdom suggests that improvements to greenways, fitness equipment, play areas are likely to lead to cost-effective improvements in physical activity at the £20,000-£30,000 threshold. Improving/installing fitness equipment is more likely to lead to cost-effective improvements compared to investments in playgrounds or walkways, but improvements in physical activity from playground upgrades are likely to have the highest return on investment. Future iterations of THEAGS may incorporate additional evidence on the impact of interventions for urban green spaces, including evidence on additional outcomes such as the environment.

**Chapter 4: Can improvements to parks and playgrounds in a deprived setting effect prescriptions for anxiety and depression? A case study from Bradford, United Kingdom**

Preface

This chapter describes a longitudinal study to evaluate the impact of a UGS intervention in Bradford. The intervention named 'Better Place', is a part of the Better Start Bradford programme established in 2015 following a 10-year £215 million investment in five cities, namely Blackpool, Bradford, Lambeth, Nottingham and Southend-On-Sea, through the National Lottery Community Fund (Better Start Bradford).

Better Place Bradford includes several different UGS investments, such as planting trees, improving playgrounds, building new places and installing sculptures. These investments have been implemented across green spaces in the three most deprived wards of Bradford.

The evaluation in this paper was conducted with the support of the Born in Bradford, and Better Start teams. An application to recieve the Born in Bradford database was developed with the Born in Bradford team. Data access included the more recently linked National Health Services in Bradford health statistics. The exact codes for the relevant medicines, and diagnosis codes were developed with the support of the Born in Bradford team.

This initial data cleaning and linkages were relatively time-intensive for two main reasons: the first was that the data for the relevant Born in Bradford datasets were in 19 different datasets, which often used different unique identifiers. The datasets have been listed in Table 4.1 below. This made it difficult to collate the database, especially participant address which was necessary to determine exposure to the intervention. The second major challenge was that the database on medicine prescriptions was collected as open text with various dosage types such 'od' 'once in the morning' and others. This was cleaned manually to collect numeric values for prescription. The *do file* for this data cleaning is attached in appendix 4 and is available for use in any future analysis using National Health Service prescription data.

Table 4.1: List of datasets used from Born in Bradford

| Name of dataset | Year collected | No. of observations | Variables | Main id | Brief description |
|---|---|---|---|---|---|
| 1898_Green_Space_cohort_BiB_Baseline.base_m_survey | 2007–2010 | 3'387 | 23 | Father id | Descriptive information about fathers from original BiB cohort |
| 1898_Green_Space_cohort_BiB_Baseline.base_f_survey | 2007–2010 | 11'395 | 314 | Mother id | Desciptive details about mother and behaviours |
| 1898_Green_Space_cohort_BiB_Baseline.base_m1_exercise | 2007–2010 | 1'791 | 15 | Mother id | Exercise information for subset of original BiB population |
| 1898_Green_Space_cohort_BiB_Baseline.base_m23_exercise | 2007–2010 | 9'739 | 13 | Mother id | More exercise information for original BiB cohort |
| 1898_Green_Space_cohort_BiB_CohortInfo.id_linkage | 2007–2010 | 13'959 | 5 | family id | Provides mother, father and child id for each family |
| 1898_Green_Space_cohort_BiB_Geographic.bib_geog_house | 2011-2022 | 31'186 | 6 | House id | Links house with ward, LSOA, and information on BiBBS |
| 1898_Green_Space_cohort_BiB_Geographic.bib_geog_house | 2011-2022 | 3'358 | 6 | LSOA code | Provides iMD data by LSOA |
| 1898_Green_Space_cohort_BiB_GrowingUp.adult_survey | 2016–2020, | 5'404 | 265 | person id | Descriptive follow-up information for the original BiB parents. Collected between 2018-2020 |
| 1898_Green_Space_cohort_BiB_GrowingUp.child_survey_adult_comp | 2016–2020 | 5'141 | 131 | person id | Information on health of child provided by parent |
| 1898_Green_Space_cohort_BiB_GrowingUp.child_survey_child_comp | 2016–2020 | 4'678 | 126 | child id | Information on child health and activities provided by child |

| | | | | | |
|---|---|---|---|---|---|
| 1898_Green_Space_cohort_BiB_GrowingUp.participant_pathway | 2016–2020 | 30'134 | 8 | person id | Administrative data about BiB questionnaire |
| 1898_Green_Space_cohort_BiB_SDQs.COVID_phase1_sdq | 2020–2021 | 913 | 31 | child id | Variables on SDQs for child in first phase of Covid survey |
| 1898_Green_Space_cohort_BiB_SDQs.COVID_phase1_sdq | 2020–2021 | 631 | 31 | child id | Variables on SDQs for child in second phase of Covid survey |
| 1898_Green_Space_cohort_BiB_SDQs.COVID_phase3_sdq | 2020–2021 | 582 | 29 | child id | Variables on SDQs for child in third phase of Covid survey |
| 1898_Green_Space_cohort_BiB_COVID_survey.adult_bib_phase2 | 2020–2021 | 631 | 449 | person id | Covid survey for adult |
| 1898_Green_Space_cohort_BiB_COVID_survey.adult_bib_phase1 | 2020–2021 | 1'581 | 182 | person id | Covid survey for adult |
| BiBcohortethnicity | 2007–2010 | 29'664 | 5 | person id | ethnicity |
| 1898_Green_Space_cohort_primary care_BNFcodes | 2011-2022 | 165'180 | 8 | person id | Medicines data |
| 1898_Green_Space_cohort_primary care_ctv3codes | 2011-2022 | 34174 | 9 | person id | Diagnosis codes |

This paper includes an analysis of the impact of Better Place on mental health prescriptions using a two-part model and difference-in-differences approach. The exploratory analysis also included additional analyses that were ultimately not included in the final paper.

I used antidepressant prescriptions for two reasons. First, they're the one mental-health measure I could cost, which the economic evaluation needs, and they gave a continuous outcome (drug cost over time) rather than the binary a recorded diagnosis would provide. Second, prescriptions were captured continuously across the whole 2011–2022 window, whereas the symptom questionnaires (GAD-7, patient health questionnaire) were only collected once, before the intervention, so they couldn't track change over time. The trade-off is that prescriptions only capture people whose distress was treated with medication, and so they miss untreated cases and anyone managed through talking therapies. Therefore, the outcome should be viewed as a signal not a definitive result.

The first analysis as presented in Additional File 1 was a mapping of prescription data to mental health indicators such as generalised anxiety disorder, and the patient health questionnaire. This was then used to estimate the quality-adjusted life year impact and net monetary benefit of the intervention using an existing mapping of generalised anxiety disorder and patient health questionnaire to quality-adjusted life year. Initially, I intended to include the mental health impact as part of the net monetary benefit in the toolkit presented in chapter 3. However, ultimately this was not included in this paper or the toolkit as the only data I had access to for generalised anxiety disorder and patient health questionnaire was for mothers and limited data on fathers in the follow-up dataset for the Born in Bradford study. A mapping of generalised anxiety disorder and patient health questionnaire would ideally require a population-level dataset with more careful consideration of control variables to determine the age and gender specific relationship between generalised anxiety disorder, patient health questionnaire and prescription costs. The limitations of this dataset meant that it would not be able to do a proper analysis of the relationship between generalised anxiety disorder, patient health questionnaire and mental health prescriptions, and therefore after consultations with my supervisors, we ultimately decided to remove this analysis from the paper and thesis.

A second analysis presented in Additional File 2 was the relationship between mental health prescriptions and the count of green spaces within a 1000 metre radius. The results of this analysis found every 1 count increase in the number of green spaces was associated with 0.2 percentage point reduction in the probability of requiring a mental health prescription, and a £0.7 reduction in the cost of the prescriptions, holding all other factors constant. The results of this analysis have been included in additional file 2. This analysis was not included in this paper as it was addressing a tangential research question about the cross-sectional association between green spaces and mental health prescriptions, whereas this paper uses a longitudinal analysis to explore the relationship between a UGS intervention and its

impact on mental health prescriptions. Overall, the research question for the thesis is also related to interventions for UGS, compared to correlations between UGS and health outcomes.

Lastly, several other exploratory analyses using the Born in Bradford Growing Up study were estimated, including summary descriptives, correlations, and simple regressions. These were not included in this paper but informed the broader understanding of the dataset and the research question around the link between green spaces, mental health and physical activity. These results have been presented in Additional File 3.

The results from chapter 4 were presented at the EUHEA PhD conference in 2024, and for a brown bag session at the University of Luzern.

The paper in chapter 4 will be submitted as a research article to Value in Health.

Abstract

Background

The availability of urban green spaces is associated with improved mental health. This study evaluates the impact of improvements to urban green spaces, such as improving walking trails and greenery in urban parks, on mental health outcomes in a multi-ethnic deprived setting.

Methods

This study uses prescription data for depression and anxiety between 2011 to 2022 for participants enrolled in the longitudinal Born in Bradford cohort and analysed using a two-part difference-in-differences model to estimate changes in prescription rates related to park improvements, and associated costs.

Results

The intervention reduced prescription costs by £2.8 for women and £1.2 for men annually in the intervention area, representing a 15% and 6.6% decrease, respectively. Over five years, the intervention is projected to save the National Health Service £96,000 in prescription costs. However, the findings also highlight mixed effects on the likelihood of requiring a prescription, with women in the intervention area showing a slight increase in prescription rates compared to men, who experienced a decrease.

Discussion

While the intervention's cost (£1.6 million) outweighs the direct prescription savings, this analysis captures only a fraction of the potential benefits, excluding improvements in overall well-being, physical activity, and other health outcomes. The study underscores the importance of UGS quality and contextual factors in shaping health impacts, particularly in deprived areas. Future research should explore the long-term sustainability of these effects and broader societal benefits.

Conclusion

Improvements to green spaces have the potential to contribute to mental health improvements and health equity. Policymakers are encouraged to integrate UGS enhancements into strategies addressing mental health and urban health disparities in areas of health needs.

## 4.1 Introduction

Common mental disorders, including depression and anxiety, rank amongst the leading contributors to the global burden of disease, with depression being the fifth leading cause of disability worldwide (World Health Organization). A growing body of research has explored the potential role of urban green spaces (UGS) in supporting mental health. Urban green spaces (UGS) are publicly accessible areas within towns and cities that are intended for recreation and contact with nature, such as parks, playgrounds, urban forests and greenways, as opposed to private green areas such as residential gardens. Access to green space is associated with higher levels of physical activity, lower all-cause mortality, and lower rates of non-communicable diseases such as cardiovascular disease and type 2 diabetes, alongside environmental benefits such as reduced air pollution and lower urban temperatures (Markevych et al., 2017; Hunter et al., 2019).

There are multiple pathways through which UGS may improve mental health, such as by encouraging physical activity, enhancing social cohesion, and promoting a feeling of connectedness with nature (Akpinar, 2016; Fitzhugh, Bassett and Evans, 2010; University of Leeds, 2015; Lee and Maheswaran, 2011; van den Berg et al., 2015; Vieira et al., 2018; World Health Organization Regional Office for Europe, 2016). Previous models such as the stress reduction theory by Robert Ulrich (Ulrich et al., 1991) or the Attention Restoration Theory by Kaplan and Kaplan (Kaplan and Kaplan, 1989) also suggest that simply being around nature may reduce stress through a shift in attention and encouraging “soft fascination” of our surroundings. These pathways have also been described in more detail in the logic model in chapter 2.

Recently, studies have attempted to quantify the relationship between urban green spaces and mental health by using data on mental health prescriptions. Using prescription data allows researchers to use routinely collected individual or population-level data that is easily quantifiable to evaluate public health interventions. Their main limitation, especially for mental health, is that it does not capture the effect in populations without a prescription (Helbich et al., 2018; Astell-Burt et al., 2022b); even so, it may still serve as a useful indication of the direction of impact.

The current evidence of the link between UGS and prescription is mixed. Studies from Europe have found access to urban green spaces can lead to reduced prescriptions for antidepressants, but other studies, including a recent analysis from Bradford, United Kingdom, have found no association between greenness and prescriptions and diagnosis of common mental disorders (Aerts et al., 2022; Helbich et al., 2018; Subiza-Pérez et al., 2024). Paradoxically, a study on green spaces and mental health prescriptions in Australia found that greenness and tree cover was positively associated with anti-depressent prescribing (Astell-Burt et al., 2022b), suggesting that contextual factors such as the quality of the space

and the safety of the area may play an important mediating role in the relationship between green spaces and mental health.

The *quality* of green spaces has emerged as a crucial determinant of the health benefits of urban green spaces[5]. A study by McEachan et al. (2018b) found satisfaction with the quality of the green space to be a more important predictor for wellbeing than the availability of green space near their place of residence. A systematic review of the quality of green spaces and health outcomes found that areas with more tree canopy may have higher health benefits, compared to green spaces with more grassland (Nguyen et al., 2021). However, in more deprived urban areas, lower quality green space with barriers to accessibility, such as safety concerns, poor maintenance, and lack of facilities, can limit the potential health benefits of the urban green spaces (Holland, 2021; Patrick, Noy and Henderson-Wilson, 2016; Rigolon et al., 2021). Other determinants of the impact of green spaces on health include individual characteristics such as age or ethnicity, or contextual socio-economic factors such as socio-economic status, and urban density (Chen et al., 2021).

Targeted interventions can improve the quality of UGS, but there is limited evidence on whether these interventions for UGS translate into measurable mental health benefits. Reviews by Hunter et al. (2019) and Roberts et al. (2018) highlight the challenges of evaluating green space interventions, particularly due to the complex pathways linking green space interventions with mental health outcomes. The review in chapter 2 (Raza et al., 2024), related to interventions for urban green spaces, found that interventions such as improving playgrounds may have a positive impact on physical activity, but the impact on mental health was limited and mixed. The limited longitudinal evidence linking urban green space interventions with mental health outcomes has been further emphasised through reviews by Bojke et al (2018) and Hunter et al (2023).

In this study, this evidence gap is addressed by evaluating the impact of a green space intervention on common mental health disorders, specifically for depression and anxiety, by quantifying the impact of the green space intervention on medication for depression and anxiety. By focusing on prescriptions as a proxy for mental health treatment needs, this research provides critical evidence on the budget impact of urban green space initiatives as a potential public health intervention. This is especially relevant given that the recent National Health Service 10 Year Health Plan from 2025 sets out a "shift from treatment to prevention. Improving the quality of urban green space is one such preventive, population-level measure, and evidence on whether it reduces mental health prescribing speaks directly to this agenda. Alongside wider global policies such as the United Nations's Sustainable

[5] Quality of urban green spaces may be defined differently by different groups. This study reviews urban green spaces as a tool to improve mental health outcomes, through increased utilization, physical activity and social cohesion. As a result, a high-quality green space is defined as one that has features such as well-maintained walking paths, play areas, and amenities such as toilets that may make it more attractive for residents.

Development Goal 11.7 (United Nations), the findings from this study can contribute to evidence-based decision-making on the role of green space investments in alleviating the burden of mental health disorders.

## 4.2 Methodology

### 4.2.1 Study setting

Bradford is a city in northern England with a population of just over 560,000 people in 2023 (City of Bradford Metropolitan District Council; City of Bradford Metropolitan City Council, 2017). Of the 317 local authority districts in England, Bradford district is ranked the fifth most income-deprived and the sixth most employment-deprived local authority in England. Bradford is a relatively ethnically diverse city compared with other cities in England, with non-white minorities representing 38.9% of the population, and a significant proportion of people of Pakistani origin (25.5%) (City of Bradford Metropolitan District Council).

#### 4.2.1.1 The Better Place intervention

Better Place is a Lottery funded green space intervention implemented in the city of Bradford, aimed at improving public green areas to promote use and wellbeing, especially among young children (Better Start Bradford). This intervention included 51 projects for improving UGS implemented in three of the most deprived electoral wards in Bradford (Bowling and Barkerend, Bradford Moor, and Little Horton). An electoral ward is the standard administrative geography used to divide local authorities in England for local government and elections. Bradford district is divided into 30 wards, each represented by three councillors, with an average of roughly 18,000–19,000 residents per ward (City of Bradford Metropolitan District Council).

The list of interventions includes planting trees and improving vegetation, improving play areas especially for young children, improving trails, and including interactive activities such as a trail walk (Better Start Bradford).

Figure 4.1 shows some photos from after the intervention in Bowling Park, one of the sites for improvements.



Figure 4.1: Examples of park improvements in Bowling Park, Bradford

4.2.2 The Born in Bradford cohort

Born in Bradford (BiB) which is a birth cohort set up in 2007 for new parents across the city of Bradford and includes a range of economic and socio-demographic indicators. Between 2007 and 2010, the study recruited around 12,450 women across roughly 13,800 pregnancies, usually at their 26–28 week appointment at Bradford Royal Infirmary, together with a sub-study of their partners (Wright et al., 2013). The cohort mirrors Bradford's population and is one of the most ethnically diverse birth cohorts in the United Kingdom, with a large proportion of mothers of Pakistani origin. The survey includes questions on age, address, ethnicity, and a range of other questions on socio-economic and health status. The analysis uses the responses on age and ethnicity, as identified by the participants of the initial survey in 2007.

The survey has also been linked with a range of environmental, and health statistics from other databases, such as the National Health Service database. More information on the Born in Bradford dataset can be found elsewhere (Raynor, 2008; Wright et al., 2013). This study used data from 10,486 women and 3,287 men enrolled as part of the Born in Bradford cohort.

4.2.3 Study sample

This study analyses the adult parents in the BiB cohort (the mothers and fathers) from the survey. Parents are the relevant population here because they are adults with continuous primary care records across the study period (2011–2022), whereas the children were too young for adult mental health prescribing to be meaningfully observed. The final sample comprises 10,486 women and 3,287 men enrolled in Born in Bradford, for whom baseline age and ethnicity and linked prescription records were available. Analyses are run separately for women and men throughout.

### 4.2.3 Mental health prescriptions

This study used prescription data from the adult parents enrolled in the Born in Bradford study. Data available over the period 2011 to 2022 was included. 2022 was the last year where the data was available for extraction at the time of this analysis. The prescription data served as a proxy for anxiety and depression severity, and were extracted using linked health statistics from the primary care database of the National Health Service in England. The list of medicines for inclusion was defined using the categorisation by the British National Formulary for depression and anxiety (National Institute for Health and Care Excellence, 2024a). After extracting prescription data from the National Health Service database, the data were cleaned by coding all the different types of prescriptions from open text to specific quantities. Supplementary File 1 details the name and frequency of each medicine prescribed amongst the study participants between 2011 and 2022.

### 4.2.4 Cost of prescriptions

The unit cost for each unit of each medicine was collected using the 'National Health Service drug price' for the British National Formulary formulations from 2022 (National Institute for Health and Care Excellence, 2024a).The total cost of medicine was calculated by multiplying the dosage for each medicine in each prescription by the unit cost of the medicine, to estimate a cost of the medicines prescribed. This cost was then aggregated for each participant for every year to estimate the total cost of all medicine prescriptions for depression and anxiety for each participant for each year.

### 4.2.5 Cost of intervention

The per capita cost of the intervention for each of the three wards was calculated using the following formula:

$$\frac{Total\ cost\ of\ upgrades}{Total\ population\ of\ the\ ward}$$

The total cost of the interventions was received from the Better Place implementation team, and the population of the ward was obtained from the local census data in 2021.

### 4.2.6 Intervention v control group

The Better Place intervention was implemented across UGS in three of the most deprived electoral wards of Bradford, Bowling and Barkerend, Bradford Moor, and Little Horton. The intervention group was defined as the residents of these three wards after the intervention had been implemented. The variable for the intervention area was organised to reflect each participant's latest address for each year, to account for those individuals that may have changed their address in this 11-year period. The follow-up period for this analysis was from 2021 to 2022. The control group comprises residents of all other wards in Bradford in this time period.

### 4.2.7 Analysis

#### 4.2.7.1 Two-part model using a difference-in-differences approach

This study used a two-part model (Farewell et al., 2017; Belotti et al., 2015) using a difference-in-differences approach (Card and Krueger, 1994) to estimate the impact of Better Place on prescriptions for depression and anxiety.

Two-part models are commonly used in health economics, as cost data are often negatively skewed with many zero values (Belotti et al., 2015; Leung & Yu, 1996). The first part of the model estimates the change in the proportion of participants who needed a prescription for depression or anxiety after the intervention, so the outcome of interest is coded as a binary of 0 for those who do not have a prescription and 1 for those with a prescription. The second part of the model estimates the change in the cost of the prescription after the intervention for those that needed a prescription, so it only uses data from participants with a prescription.

A difference-in-differences approach was used to estimate the intervention effect. This approach is used to isolate the impact of an intervention by comparing the outcomes of the group receiving the treatment and the control group over time (Card and Krueger, 1994). It is a useful tool to measure the effect of public policies, such as the public health intervention and environmental intervention evaluated in this study.

The difference-in-differences in this study used a generalised linear model with log-link distribution. A two-part model was considered the most appropriate for this analysis, as the data on cost of prescription are continuous, but highly negatively skewed with no negative values (Farewell et al., 2017).

The difference-in-differences estimator relies on the parallel trends assumption: in the absence of the Better Place intervention, prescriptions for depression and anxiety in the intervention wards would have followed the same trend over time as those in the control wards. Under this assumption the control group serves as a valid counterfactual, and the interaction term isolates the effect of the intervention from any change common to both groups. The assumption cannot be observed after the intervention, but it was examined for the pre-intervention years and is reported in Section 4.3.2. For a difference-in-differences analysis, adding covariates is only considered necessary where it may impact the rate of change in our outcomes of interest, which in this case includes whether a participant received a prescription for common mental disorders, or the cost of the prescription. There is some evidence on differences in care seeking for mental health care across different ethnicities (McEachan et al., 2018) so the analysis was run both unadjusted, and including ethnicity as a covariate for the analysis.

The equations for the 2-part analysis are as follows:

Unadjusted analysis

Part 1 (Change in proportion of residents needing a prescription):

$$Binary\ value\ indicating\ whether\ there\ was\ a\ prescription\ in\ a\ given\ year = \beta o + \beta 1 postinterventionyears + \beta 2.Betterstartresidents + \beta 3 interventionyr.Betterstartresidents + \varepsilon$$

Part 2 (Expected change in the cost of prescriptions):

$$Cost\ of\ mental\ health\ \ prescription\ = \ \beta o + \beta 1 postinterventionyears + \beta 2.Betterstartresidents + \beta 3 interventionyr.Betterstartresidents + \varepsilon$$

where $\beta 3$ is the coefficient of interest that estimates the impact of the intervention on mental health prescriptions. $\beta 2$ estimates the impact of living in the Better Place wards, and $\beta 1$ estimates the impact of the post-intervention period on mental health prescriptions.

Including a covariate for ethnicity

Part 1 (Change in proportion of residents needing a prescription)::

$$Binary\ value\ indicating\ whether\ there\ was\ a\ prescription\ in\ a\ given\ year = \beta o + \beta 1 postinterventionyears + \beta 2.Betterstartresidents + \beta 3 ethnicity + \beta 4 interventionyr.Betterstartresidents + \varepsilon$$

Part 2 (Expected change in the cost of prescriptions):

$$Cost\ of\ mental\ health\ prescription = \beta o + \beta 1 postinterventionyears + \beta 2.Betterstartresidents + \beta 3 ethnicity + \beta 4 interventionyr.Betterstartresidents + \varepsilon$$

where $\beta 4$ is the coefficient of interest that estimates the impact of the intervention on mental health prescriptions. $\beta 3$ estimates the effect of ethnicity, $\beta 2$ estimates the impact of living in the Better Place wards, and $\beta 1$ estimates the impact of the post-intervention period on mental health prescriptions.

The analysis was run separately for men and women, as the dataset included separate surveys for mothers and fathers. Separating the results for men and women had the benefit of preventing any collinearity, as the mothers and fathers are typically from the same household. The analysis was conducted using STATA 17 (StataCorp, 2021)

#### 4.2.7.2 Long term savings from the intervention

The results from the difference-in-differences study were extrapolated across the intervention population over the longer term to estimate the total longer-term impact on medicines spending for anxiety and depression. This extrapolation was conducted for a single scenario, which assumes that the intervention will last for five years. Extrapolating results beyond this time horizon was deemed uncertain, due to the short duration of the observed period. The costs were discounted by 3% after year 1.

## 4.3. Results

### 4.3.1 Descriptive statistics

For the participants included in this analysis, in 2022, 16% of women and 14% of men were living the in the intervention area. The average age of men and women was 30.8 and 27.3 respectively in the intervention group, and 30 and 27.5 respectively in the control group at the time that the survey was conducted (Table 4.2).

Table 4.2 shows the proportion of Bradford residents in each of the 2019 Index of Multiple Deprivation deciles.
Overall, 43% of women surveyed and 38% of men surveyed lived in neighbourhoods that are ranked as the most deprived decile across England. The intervention area shows a much higher level of deprivation than the city as a whole since 85% of the participants were living in the most deprived decile, and all participants lived in areas ranked in the two most deprived deciles. There is a high proportion of ethnically South-Asian families of Pakistani origin in Bradford as a whole, with a much higher proportion (71% compared to 44% in women, and 55% compared to 25% in men) in the intervention group (Table1).

Table 4.2: Descriptive characteristics from men and women in the intervention and control populations

| | **Women** | | | | | | **Men** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Overall** | | **Intervention** | | **Control** | | **Overall** | | **Intervention** | | **Control** | |
| **Characteristic** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** |
| **N** | 10486 | 100 | 1727 | 16% | 8759 | 84% | 3287 | 100 | 452 | 14% | 2769 | 76% |
| | | | | | | | | | | | | |
| **Average age** | 27.3 | - | 27.3 | - | 27.5 | - | 30.1 | - | 30.8 | - | 30 | - |
| | | | | | | | | | | | | |
| **IMD Decile** | | | | | | | | | | | | |
| 1 | 4518 | 43% | 1446 | 84% | 3072 | 35% | 1214 | 38% | 384 | 85% | 830 | 30% |
| 2 | 1632 | 16% | 281 | 16% | 1351 | 15% | 495 | 15% | 68 | 15% | 427 | 15% |
| 3 | 1704 | 16% | 0 | 0% | 1704 | 19% | 519 | 16% | 0 | 0% | 519 | 19% |
| 4 | 681 | 7% | 0 | 0% | 681 | 8% | 223 | 7% | 0 | 0% | 223 | 8% |
| 5 | 446 | 4% | 0 | 0% | 446 | 5% | 161 | 5% | 0 | 0% | 161 | 6% |
| 6 | 507 | 5% | 0 | 0% | 507 | 6% | 190 | 6% | 0 | 0% | 190 | 7% |
| 7 | 327 | 3% | 0 | 0% | 327 | 4% | 129 | 4% | 0 | 0% | 129 | 5% |
| 8 | 294 | 3% | 0 | 0% | 294 | 3% | 132 | 4% | 0 | 0% | 132 | 5% |
| 9 | 215 | 2% | 0 | 0% | 215 | 2% | 93 | 3% | 0 | 0% | 93 | 3% |
| 10 | 152 | 1% | 0 | 0% | 152 | 2% | 61 | 2% | 0 | 0% | 61 | 2% |
| | | | | | | | | | | | | |
| **Ethnicity** | | | | | | | | | | | | |
| White | 4469 | 43% | 263 | 15% | 4206 | 48% | 1650 | 51% | 85 | 19% | 1565 | 57% |
| Pakistani-SA | 4648 | 44% | 1233 | 71% | 3415 | 39% | 929 | 29% | 248 | 55% | 681 | 25% |
| Other | 1369 | 13% | 231 | 13% | 1138 | 13% | 642 | 20% | 119 | 26% | 523 | 19% |

4.3.2 Trends in prescription data for depression and anxiety

Overall, the proportion of adults receiving prescriptions for depression and anxiety increased in both the intervention and control group over the 12-year period used in this

analysis, with a slight decline in 2022 as seen in Figure 4.2. The proportion of people receiving prescriptions was consistently lower in the intervention group compared with the control group

A breakdown by gender reveals that a higher proportion of women received a prescription for depression and anxiety in both the intervention area (10.6% of women compared to 7.84% men) and control area (13.7% women compared to 8.4% men) as seen in Table 4.3. Appendix 1 also shows the comparison of the intervention population to the Bradford district population.

For those who received a prescription, the average cost of the prescription is higher in the control area (£18 per person), compared to the intervention area (£13.7 per person). This difference in average prescription costs appears to be driven by prescriptions for women, where there is a much bigger difference compared to the difference for men. We explored whether this difference in prescription cost may be driven by differences in prescription practices, for example to see if certain general practitioners in the control area have switched to prescribing more expensive medication or vice-versa. To test our hypothesis, we reviewed prescription trends for the three medicines that made up more than 60% of the total prescriptions across all participants. The parallel trends assumption was tested formally rather than by visual inspection of Figure 4.2. The difference-in-differences models were re-estimated with the intervention interaction reassigned to a pre-intervention period, and the interaction term was examined under the specifications used in the main analysis: a random-effects logistic model for the probability of a prescription and a gamma generalised linear model for prescription cost. The group-by-period interaction was not statistically significant in either the unadjusted or adjusted probability models ($p = 0.09$ and $p = 0.11$), nor in the gamma cost model ($p = 0.86$), indicating no evidence of differential trends between the intervention and comparator groups before the intervention.. Further details can be found in Supplementary file 2.

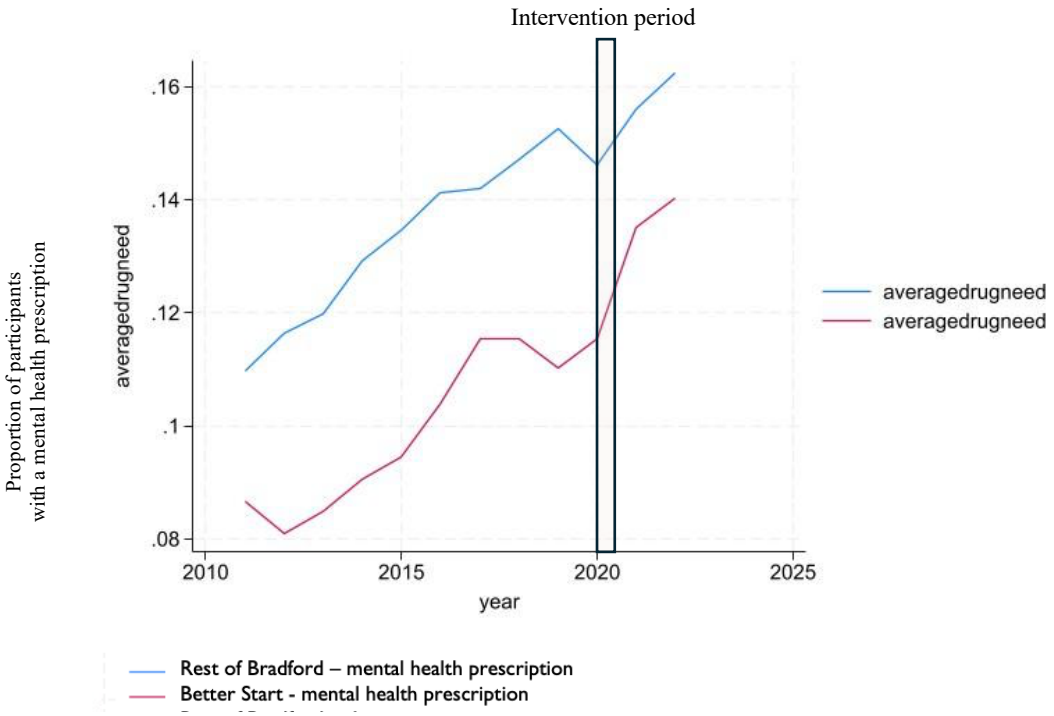



Figure 4.2: Proportion of participants requiring a prescription for common mental disorders across intervention and control areas

Table 4.3: Average prescriptions in intervention and control groups

| | | **Intervention group*** | **Control group*** |
|---|---|---|---|
| **Average proportion of people with a prescription** | All participants | 10% | 12.4% |
| | Women only | 10.6% | 13.7% |
| | Men only | 7.84% | 8.41% |
| **Average cost of prescription (in £)** | All participants | 1.37 | 2.23 |
| | Women only | 1.36 | 2.47 |
| | Men only | 1.40 | 1.54 |
| **Average prescription cost for participants with a prescription (in £)** | All participants | 13.7 | 18.0 |
| | Women only | 12.8 | 17.9 |
| | Men only | 17.9 | 18.3 |

*Based on participants latest address

4.3.3.1 Unadjusted analysis

The results presented in Table 4.4 shows the unadjusted difference-in-differences analysis for requiring a prescription. Based on these results, both men and women were more likely to require a prescription in the years following the intervention. The interaction term, which estimates the impact of the intervention, shows that women were 28% less likely, and men were 1.8% less likely to require a prescription in the intervention years (2021/2022) and in the intervention group, compared to the control group.

The results in Table 4.5, from the analysis which measures the impact on prescriptions costs, suggests that the intervention may have led to a £2.80 decrease in the cost of the prescription for women and a £1.19 decrease for men living in the intervention wards compared to the control group. By comparing against the average cost of prescription for women and men, this represents approximately a 15% yearly decrease in prescription costs for women, and a 6.6% yearly decrease in the prescription costs for men.

Table 4.4: Estimating the impact of Better Place on requiring a prescription for a depression and anxiety (unadjusted)

| | **Women (n= 10,485)** | | | | **Men (n= 3,287)** | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** |
| Post-intervention period (2021–2022 | 0.597 | <0.001 | 0.592 | 0.602 | 0.021 | <0.001 | 0.015 | 0.027 |
| Intervention area (Better Place wards) | -0.174 | <0.001 | 0.162 | 0.186 | 0.00 | 0.984 | -0.014 | 0.013 |
| Intervention effect (difference-in-differences) | -0.28 | <0.001 | -0.296 | -0.273 | -0.018 | 0.012 | -0.03 | -0.004 |

Table 4.5: Estimating the impact of Better Place on prescription costs for depression and anxiety for those who had a prescription (Unadjusted)

| | **Women (n= 10,485)** | | | | **Men (n= 3,287)** | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** |
| Post-intervention period (2021–2022 | 6.661 | <0.001 | 6.60 | 6.72 | 3.178 | <0.001 | 3.01 | 3.34 |
| Intervention area (Better Place wards) | 2.07 | <0.001 | 1.91 | 2.22 | -1.48 | <0.001 | -1.90 | -1.07 |
| Intervention effect (difference-in-differences) | -2.80 | <0.001 | -2.90 | -2.70 | -1.19 | <0.001 | -1.65 | -0.72 |

4.3.3.2 Adjusted analysis

The analysis was repeated including the variable for ethnicity as a covariate. Women in the intervention area were 1.9% more likely to receive a prescription after the intervention, while men in the intervention area were 1.9% less likely to receive prescription after the intervention as seen in Table 4.6. Women of Pakistani origin were estimated to be 10% less likely, and men of Pakistani were 2.8% less likely, to need a prescription compared to participants that identified as white. All participants were more likely to require a prescription in the years 2021 and 2022 compared to previous years.

The results from part two of the adjusted analysis reveals that the intervention may have led to a £2.76 decrease in the cost of the prescription for women and a £1.19 decrease for men compared the control group. By comparing against the average cost of prescription for women and men, this represents approximately a 15% yearly decrease in prescription costs for women, and a 6.6% yearly decrease in the prescription costs for men.

Table 4.6: Estimating the impact of Better Place on requiring a prescription for depression and anxiety (adjusted)

| | **Women (n= 10,485)** | | | | **Men (n= 3,287)** | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** |
| Post-intervention period (2021–2022) | 0.023 | <0.001 | 0.019 | 0.027 | 0.020 | <0.001 | 0.015 | 0.027 |
| Intervention area (Better Place wards) | -0.002 | 0.457 | -0.011 | 0.005 | 0.009 | 0.222 | -0.006 | 0.024 |
| Pakistani or South Asian (vs White British) | -0.106 | <0.001 | -0.116 | -0.097 | -0.028 | <0.001 | -0.043 | -0.013 |
| Other ethnic group (vs White British) | -0.123 | <0.001 | -0.134 | -0.111 | -0.066 | <0.001 | -0.08 | -0.053 |
| Intervention effect (difference-in-differences) | 0.019 | <0.001 | 0.008 | 0.0307 | -0.019 | 0.011 | -0.034 | -0.004 |

Table 4.7: Estimating the impact of Better Place on the cost of prescriptions for those who had a prescription (adjusted)

| | **Women (n= 10,485)** | | | | **Men (n= 3,287)** | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** |
| Post-intervention period (2021–2022) | 6.68 | <0.001 | 6.63 | 6.74 | 3.19 | <0.001 | 3.02 | 3.35 |
| Intervention area (Better Place wards) | 2.25 | <0.001 | 2.09 | 2.40 | -1.05 | <0.001 | -1.48 | -0.62 |
| Pakistani or South Asian (vs White British) | -1.28 | <0.001 | -1.48 | -1.09 | -2.34 | <0.001 | -1.66 | -0.721 |
| Other ethnic group (vs White British) | -1.68 | <0.001 | -1.99 | -1.37 | -2.92 | <0.001 | -2.75 | -1.92 |
| Intervention effect (difference-in-differences) | -2.76 | <0.001 | -2.86 | -2.66 | -1.19 | <0.001 | -3.48 | -2.37 |

4.3.4 Cost of interventions per capita

The costs in Table 4.8 represent the fixed costs of the interventions from the lottery fund received for Better Place. The cost of maintenance was not included, as the maintenance is expected to be included in the existing maintenance budgets for the UGS.

In this analysis, we have also limited the cost to the 36 projects completed by 2021, and approximately £1.6 million was budgeted to be spent by 2021. A breakdown of the cost per person spent by 2021 can be found in Table 4.8 below, which reveals that the cost per person ranges from £14.8 to £38.8.

Table 4.8 – Cost per capita (£) of the intervention 'Better Place'

| **Name of Ward** | **Cost per person (£)** |
|---|---|
| Bowling and Barkerend | 15.4 |
| Bradford Moor | 14.8 |
| Little Horton | 38.8 |

4.3.5 Long-term implications of intervention

The results from the difference-in-differences analysis have been used to estimate the longer-term savings for the National Health Service from this green space intervention in Bradford, United Kingdom. The results from part one and part two of the model, using the more conservative estimates of the model which includes the covariate for ethnicity, were extrapolated over 5 years to estimate the change in the proportion of people requiring a prescription, and the expected change in the National Health Service spending on prescriptions for depression and anxiety.

Table 4.9 shows a breakdown of the expected change in the average cost of the prescription, the change in the proportion of people requiring a prescription, and the expected savings from the changes in prescription as a result of the intervention for men and women in each year. In a scenario where the intervention effect lasts for five years, the NHS in Bradford can expect total savings of over **£**96,000 in prescription costs alone.

Table 4.9 – Predicted long-term changes (£) in population mental health prescription for Bradford

| | | Baseline | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|---|---|
| **Average cost of a prescription (in £)** | Women | 13 | 11 | 9 | 8 | 7 | 6 |
| | Men | 18 | 17 | 16 | 15 | 14 | 13 |
| | | | | | | | |
| **Expected numbers of people requiring prescriptions** | Women | 2700 | 2752 | 2802 | 2854 | 2907 | 2960 |
| | Men | 1964 | 1927 | 1891 | 1856 | 1822 | 1788 |
| | | | | | | | |
| **Expected total prescription cost per year (in £)** | Women | 34566 | 29939 | 26054 | 22674 | 19732 | 17172 |
| | Men | 35155 | 32211 | 29593 | 27188 | 24978 | 22948 |
| | | | | | | | |
| **Expected savings per year (in £)** | Women | 0 | 4627 | 8511 | 11892 | 14834 | 17394 |
| | Men | 0 | 2944 | 5562 | 7967 | 10176 | 12206 |
| | | | | | | | |
| **Total savings in 5 years (in £)** | 96,113 | | | | | | |

4.4 Discussion

This analysis has shown that, the investment by the Bradford Better Place project to improve playgrounds and greenery across parks in selected wards, does appear to represent an effective policy choice to improve mental health. The results of the difference-in-differences analysis indicate a reduction in spending on mental health prescriptions across men and women which would suggest that interventions in the parks have led to an improvement in mental health. The unadjusted model with no covariates found a significant reduction in both the likelihood of needing a prescription and the expected cost of the prescription, whilst the adjusted model found that women in the intervention group were more likely to require a prescription albeit the cost of the prescription would be lower. The adjusted model for men found that men in the intervention group were both less likely to require a prescription, and those prescriptions were relatively cheaper compared to the control group. Using the more conservative findings from the adjusted model, the intervention impact on prescriptions for depression and anxiety could lead to overall savings of £96,000 for National Health Service Bradford through prescription costs alone, whilst the actual savings from any improved mental health are likely much higher.

This potential improvement in mental health should be interpreted with caution in light of the observed increase in mental health prescriptions amongst women using the adjusted

model. It is unlikely that the increase in prescriptions would be due to the intervention, but rather that the factors driving increased number of men and women requiring prescriptions over time may have more impact than the intervention itself. National surveys from this period found that common mental disorders reported amongst adults in the United Kingdom had increased from 10% to 16% between 2019 and 2022 (Office of National Statistics, 2022). One potential cause of the worsening mental health in the intervention period was the cost-of-living crisis in the United Kingdom, which has been linked to poor mental health amongst deprived populations (Office of National Statistics, 2022; King's College London, 2023).

These results add to the limited literature reviewing the effect of green space interventions and mental health outcomes. The findings from this analysis differ from the most closely related evaluation using mental health which found no improvements to stress from an urban green space intervention (Ward Thompson et al., 2019a). However, as seen in chapter 2, other articles reviewing the impact of urban green space interventions on physical activity found predominantly positive effects on physical activity (Raza et al., 2024). There are also other studies from the Netherlands and Belgium which measure the overall impact of UGS with mental health prescriptions with mixed results, but these studies did not focus on specific features or improvements to UGS (Aerts et al., 2022; Helbich et al., 2018).

Based on this analysis, the National Health Service in Bradford is projected to achieve savings of approximately £100,000 over five years, which is substantially lower than the intervention cost of £1.6 million. However, this analysis only captures a small proportion of the potential total benefit from the intervention. Firstly, the analysis only captures the impact on those participants whose depression and anxiety are severe enough to require a prescription, and so improvements in wellbeing for participants without a prescription would not be captured here. By limiting the analysis to those with a prescription, this study also will not capture the impact on the prevention of mental health conditions, which is a key focus for the National Health Service (National Health Services, 2019). Secondly, the analysis does not include the other health or multi-sectoral benefits of urban greenspace interventions, as it does not include changes in physical activity, education, or environmental improvements. It also does not assess changes in general practitioner visits or respiratory or cardiovascular benefits from physical activity. Therefore, this analysis does not capture the full range of impacts from interventions for UGS. Thirdly, the analysis does not specifically include young children or their parents, who were the primary beneficiaries of some interventions like the improved play areas for (Hossain et al., 2020; King's College London, 2023). The intervention group is considerably more deprived than the control group and the economic difficulties of these macro events such as the cost-of-living may have had a more detrimental impact on the mental health of participants in the intervention group. As most of these limitations may lead to an underestimation of the intervention's

true impact, it is still reasonable to conclude that the intervention is likely to reduce prescriptions for depression and anxiety and may improve mental health.

This study estimated the benefit to the National Health Service for a scenario where the intervention effect was assumed to last for five years; however, future research could help determine how long the intervention effect lasts, and whether there is a waning effect of the intervention over time. Furthermore, additional research that includes the impact on other parameters such as physical activity, and the impact on additional populations including children and older adults may also provide a more complete overview of the impact of the intervention. Lastly, this study used residence in the intervention wards as a proxy for exposure to the intervention, which is those residents who make use of the green space upgrades. Future research may be able to use more precise data on the use of UGS as exposure to the intervention, where these data are available.

Estimating the health impact of interventions in green spaces can be challenging, and most of the current research comprises cross-sectional studies, with very few longitudinal studies (Hunter et al., 2019; Raza et al., 2024). This study provides a novel approach of using routinely collected prescription data, to estimate the effectiveness of a green space intervention. Our findings indicate that the intervention may have led to some improvements in the mental health of both men and women who have prescriptions, but the impact on whether an adult needs a prescription is mixed.

In conclusion, the results of this analysis indicate that UGS interventions such as the Better Place improvements in Bradford can be an effective policy approach to addressing current mental health challenges. While the effect of the intervention on the need for prescriptions was mixed, the findings highlight a reduction in prescriptions, with expected savings of approximately £100,000 over five years. Future research should explore the long-term sustainability of these effects, the broader health and societal benefits of UGS improvements, and impacts on additional populations, including children and older adults. Despite some limitations, this study adds to the growing evidence base supporting urban greening as a viable public health intervention, particularly in deprived settings. Policymakers should consider urban green space investments as part of broader strategies to improve mental health and promote health equity.

## Chapter 5: Discussion

### 5.1 Importance of findings

The literature on urban green spaces consistently demonstrates that improving access to UGS is an effective public health intervention, particularly in relation to improving physical activity and mental health. Systematic reviews and epidemiological studies have found that living near an UGS may be linked to increased physical activity (Shen et al., 2021; Zhang et al., 2022), reduced risk of mental health conditions (Vanaken and Danckaerts, 2018; Xian et al., 2024; Liu et al., 2023), and overall improved mortality (Rojas-Rueda et al., 2019). In addition to health, there is emerging evidence on the links between UGS and cognitive function or educational performance, particularly among children (Dadvand et al., 2015; de Keijzer et al., 2016; Glover et al., 2024).

However, the existing literature has several limitations. Much of the research on UGS relies on cross-sectional analysis using aggregate measures of greenness, such as the Normalized Difference Vegetation Index, or proximity to green space instead of specific investments or interventions to improve the features of UGS (Lee and Maheswaran, 2011). Additionally, there is limited research on the efficiency or cost-effectiveness of UGS investments, which could assist in prioritisation decisions for local policy makers. More evidence on the efficiency of spending on improvements for UGS would help policymakers and researchers advocate for UGS interventions and support informed choices for their investments. The lack of evidence is partly due to the complexity of the intervention, which would require a framework that synthesises all available evidence to inform policy decisions, reflecting uncertainty in the current evidence base. A recent viewpoint article published by Hunter et al., (2023) re-emphasises the lack of economic evidence for UGS investments, and the need to move beyond cross-sectional research designs for UGS research.

This thesis addresses some of these gaps in the literature. Firstly, the research question for the thesis focuses on *investments or modifications*, such as improving playground equipment or improving walkways, instead of using summary measures of greenness. Chapter 2 introduces a logic model which outlines the pathways through which these investments for UGS can impact population health and wellbeing, and the results from a systematic review of the evidence on the effectiveness and cost-effectiveness of specific changes or modifications to UGS. The logic model and review of the evidence on specific interventions helps advance the discourse on the impact of UGS interventions beyond associational, cross-sectional, broad evidence, to provide evidence on specific interventions for UGS.

Other limitations in the existing literature include heterogeneity in outcome measures, which make it difficult to consolidate the evidence, and a general scarcity of economic evidence (Tate et al., 2024; Hunter et al., 2015, 2023). These limitations complicate decision-making around prioritising UGS interventions and may contribute to the under-investment in UGS. To address these limitations, a toolkit (THEAGS) was developed which converts and consolidates the evidence on costs and effects using data from the systematic review in chapter 2 and calculates the expected net monetary benefit for each intervention, as described in chapter 3. The toolkit provides a user-friendly interface for decision-makers to calculate their own expected net monetary benefit, and budget impact for different populations across a range of waning scenarios and values for the opportunity cost of a quality-adjusted life year. Users can also use the toolkit to calculate the probability of cost-effectiveness and compare the efficiency of UGS investments across investmentsscenarios looking at the longevity of treatment effects. The toolkit addresses the existing gap in economic evidence for UGS investments by (1) consolidating available evidence on UGS interventions, (2) enabling customised calculations on the net monetary benefit for these interventions, and (3) clearly presenting results in a single framework, thereby supporting more informed and evidence-based decision-making regarding UGS investments.

Another gap in the literature is the lack of evidence on the link between UGS investments and mental health, especially longitudinal studies that evaluate the impact of specific changes to UGS (Raza et al., 2024; Hunter et al., 2019). In their review of the challenges and developments of economic evaluations of environmental interventions, Bojke et al (2018) recommend conducting longitudinal analysis with study designs such as a difference-in-differences approach and using natural experiments to assess the impact of an environmental interventions. Chapter 4 follows this approach to addresses this gap through an evaluation of a real-world UGS intervention in Bradford, United Kingdom using mental health prescriptions as the outcome of interest. This evaluation contributes to the literature by: (1) addressing the existing gap in research on the effects of interventions for urban green spaces (UGS), (2) examining the relationship between UGS investments and mental health outcomes, and (3) developing a methodological approach that utilises routinely collected data to assess environmental interventions.

Evaluating the cost-effectiveness of UGS interventions is an emerging area of research, and since the review in chapter 2, there has been additional research which can complement the findings from this thesis, especially using a social return on investment. For instance, (Tate et al., 2023). A previous study estimating the *projected* Social Return on Investment of the same intervention had estimated a considerably higher return of £2.90–£5.80 per £1 invested, despite excluding crime and biodiversity in their list of criteria (Hunter et al., 2022b). Researchers in Italy have used also recently used an Social Return on Investment to predict the impact of ecological enhancements (plants, ponds, sensory plantings) and predicted a 2:1 social return (Vasiliu et al., 2024). Social Return on Investment can be a

useful tool for evaluating interventions like UGS, with multi-sectoral outcomes as it uses stakeholder input to provide a monetary value for each outcome. However, this high reliance on stakeholder valuation also poses challenges for generalisability, and reproducibility, which may explain why there is limited use of Social Return on Investment analyses within National Institute for Health and Care Excellence decision-making, and was therefore not considered suitable for this thesis (National Institute for Health and Care Excellence process and methods, 2012; National Institute for Health and Care Excellence).

## 5.2 Cost-effectiveness of UGS interventions

The results from chapter 2, 3 and 4 add to the body of economic evidence supporting investments in UGS. This section provides more details on the impact of UGS investments on physical and mental health.

### 5.2.1 Impacts of UGS interventions on physical activity

The toolkit (THEAGS) in chapter 3 calculates the impact of different investments on moderate-to-vigorous physical activity and converting these benefits to measurable quality-adjusted life year gains using the mapping by Beale et al. (2012).

THEAGS uses population-wide data from the United Kingdom as a default, and the findings suggest that a range of investments in UGS, including improving play areas, installing fitness equipment, and improving walkways, are likely to lead to a positive net monetary benefit using an opportunity cost of £20,000 for a single quality-adjusted life year as recommended by National Institute for Health and Care Excellence(National Institute for Health and Care Excellence, 2022). In a scenario with no waning effect, the average net monetary benefit of investing in play areas is £64 per child, with a median net monetary benefit of £105 and the probability of cost-effectiveness is 75%. A similar scenario with an investment in walkways for adults is expected to lead to an average net monetary benefit gain of of £0.68 per person, and the probability of cost-effectiveness is 76%. The intervention to improve or install fitness equipment is more likely to be cost-effective with a probability of cost-effectiveness of 99% in this scenario, and an average net monetary benefit of £6 and median net monetary benefit of £6.1.

Overall, the toolkit shows that even modest improvements in physical activity resulting from UGS interventions are likely to lead to a positive net monetary benefit or a cost-effective outcome. This finding builds on existing, albeit limited, evidence suggesting that UGS investments are (Raza et al., 2024). The review in chapter 2 found three studies that had evaluated the cost-effectiveness of investments in UGS, two of which measured the cost of the intervention against the MET-h (metabolic equivalent hours), which accounts for the energy expended through physical activity (Matthews et al., 2020) . A study by Lal et al.

(2019) estimated the cost-effectiveness of building a new playscape in a park and reported a cost-effectiveness ratio of AU$0.58 (£0.32) per MET-h gained, while Cohen et al. (2012) measured the impact of fitness zones reported a similar effect of $0.105(£0.066) per MET-h gained, and a study by Ward Thompson (2019) found no improvements from investing in walkways, but noted that very small changes would make the investment cost-effective. The findings from the toolkit builds on this literature, as the results also suggest that small changes in physical activity would lead to investments in UGS to be considered cost-effective.

The results from the toolkit also suggest that there is considerable uncertainty in the results, which is a representation of the uncertainty in the literature around UGS investments. One of the sources of uncertainty appear to be the maintenance of interventions, for instance, one of the studies used in the toolkit found that physical activity had decreased in the intervention area due to vandalism and a lack of upkeep in the interventions (Veitch et al., 2018). This finding underscores the importance of investing in the maintenance of the interventions.

Given the relatively low per capita cost of many infrastructure-based UGS interventions (Raza et al. 2024), the results from this thesis support investments in UGS as a cost-effective approach to improving public health, especially in underserved areas with attention for the maintenance of these interventions.

### 5.2.2 UGS interventions and mental health

There is some evidence on the association between living near UGS and improvements in mental health conditions such as depression and anxiety, but there is scarce and mixed research on how specific investments in UGS may impact mental health outcomes. The analysis in chapter 4 addresses this gap by presenting the results of the impact of an urban green space intervention on mental health prescriptions using a two-part model and a difference-in-differences approach. These results report mixed findings for the probability of needing a prescription but found a significant reduction in the cost of prescriptions for mental health with expected savings of approximately £100,000 across the city of Bradford over a five-year time frame. The reduction in the average cost of a prescription would suggest that the UGS investments may lead to improvements in mental health. Whilst the yearly economic benefit of the savings is modest, the actual monetary benefit of improved mental health, especially with its links to education and productivity, are expected to be far greater than the £100,000 saved on prescription costs.

The research presented in chapter 4 is, to my knowledge, the first study to evaluate the impact of investments for urban green spaces using mental health prescriptions and adds to

the limited and mixed research on UGS and mental health. The review in chapter 2 found two studies that reviewed the impact of investments to UGS on mental health outcomes using alternative indicators for mental health such as perceived stress, and self-reported depression. The study by Ward Thompson (2019a) reported an increase in stress which the authors attributed to external factors, whilst the study by South(2018a) reported that greening vacant land may have led to reduced depression amongst residents. The findings from the research presented in chapter 4 adds to the literature by demonstrating that green space investments may improve mental health, and reduce the cost of mental health services, amongst participants from a deprived part of England. However, these findings should be read with some caution. They come from the Born in Bradford cohort, which is largely young parents in a deprived, multi-ethnic area and so it may not generalise widely. Further, prescriptions capture only more severe mental health needs. However,x as most limitations would understate rather than overstate the effect, they remain consistent with a likely improvement in mental health

## 5.3 Beyond the results: Unique contributions of this thesis

The section 5.2 describes how the results from chapter 2, 3 and 4 contribute to the existing literature around the effectiveness and cost-effectiveness of UGS interventions. However, beyond the individual results this thesis also provides unique methodological and practical contributions to the research question around the economic impact of UGS interventions. The thesis includes a logic model and a user-friendly toolkit to estimate net monetary benefit, thereby providing useful tools for researchers and policy makers interested in this research question. Chapter 4 also outlines a methodology to use routinely collected prescription data and a difference-in-differences approach for evaluating UGS interventions, that may be replicated for evaluations of other UGS interventions, or other public health interventions.

### 5.3.1 Logic Model

The relationship between UGS interventions and population well-being is a complex relationship as there are multiple interconnected short- and long-term outcomes. A logic model can support the evaluation of complex relationships like interventions for UGS, as it provides a visual framework for the “if then” relationship, for how *if* an intervention happens, *then* what may be the potential intended and unintended short- and long-term consequences of the intervention (W.K Kellogg Foundation, 2004; Voss et al., 2025). A logic model (or an alternative visual depiction of the theory of change) is also recommended by the medical research council guidance on evaluating complex interventions (Craig et al., 2008).

Figure 2.2 in chapter 2 provides a logic model to depict the relationship between interventions for UGS, and population well-being. The model outlines the pathways between interventions such as improving walkways, or playgrounds and changes to physical activity, and mental health through both improvements to physical activity, as well as due to improved connectedness with nature and social cohesion. The model can serve as a useful tool to communicate the multi-dimensional impact of interventions for UGS, and as a starting point for any future evaluations of interventions for UGS.

### 5.3.2 A toolkit to support decision-making in UGS for local authorities

Evidence-based decision making for public health can increase the probability of 'success' as measured by improved population health, but local authorities face several challenges in using evidence for decision-making (Kneale et al., 2017). Health Technology Assessment processes by national agencies such as National Institute for Health and Care Excellence heavily rely on economic evidence on cost-effectiveness to make resource allocation decisions, but this evidence is typically less central in decision-making by local authorities (Howdon et al., 2022a). Some of the challenges in using economic evidence for decision-making includes a lack of accessible evidence, especially at a more local level, political pressures from elected officials, and constrained budgets with competing priorities, which may lead to hesitancy in adopting policies deemed cost-effective by National Institute for Health and Care Excellence (Kneale et al., 2017; Howdon et al., 2022b).

The toolkit THEAGS addresses some of these challenges in three ways: (1) it presents a user-friendly interface, thereby making the evidence more accessible to policy makers, especially those that may be not well versed in health economics; (2) it allows users to adapt and use local evidence on physical activity baselines, thereby supporting the generation of more localised results for net monetary benefit, and (3) it presents options on a range of different scenarios including different values for the opportunity cost in health, for cases where policy makers find that the opportunity cost used by National Institute for Health and Care Excellence may not be an appropriate reflection of the opportunity cost of the budget available in their setting.

Toolkits can be a useful resource to support local authorities review and use evidence on cost-effectiveness for resource allocation decisions. Public health England has also developed a number of toolkits to support local authorities estimate the return on investment for public health programmes, such as interventions to reduce air pollution (GOV.UK). A similar toolkit called the health economic assessment tool for walking and cycling has been used in multiple cities across the world to support urban planning (Kriit et al., 2019; Kahlmeier et al., 2023). Therefore, the development of the toolkit for assessing the net monetary benefit for different interventions in UGS may be a useful contribution

towards making the results more accessible for researchers and policy makers interested in the economic value of UGS interventions.

### 5.3.3 The use of prescription data for an environmental health evaluation

Environmental health interventions may be difficult and costly to review. In their article, Bojke el al. (2018) identify a number of challenges with evaluating environmental interventions, including their long-term impacts and the prohibitive costs of funding large-scale surveys over a long period. The review in chapter 2 also finds that there is limited evidence on the impact of interventions for urban green space, with only two studies estimating the impact of interventions on mental health.

Chapter 4 uses a relatively low-cost approach of using routinely collected mental health prescription data and estimates the impact of the intervention using a difference-in-differences approach. Other studies have also reviewed the link between green space exposure and mental health prescriptions (Aerts et al., 2022; Newbury et al., 2021; Astell-Burt et al., 2022b), but this may be the first data to use routinely collected data to review the impact of green space interventions. This thesis thereby provides a methodology (including the code in the appendix) that may be easily adapted or replicated for future research on UGS interventions, or other environmental health interventions.

## 5.4 Limitations and areas for future research

This thesis has a number of contributions to the evidence base on the effectiveness of investments for urban green spaces. Nevertheless, there are several limitations to the analysis presented. These limitations are partly due to the complexity of the types of interventions evaluated, and the limited evidence base available to evaluate a multi-sectoral public health intervention such as investments for UGS.

Firstly, urban green spaces have been shown to have multi-sectoral impacts on physical health, mental health, education outcomes, and environmental factors including air pollution, carbon capture and temperature regulation. If UGS are linked to education and environmental outcomes, changes to UGS may also yield additional benefits for these multi-sectoral impacts. However, it was not possible to capture these effects for several reasons. For educational outcomes, the review in chapter 2 found no studies that had reviewed the impact of specific investments for UGS on educational outcomes (for example, test scores). It was also not possible to estimate the impact of a UGS on educational attainment, as this impact was expected to have a long timeframe, and there were no existing datasets identified that captured the relevant variables required for such an analysis (or none that were found). Another important impact not captured in the results is the environmental impact of UGS interventions. While the research question for this thesis focused on human

development outcomes, UGS interventions may also generate wider environmental benefits (Bai et al., 2017; Hunter et al., 2019). This thesis considered several types of UGS interventions, including modifications to play areas and fitness zones. Of these, changes to play areas or fitness zones are unlikely to have substantial environmental effects. However, interventions that increase greenery or vegetation could provide important ecological benefits. Estimating such environmental gains, such as carbon sequestration, is complex and depends on factors such as the life cycle of the vegetation and the level of maintenance of the green space (University of Leeds, 2015; Hazarin, Rokhmatuloh and Ash Shidiq, 2019; Strohbach, Arnold and Haase, 2012). Therefore, while this thesis offers valuable insights into the health benefits of UGS interventions, it may underestimate their broader environmental and multi-sectoral impacts, especially from investing in the greenery.

Secondly, most studies in the review in chapter 2, and the analysis in chapter 4 used relatively short follow-up periods, mostly one year, compared to other evaluations of UGS, especially cost-benefit analyses of UGS which can use timeframes of up to 30-40 years (Tate et al., 2024). This makes it difficult to assess the long-term benefits of UGS interventions, or the 'stickiness' of the effect of these interventions. The toolkit in chapter 3 addresses this by modelling the impact over 10 years, using a 3% discount rate, and allowing users to incorporate waning effects to account for potential stickiness, limiting the impact to 5 years and 3 years. Chapter 4 also addresses this limitation by extrapolating the impact over a 5-year time frame and using a 3% discount rate to address longer term implications of the interventions. However, further research is needed to validate the assumptions around the longevity of the intervention, and the stickiness of its impact.

Third, the analyses presented in this thesis do not include an assessment of the distributional impact of the effect of UGS interventions. Decision-makers may be interested in the impact of investments for UGS on reducing inequity, but a specific distributional analysis was not feasible in this thesis due to limitations with the available data. The studies included in the review in chapter 2 typically used observational data which does not allow for a more detailed assessment of differential impact on different populations. However, chapters 2 and 4 do indicate that investments in UGS are likely to have positive impacts on disadvantaged populations, as studies from relatively impoverished areas were more likely to report a higher impact on health improvements. This hypothesis is further supported by the analysis in chapter 4, which was estimated from the population in Bradford, a relatively disadvantaged city in North England, and reported a positive impact on mental health. This would suggest that investing in UGS in deprived areas could reduce overall health inequities, but additional research on the distributional impact of investments for UGS would provide better insight into its effect on inequity.

Relatedly, whilst the Bradford case study in chapter 4 provides valuable empirical data, the findings may not be fully generalisable to other contexts. The intervention took place in a

highly deprived, multi-ethnic urban setting, where mental health needs and access to green space may differ from national averages. This is reflective of a broader challenge for UGS research, that it is difficult to fully capture the effect of contextual factors including levels of deprivation, cultural contexts, crime, climate and other external variables on outcomes. More studies are needed across diverse geographies and population groups to better understand who benefits most, and under what conditions.

However, future research may address these limitations by:

1. Generating more high-quality, longitudinal, multi-sectoral evidence on the impact of specific UGS interventions, particularly on mental health and educational outcomes.
2. Reviewing the longetivity and stickiness of the intervention impacts on physical activity, and by extension on physical and mental health.
3. Developing a standardised metric for the effects on physical activity, mental health and educational outcomes. The research base currently uses a range of tools and metrics to assess the impact of UGS interventions. This limits the ability to consolidate the existing evidence, or to evaluate the opportunity cost of the intervention. Ideally the impact of the interventions should be mapped in quality-adjusted life year outcomes to meet National Institute for Health and Care Excellence guidelines and allow for better consolidation and comparison (National Institute for Health and Care Excellence, 2022).
4. Developing frameworks which incorporate the environmental changes and their consequences, alongside those related to health and education.
5. Understanding the opportunity cost of investment in environmental interventions, reflecting current and future populations.
6. Understanding how outcomes across multiple sectors could be traded off and what the policy priorities are for local government, faced with these trade-offs.
7. Collecting data to allow the exploration of the distributional effects of UGS interventions, especially their role in reducing health inequities in marginalised communities.

## 5.5 Policy recommendations

The United Kingdom faces an ageing population, an increased prevalence of mental health conditions, deep inequities in health outcomes, and public health services that are in a ‘critical condition’ (Department of Health and Social Care, 2024). Both the National Health Service Long Term Plan, and the independent report on the National Health Service recommended an increased investment in public and promotive health investments (National Health Services, 2019; Department of Health and Social Care, 2024). In the

backdrop of these challenges, this thesis provides evidence to support policies related to investments in UGS as an environmental and public health intervention.

The systematic review, toolkit and empirical research in chapters 2, 3 and 4 respectively all suggest that investing in improving urban green spaces is likely to be an effective and a cost-effective policy choice to improve population health through improvements in physical activity and mental health. The approach used by this thesis to focus on health outcomes and model long-term impacts is consistent with related policy documents in the United Kingdom, both used by National Institute for Health and Care Excellence and Public Health England. For instance, National Institute for Health and Care Excellence evaluation of similar public health interventions such as reducing air pollution and increasing physical activity also focuses on health outcomes, using modelling to estimate the long-term benefits on several health outcomes (National Institute for Health and Care Excellence, 2018, 2017). Similarly, a Public Health England evaluation of "Access to Urban Green Spaces" models the impact on physical activity to estimate the benefit of access UGS (Public Health England, 2020). All three chapters found that very small improvements in health outcomes are needed to make investments in UGS cost-effective from a health perspective. These investments may therefore constitute *effective* policy choices from both a physical and mental health perspective.

The National Institute for Health and Care Excellence guidelines on physical activity developed in 2019 specifically identifies a need for more evidence on "How effective and cost effective are changes to public open spaces (including blue, green and grey spaces) in creating and sustaining an increase in physical activity at a population level?" (National Institute for Health and Care Excellence, 2018). In their notes, the committee determining the quality standards for physical activity highlighted that there was insufficient evidence on the effectiveness of interventions for open spaces such as UGS, to include this in the receommendation. The existing evidence and research reported by NIHR focuses more on promoting active modes of transport, or community-led programmes to encourage physical activity (National Institute of Healthcare and Research, 2019) The results from chapters 2 and 3, respond to this evidence gap, and find that changes to UGS, more specifically improving walkways, improving play areas, and installing fitness equipment, are *all likely lead to cost-effective increases* in moderate-to-vigorous physical activity. These findings support the inclusion of a recommendation for interventions for UGS, and may be incorporated in future updates for the guidelines for physical activity in the United Kingdom.

A public health approach that focuses on mental health may also advocate for more investments in UGS, although more evidence is required to assess the cost-effectiveness of these interventions from a mental health perspective. The decline in good mental health in England was highlighted as a key issue in the review of the National Health Service, especially for younger people, as survey data shows a stark increase in the prevalence of

mental health conditions for young people in the United Kingdom, and the labour government has included improving mental (Baker, 2024; Department of Health and Social Care, 2024). The empirical analysis in chapter 4 suggests that improvements to UGS are likely to lead to a reduction in mental health prescription costs, and a potential improvement in mental health. Given the current challenges for mental health, encouraging the use of UGS by increasing investments may be an effective policy to reduce the burden of depression and anxiety. However, more research is required to estimate the quality-adjusted life year gains from these investments, and to determine whether changes in mental health are cost-effective.

Lastly, the evidence from this thesis suggests that policies related to investments for UGS could reasonably prioritise more deprived areas. The review in chapter 2 reports that studies amongst relatively deprived populations more consistently found positive impacts on physical activity, whilst chapter 4 presents an evaluation of an existing UGS intervention in a deprived city, Bradford, and found a reduction in the cost of mental health prescriptions, suggesting improved mental health. Inequity is another major concern highlighted in the National Health Service review, as recent population trends finds that men from a higher socioeconomic group in the United Kingdom live on average 9 years longer compared to men in an unclassified socioeconomic group (ONS.GOV.UK, 2022). This focus is also consistent with the principle of proportionate universalism set out in the Marmot Review (Marmot, 2010; 2020) and endorsed by National Institute for Health and Care Excellence, whereby action is delivered universally but with an intensity proportionate to need, and with current National Health Service policy such as the Core20PLUS5 framework and the statutory duty on Integrated Care Systems to reduce health inequalities. Whilst the results from this thesis point towards consistency in prioritising vulnerable populations, this specific policy relevance must be interpreted with caution as chapter 4 does not include a counter factual, so it is not possible to determine the impact in a less deprived setting.

## 5.6 Conclusion

This thesis addresses a critical gap in the literature around the effectiveness and cost-effectiveness of investments for urban green spaces, moving the discussion from associational evidence of UGS to more a policy actionable evidence base concluding on the efficiency and cost-effectiveness of investments such as improving walkways or playgrounds in UGS. The thesis presents a conceptual model, as well as empirical evidence on investments for UGS through a systematic review, a conceptual logic model, a practical economic evaluation toolkit (THEAGS), and an empirical analysis of a real-life investment for UGS. The findings reveal that targeted interventions for UGS, including improving

playgrounds, investing in walkways, and installing fitness equipment may lead to cost-effective improvements in population health.

From a policy perspective, the findings reflect improvements for mental health and physical activity, which may encourage the prioritisation of specific investments to UGS by local authorities and the central government, especially in more deprived areas. The research from this thesis also highlights areas for additional research, such as the impact of these investments on other sectors, including education, environment and productivity. However, in the absence of more detailed evidence on multi-sectoral outcomes, the evidence from this thesis provides a clear message that improving UGS represents an important, effective, and cost-effective public policy for the United Kingdom, which may improve population health and reduce the burden on the National Health Service.

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## Appendix 1: Search Strategies

**Search 1: 2022 - Feb 15 2024**
**Ovid MEDLINE(R) ALL**
via Ovid http://ovidsp.ovid.com/
Date range searched: 2022 to February 15, 2024
Date searched: February 15, 2024
Records retrieved: 1127

1 *Urban Population/ 17785
2 Suburban Population/ 1970
3 City Planning/ 2619
4 Urban Renewal/ 1457
5 Built Environment/ 1396
6 *Cities/ 3164
7 urban*.ti,ab. 214163
8 (built environment* or built-environment*).ti,ab. 5313
9 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. 274784
10 ((built-up or built up or industrial) adj area*).ti,ab. 3844
11 ((population dens* or population-dens*) adj2 high*).ti,ab. 2673
12 or/1-11454614
13 *Environment/27566
14 *Environment Design/ 4449
15 Parks, Recreational/ 2654
16 *Nature/ 633
17 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. 4442
18 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. 4888
19 (greenspace* or greenery or greenness).ti,ab.3150
20 ((natural or outdoor*) adj2 environment*).ti,ab. 21279
21 ((nature or natural) adj2 space*).ti,ab. 635
22 sports field*.ti,ab. 173
23 wilderness area*.ti,ab.208
24 public open space*.ti,ab. 151
25 neighbo?rhood open space*.ti,ab. 10
26 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (forest* or wood* or wilderness or meadow* or tree* or hill*1 or moor* or dale or dales)).ti,ab. 6328
27 ((public* or near or nearby or local* or residential or industrial or access*) adj4 ((footpath* or trail* or coast* or cliff*) adj2 green)).ti,ab. 2
28 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. 1229
29 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. 157978
30 or/13-29 221524

31 12 and 30 18643
32 *Lakes/ 6924
33 Ponds/ 2169
34 *Rivers/ 16178
35 (bluespace* or blue space*).ti,ab. 314
36 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*)).ti,ab. 5715
37 (water* adj2 (environment* or inland)).ti,ab. 15568
38 or/32-37 44697
39 12 and 38 5689
40 12 and (30 or 38) 23586
41 *Public Health/ 57779
42 *Urban Health/ 6492
43 Suburban Health/ 475
44 *"Social Determinants of Health"/ 4072
45 *Health Status/ 41960
46 exp *Physical Fitness/22252
47 ((physical* or public* or communit* or population*) adj health).ti,ab. 411402
48 (health adj (status or determinant*)).ti,ab. 76665
49 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. 168198
50 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. 76118
51 (physical* adj2 inactiv*).ti,ab. 12916
52 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. 3647
53 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. 184959
54 (life adj2 (expectan* or quality)).ti,ab. 431680
55 *Quality-Adjusted Life Years/ 2553
56 (DALY or "disability adjusted life year" or "disability-adjusted life year" or "disability adjusted life years" or "disability-adjusted life years").ti,ab. 6309
57 (healthy life-year or HeaLY or HALY).ti,ab. 363
58 or/41-57 1296461
59 *Mental Health/ 33937
60 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. 268460
61 (depression or depressive).ti,ab. 491426
62 ((depressed or low) adj2 mood).ti,ab. 7052
63 (anxiet* or anxious*).ti,ab. 282358
64 exp *Stress, Psychological/ 98716
65 (stress* adj2 (manage* or event* or resilien*)).ti,ab. 25072
66 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. 25688
67 or/59-66 926782
68 *Education/ 9807
69 Learning/ 84692
70 *Cognition/ 66247
71 exp *Educational Measurement/ 83705
72 exp Academic Performance/ 4267
73 *Educational Status/ 9330

74 Academic Failure/ 60
75 Literacy/ 1790
76 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. 80238
77 (education adj2 (status or level or determinant*)).ti,ab. 47066
78 cognition.ti,ab. 96741
79 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. 211712
80 (literate or literac*).ti,ab. 33150
81 (neurodevelopment or neurological development).ti,ab. 14818
82 (communication adj (skill* or difficult* or deficit*)).ti,ab. 16899
83 or/68-82 633672
84 40 and 58 4722
85 40 and 67 1105
86 40 and 83 523
87 84 or 85 or 86 5620
88 exp animals/ not humans.sh. 5197326
89 87 not 88 5513
90 letter/ 1243597
91 editorial/ 682344
92 news/ 223586
93 exp historical article/ 410292
94 anecdotes as topic/ 4747
95 comment/ 1031211
96 or/90-95 2819158
97 89 not 96 5403
98 remove duplicates from 97 5392
99 98 5392
100 limit 99 to yr="2022 -Current" 1127

**Embase**
via Ovid http://ovidsp.ovid.com/
Date range searched: 2022 to 2024 February 15
Date searched: 15 February 2025
Records retrieved: 1015

1 *urban population/ 12221
2 *suburban population/152
3 *city planning/ 1382
4 *built environment/ 904
5 urban*.ti,ab. 270257
6 (built environment or built-environment).ti,ab. 4991
7 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. 352483
8 ((population dens* or population-dens*) adj2 high*).ti,ab. 2693
9 or/1-8 575147
10 *environment/ 23127
11 exp *recreational park/ 1593

12 *aquatic environment/4327
13 *lake/ 5973
14 exp *pond/ 1627
15 *river/ 12255
16 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. 4480
17 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. 5135
18 (greenspace* or greenery or greenness).ti,ab.3160
19 ((natural or outdoor*) adj2 environment*).ti,ab. 22912
20 ((nature or natural) adj2 space*).ti,ab. 658
21 sports field*.ti,ab. 242
22 wilderness area*.ti,ab.251
23 public open space*.ti,ab. 159
24 neighbo?rhood open space*.ti,ab. 9
25 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (forest* or wood* or wilderness or meadow* or tree* or hill* or moor* or dale or dales)).ti,ab. 7057
26 ((public* or near or nearby or local* or residential or industrial or access*) adj4 ((footpath* or trail* or coast* or cliff*) adj2 green)).ti,ab. 0
27 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. 1178
28 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. 177574
29 (bluespace* or blue space*).ti,ab. 316
30 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*)).ti,ab. 6756
31 (water* adj2 (environment* or inland)).ti,ab.16852
32 or/10-31 276657
33 9 and 32 23303
34 *public health/72793
35 *urban health/ 587
36 *"social determinants of health"/ 7937
37 *health status/ 39997
38 ((physical* or public* or communit* or population*) adj health).ti,ab. 483913
39 (health adj (status or determinant*)).ti,ab. 98322
40 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. 226036
41 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. 102866
42 (physical* adj2 inactiv*).ti,ab. 17145
43 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. 4861
44 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. 286468
45 (life adj2 (expectan* or quality)).ti,ab. 672130
46 *quality adjusted life year/ 1942
47 *disability-adjusted life year/ 574
48 (healthy life-year or healy).ti,ab. 347
49 *mental health/ 62451
50 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. 333218

51 ((depressed or low) adj2 mood).ti,ab. 10345
52 (stress* adj2 (manage* or event* or resilien*)).ti,ab. 32526
53 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. 31251
54 or/34-53 2054281
55 *education/ 97974
56 *learning/ 83845
57 *cognition assessment/ 1549
58 *academic achievement/ 10246
59 *educational status/ 15223
60 *academic failure/ 167
61 *literacy/ 2337
62 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. 100724
63 (education adj2 (status or level or determinant*)).ti,ab. 67063
64 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. 304878
65 (neurodevelopment or neurological development).ti,ab. 20088
66 (communication adj (skill* or difficult* or deficit*)).ti,ab. 22994
67 or/55-66 669811
68 33 and (54 or 67) 4776
69 letter/ 1227760
70 case report/ 2970091
71 case study/ 99213
72 (letter or comment*).ti. 242007
73 (comment or note).pt. 976585
74 or/69-73 5014523
75 68 not 74 4701
76 (rat or rats or mouse or mice or swine or porcine or murine or sheep or lambs or pigs or piglets or rabbit or rabbits or cat or cats or dog or dogs or cattle or bovine or monkey or monkeys or trout or marmoset$).ti,ot. and animal experiment/ 1240316
77 animal experiment/ not (human experiment/ or human/) 2606341
78 76 or 77 2677800
79 75 not 78 4673
80 remove duplicates from 79 4615
81 80 4615
82 limit 81 to yr="2022 -Current" 1015

**Web of Science**
via clarivate https://www.webofscience.com/wos/woscc/advanced-search
Date range searched: 03 Mar 2022-present
Date searched: 15 February 2022
Records retrieved: 434

1: TS=(city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*) 286477

2: TS=(city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*) 286477

3: TS=(("population dens*" NEAR/2 high) or (population-dens* NEAR/2 high)) 1282

4: #1 OR #2 OR #3 287262

5: TS=((green*) NEAR/2 (urban* or city or cities or environment* or neighbo?rhood or residential or community or park*)) 10973

6: TS=((green*) NEAR/2 (area* or environment* or space* or neighbo?rhood*)) 11939

7: TS=((greenspace* or greenery or greenness))3254

8: TS=((environment*) NEAR/2 (natural or outdoor*) 11327

9: TS=(natur* NEAR/2 space*) 1308

10: TS=("sports field*") 131

11: TS=("wilderness area*") 221

12: TS=(forest* or wood* or wilderness or meadow* or tree* or hill or hills or moor* or dale or dales) 113136

13: TS=(conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)) Editions: WOS.SSCI 2098

14: TS=(lake* or pond* or river*) 47691

15: TS=(bluespace* or "blue space*") 620

16: TS=(("fresh water*" or lake* or pond* or river* or waterway* or "open water*" or waterfront* or waterscape* or waterbod* or "water feature*" or seafront or seaside or "aquatic landscape*") and (environment* or space* or area*)) 25435

17: TS=((water*) NEAR/2 (environment* or inland)) 3179

18: #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 181954

19: #4 AND #18 22515

20: TS=("social determinant* of health") 8274

21: TS= (health NEAR (physical* or public* or communit* or population*)) 362296

22: TS= (physical* NEAR/2 (activ* or wellness or welfare or well-being or wellbeing)) 119955

23: TS= (living NEAR/3 (active or physically-active or health*)) or TS=(life* NEAR/3 (active or physically-active or health*)) 81351

24: TS= (exercise* or exercising or fitness) 147049

25: TS= (physical* NEAR/2 inactiv*) 5808

26: TS= (living NEAR/2 (inactive or unhealthy)) or TS=(life* NEAR/2 (inactive or unhealthy)) 1593

27: TS= (weight NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) or TS= ("body mass" NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) or TS= ("BMI" NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) 34589

28: TS=(obese or obesity or overweight) 91890

29: TS=(life NEAR/2 (expectan* or quality)) 197849

30: TS=(daly or "disability adjusted life year*" or "disability-adjusted life year*" or "disability adjusted life-year*") 2671

31: TS=(qaly or "quality adjusted life year*" or "quality-adjusted life year*" or "quality adjusted life-year*") 6316

32: TS=(healy or "healthy life year*" or "healthy life-year*") 440

33: TS=(mental* NEAR/2 (health* or ill*)) or TS=(psychological* NEAR/2 (health* or ill*)) 310795

34: TS=(mood NEAR/2 (depressed or low)) 6314

35: TS=(anxiet* or anxious*) 247075

36: TS=(stress NEAR/3 (psychological or mental)) 20126

37: TS=(stress* NEAR/2 (manage* or event* or resilien*)) 21491

38: TS=(mental* NEAR/3 (wellness or welfare or well-being or wellbeing)) OR TS=(psychological* NEAR/3 (wellness or welfare or well-being or wellbeing)) 32729

39: #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 1152279

40: TS=((student*) NEAR/1 (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test))
69628

41: TS=((school*) NEAR/1 (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test))
28735

42: TS=(education* NEAR/2 (status or level or determinant*))
60046

43: TS=(cognitive NEAR/1 (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)) 123716

44: TS=(neurodevelopment or "neurological development") 4519

45: TS=(communication NEAR/1 (skill* or difficult* or deficit*))
13746

46: #40 OR #41 OR #42 OR #43 OR #44 OR #45 285653

47: #39 OR #46 1364860

48: #19 AND #47 3783

49: TI=(animal or animals or rat or rats or mouse or mice or rodent or rodents or porcine or murine or sheep or lamb or lambs or ewe or ewes or pig or pigs or piglet or piglets or sow or sows or pig or pigs or rabbit or rabbits or kitten or kittens or dog or dogs or puppy or puppies or monkey or monkeys or horse or horses or foal or foals or equine or calf or calves or cattle or heifer or heifers or hamster or hamsters or chicken or chickens or livestock or alpaca* or llama*) 90739

50: #48 NOT #49 3771

51: #50 Timespan: 2022-03-03 to 2023-02-15 434

**Econlit**
Econlit <1886 to January 25, 2024>

1 urban*.ti,ab. 44779
2 (built environment* or built-environment*).ti,ab. 933
3 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. 50345
4 ((built-up or built up or industrial) adj area*).ti,ab. 284
5 or/1-4 79883
6 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. 660
7 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. 570
8 (greenspace* or greenery or greenness).ti,ab.174

9 ((natural or outdoor*) adj2 environment*).ti,ab. 1309
10 ((nature or natural) adj2 space*).ti,ab. 78
11 sports field*.ti,ab. 6
12 wilderness area*.ti,ab. 48
13 public open space*.ti,ab. 31
14 neighbo?rhood open space*.ti,ab. 2
15 (forest* or wood* or wilderness or meadow* or tree* or hill*1 or moor* or dale or dales).ti,ab. 17986
16 ((footpath* or trail* or coast* or cliff*) adj2 green).ti,ab. 2
17 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. 185
18 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. 11369
19 (bluespace* or blue space*).ti,ab. 6
20 ((fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*) and (environment* or space* or area*)).ti,ab. 2338
21 (water* adj2 (environment* or inland)).ti,ab. 434
22 or/6-2132600
23 5 and 22 3685
24 ((physical* or public* or communit* or population*) adj health).ti,ab. 7116
25 (health adj (status or determinant*)).ti,ab. 2646
26 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. 754
27 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. 1936
28 (exercise* or exercising or fitness).ti,ab. 15053
29 (physical* adj2 inactiv*).ti,ab. 37
30 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. 38
31 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. 554
32 (obese or obesity or overweight).ti,ab. 2539
33 (life adj2 (expectan* or quality)).ti,ab. 7360
34 (DALY or "disability adjusted life year" or "disability-adjusted life year" or "disability adjusted life years" or "disability-adjusted life years").ti,ab. 248
35 (healthy life-year or HeaLY or HALY).ti,ab. 38
36 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. 3190
37 (depression or depressive).ti,ab. 5235
38 ((depressed or low) adj2 mood).ti,ab. 17
39 (anxiet* or anxious*).ti,ab. 1486
40 (stress* adj2 (manage* or event* or resilien*)).ti,ab. 258
41 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. 568
42 or/24-41 43775
43 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. 12978
44 (education adj2 (status or level or determinant*)).ti,ab. 3906
45 cognition.ti,ab. 1671
46 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. 1503
47 (literate or literac*).ti,ab. 3834

48 (neurodevelopment or neurological development).ti,ab. 6
49 (communication adj (skill* or difficult* or deficit*)).ti,ab. 189
50 or/43-49 22905
51 23 and (42 or 50) 272
52 51 272
53 limit 52 to yr="2022 - 2024" 27

**Ovid APA PsycInfo**
via Ovid http://ovidsp.ovid.com/
Date range searched: 2022 to February 15, 2024
Date searched: 15 February 2024
Records retrieved: 211

1 *urban environments/ 13037
2 ghettoes/ 90
3 suburban environments/ 571
4 built environment/ 1509
5 urban*.ti,ab. 59089
6 (built environment* or built-environment*).ti,ab. 2311
7 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. 72890
8 ((built-up or built up or industrial) adj area*).ti,ab. 101
9 ((population dens* or population-dens*) adj2 high*).ti,ab. 242
10 or/1-9 122149
11 exp "nature (environment)"/ 3497
12 recreation areas/ 1141
13 environmental planning/ 1452
14 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. 616
15 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. 817
16 (greenspace* or greenery or greenness).ti,ab.321
17 ((natural or outdoor*) adj2 environment*).ti,ab. 4650
18 ((nature or natural) adj2 space*).ti,ab. 202
19 sports field*.ti,ab. 67
20 wilderness area*.ti,ab.32
21 public open space*.ti,ab. 57
22 neighbo?rhood open space*.ti,ab. 5
23 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (forest* or wood* or wilderness or meadow* or tree* or hill* or moor* or dale or dales)).ti,ab. 455
24 ((public* or near or nearby or local* or residential or industrial or access*) adj4 ((footpath* or trail* or coast* or cliff*) adj2 green)).ti,ab. 0
25 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. 132
26 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. 20872
27 (bluespace* or blue space*).ti,ab. 80

28 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*)).ti,ab. 183
29 (water* adj2 (environment* or inland)).ti,ab. 162
30 or/11-29 31430
31 10 and 30 3551
32 public health/ 27621
33 urban health/ 293
34 health status/ 1682
35 physical fitness/ 3640
36 ((physical* or public* or communit* or population*) adj health).ti,ab. 88444
37 (health adj (status or determinant*)).ti,ab. 17071
38 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. 46034
39 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. 23439
40 (exercise* or exercising or fitness).ti,ab. 72515
41 (physical* adj2 inactiv*).ti,ab. 2966
42 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. 864
43 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. 19432
44 (obese or obesity or overweight).ti,ab. 44260
45 (life adj2 (expectan* or quality)).ti,ab. 83692
46 "quality of life"/ 43436
47 *"health related quality of life"/ 4951
48 (DALY or "disability adjusted life year" or "disability-adjusted life year" or "disability adjusted life years" or "disability-adjusted life years").ti,ab. 798
49 (healthy life-year or HeaLY or HALY).ti,ab. 231
50 or/32-49 328700
51 *mental health/ 60790
52 public mental health/ 727
53 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. 224789
54 *"depression (emotion)"/ 0
55 (depression or depressive).ti,ab. 256663
56 ((depressed or low) adj2 mood).ti,ab. 4893
57 affective disorders/ 10090
58 anxiety disorders/ 15845
59 (anxiet* or anxious*).ti,ab. 182015
60 stress/ 57805
61 (stress* adj2 (manage* or event* or resilien*)).ti,ab. 16333
62 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. 21808
63 or/51-62 579445
64 *education/ 23795
65 *learning/ 43505
66 *cognition/ 21041
67 exp educational measurement/ 13436
68 academic achievement/ 42397
69 educational attainment level/ 5293
70 academic failure/ 981

71 literacy/ 15601
72 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. 101885
73 (education adj2 (status or level or determinant*)).ti,ab. 17633
74 cognition.ti,ab. 78653
75 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. 109144
76 (literate or literac*).ti,ab. 35916
77 (neurodevelopment or neurological development).ti,ab. 4241
78 (communication adj (skill* or difficult* or deficit*)).ti,ab. 9845
79 or/64-78 400119
80 31 and (50 or 63 or 79) 1551
81 remove duplicates from 80 1545
82 81 1545
83 limit 82 to yr="2022 -Current" 211

**Search 2: March 2022**

**Ovid MEDLINE(R) ALL**
via Ovid http://ovidsp.ovid.com/
Date range searched: 1946 to February 28, 2022
Date searched: 03 March 2022
Records retrieved: 4811

1 *Urban Population/ (17740)
2 Suburban Population/ (1963)
3 City Planning/ (2438)
4 Urban Renewal/ (1331)
5 Built Environment/ (1017)
6 *Cities/ (3127)
7 urban*.ti,ab. (181967)
8 (built environment* or built-environment*).ti,ab. (4078)
9 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. (237843)
10 ((built-up or built up or industrial) adj area*).ti,ab. (3166)
11 ((population dens* or population-dens*) adj2 high*).ti,ab. (2285)
12 or/1-11 (392052)
13 *Environment/ (26922)
14 *Environment Design/ (4297)
15 Parks, Recreational/ (1844)
16 *Nature/ (619)
17 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. (2855)
18 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. (3250)
19 (greenspace* or greenery or greenness).ti,ab. (1873)

20 ((natural or outdoor*) adj2 environment*).ti,ab. (17454)
21 ((nature or natural) adj2 space*).ti,ab. (487)
22 sports field*.ti,ab. (132)
23 wilderness area*.ti,ab. (187)
24 public open space*.ti,ab. (117)
25 neighbo?rhood open space*.ti,ab. (10)
26 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (forest* or wood* or wilderness or meadow* or tree* or hill*1 or moor* or dale or dales)).ti,ab. (5417)
27 ((public* or near or nearby or local* or residential or industrial or access*) adj4 ((footpath* or trail* or coast* or cliff*) adj2 green)).ti,ab. (1)
28 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. (939)
29 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. (124836)
30 or/13-29 (180514)
31 12 and 30 (14578)
32 *Lakes/ (5917)
33 Ponds/ (1835)
34 *Rivers/ (14391)
35 (bluespace* or blue space*).ti,ab. (172)
36 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*)).ti,ab. (4923)
37 (water* adj2 (environment* or inland)).ti,ab. (12356)
38 or/32-37 (37733)
39 12 and 38 (4654)
40 12 and (30 or 38) (18692)
41 *Public Health/ (54966)
42 *Urban Health/ (6435)
43 Suburban Health/ (475)
44 *"Social Determinants of Health"/ (3273)
45 *Health Status/ (41093)
46 exp *Physical Fitness/ (21113)
47 ((physical* or public* or communit* or population*) adj health).ti,ab. (340736)
48 (health adj (status or determinant*)).ti,ab. (66507)
49 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. (141788)
50 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. (62332)
51 (physical* adj2 inactiv*).ti,ab. (10903)
52 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. (2886)
53 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. (162521)
54 (life adj2 (expectan* or quality)).ti,ab. (360807)
55 *Quality-Adjusted Life Years/ (2545)
56 (DALY or "disability adjusted life year" or "disability-adjusted life year" or "disability adjusted life years" or "disability-adjusted life years").ti,ab. (4700)
57 (healthy life-year or HeaLY or HALY).ti,ab. (314)
58 or/41-57 (1099855)

59 *Mental Health/ (28635)
60 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. (215605)
61 (depression or depressive).ti,ab. (427378)
62 ((depressed or low) adj2 mood).ti,ab. (6298)
63 (anxiet* or anxious*).ti,ab. (234923)
64 exp *Stress, Psychological/ (93523)
65 (stress* adj2 (manage* or event* or resilien*)).ti,ab. (21182)
66 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. (19243)
67 or/59-66 (800456)
68 *Education/ (9769)
69 Learning/ (73704)
70 *Cognition/ (63758)
71 exp *Educational Measurement/ (81460)
72 exp Academic Performance/ (3405)
73 *Educational Status/ (9233)
74 Academic Failure/ (55)
75 Literacy/ (1193)
76 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. (67559)

77 (education adj2 (status or level or determinant*)).ti,ab. (38396)
78 cognition.ti,ab. (80110)
79 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. (175980)
80 (literate or literac*).ti,ab. (25455)
81 (neurodevelopment or neurological development).ti,ab. (11634)
82 (communication adj (skill* or difficult* or deficit*)).ti,ab. (14367)
83 or/68-82 (545609)
84 40 and 58 (3933)
85 40 and 67 (800)
86 40 and 83 (407)
87 84 or 85 or 86 (4587)
88 exp animals/ not humans.sh. (4966085)
89 87 not 88 (4498)
90 letter/ (1170974)
91 editorial/ (596830)
92 news/ (211236)
93 exp historical article/ (407727)
94 anecdotes as topic/ (4746)
95 comment/ (953016)
96 or/90-95 (2619024)
97 89 not 96 (4396)
98 remove duplicates from 97 (4395)**Key:**
/ or .sh. = indexing term (Medical Subject Heading: MeSH)
exp = exploded indexing term (MeSH)
* before a MeSH term = focussed subject heading
/ae, co, mo = MeSH subheadings for adverse effects, complications, mortality
* or $ = truncation

? or # = optional wild card character - stands for zero or one letters
ti,ab,kf = terms in either title, abstract, or keyword field
mp = multipurpose field
adj3 = terms within three words of each other (any order)
hw = subject heading word
pt = publication type
is = ISSN electronic

**Embase**
via Ovid http://ovidsp.ovid.com/
Date range searched: 1974 to 2022 February 18
Date searched: 28 February 2022
Records retrieved: 3663

1 *urban population/ (11570)
2 *suburban population/ (131)
3 *city planning/ (1240)
4 *built environment/ (557)
5 urban*.ti,ab. (232145)
6 (built environment or built-environment).ti,ab. (3937)
7 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. (305954)
8 ((population dens* or population-dens*) adj2 high*).ti,ab. (2283)
9 or/1-8 (498048)
10 *environment/ (21837)
11 exp *recreational park/ (1204)
12 *aquatic environment/ (3395)
13 *lake/ (4774)
14 exp *pond/ (1371)
15 *river/ (9814)
16 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. (3003)
17 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. (3586)
18 (greenspace* or greenery or greenness).ti,ab. (1947)
19 ((natural or outdoor*) adj2 environment*).ti,ab. (19165)
20 ((nature or natural) adj2 space*).ti,ab. (519)
21 sports field*.ti,ab. (187)
22 wilderness area*.ti,ab. (228)
23 public open space*.ti,ab. (133)
24 neighbo?rhood open space*.ti,ab. (9)
25 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (forest* or wood* or wilderness or meadow* or tree* or hill* or moor* or dale or dales)).ti,ab. (6132)
26 ((public* or near or nearby or local* or residential or industrial or access*) adj4 ((footpath* or trail* or coast* or cliff*) adj2 green)).ti,ab. (0)
27 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. (942)
28 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. (145079)
29 (bluespace* or blue space*).ti,ab. (172)

30 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*)).ti,ab. (5952)
31 (water* adj2 (environment* or inland)).ti,ab. (13840)
32 or/10-31 (229053)
33 9 and 32 (18316)
34 *public health/ (65617)
35 *urban health/ (447)
36 *"social determinants of health"/ (5083)
37 *health status/ (37233)
38 ((physical* or public* or communit* or population*) adj health).ti,ab. (400390)
39 (health adj (status or determinant*)).ti,ab. (85162)
40 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. (191784)
41 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. (84786)
42 (physical* adj2 inactiv*).ti,ab. (14513)
43 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. (3876)
44 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. (249435)
45 (life adj2 (expectan* or quality)).ti,ab. (565749)
46 *quality adjusted life year/ (1828)
47 *disability-adjusted life year/ (419)
48 (healthy life-year or healy).ti,ab. (303)
49 *mental health/ (47302)
50 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. (268025)
51 ((depressed or low) adj2 mood).ti,ab. (9057)
52 (stress* adj2 (manage* or event* or resilien*)).ti,ab. (27913)
53 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. (24118)
54 or/34-53 (1731030)
55 *education/ (90476)
56 *learning/ (70769)
57 *cognition assessment/ (1140)
58 *academic achievement/ (9104)
59 *educational status/ (10660)
60 *academic failure/ (145)
61 *literacy/ (1589)
62 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. (85764)

63 (education adj2 (status or level or determinant*)).ti,ab. (55427)
64 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. (257393)
65 (neurodevelopment or neurological development).ti,ab. (15861)
66 (communication adj (skill* or difficult* or deficit*)).ti,ab. (19508)
67 or/55-66 (570902)
68 33 and (54 or 67) (3785)
69 letter/ (1140097)

70 case report/ (2713980)
71 case study/ (84208)
72 (letter or comment*).ti. (219223)
73 (comment or note).pt. (885312)
74 or/69-73 (4590960)
75 68 not 74 (3726)
76 (rat or rats or mouse or mice or swine or porcine or murine or sheep or lambs or pigs or piglets or rabbit or rabbits or cat or cats or dog or dogs or cattle or bovine or monkey or monkeys or trout or marmoset$).ti,ot. and animal experiment/ (1140839)
77 animal experiment/ not (human experiment/ or human/) (2394272)
78 76 or 77 (2452400)
79 75 not 78 (3707)
80 remove duplicates from 79 (3663)

**Key:**
/ = indexing term (Emtree Subject Heading)
exp = exploded indexing term (Emtree)
* before an Emtree term = focussed subject heading
/ae = Emtree subheading for adverse effects
$ or * = truncation
? or # = optional wild card character - stands for zero or one letters
ti,ab,kw,kf = terms in either title, abstract, keyword, or keyword field
hw = heading word field
jx = journal word
is = ISSN
pt = publication type
ot = original title
mp = multipurpose field
de = MeSH subject headings
adj3 = terms within three words of each other (any order)

**Web of Science**
via clarivate https://www.webofscience.com/wos/woscc/advanced-search
Date range searched: 1900-present
Date searched: 28 February 2022
Records retrieved: 2775
50 #48 NOT #49 (2,775)
49 TI=(animal or animals or rat or rats or mouse or mice or rodent or rodents or porcine or murine or sheep or lamb or lambs or ewe or ewes or pig or pigs or piglet or piglets or sow or sows or pig or pigs or rabbit or rabbits or kitten or kittens or dog or dogs or puppy or puppies or monkey or monkeys or horse or horses or foal or foals or equine or calf or calves or cattle or heifer or heifers or hamster or hamsters or chicken or chickens or livestock or alpaca* or llama*) (86,299)
48 #19 AND #47 (2,785)
47 #39 OR #46 (1,180,606)
46 #40 OR #41 OR #42 OR #43 OR #44 OR #45 (241,263)
45 TS=(communication NEAR/1 (skill* or difficult* or deficit*)) (11,896)
44 TS=(neurodevelopment or "neurological development") 3,893
43 TS=(cognitive NEAR/1 (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)) 110,836
42 TS=(education* NEAR/2 (status or level or determinant*)) 42,820

41 TS=((school*) NEAR/1 (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test)) 25,398
40 TS=((student*) NEAR/1 (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test)) 58,27739 #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 999,050
38 TS=(mental* NEAR/3 (wellness or welfare or well-being or wellbeing)) OR TS=(psychological* NEAR/3 (wellness or welfare or well-being or wellbeing)) 25,798
37 TS=(stress* NEAR/2 (manage* or event* or resilien*)) 18,837
36 TS=(stress NEAR/3 (psychological or mental)) 17,168
35 TS=(anxiet* or anxious*) 212,325
34 TS=(mood NEAR/2 (depressed or low)) 5,406
33 TS=(mental* NEAR/2 (health* or ill*)) or TS=(psychological* NEAR/2 (health* or ill*)) 260,885
32 TS=(healy or "healthy life year*" or "healthy life-year*") 420
31 TS=(qaly or "quality adjusted life year*" or "quality-adjusted life year*" or "quality adjusted life-year*") 5,549
30 TS=(daly or "disability adjusted life year*" or "disability-adjusted life year*" or "disability adjusted life-year*") 2,253
29 TS=(life NEAR/2 (expectan* or quality)) 175,054
28 TS=(obese or obesity or overweight) 83,000
27 TS= (weight NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) or TS= ("body mass" NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) or TS= ("BMI" NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) 30,612
26 TS= (living NEAR/2 (inactive or unhealthy)) or TS=(life* NEAR/2 (inactive or unhealthy)) 1,339
25 TS= (physical* NEAR/2 inactiv*) 5,033
24TS= (exercise* or exercising or fitness) 129,487
23 TS= (living NEAR/3 (active or physically-active or health*)) or TS=(life* NEAR/3 (active or physically-active or health*)) 67,962
22 TS= (physical* NEAR/2 (activ* or wellness or welfare or well-being or wellbeing)) 104,038
21 TS= (health NEAR (physical* or public* or communit* or population*)) 308,617
20 TS=("social determinant* of health") 5,986
19 #4 AND #18 17,173
18 #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
156,352
17 TS=((water*) NEAR/2 (environment* or inland)) 2,582
16 TS=(("fresh water*" or lake* or pond* or river* or waterway* or "open water*" or waterfront* or waterscape* or waterbod* or "water feature*" or seafront or seaside or "aquatic landscape*") and (environment* or space* or area*)) 20,480

15 TS=(bluespace* or "blue space*") 413
14 TS=(lake* or pond* or river*) 40,703
13 TS=(conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)) 1,782

12 TS=(forest* or wood* or wilderness or meadow* or tree* or hill or hills or moor* or dale or dales)
99,313
11 TS=("wilderness area*") 203
10 TS=("sports field*") 105
9 TS=(natur* NEAR/2 space*) 1,077
8 TS=((environment*) NEAR/2 (natural or outdoor*) ) 9,511
7 TS=((greenspace* or greenery or greenness)) 2,296
6 TS=((green*) NEAR/2 (area* or environment* or space* or neighbo?rhood*)) 8,576
5 TS=((green*) NEAR/2 (urban* or city or cities or environment* or neighbo?rhood or residential or community or park*)) 7,814
4 #1 OR #2 OR #3 250,370
3 TS=(("population dens*" NEAR/2 high) or (population-dens* NEAR/2 high)) 690
2 TS=(city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*) 249,928
1 TS=(city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*) 249,928

**Cochrane Central Register of Controlled Trials (CENTRAL)**
via Wiley http://onlinelibrary.wiley.com/
Date range: Issue 2 of 12, February 2022
Date searched: 03 March 2022
Records retrieved: 350
#1 [mh ^"Urban Population"] 1316
#2 [mh ^"Suburban Population"] 33
#3 [mh ^"City Planning"] 4
#4 [mh ^"Urban Renewal"] 11
#5 [mh ^"Built Environment"] 14
#6 [mh ^Cities] 94
#7 urban*:ti,ab 9227
#8 (built NEXT environment*):ti,ab 137
#9 (city or cities or megacity or megacities or muncipalit* or town* or metropoli* or megalopolis or suburb* or conurbation*):ti,ab 13734
#10 ((built NEXT up or industrial) NEAR area*):ti,ab 22
#11 (population NEXT dens* NEAR/2 high*):ti,ab 9
#12 {OR #1-#11} 22217
#13 [mh ^Environment] 430
#14 [mh ^"Environment Design"] 119
#15 [mh ^"Parks, Recreational"] 21
#16 [mh ^Nature] 25
#17 (green* NEAR/2 (urban* or city or cities or environment* or neighb*rhood or residential or community)):ti,ab 40
#18 (green NEAR/2 (area* or environment* or space* or neighb*rhood*)):ti,ab 65
#19 (greenspace* or greenery or greenness):ti,ab 29
#20 ((natural or outdoor*) NEAR/2 environment*):ti,ab 462
#21 ((nature or natural) NEAR/2 space*):ti,ab 9
#22 sports NEXT field*:ti,ab 10

#23 wilderness NEXT area*:ti,ab 0
#24 (public NEXT (open NEXT space*)):ti,ab 0
#25 (neighb*rhood NEXT (open NEXT space*)):ti,ab 0
#26 (forest* or wood* or wilderness or meadow* or tree* or hill or hills or moor* or dale or dales):ti,ab 6455
#27 ((footpath* or trail* or coast* or cliff*) NEAR/2 green):ti,ab 0
#28 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)):ti,ab 4
#29 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)):ti,ab 2009
#30 {OR #13-#29} 9396
#31 #12 and #30 536
#32 [mh ^Lakes] 5
#33 [mh ^Ponds] 0
#34 [mh ^Rivers] 5
#35 (bluespace* or blue NEXT space*):ti,ab 5
#36 ((fresh NEXT water* or lake* or pond* or river* or waterway* or open NEXT water* or waterfront* or waterscape* or waterbod* or water NEXT feature* or seafront or seaside or aquatic NEXT landscape*) and (environment* or space* or area*)):ti,ab 506
#37 (water* NEAR/2 (environment* or inland)):ti,ab 46
#38 {OR #32-#37} 565
#39 #12 and #38 86
#40 #12 and (#30 or #38) 603
#41 [mh ^"Public Health"] 282
#42 [mh ^"Urban Health"] 353
#43 [mh ^"Suburban Health"] 18
#44 [mh ^"Social Determinants of Health"] 28
#45 [mh ^"Health Status"] 3896
#46 [mh "Physical Fitness"] 3685
#47 ((physical* or public* or communit* or population*) NEXT health):ti,ab 21022
#48 (health NEXT (status or determinant*)):ti,ab 9734
#49 (physical* NEAR/2 (activ* or wellness or welfare or well NEXT being or wellbeing)):ti,ab 35251
#50 ((active or health*) NEAR/3 (living or life*)):ti,ab 25544
#51 (exercise* or exercising or fitness):ti,ab 105638
#52 (physical* NEAR/2 inactiv*):ti,ab 1898
#53 ((inactiv* or unhealthy) NEAR/2 (living or life*)):ti,ab 348
#54 ((weight or body NEXT mass or BMI) NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)):ti,ab 30637
#55 (obese or obesity or overweight):ti,ab 46297
#56 (life NEAR/2 (expectan* or quality)):ti,ab 122172
#57 {OR #41-#56} 291054
#58 [mh ^"Mental Health"] 1860
#59 ((mental* or psychological*) NEAR/2 (health* or ill*)):ti,ab 24781
#60 [mh "Depressive Disorder"] 13119
#61 (depression or depressive):ti,ab 81540
#62 ((depressed or low) NEAR/2 mood):ti,ab 1437
#63 [mh ^"Mood Disorders"] 871
#64 [mh "Anxiety Disorders"] 7609
#65 (anxiet* or anxious*):ti,ab 53479

#66 [mh "Stress, Psychological"] 6707
#67 (stress* NEAR/2 (manage* or event* or resilien*)):ti,ab 3868
#68 ((mental* or psychological*) NEAR/2 (wellness or welfare or well NEXT being or wellbeing)):ti,ab 4025
#69 [mh ^"Quality-Adjusted Life Years"] 1432
#70 (DALY or ((disability NEXT adjusted) NEXT (life NEXT year*))):ti,ab 318
#71 ((healthy NEXT (life NEXT year)) or (HEALY or HALY)):ti,ab 15
#72 {OR #58-#71} 134339
#73 [mh ^Education] 605
#74 [mh ^Learning] 2511
#75 [mh ^Cognition] 8570
#76 [mh "Educational Measurement"] 5148
#77 [mh "Academic Performance"] 113
#78 [mh ^"Educational Status"] 1520
#79 [mh ^"Academic Failure"] 2
#80 [mh ^Literacy] 44
#81 ((education* or academic or intellectual* or learning or school* or student*) NEXT (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)):ti,ab 7443
#82 (education NEAR/2 (status or level or determinant*)):ti,ab 2750
#83 cognition:ti,ab 13451
#84 (cognitive NEXT (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)):ti,ab 27600
#85 (literate or literac*):ti,ab 5062
#86 (neurodevelopment or neurological NEXT development):ti,ab 1015
#87 (communication NEXT (skill* or difficult* or deficit*)):ti,ab 1987
#88 {OR #73-#87} 62111
#89 #40 and #57 278
#90 #40 and #72 137
#91 #40 and #88 50
#92 #89 or #90 or #91 in Trials 350

**Key:**
* = truncation
adj2 = adjacent by 2 words (either order)

**Cochrane CSDR**
Date searched: 24 February 2022
Records retrieved: 11

1. #1 [mh ^"Urban Population"] 1315
2. #2 [mh ^"Suburban Population"] 33
3. #3 [mh ^"City Planning"] 4
4. #4 [mh ^"Urban Renewal"] 11
5. #5 [mh ^"Built Environment"] 14
6. #6 [mh ^Cities] 94
7. #7 urban*:ti,ab 9141

8. #8 (built NEXT environment*):ti,ab 135
9. #9 (city or cities or megacity or megacities or muncipalit* or town* or metropoli* or megalopolis or suburb* or conurbation*):ti,ab 13630
10. #10 ((built NEXT up or industrial) NEAR area*):ti,ab 22
11. #11 (population NEXT dens* NEAR/2 high*):ti,ab 8
12. #12 {OR #1-#11} 22031
13. #13 [mh ^Environment] 429
14. #14 [mh ^"Environment Design"] 118
15. #15 [mh ^"Parks, Recreational"] 19
16. #16 [mh ^Nature] 25
17. #17 (green* NEAR/2 (urban* or city or cities or environment* or neighb*rhood or residential or community)):ti,ab 39
18. #18 (green NEAR/2 (area* or environment* or space* or neighb*rhood*)):ti,ab 63
19. #19 (greenspace* or greenery or greenness):ti,ab 28
20. #20 ((natural or outdoor*) NEAR/2 environment*):ti,ab 458
21. #21 ((nature or natural) NEAR/2 space*):ti,ab 9
22. #22 sports NEXT field*:ti,ab 10
23. #23 wilderness NEXT area*:ti,ab 0
24. #24 (public NEXT (open NEXT space*)):ti,ab 0
25. #25 (neighb*rhood NEXT (open NEXT space*)):ti,ab 0
26. #26 (forest* or wood* or wilderness or meadow* or tree* or hill or hills or moor* or dale or dales):ti,ab 6408
27. #27 ((footpath* or trail* or coast* or cliff*) NEAR/2 green):ti,ab 0
28. #28 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)):ti,ab 4
29. #29 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)):ti,ab 1992
30. #30 {OR #13-#29} 9325
31. #31 #12 and #30 531
32. #32 [mh ^Lakes] 5
33. #33 [mh ^Ponds] 0
34. #34 [mh ^Rivers] 5
35. #35 (bluespace* or blue NEXT space*):ti,ab 5

36. #36 ((fresh NEXT water* or lake* or pond* or river* or waterway* or open NEXT water* or waterfront* or waterscape* or waterbod* or water NEXT feature* or seafront or seaside or aquatic NEXT landscape*) and (environment* or space* or area*)):ti,ab 505
37. #37 (water* NEAR/2 (environment* or inland)):ti,ab 46
38. #38 {OR #32-#37} 564
39. #39 #12 and #38 86
40. #40 #12 and (#30 or #38) 598
41. #41 [mh ^"Public Health"] 279
42. #42 [mh ^"Urban Health"] 353
43. #43 [mh ^"Suburban Health"] 18
44. #44 [mh ^"Social Determinants of Health"] 27
45. #45 [mh ^"Health Status"] 3883
46. #46 [mh "Physical Fitness"] 3652
47. #47 ((physical* or public* or communit* or population*) NEXT health):ti,ab 20783
48. #48 (health NEXT (status or determinant*)):ti,ab 9671
49. #49 (physical* NEAR/2 (activ* or wellness or welfare or well NEXT being or wellbeing)):ti,ab 34890
50. #50 ((active or health*) NEAR/3 (living or life*)):ti,ab 25262
51. #51 (exercise* or exercising or fitness):ti,ab 104693
52. #52 (physical* NEAR/2 inactiv*):ti,ab 1871
53. #53 ((inactiv* or unhealthy) NEAR/2 (living or life*)):ti,ab 341
54. #54 ((weight or body NEXT mass or BMI) NEAR/2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)):ti,ab 30354
55. #55 (obese or obesity or overweight):ti,ab 45865
56. #56 (life NEAR/2 (expectan* or quality)):ti,ab 121132
57. #57 {OR #41-#56} 288434
58. #58 [mh ^"Mental Health"] 1842
59. #59 ((mental* or psychological*) NEAR/2 (health* or ill*)):ti,ab 24503
60. #60 [mh "Depressive Disorder"] 13038
61. #61 (depression or depressive):ti,ab 80959
62. #62 ((depressed or low) NEAR/2 mood):ti,ab 1430
63. #63 [mh ^"Mood Disorders"] 866
64. #64 [mh "Anxiety Disorders"] 7539

65. #65 (anxiet* or anxious*):ti,ab 53003
66. #66 [mh "Stress, Psychological"] 6674
67. #67 (stress* NEAR/2 (manage* or event* or resilien*)):ti,ab 3835
68. #68 ((mental* or psychological*) NEAR/2 (wellness or welfare or well NEXT being or wellbeing)):ti,ab 3963
69. #69 [mh ^"Quality-Adjusted Life Years"] 1421
70. #70 (DALY or ((disability NEXT adjusted) NEXT (life NEXT year*))):ti,ab 314
71. #71 ((healthy NEXT (life NEXT year)) or (HEALY or HALY)):ti,ab 15
72. #72 {OR #58-#71} 133308
73. #73 [mh ^Education] 606
74. #74 [mh ^Learning] 2485
75. #75 [mh ^Cognition] 8479
76. #76 [mh "Educational Measurement"] 5114
77. #77 [mh "Academic Performance"] 112
78. #78 [mh ^"Educational Status"] 1512
79. #79 [mh ^"Academic Failure"] 2
80. #80 [mh ^Literacy] 43
81. #81 ((education* or academic or intellectual* or learning or school* or student*) NEXT (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)):ti,ab 7376
82. #82 (education NEAR/2 (status or level or determinant*)):ti,ab 2723
83. #83 cognition:ti,ab 13314
84. #84 (cognitive NEXT (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)):ti,ab 27352
85. #85 (literate or literac*):ti,ab 5014
86. #86 (neurodevelopment or neurological NEXT development):ti,ab 1004
87. #87 (communication NEXT (skill* or difficult* or deficit*)):ti,ab 1963
88. #88 {OR #73-#87} 61553
89. #89 #40 and #57 273
90. #90 #40 and #72 134
91. #91 #40 and #88 48
92. #92 #89 or #90 or #91 in Cochrane Reviews 11

**ERIC**
via https://trialsearch.who.int/AdvSearch.aspx
Date searched: 24 February 2022
Records retrieved: 536

S75 S32 AND S74 536
S74 S49 OR S59 OR S73 260,573
S73 S60 OR S61 OR S62 OR S63 OR S64 OR S65 OR S66 OR S67 OR S68 OR S69 OR S70 OR S71 OR S72 175,632
S72 TI (communication NEAR (skill* or difficult* or deficit*)) OR AB (communication NEAR (skill* or difficult* or deficit*)) 98
S71 TI (neurodevelopment or neurological development) OR AB (neurodevelopment or neurological development) 208
S70 TI (literate or literac*) OR AB (literate or literac*) 60,839
S69 TI (cognitive NEAR (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)) OR AB (cognitive NEAR (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)) 8
S68 TI cognition OR AB cognition 9,498
S67 TI (education NEAR2 (status or level or determinant*)) OR AB (education NEAR2 (status or level or determinant*)) 379
S66 TI ((education* or academic or intellectual* or learning or school* or student*) NEAR (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)) OR AB ((education* or academic or intellectual* or learning or school* or student*) NEAR (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)) 283
S65 DE "Literacy" 16,272
S64 DE "Academic Failure" 2,850
S63 DE "Academic Achievement" 90,483
S62 DE "Cognitive Measurement" 2,244
S61 DE "Learning" 9,445
S60 DE "Education" 4,399
S59 S50 OR S51 OR S52 OR S53 OR S54 OR S55 OR S56 OR S57 OR S58 41,008
S58 TI ((mental* or psychological*) NEAR2 (wellness or welfare or well-being or wellbeing)) OR AB ((mental* or psychological*) NEAR2 (wellness or welfare or well-being or wellbeing)) 95
S57 TI (stress* NEAR2 (manage* or event* or resilien*)) OR AB (stress* NEAR2 (manage* or event* or resilien*)) 26
S56 TI (anxiet* or anxious*) OR AB (anxiet* or anxious*) 18,961
S55 DE "Anxiety Disorders" 957
S54 TI ((depressed or low) NEAR2 mood) OR AB ((depressed or low) NEAR2 mood)27
S53 TI (depression or depressive) OR AB (depression or depressive) 12,093
S52 DE "Depression (Psychology)" 11,068
S51 TI ((mental* or psychological*) NEAR2 (health* or ill*)) OR AB ((mental* or psychological*) NEAR2 (health* or ill*)) 57
S50 DE "Mental Health" 13,691
S49 S33 OR S34 OR S35 OR S36 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47 OR S48 54,316
S48 TI (healthy life-year or HeaLY or HALY) OR AB (healthy life-year or HeaLY or HALY) 96

S47 TI (DALY or disability adjusted life year* or disability-adjusted life year*) OR AB (DALY or disability adjusted life year* or disability-adjusted life year*) 177
S46 DE "Quality of Life" 6,456
S45 TI (life NEAR2 (expectan* or quality)) OR AB (life NEAR2 (expectan* or quality)) 31
S44 TI (obese or obesity or overweight) OR AB (obese or obesity or overweight) 3,356
S43 TI ((weight or body mass or BMI) NEAR2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) OR AB ((weight or body mass or BMI) NEAR2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)) 0
S42 TI ((inactiv* or unhealthy) NEAR2 (living or life*)) OR AB ((inactiv* or unhealthy) NEAR2 (living or life*)) 191
S41 TI (physical* NEAR2 inactiv*) OR AB (physical* NEAR2 inactiv*) 17
S40 TI (exercise* or exercising or fitness) OR AB (exercise* or exercising or fitness) 35,176
S39 TI ((active or physically-active or health*) NEAR3 (living or life*)) OR AB ((active or physically-active or health*) NEAR3 (living or life*)) 64
S38 TI (physical* NEAR2 (activ* or wellness or welfare or well-being or wellbeing)) OR AB (physical* NEAR2 (activ* or wellness or welfare or well-being or wellbeing))2
S37 TI (health NEAR (status or determinant*)) OR AB (health NEAR (status or determinant*))2
S36 TI ((physical* or public* or communit* or population*) NEAR health) OR AB ((physical* or public* or communit* or population*) NEAR health) 2
S35 DE "Physical Health" 4,229
S34 DE "Physical Fitness" 3,967
S33 DE "Public Health" 6,103
S32 S11 AND S31 3,166
S31 S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 30,303
S30 TI (water* NEAR2 (environment* or inland)) OR AB (water* NEAR2 (environment* or inland)) 55
S29 TI ((fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*) and (environment* or space* or area*)) OR AB ((fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*) and (environment* or space* or area*)) 2,221
S28 (bluespace* or blue space*) OR AB (bluespace* or blue space*) 5
S27 DE "Water" 1,986
S26 TI (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)) OR AB (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)) 7,316
S25 TI (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)) OR AB conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)) 230
S24 TI ((footpath* or trail* or coast* or cliff*) NEAR2 green) OR AB ((footpath* or trail* or coast* or cliff*) NEAR2 green) 3

S23 TI (forest* or wood* or wilderness or meadow* or tree* or hill or hills or moor or moors or dale or dales) OR AB (forest* or wood* or wilderness or meadow* or tree* or hill or hills or moor or moors or dale or dales) 15,536
S22 TI (neighborhood open space* or neighbourhood open space*) OR AB (neighborhood open space* or neighbourhood open space*) 3
S21 TI public open space* OR AB public open space* 25
S20 TI wilderness area* OR AB wilderness area* 85
S19 TI sports field* OR AB sports field* 340
S18 TI ((nature or natural) NEAR2 space*) OR AB ((nature or natural) NEAR2 space*) 33
S17 TI ((natural or outdoor*) NEAR2 environment*) OR AB ((natural or outdoor*) NEAR2 environment*) 46
S16 TI (greenspace* or greenery or greenness) OR AB (greenspace* or greenery or greenness) 36
S15 TI (green NEAR2 (area* or environment* or space* or neighborhood* or neighbourhood*)) OR AB (green NEAR2 (area* or environment* or space* or neighborhood* or neighbourhood*)) 196
S14 TI (green* NEAR2 (urban* or city or cities or environment* or neighborhood or neighbourhood or residential or community)) OR AB (green* NEAR2 (urban* or city or cities or environment* or neighborhood or neighbourhood or residential or community)) 27,233
S13 DE "Physical Environment" 3,499
S12 DE "Parks" 1,052
S11 S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 92,432
S10 TI ((population dens* or population-dens*) NEAR2 high*) OR AB ((population dens* or population-dens*) NEAR2 high*) 1
S9 TI ((built-up or built up or industrial) NEAR area*) OR AB ((built-up or built up or industrial) NEAR area*) 2
S8 TI (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*) OR AB (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*) 57,422
S7 TI (built environment* or built-environment*) OR AB (built environment* or built-environment*) 647
S6 TI urban* OR AB urban* 43,860
S5 DE "Municipalities" 1,093
S4 DE "Metropolitan Areas" 1,834
S3 DE "Urbanization" 792
S2 DE "Urban Renewal" 464
S1 DE "Urban Population" 854

**Econlit**
Date range searched: 1886 to February 24, 2022
Date searched: 03 March 2022
Records retreived:237

Search Strategy:

1 urban*.ti,ab. (40296)
2 (built environment* or built-environment*).ti,ab. (779)
3 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. (44739)
4 ((built-up or built up or industrial) adj area*).ti,ab. (254)
5 or/1-4 (71560)
6 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. (505)
7 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. (440)
8 (greenspace* or greenery or greenness).ti,ab. (128)
9 ((natural or outdoor*) adj2 environment*).ti,ab. (1163)
10 ((nature or natural) adj2 space*).ti,ab. (64)
11 sports field*.ti,ab. (4)
12 wilderness area*.ti,ab. (45)
13 public open space*.ti,ab. (28)
14 neighbo?rhood open space*.ti,ab. (2)
15 (forest* or wood* or wilderness or meadow* or tree* or hill*1 or moor* or dale or dales).ti,ab. (16426)
16 ((footpath* or trail* or coast* or cliff*) adj2 green).ti,ab. (2)
17 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. (157)
18 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. (9633)
19 (bluespace* or blue space*).ti,ab. (5)
20 ((fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*) and (environment* or space* or area*)).ti,ab. (2096)
21 (water* adj2 (environment* or inland)).ti,ab. (397)
22 or/6-21 (28853)
23 5 and 22 (3105)
24 ((physical* or public* or communit* or population*) adj health).ti,ab. (5879)
25 (health adj (status or determinant*)).ti,ab. (2426)
26 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. (673)
27 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. (1667)
28 (exercise* or exercising or fitness).ti,ab. (13682)
29 (physical* adj2 inactiv*).ti,ab. (31)
30 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. (33)
31 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. (504)
32 (obese or obesity or overweight).ti,ab. (2308)
33 (life adj2 (expectan* or quality)).ti,ab. (6573)
34 (DALY or "disability adjusted life year" or "disability-adjusted life year" or "disability adjusted life years" or "disability-adjusted life years").ti,ab. (225)
35 (healthy life-year or HeaLY or HALY).ti,ab. (36)
36 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. (2614)
37 (depression or depressive).ti,ab. (4843)
38 ((depressed or low) adj2 mood).ti,ab. (14)
39 (anxiet* or anxious*).ti,ab. (1219)
40 (stress* adj2 (manage* or event* or resilien*)).ti,ab. (215)

41 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. (473)
42 or/24-41 (38932)
43 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. (11664)

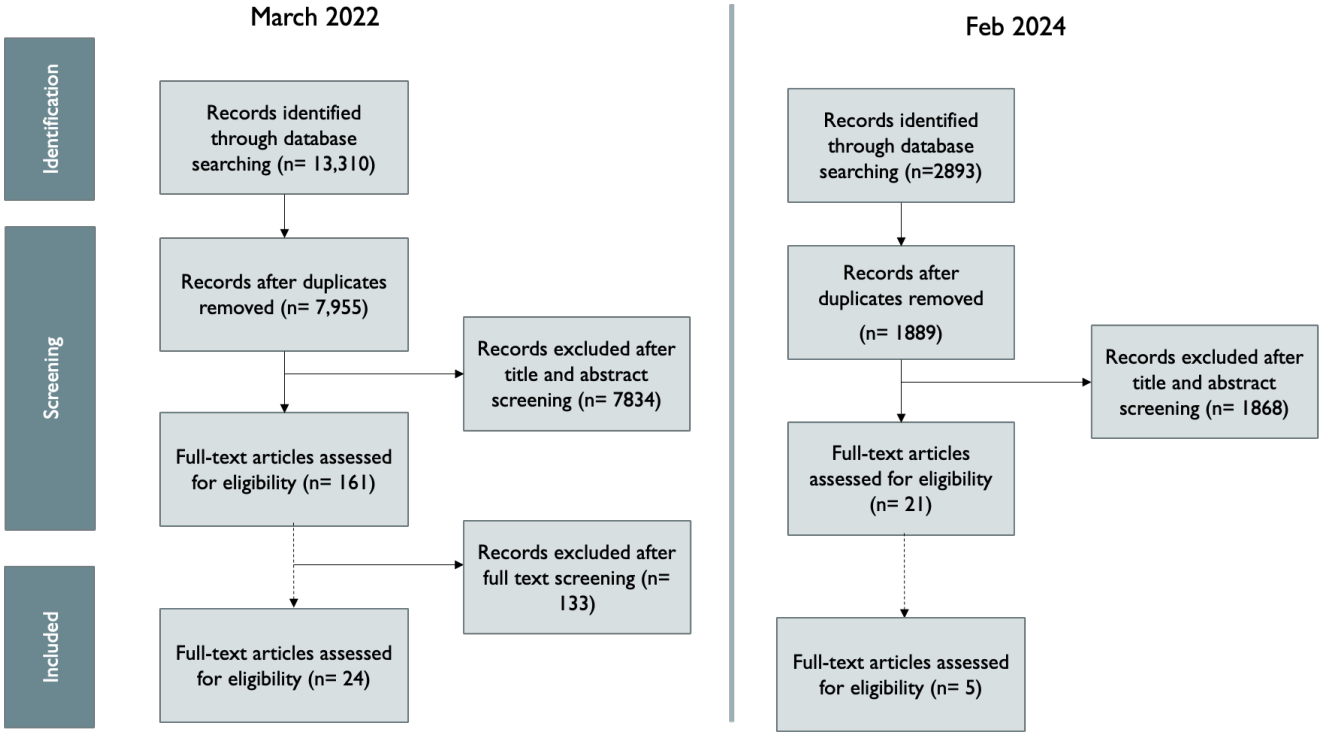
44 (education adj2 (status or level or determinant*)).ti,ab. (3399)
45 cognition.ti,ab. (1396)
46 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. (1285)
47 (literate or literac*).ti,ab. (3214)
48 (neurodevelopment or neurological development).ti,ab. (4)
49 (communication adj (skill* or difficult* or deficit*)).ti,ab. (160)
50 or/43-49 (20092)
51 23 and (42 or 50) (237)

**Psychinfo**
Date range searched: 1806 to February Week 3 2022
Date searched: 03 March 2022
Records retrieved: 1358
1 *urban environments/ (15661)
2 ghettoes/ (224)
3 suburban environments/ (1080)
4 built environment/ (1181)
5 urban*.ti,ab. (67799)
6 (built environment* or built-environment*).ti,ab. (2054)
7 (city or cities or city-centre* or megacity or mega-city or megacities or mega-cities or muncipalit* or town* or metropoli* or megalopolis or suburb* or sub-urb* or conurbation*).ti,ab. (87582)
8 ((built-up or built up or industrial) adj area*).ti,ab. (144)
9 ((population dens* or population-dens*) adj2 high*).ti,ab. (280)
10 or/1-9 (144734)
11 exp "nature (environment)"/ (3068)
12 recreation areas/ (1229)
13 environmental planning/ (1939)
14 (green* adj2 (urban* or city or cities or environment* or neighbo?rhood or residential or community)).ti,ab. (511)
15 (green adj2 (area* or environment* or space* or neighbo?rhood*)).ti,ab. (650)
16 (greenspace* or greenery or greenness).ti,ab. (260)
17 ((natural or outdoor*) adj2 environment*).ti,ab. (5327)
18 ((nature or natural) adj2 space*).ti,ab. (215)
19 sports field*.ti,ab. (57)
20 wilderness area*.ti,ab. (42)
21 public open space*.ti,ab. (48)
22 neighbo?rhood open space*.ti,ab. (5)
23 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (forest* or wood* or wilderness or meadow* or tree* or hill* or moor* or dale or dales)).ti,ab. (537)
24 ((public* or near or nearby or local* or residential or industrial or access*) adj4 ((footpath* or trail* or coast* or cliff*) adj2 green)).ti,ab. (0)

25 (conservation* and natural and environment* and (renewal or regenerat* or restor* or maintain* or enhance* or preserv* or creat*)).ti,ab. (122)
26 (environmental* and (regenerat* or restor* or redevelop* or maintain* or enhance* or preserv* or create* or creation or establish* or build*)).ti,ab. (21963)
27 (bluespace* or blue space*).ti,ab. (59)
28 ((public* or near or nearby or local* or residential or industrial or access*) adj4 (fresh water* or lake* or pond* or river* or waterway* or open water* or waterfront* or waterscape* or waterbod* or water feature* or seafront or seaside or aquatic landscape*)).ti,ab. (215)
29 (water* adj2 (environment* or inland)).ti,ab. (170)
30 or/11-29 (33640)
31 10 and 30 (3461)
32 public health/ (24678)
33 urban health/ (216)
34 health status/ (1521)
35 physical fitness/ (4623)
36 ((physical* or public* or communit* or population*) adj health).ti,ab. (82913)
37 (health adj (status or determinant*)).ti,ab. (19519)
38 (physical* adj2 (activ* or wellness or welfare or well-being or wellbeing)).ti,ab. (43493)
39 ((active or physically-active or health*) adj3 (living or life*)).ti,ab. (22987)
40 (exercise* or exercising or fitness).ti,ab. (86364)
41 (physical* adj2 inactiv*).ti,ab. (2665)
42 ((inactiv* or unhealthy) adj2 (living or life*)).ti,ab. (779)
43 ((weight or body mass or BMI) adj2 (healthy or manage* or control* or loss* or loos* or decreas* or reduc*)).ti,ab. (22449)
44 (obese or obesity or overweight).ti,ab. (46275)
45 (life adj2 (expectan* or quality)).ti,ab. (81002)
46 "quality of life"/ (44264)
47 *"health related quality of life"/ (3509)
48 (DALY or "disability adjusted life year" or "disability-adjusted life year" or "disability adjusted life years" or "disability-adjusted life years").ti,ab. (803)
49 (healthy life-year or HeaLY or HALY).ti,ab. (439)
50 or/32-49 (341508)
51 *mental health/ (56380)
52 public mental health/ (881)
53 ((mental* or psychological*) adj2 (health* or ill*)).ti,ab. (245013)
54 *"depression (emotion)"/ (20149)
55 (depression or depressive).ti,ab. (308461)
56 ((depressed or low) adj2 mood).ti,ab. (6121)
57 affective disorders/ (15119)
58 anxiety disorders/ (19736)
59 (anxiet* or anxious*).ti,ab. (223224)
60 stress/ (69096)
61 (stress* adj2 (manage* or event* or resilien*)).ti,ab. (20235)
62 ((mental* or psychological*) adj2 (wellness or welfare or well-being or wellbeing)).ti,ab. (20735)
63 or/51-62 (714104)
64 *education/ (28327)
65 *learning/ (55113)

66 *cognition/ (25477)
67 exp educational measurement/ (20323)
68 academic achievement/ (60255)
69 educational attainment level/ (5691)
70 academic failure/ (1913)
71 literacy/ (15935)
72 ((education* or academic or intellectual* or learning or school* or student*) adj (assess* or measure* or develop* or attain* or achieve* or perform* or success* or skill* or abilit* or aptitude or fail* or exam* or score* or test*)).ti,ab. (129200)
73 (education adj2 (status or level or determinant*)).ti,ab. (18310)
74 cognition.ti,ab. (85112)
75 (cognitive adj (function* or develop* or abilit* or dysfunction* or inabilit* or declin* or deteriorat* or impair*)).ti,ab. (118069)
76 (literate or literac*).ti,ab. (35625)
77 (neurodevelopment or neurological development).ti,ab. (3841)
78 (communication adj (skill* or difficult* or deficit*)).ti,ab. (11433)
79 or/64-78 (478246)
80 31 and (50 or 63 or 79) (1364)
81 remove duplicates from 80 (1358)

Figure A2.1 : PRISMA diagram for both waves



Appendix 2 – Risk of Bias

Table A2.1: Risk of Bias results from all included articles

| Article Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Is the setting (source population/area) adequately described?** | + | + | + | + | + | + | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | + | + | + | + | + | + |
| **Is this a longitudinal study?** | + | + | + | - | + | + | - | + | - | + | + | - | + | + | + | + | + | + | + | + | - | - | + | + | + | + | + | + | + |
| **Is the definition of changes in the characteristics in urban green spaces adequate?** | ++ | ++ | + | ++ | - | ++ | + | + | + | + | ++ | - | ++ | + | ++ | ++ | ++ | + | ++ | ++ | ++ | + | + | + | ++ | ++ | + | ++ | + |
| **Were the exposed cases/cohort representative for the general population?** | ++ | + | ++ | + | + | ++ | + | ++ | + | ++ | ++ | - | ++ | + | + | + | ++ | + | ++ | + | + | + | + | + | + | + | + | ++ | + |
| **Was the control group representative and appropriate for the intervention group?** | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | ++ | ++ | ++ | ++ |
| **How was the exposure to the change in urban green spaces assessed?** | + | ++ | + | ++ | ++ | ++ | ++ | ++ | ++ | + | + | - | + | ++ | ++ | ++ | + | ++ | ++ | ++ | ++ | + | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| **Were outcome measures and procedures valid and reliable?** | + | + | + | + | + | ++ | + | + | + | ++ | + | ++ | + | + | + | + | ++ | ++ | ++ | + | + | + | + | ++ | + | + | + | + | + |
| **Were the models adjusted for potential confounders?** | + | + | + | - | + | + | + | - | - | + | - | + | ++ | + | ++ | - | ++ | + | + | - | - | - | - | + | - | - | - | + | + |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Were confidence intervals and/or p-values for effect estimates given?** | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | + | - | + | + | + | + | + | + | + | + |

Table A2.2: Risk of Bias in Economic evaluations

| **Article no.** | 1 | 6 | 16 | 20 |
|---|---|---|---|---|
| **Study** | Thompson 2019 | Thompson 2019 | Lal 2019 | Cohen 2012 |
| **Research question well defined?** | Yes | Yes | Yes | Yes |
| **Comprehensive description of alternatives?** | No | No | No | No |
| **Effectiveness of programme established?** | Yes | Yes | Yes | Yes |
| **Important & relevant costs & consequences for each alternative identified?** | No | No | No | No |
| **Costs & consequences measured accurately & appropriately?** | Yes | Yes | Yes | Yes |
| **Costs & consequences valued credibly?** | Yes | Yes | Yes | Yes |
| **Costs & consequences adjusted for differential timing?** | No | No | No | No |
| **Incremental analysis of costs & consequences performed?** | Yes | Yes | Yes | Yes |
| **Allowance made for uncertainty in estimates?** | No | No | No | No |
| **Presentation & discussion of study results include all issues of concern to users?** | Yes | Yes | Yes | Yes |

Table A2.3- List of articles

| Article Number | Article title | First Author | Year of publication | Author, Year |
|---|---|---|---|---|
| 1 | Enhancing Health Through Access to Nature:<br>How Effective are Interventions in Woodlands in Deprived Urban Communities? A Quasi-experimental Study in Scotland, UK | Catharine Ward Thompson | 2019 | Catharine Ward Thompson2019 |
| 2 | Changes in physical activity after building a greenway in a disadvantaged urban community: A natural experiment | Amy H. Auchinclossa | 2019 | Amy H. Auchinclossa2019 |
| 3 | Causal evaluation of urban greenway retrofit: A longitudinal study on physical activity and sedentary behavior | Lawrence D. Frank | 2019 | Lawrence D. Frank2019 |
| 4 | Changes in Physical Activity After Installation of a Fitness Zone in a Community Park | Mojgan Sami | 2018 | Mojgan Sami2018 |
| 5 | Effect of changes to the neighbourhood built environment on physical activity in a low-income African American neighbourhood | Jeanette Gustat | 2012 | Jeanette Gustat2012 |
| 6 | Health impacts of environmental and social interventions designed to increase deprived communities' access to urban woodlands:a mixed-methods study | Catharine Ward Thompson | 2019 | Catharine Ward Thompson2019 |
| 7 | Improved Street Walkability, Incivilities, and Esthetics Are Associated with Greater Park Use in Two Low-Income Neighbourhoods | Andrea S. Richardson | 2020 | Andrea S. Richardson2020 |
| 8 | New recreational facilities for the young and the old in Los Angeles: policy and programming implications | Deborah A. Cohen | 2009 | Deborah A. Cohen2009 |
| 9 | Using an integrated approach to evaluate "Where do Flint's families play" | Sarah L. Panken | 2015 | Sarah L. Panken2015 |
| 10 | The impact of intervening in green space in Dutch deprived neighbourhoods on physical activity and general health: results from the quasi-experimental URBAN40 study | Mariël Droomers | 2015 | Mariël Droomers2015 |
| 11 | Effect of Greening Vacant Land on Mental Health of Community-Dwelling Adults: A Cluster Randomised Trial | Eugenia C. South | 2018 | Eugenia C. South2018 |
| 12 | The effect of upgrades to childcare outdoor spaces on preschoolers' physical activity: Findings from a natural experiment | Michelle Ng | 2020 | Michelle Ng2020 |
| 13 | Addressing Inequity: Evaluation of an Intervention to Improve Accessibility and Quality of a Green Space | Kirsti S. Anthun | 2019 | Kirsti S. Anthun2019 |
| 14 | The REVAMP natural experiment study: the impact of a play-scape installation on park visitation and park-based physical activity | Jenny Veitch | 2018 | Jenny Veitch2018 |

| | | | | |
|---|---|---|---|---|
| 15 | Tunneling a crosstown highway: a natural experiment testing the longitudinal effect on physical activity and active transport | Nicole E. H. Stappers | 2021 | Nicole E. H. Stappers2021 |
| 16 | The impact of a park refurbishment in a low socioeconomic area on physical activity: a cost-effectiveness study | Anita Lal | 2019 | Anita Lal2019 |
| 17 | Investigating the physical activity, health, wellbeing, social and environmental effects of a new urban greenway: a natural experiment (the PARC study) | Ruth F. Hunter | 2021 | Ruth F. Hunter2021 |
| 18 | Closing the loop: short term impacts on physical activity of the completion of a loop trail in Sydney, Australia | Anne Grunseit, | 2019 | Anne Grunseit,2019 |
| 19 | A natural experimental study of improvements along an urban canal: impact on canal usage, physical activity and other wellbeing behaviours | Jack S. Benton | 2021 | Jack S. Benton2021 |
| 20 | Impact and cost-effectiveness of family Fitness Zones: a natural experiment in urban public parks | Deborah A. Cohen | 2012 | Deborah A. Cohen2012 |
| 21 | Will the children use it?-A RE-AIM evaluation of a local public open space intervention involving children from a deprived neighbourhood | Charlotte Skau Pawlowski | 2019 | Charlotte Skau Pawlowski2019 |
| 22 | Do changes to the local street environment alter behaviour and quality of life of older adults? The 'DIY Streets' intervention | Catharine Ward Thompson | 2014 | Catharine Ward Thompson2014 |
| 23 | Urban trails and physical activity: a natural experiment | Eugene C. Fitzhugh, PhD | 2010 | Eugene C. Fitzhugh, PhD 2010 |
| 24 | Increases in Use and Activity Due to Urban Renewal: Effect of a Natural Experiment | Henriette Bondo Andersen | 2017 | Henriette Bondo Andersen2017 |
| 25 | Delapré Walk project: Are signposted walking routes an effective intervention to increase engagement in urban parks? –Natural experimental study | Declan J. Ryan | 2023 | Declan J. Ryan2023 |
| 26 | The effect of local neighbourhood park redevelopments on park visitations and user physical activity levels: a pre–post test evaluation | Mitch J. Duncan | 2022 | Mitch J. Duncan2022 |
| 27 | A Natural Experiment: Results of Community-Designed Park Improvements on Park Use and Physical Activity | Cheryl Kelly | 2021 | Cheryl Kelly2021 |
| 28 | The relationship between changes in neighbourhood physical environment and changes in physical activity among children: a prospective cohort study | Francesco Acciai | 2023 | Francesco Acciai2023 |
| 29 | If You Build It Will They Come? Park Upgrades, Park Use and Park-Based Physical Activity in Urban Cape Town, South Africa—The SUN Study | Clare Bartels | 2023 | Clare Bartels2023 |

## Appendix 3: Data extraction form

| Study details | |
|---|---|
| Article number | |
| Article title | |
| First author | |
| Year of publication | |
| Author, year | |
| Country | |
| Target population | |
| Setting | |
| Data collection period | |
| Study design | |
| Data collection methods | |
| Sample size | |
| Type of green space | |
| Green space code | |
| **Intervention** | |
| Intervention type | |
| Intervention (details) | |
| Comparator type | |
| Comparator details | |

| Results | |
|---|---|
| Primary education outcome | |
| Primary health outcome | |
| Health outcome tool | |
| Primary health outcome measure | |
| Result | |
| Primary outcome results | |
| Secondary health outcomes (list all in separate rows) | |
| Secondary health outcome measure | |
| Secondary outcome results | |
| Relevant disease areas / risk factors | |
| Details on health outcomes | |
| Other outcome measures | |
| Other outcome results | |
| Economic evaluation information | |
| Is this an economic evaluation? | |
| Type of economic evaluation | |
| Perspective (economic evaluation only) | |
| Was there a distributional analysis for subgroups? | |
| Which subpopulations were measured? | |
| Measures of effectiveness | |

| | |
|---|---|
| Cost / resource use (if applicable) | |
| Cost-effectiveness results | |
| Limitations | |
| Additional notes | |

Chapter 3 – Appendices

Appendix 1 – Screenshots of the toolkit

**Please select from the following options:**

For explanations of each option, please consult the user manual

**Baseline population:**

UK

To enter custom values, please click here

**Type of intervention:**

Installing/Improving fitness equipment in a public green spa

See logic model on the impact of Urban Green Space interventions

**Target population:**

Adults

**Waning effect:**

No waning effect

**Type of model:**

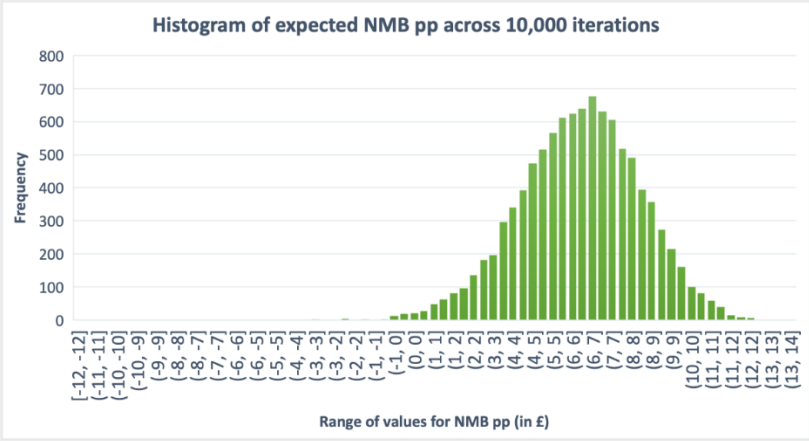
Probabilistic

**Value of a QALY (in £):**

£20'000

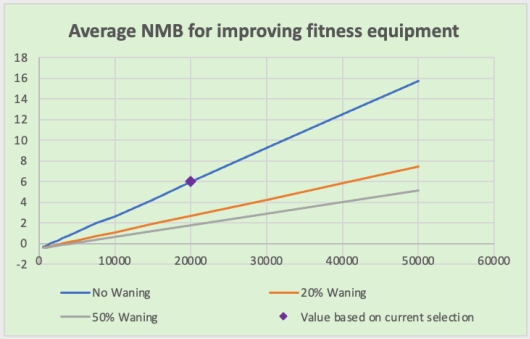
**RESULTS: Net Monetary Benefit (NMB) pp**

| | |
|---|---|
| Average NMB per capita: | £6.02 |
| Median NMB per capita: | £6.10 |
| Probability of cost-effectiveness: | 99% |

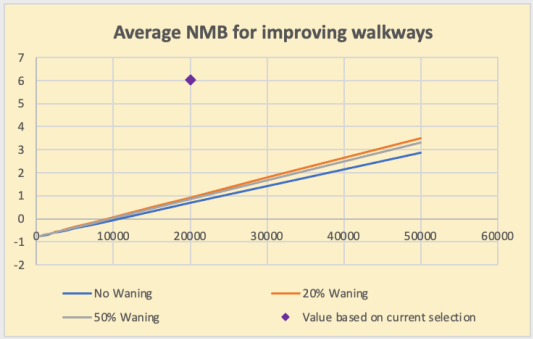


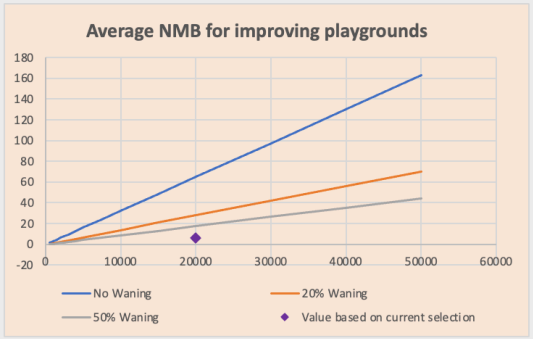

Compare results with other scenarios (probablistic only)

**Comparing average NMB across CEA thresholds and waning effects for selected intervention:**

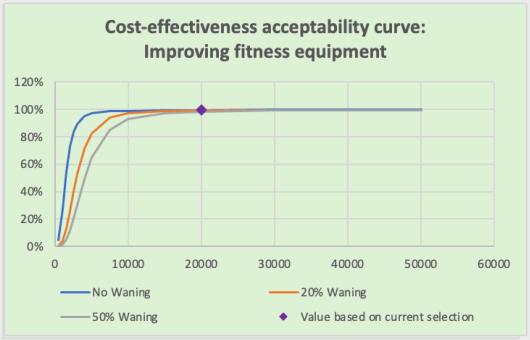



**Comparing average NMB across CEA thresholds and waning effects for other interventions:**

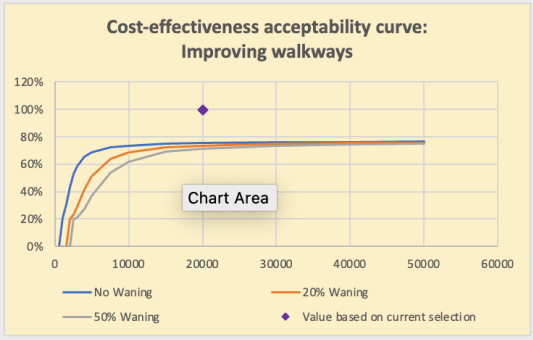


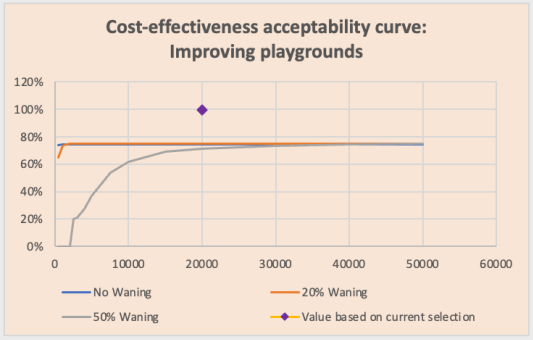




**Cost-effectiveness acceptability curve for selected intervention:**




**Cost-effectiveness acceptability curve for other interventions:**



Appendix 2 – User manual for the toolkit

User Manual for the "Toolkit for the Health Economic Assessment of urban Green Space interventions (THEAGS)"

## Overview

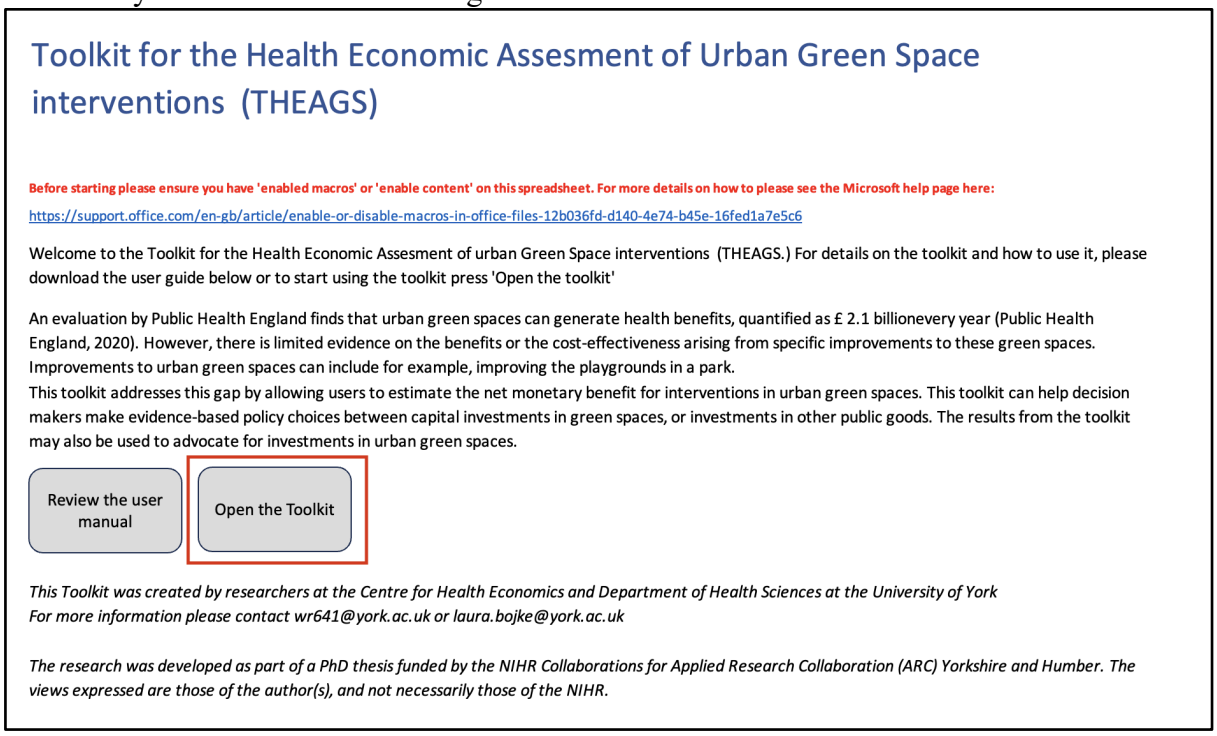
This tool helps analyse the impact of green spaces on various health and economic outcomes using either pre-set UK data or custom data. The steps differ depending on your choice of data.

Follow the instructions below carefully to ensure accurate results.
For UK Data Users
For Custom Data Users

**For UK Data Users**

**1. Navigate to the Toolkit Tab**

Go directly to the Toolkit sheet using the button here

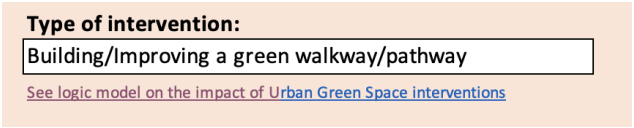



This sheet allows you to make your selections and view results using pre-set UK baseline data. The toolkit uses default data about physical activity amongst adults and children as a baseline. It then uses data on impact from selected studies to estimate the change in physical activity, and the resulting gains in QALY. For more details on the methodology, please see the report on the toolkit linked here.

**2. Making Selections in the Toolkit Tab**

The 'Toolkit' tab provides the following selection fields for customizing your analysis:

*a. Type of Intervention*




Choose the type of intervention (e.g., fitness equipment or walkway installation). This option determines the model's input parameters for the toolkit. The toolkit will then calculate the net monetary benefit based on the evidence available for your selected intervention type. For instance, if you select improving fitness equipment, the model uses the existing evidence on the effectiveness of improving fitness equipment to estimate the net monetary benefit per person.

*b. Target Population*



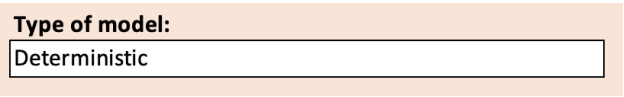

This option is currently pre-selected by default for the user. The current evidence used by the tool is only available for a single target population. Once more data become available, these can be updated so that users can select their own target population of interest.

*c. Waning Effect*




There is some evidence that the effects of interventions related to behaviour change (in this case, increase physical activity) may diminish over time. To account for this variation, users are able to incorporate a 20% or 50% waning effect in this option. The 20% waning effect will reduce the intervention effect by 20% of the original effect each year starting from year 2, such that the intervention effect is 0 by year 6. The 50% waning effect will reduce the intervention effect by 50% of the original effect for each year starting from year 2, such that the intervention effect is 0 by year 4.

*d. Type of Model*




The toolkit currently uses two different types of models: (1) Probabilistic and (2) Deterministic.
For the probabilistic model, the toolkit calculates 10,000 iterations of the expected net monetary benefit. For each iteration, costs are estimated using standard errors either reported by the studies, or calculated by the authors, and a gamma distribution. The QALYs gained are estimated by using normal distribution for the effect size based on the uncertainty reported by the study, where applicable. Finally, the toolkit will also randomly pick values from each of the included articles in the final iterations, to account for the variation and uncertainty between studies. This process allows the toolkit to account for uncertainty in the final estimates. The toolkit then allows users to review the average and median net monetary benefit based on the 10,000 iterations. It also provides a histogram of the NMB, which gives a visual representation of the uncertainty, and range of values estimated for the NMB. More information on the methodology and range of values can be found in the detailed report here
The deterministic analysis uses the point estimates for both cost and effectiveness. Therefore, for each article this provides a single estimate of the net monetary benefit. The toolkit then calculates an average NMB of each included article.
If a user is not sure whether to use a deterministic or probabilistic model, we would recommend using a probabilistic model as it allows users to view the uncertainty in the evidence.

*e. Value of a QALY (in £)*

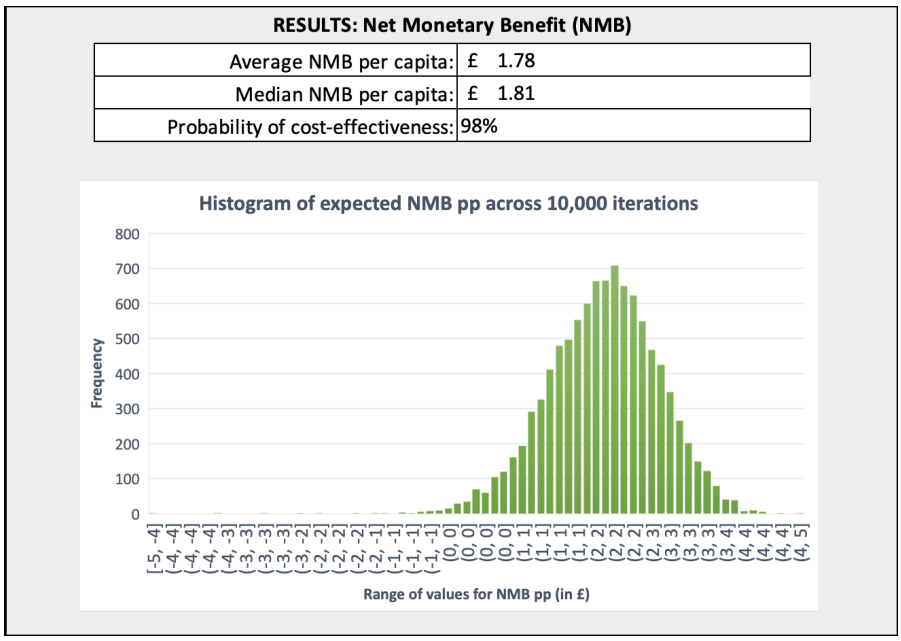



This option here allows users to select the opportunity cost for one quality-adjusted life year. In other words, this is the monetary value associated with a one unit gain in QALY per

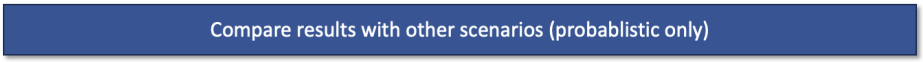
person. According to NICE, an intervention is considered to be cost-effective against the reference scenario (in this case, no intervention) if NMB > 0, and the opportunity cost for health falls between £20,000 – £30,000 per QALY gain (National Institute for Health and Care Excellence, n.d.). A recent evaluation finds that this may be an overestimate, and the value of the opportunity cost should be closer to £12,936 (Lomas et al., 2019). Given the variation in cost-effectiveness thresholds, the toolkit allows users to select from a range of options to calculate the NMB of interest for their use-case.

The value of a QALY is then used to calculate the net monetary benefit using the following formula: $NMB = \lambda \times \Delta E - \Delta C$ where $\Delta E$ is the incremental effect and $\Delta C$ is the cost of the intervention per person and $\lambda$ is the opportunity cost of a QALY.

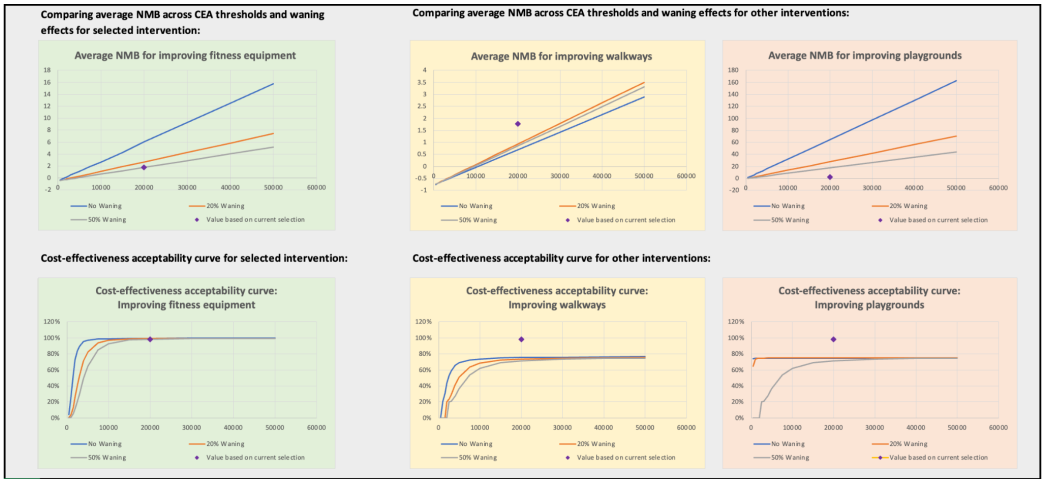
**3. View Results**




The right side of the 'Toolkit' tab automatically updates the results based on your selections. The results as shown in the screenshot above allow users to review the average net monetary benefit, the median net monetary benefit and the probability of cost-effectiveness for their selections. The results also show a histogram of the values for net monetary benefit. For deterministic models, users can only review the average and median NMB.
Users can also compare the expected benefits from their selections compared to other interventions and scenarios by clicking on the button shown below:




This allows users to review how their selection compares with other scenarios, including different cost-effectiveness thresholds, different waning effects, and other interventions as shown in the figure below.




## For Custom Data Users

### 1. Input Custom Data

Go to the 'Custom baseline PA' sheet. Enter your custom data in the specified fields.
For adults

| Physical Activity distribution (adults) | |
|---|---|
| Less than 30 mins per week | |
| 30 to 150 mins per week | |
| More than 150 minutes per week | |
| Check sum | 0.00 |

In the fields above, please enter the proportion of the adults for each category of physical activity. Data should be entered in values between 0 to 1, such that the sum of values is equal to 1. This baseline values is what will be used to calculate the expected NMB for interventions for adults

| Utilisation of outdoor space for health reasons | |
|---|---|
| Adults | |

In the field above, please enter the proportion of adults that use outdoor spaces or green spaces for exercise. Since the studies used were typically using the users of the green space as their population of interest, in this model, we assume that the intervention will only impact those that regularly use an UGS for exercise, or adults that spend considerable time (>3 times a week) in outdoor green spaces.

For children

| Physical Activity distribution (children) | |
|---|---|
| Less than 30 mins/day | |
| Avg 30-59 minutes a day | |
| More than 60 mins a day | |
| Check sum | 0.00 |

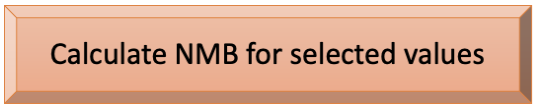
In the fields above, please enter the proportion of the children for each category of physical activity. Data should be entered in values between 0 to 1, such that the sum of values is equal to 1. This baseline values are what will be used to calculate the expected net monetary benefit for interventions for children.

| Spending time in a green space everyday | |
|---|---|
| Children | |

In the field above, please enter the proportion of children under 12 that spend time in a green space everyday. Since the studies included were typically analysing the users of the green space as their population of interest, in this model, we assume that the intervention will only impact those populations that regularly use an UGS.

**2. Re-run the Model**

Locate the macro button or use the 'Simulation' macro from the 'Developer' tab or 'Macros' menu to re-run the model. The macro button can be seen in the image below




**3. Copy Results**

Navigate to the 'NMB Results (raw)' sheet. Copy the generated values in all columns. A partial screenshot of the sheet can be seen below:

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adults | | | Children | | | Adults | | | Children | |
| | Probabilistic | | | Probabilistic | | | Probabilistic | | | Probabilistic | |
| | Improving/building walkways | | | Improving/building walkways | | | Improving outdoor fitness equipment | | | Improving playgrounds | |
| Iteration | No waning | 20% waning | 50% waning | No waning | 20% waning | 50% waning | No waning | 20% waning | 50% waning | No waning | 20% waning |
| 1 | 0.00048207 | 0.00013314 | -0.0002963 | 0.00048207 | 0.00013314 | 0.00013411 | 0.000156 | 7.5856E-05 | 5.4143E-05 | 0.00858142 | 0.00281878 |
| 2 | -0.0022067 | 0.00025826 | 8.8897E-05 | 0.00052954 | 0.00012309 | 8.7857E-05 | 0.000287 | 0.00013943 | 9.9527E-05 | -0.0063202 | -0.002076 |
| 3 | 0.00079452 | 6.6136E-05 | -0.0004017 | 0.00013605 | 0.00038913 | 4.7205E-05 | 0.000416 | 0.00020274 | 0.00014473 | 0.01364615 | 0.00448241 |
| 4 | 0.00029195 | 0.00014204 | -0.0002637 | -0.0007484 | 0.00014204 | -0.0002728 | 0.000381 | 0.00018556 | 0.00013245 | 0.0048751 | -0.002076 |
| 5 | 0.00049899 | 0.0002786 | 0.00016434 | 0.00047234 | -0.0005907 | 0.00036628 | 0.000297 | 0.00014453 | 0.00010316 | 0.01012952 | -0.002076 |
| 6 | 0.0003577 | 0.00051271 | 0.00016906 | 0.0003577 | 0.00051271 | 0.00036628 | 0.000191 | 9.2689E-05 | 6.6158E-05 | 0.01114928 | 0.00366225 |
| 7 | 0.00042163 | -0.0003922 | -0.0002019 | -0.001194 | -0.0003922 | 0.0001466 | 0.000432 | 0.00021048 | 0.00015025 | -0.0063202 | -0.002076 |
| 8 | -0.0025262 | 6.5901E-05 | 0.00036628 | 0.00019078 | 6.5901E-05 | 0.0001735 | 0.000339 | 0.00016477 | 0.00011761 | 0.01388571 | 0.00182664 |
| 9 | 0.00104138 | 0.00014045 | -0.0004631 | 0.00104138 | -0.0008996 | 8.0826E-05 | 0.000242 | 0.00011773 | 8.4035E-05 | 0.00614936 | 0.00201991 |
| 10 | 0.00055446 | 0.00017489 | 0.00018632 | 0.00104138 | 0.00051271 | 0.00019312 | 0.000338 | 0.0001645 | 0.00011742 | 0.01303435 | 0.00130285 |
| 11 | -0.0015442 | -0.000213 | -0.0002611 | 0.00065083 | 0.00017407 | 0.00022702 | 0.000388 | 0.00018883 | 0.00013479 | 0.01064449 | 0.00339909 |
| 12 | 0.00032483 | 0.00015808 | 0.00011284 | 0.00028205 | 0.00013721 | -0.0002143 | 0.000226 | 0.00010968 | 7.829E-05 | -0.0063202 | 0.00342048 |
| 13 | 0.00017912 | -0.0004953 | 6.2158E-05 | 0.00104138 | 0.00025172 | 6.4969E-05 | 0.000336 | 0.00016369 | 0.00011684 | 0.00643213 | 0.00406556 |
| 14 | 0.00024559 | 0.00010534 | 8.5259E-05 | 0.00104138 | -0.0003543 | 7.5187E-05 | 0.000469 | 0.00022843 | 0.00016307 | 0.003343 | -0.002076 |
| 15 | 0.00059622 | 0.00029105 | 0.00012207 | 0.00104138 | -0.0008024 | 0.0002078 | 0.000201 | 9.7823E-05 | 6.9823E-05 | 0.00643213 | 0.00339909 |
| 16 | 0.00048991 | 0.00039018 | -0.0003319 | -0.001963 | 0.00051271 | -0.0003319 | 0.000143 | 6.9274E-05 | 4.9445E-05 | 0.00232737 | 0.00339909 |
| 17 | -0.0002402 | 0.0001507 | -8.373E-05 | 0.00030972 | -0.0001172 | 0.00022444 | 0.000357 | 0.00017388 | 0.00012412 | -0.0063202 | 0.00339909 |
| 18 | 0.00034824 | 0.00014998 | -0.0002243 | 0.00031355 | 0.00051271 | 0.000121 | 0.000320 | 0.00015566 | 0.00011111 | -0.0063202 | -0.002076 |
| 19 | 0.00039437 | 0.00019204 | -0.0002687 | 0.00033557 | 0.00019204 | 0.00014227 | 0.000303 | 0.00014762 | 0.00010537 | 0.00392202 | -0.002076 |
| 20 | 0.00070175 | -0.0005594 | 0.00036628 | 0.0003859 | -0.0005594 | 0.00010994 | 0.000466 | 0.00022706 | 0.00016209 | -0.0063202 | 0.00339909 |
| 21 | 0.00052034 | 3.8276E-06 | -0.0002916 | 0.00052034 | 0.00025374 | -0.0002916 | 0.000395 | 0.00019231 | 0.00013728 | 0.00643213 | -0.002076 |
| 22 | 0.00104138 | -0.0005387 | 9.6029E-05 | 0.00027655 | 0.00011826 | -0.0002773 | 0.000402 | 0.00019561 | 0.00013964 | 0.00643213 | 0.00141007 |
| 23 | 0.00104138 | 0.00022071 | 0.00015756 | 0.00040732 | -0.0006551 | 0.00017273 | 0.000420 | 0.00020436 | 0.00014588 | 0.00643213 | 0.00120246 |
| 24 | 0.00031324 | 0.00022977 | 0.00016402 | 0.00104138 | -0.0003596 | 0.00016402 | 0.000250 | 0.00012163 | 8.6816E-05 | 0.00643213 | 0.00339909 |
| 25 | 0.00104138 | 0.00019011 | 0.00010721 | 0.00104138 | 0.00020638 | 0.00036628 | 0.000150 | 7.2853E-05 | 5.1999E-05 | -0.0063202 | 0.0021452 |
| 26 | 6.8207E-05 | 0.00018961 | 2.366E-05 | 0.0003894 | 3.3149E-05 | 0.00036628 | 0.000265 | 0.00012904 | 9.2109E-05 | 0.00916986 | 0.00339909 |
| 27 | 0.00104138 | 0.00014418 | 8.7689E-05 | 0.00029634 | 0.00011184 | 8.7689E-05 | 0.000457 | 0.00022289 | 0.00015912 | 0.00220755 | 0.00368303 |
| 28 | 0.00016628 | 0.00051271 | 0.00013725 | 0.00104138 | -0.0007341 | 0.00024114 | 0.000393 | 0.00019128 | 0.00013654 | 0.01023593 | 0.00339909 |
| 29 | -0.0025887 | 0.00014961 | -0.0004377 | -0.0025887 | -0.0008503 | 4.1288E-05 | 0.000151 | 7.3633E-05 | 5.2556E-05 | 0.00463123 | -0.002076 |
| 30 | 0.00058313 | 0.00051271 | 0.00036628 | 0.00038351 | 0.00051271 | 0.00020319 | 0.000480 | 0.00023398 | 0.00016703 | 0.01205713 | 0.00339909 |
| 31 | 0.00027215 | 0.00025658 | -0.0003856 | 0.00104138 | 0.00013239 | 0.00036628 | 0.000385 | 0.00018731 | 0.00013371 | -0.0063202 | 0.00339909 |
| 32 | -0.0022252 | 0.00010949 | 0.00021477 | -0.0022252 | -0.0007309 | 0.00036628 | 0.000405 | 0.00019709 | 0.00014069 | 0.01057833 | 0.00347471 |
| 33 | 0.00018209 | 0.00051271 | 0.000153 | 0.0000947 | 8.9019E-05 | 0.000153 | 0.000228 | 0.0001111 | 7.9301E-05 | 0.00643213 | 0.00339909 |

**4.Paste Results**

Go to the 'NMB Results' sheet and paste the copied values into the respective sections. Ensure alignment to avoid errors.

**5. Make Selections**
Return to the ‘Toolkit’ tab. Adjust parameters and settings to reflect your custom data scenario. Please see here for more details on how to make the selections.

## Appendix 1: Comparison of the Chapter 4 estimation sample with the Bradford district population

| **Characteristic** | **Estimation sample: women** | **Estimation sample: men** | **Bradford district (2011 Census; IoD 2019)** |
|---|---|---|---|
| Number | 10,486 | 3,287 | 522,452 (district population) |
| Average age (years) | 27.3 | 30.1 | 34 (median); 36 (mean) |
| **Ethnicity (%)** | | | |
| White | 43 | 51 | 63.9 |
| Pakistani / South Asian | 44 | 29 | 26.8 |
| Other | 13 | 20 | 9.3 |
| **Deprivation, Index of Multiple Deprivation (%)** | | | |
| In the most deprived national decile (decile 1) | 43 | 38 | 28 |
| In the most deprived 30% nationally (deciles 1–3) | 75 | 69 | 54 |

Appendix 2: Frequency of prescription by medicine

Table A4.1: Frequency of prescription for each medicine across all participants

| Name of medicine | Frequency of prescription | % | Mean dosage | Min dosage | Max dosage |
|---|---|---|---|---|---|
| Sertraline 50mg tablets | 23,336 | 14.13 | 30.2 | 1 | 168 |
| Fluoxetine 20mg capsules | 22,477 | 13.61 | 43.4 | 3 | 270 |
| Citalopram 20mg tablets | 21,094 | 12.77 | 35.9 | 1 | 168 |
| Sertraline 100mg tablets | 20,236 | 12.25 | 33.0 | 1 | 168 |
| Citalopram 10mg tablets | 8,725 | 5.28 | 36.0 | 1 | 168 |
| Citalopram 40mg tablets | 5,984 | 3.62 | 27.0 | 1 | 1428 |
| Mirtazapine 45mg tablets | 5,652 | 3.42 | 23.1 | 1 | 392 |
| Mirtazapine 15mg tablets | 5,137 | 3.11 | 25.5 | 1 | 392 |
| Mirtazapine 30mg tablets | 4,909 | 2.97 | 24.8 | 1 | 84 |
| Diazepam 2mg tablets | 4,840 | 2.93 | 24.0 | 1 | 224 |
| Zopiclone 7.5mg tablets | 4,682 | 2.83 | 13.9 | 1 | 56 |
| Zopiclone 3.75mg tablets | 2,410 | 1.46 | 12.5 | 1 | 196 |
| Circadin 2mg modified-release tablets | 2,381 | 1.44 | 62.8 | 1 | 340 |
| Hydroxyzine 25mg tablets | 2,189 | 1.33 | 28.2 | 5 | 112 |
| Duloxetine 60mg gastro-resistant caps | 1,712 | 1.04 | 29.3 | 7 | 112 |
| Escitalopram 10mg tablets | 1,669 | 1.01 | 27.3 | 1 | 112 |
| Trazodone 150mg tablets | 1,665 | 1.01 | 37.2 | 7 | 24 |
| Venlafaxine 75mg tablets | 1,547 | 0.94 | 41.0 | 7 | 224 |
| Trazodone 100mg capsules | 1,342 | 0.81 | 37.8 | 2 | 168 |
| Trazodone 50mg capsules | 1,276 | 0.77 | 46.8 | 5 | 224 |
| Venlafaxine 37.5mg tablets | 1,177 | 0.71 | 31.7 | 7 | 112 |
| Escitalopram 20mg tablets | 1,004 | 0.61 | 29.5 | 1 | 84 |
| Promethazine hydrochloride 10mg tablets | 949 | 0.57 | 43.2 | 4 | 168 |
| Venlafaxine 75mg modified-release capsules | 914 | 0.55 | 25.6 | 3 | 168 |
| Venlafaxine 150mg modified-release capsules | 894 | 0.54 | 26.9 | 6 | 168 |
| Melatonin 2mg modified-release tablets | 838 | 0.51 | 52.9 | 14 | 120 |
| Escitalopram 5mg tablets | 805 | 0.49 | 26.3 | 1 | 84 |
| Moclobemide 150mg tablets | 782 | 0.47 | 10.5 | 3 | 42 |
| Paroxetine 20mg tablets | 746 | 0.45 | 45.7 | 7 | 180 |
| Nortriptyline 25mg tablets | 737 | 0.45 | 70.1 | 7 | 224 |
| Hydroxyzine 10mg/5ml oral solution | 712 | 0.43 | 202.8 | 35 | 600 |

| | | | | | |
|---|---|---|---|---|---|
| Lorazepam 1mg tablets | 577 | 0.35 | 27.4 | 1 | 112 |
| Clobazam 10mg tablets | 530 | 0.32 | 20.7 | 7 | 168 |
| Fluoxetine 40mg capsules | 514 | 0.31 | 26.2 | 7 | 90 |
| Dosulepin 75mg tablets | 468 | 0.28 | 30.6 | 4 | 84 |
| Venlafaxine 225mg modified-release ta.. | 444 | 0.27 | 23.5 | 7 | 90 |
| Mirtazapine 45mg orodispersible tablets | 390 | 0.24 | 29.2 | 14 | 60 |
| Clomipramine 50mg capsules | 376 | 0.23 | 44.5 | 7 | 140 |
| Zolpidem 5mg tablets | 375 | 0.23 | 27.6 | 3 | 56 |
| Venlafaxine 150mg modified-release ta.. | 343 | 0.21 | 30.9 | 7 | 112 |
| Venlafaxine 75mg modified-release tab.. | 333 | 0.2 | 34.2 | 3 | 112 |
| Promethazine hydrochloride 20mg tablets | 324 | 0.2 | 9.1 | 1 | 56 |
| Lofepramine 70mg tablets | 320 | 0.19 | 52.8 | 4 | 168 |
| Venlafaxine 37.5mg modified-release capsules | 287 | 0.17 | 21.4 | 1 | 112 |
| Paroxetine 30mg tablets | 271 | 0.16 | 52.8 | 7 | 120 |
| chloral hydrate mixture 500mg/5ml | 267 | 0.16 | 237.3 | 150 | |
| Fluoxetine 60mg capsules | 260 | 0.16 | 30.9 | 28 | 60 |
| Fluoxetine 20mg/5ml oral solution | 250 | 0.15 | 113.0 | 70 | 420 |
| Paroxetine 10mg tablets | 247 | 0.15 | 38.5 | 7 | 84 |
| Zolpidem 10mg tablets | 231 | 0.14 | 26.2 | 1 | 56 |
| Clobazam 5mg/5ml oral suspension | 223 | 0.14 | 326.2 | 100 | 450 |
| Buspirone 5mg tablets | 216 | 0.13 | 44.2 | 4 | 84 |
| Clobazam 5mg/5ml oral suspension | 204 | 0.12 | 358.0 | 100 | 600 |
| Clomipramine 25mg capsules | 196 | 0.12 | 57.3 | 7 | 280 |
| Sertraline 50mg tablets (Teva UK Ltd) | 177 | 0.11 | 27.8 | 14 | 28 |
| Melatonin 2mg capsules | 164 | 0.1 | 64.4 | 2 | 100 |
| Dosulepin 25mg capsules | 154 | 0.09 | 68.5 | 7 | 112 |
| Fluoxetine 10mg capsules | 147 | 0.09 | 29.7 | 7 | 90 |
| Mirtazapine 15mg orodispersible tablets | 146 | 0.09 | 26.3 | 2 | 60 |
| Vensir XL 150mg capsules | 124 | 0.08 | 25.0 | 1 | 56 |
| Chloral hydrate 143.3mg/5ml oral solution | 123 | 0.07 | 219.5 | 150 | 750 |
| Fluoxetine 30mg capsules | 118 | 0.07 | 28.1 | 7 | 60 |
| melatonin oral solution 5mg/5ml | 118 | 0.07 | 315.3 | 200 | 600 |
| Fluoxetine 20mg capsules (Almus Pharm.. | 102 | 0.06 | 29.1 | 14 | 56 |

| | | | | | |
|---|---|---|---|---|---|
| Trazodone 100mg capsules | 96 | 0.06 | 25.3 | 7 | 56 |
| Nytol One-A-Night 50mg tablets | 91 | 0.06 | 19.9 | 7 | 28 |
| Fluvoxamine 50mg tablets | 89 | 0.05 | 36.7 | 30 | 60 |
| Venlafaxine 225mg modified-release capsules | 88 | 0.05 | 27.8 | 7 | 28 |
| Imipramine 25mg tablets | 86 | 0.05 | 86.7 | 14 | 112 |
| Vensir XL 75mg capsules | 86 | 0.05 | 19.2 | 7 | 56 |
| Clomipramine 10mg capsules | 84 | 0.05 | 58.8 | 14 | 280 |
| Clomipramine 75mg modified-release tablets | 82 | 0.05 | 31.8 | 28 | 56 |
| Citalopram 40mg/ml oral drops | 80 | 0.05 | 17.8 | 15 | 45 |
| Fluoxetine 10mg tablets | 79 | 0.05 | 31.6 | 7 | 60 |
| Sertraline 50mg tablets | 77 | 0.05 | 29.2 | 7 | 56 |
| Fluoxetine 20mg dispersible tablets s.. | 72 | 0.04 | 43.1 | 7 | 168 |
| Citalopram 20mg tablets (Almus) | 65 | 0.04 | 31.9 | 28 | 56 |
| Citalopram 20mg tablets (Ranbaxy (UK) | 61 | 0.04 | 28.5 | 28 | 56 |
| Fluoxetine 20mg capsules (Teva UK Ltd) | 61 | 0.04 | 37.1 | 7 | 90 |
| Fluvoxamine 100mg tablets | 61 | 0.04 | 29.7 | 14 | 30 |
| Escitalopram 10mg tablets (Actavis UK.. | 59 | 0.04 | 7.0 | 7 | 7 |
| Buspirone 10mg tablets | 58 | 0.04 | 66.7 | 7 | 84 |
| Venaxx XL 75mg capsules (Advanz Pharma) | 58 | 0.04 | 28.0 | 28 | **28** |
| Citalopram 20mg tablets (Teva UK Ltd) | 55 | 0.03 | 28.0 | 14 | 56 |
| Vensir XL 225mg capsules | 55 | 0.03 | 19.2 | 7 | 28 |
| Chloral hydrate 500mg/5ml oral solution | 54 | 0.03 | 107.4 | 100 | 400 |
| Mirtazapine 30mg orodispersible tablets | 52 | 0.03 | 26.0 | 7 | 30 |
| Rodomel XL 150mg capsules (Teva UK Ltd) | 51 | 0.03 | 36.2 | 28 | 56 |
| melatonin oral liquid 2.5mg/5ml | 47 | 0.03 | 189.4 | 100 | 300 |
| Cipramil 20mg tablets (Lundbeck Ltd) | 46 | 0.03 | 56.0 | 56 | 56 |
| Venlafaxine 37.5mg tablets | 45 | 0.03 | 54.1 | 28 | 56 |
| Venlalic XL 75mg tablets | 45 | 0.03 | 63.8 | 7 | 120 |
| Citalopram 40mg tablets (Sandoz Ltd) | 43 | 0.03 | 28.7 | 28 | 56 |
| Trazodone 50mg capsules | 42 | 0.03 | 138.0 | 7 | 336 |
| Venlafaxine 37.5mg modified-release | 42 | 0.03 | 22.0 | 7 | 90 |
| Melatonin 1mg/ml oral solution sugar | 39 | 0.02 | 242.3 | 150 | 450 |

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|---|---|---|---|---|---|
| Melatonin 2mg/5ml oral solution | 39 | 0.02 | 117.9 | 100 | 200 |
| Fluoxetine 20mg capsules (Mylan) | 38 | 0.02 | 59.8 | 56 | 90 |
| Slenyto 1mg modified-release tablets | 38 | 0.02 | 58.3 | 28 | 60 |
| PAROXETINE tablets 10mg [ACTAVIS] | 37 | 0.02 | 53.0 | 28 | 56 |
| Sertraline 100mg tablets (Teva UK Ltd) | 37 | 0.02 | 47.7 | 28 | 56 |
| Rodomel XL 75mg capsules (Teva UK Ltd) | 36 | 0.02 | 28.0 | 28 | 28 |
| Trazodone 50mg/5ml oral solution | 36 | 0.02 | 275.0 | 100 | 600 |
| Venlalic XL 150mg tablets | 36 | 0.02 | 6.9 | 4 | 7 |
| Sertraline 100mg tablets | 35 | 0.02 | 28.5 | 2 | 56 |
| Dapoxetine 30mg tablets | 32 | 0.02 | 7.1 | 3 | 18 |
| Sertraline 50mg tablets | 32 | 0.02 | 26.0 | 4 | 56 |
| Flupentixol 500microgram tablets | 31 | 0.02 | 44.7 | 14 | 120 |
| Fluoxetine 20mg/5ml oral solution | 30 | 0.02 | 102.7 | 70 | 560 |
| Venlafaxine 75mg tablets (Teva UK Ltd) | 29 | 0.02 | 56.0 | 56 | 56 |
| Sertraline 50mg tablets (Sandoz Ltd) | 28 | 0.02 | 45.5 | 14 | 56 |
| Chlordiazepoxide 10mg capsules | 25 | 0.02 | 20.6 | 2 | 42 |
| Fluoxetine 20mg capsules | 25 | 0.02 | 35.8 | 3 | 60 |
| Sertraline 50mg tablets (Consilient H.. | 23 | 0.01 | 53.6 | 28 | 56 |
| Zimovane 7.5mg tablets (Sanofi) | 23 | 0.01 | 27.1 | 7 | 28 |
| Amitriptyline 50mg/5ml oral solution | 22 | 0.01 | 181.8 | 55 | 210 |
| mitriptyline 50mg/5ml oral solution | 22 | 0.01 | | | |
| Diazepam 2mg/5ml oral solution | 21 | 0.01 | 200 | 200 | 200 |
| Melatonin 3mg capsules | 21 | 0.01 | 55.28571 | 1 | 120 |
| Venlafaxine 300mg modified-release tablets | 21 | 0.01 | 28.7619 | 28 | 30 |
| Zopiclone 3.75mg tablets | 20 | 0.01 | 28 | 28 | 28 |
| Lustral 50mg tablets (Upjohn UK Ltd) | 18 | 0.01 | 24.88889 | 14 | 84 |
| Tryptophan 500mg tablets | 18 | 0.01 | 28 | 28 | 28 |
| Mirtazapine 30mg tablets | 16 | 0.01 | 28 | 28 | 28 |
| MIRTAZAPINE tablets 30mg [ACTAVIS] | 16 | 0.01 | 29 | 14 | 30 |
| Zolpidem 10mg tablets (Teva UK Ltd) | 16 | 0.01 | 12.6875 | 7 | 28 |
| Clomipramine 25mg capsules | 15 | 0.01 | 37.33333 | 28 | 56 |
| Nortriptyline 10mg capsules | 15 | 0.01 | 63.6 | 28 | 112 |
| Sertraline 50mg tablets (Mylan) | 15 | 0.01 | 28.93333 | 14 | 56 |

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|---|---|---|---|---|---|
| Lustral 100mg tablets (Upjohn UK Ltd) | 14 | 0.01 | 40 | 7 | 56 |
| Citalopram 40mg tablets (Teva UK Ltd) | 13 | 0.01 | 43.07692 | 28 | 56 |
| Sertraline 100mg tablets (Actavis UK) | 13 | 0.01 | 51.69231 | 28 | 56 |
| Sertraline 25mg tablets | 13 | 0.01 | 28 | 28 | 28 |
| Sertraline 50mg tablets (Zentiva Pharmacy) | 13 | 0.01 | 29.07692 | 14 | 56 |
| Fluoxetine 20mg/5ml oral solution | 12 | 0.01 | 134.1667 | 70 | 140 |
| Mirtazapine 15mg tablets | 12 | 0.01 | 13.16667 | 4 | 28 |
| Citalopram 10mg tablets | 11 | 0.01 | 22.45455 | 2 | 28 |
| Escitalopram 5mg tablets | 10 | 0.01 | 37.1 | 7 | 56 |
| Mirtazapine 45mg orodispersible tablets | 10 | 0.01 | 30 | 30 | 30 |
| Oxazepam 10mg tablets | 10 | 0.01 | 24.5 | 14 | 28 |
| Prothiaden 25mg capsules | 10 | 0.01 | 53.2 | 28 | 56 |
| Trazodone 50mg/5ml oral solution | 10 | 0.01 | 532 | 120 | 600 |
| Diazepam 2mg/5ml oral suspension | 9 | 0.01 | 820 | 700 | 840 |
| MELATONIN oral liquid sugar-free 1mg/.. | 9 | 0.01 | 177.7778 | 100 | 200 |
| Mirtazapine 15mg tablets (Teva UK Ltd) | 9 | 0.01 | 24.11111 | 7 | 28 |
| Nortriptyline 25mg capsules | 9 | 0.01 | 31.11111 | 28 | 56 |
| Citalopram 10mg tablets (Teva UK Ltd) | 8 | 0 | 25.375 | 7 | 28 |
| Citalopram 40mg/ml oral drops sugar | 7 | 0 | 15 | 15 | 15 |
| LORAZEPAM tablets 1mg [T & R] | 7 | 0 | 48.71429 | 5 | 56 |
| melatonin oral liquid sugar-free 1mg/ | 7 | 0 | 90 | 90 | 90 |
| Mirtazapine 15mg tablets (Arrow | 7 | 0 | 28 | 28 | 28 |
| Paroxetine 40mg tablets | 7 | 0 | 32 | 28 | 56 |
| PAROXETINE tablets 20mg [ACTAVIS] | 7 | 0 | 51.42857 | 30 | 60 |
| Sertraline 50mg tablets (Almus Pharmacy) | 7 | 0 | 28 | 28 | 28 |
| Zopiclone 3.75mg tablets (Teva UK Ltd) | 7 | 0 | 11.42857 | 7 | 28 |
| CHLORAL HYDRATE mixture 500mg/5ml | 6 | 0 | 200 | 200 | 200 |
| Mirtazapine 30mg orodispersible tablets | 6 | 0 | 28 | 28 | 28 |
| Phenergan 10mg tablets (Sanofi) | 6 | 0 | 37.33333 | 14 | 56 |
| Chlordiazepoxide 5mg capsules | 5 | 0 | 21.2 | 5 | 30 |
| Citalopram 10mg tablets | 5 | 0 | 28 | 28 | 28 |

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|---|---|---|---|---|---|
| Citalopram 10mg tablets (Ranbaxy (UK) | 5 | 0 | 28 | 28 | 28 |
| Fluoxetine 20mg capsules (Actavis UK | 5 | 0 | 36 | 30 | 60 |
| Flupentixol 1mg tablets | 5 | 0 | 54 | 30 | 60 |
| Mirtazapine 30mg tablets (Almus | 5 | 0 | 44.8 | 28 | 56 |
| Nitrazepam 5mg tablets | 5 | 0 | 12.6 | 7 | 14 |
| Vortioxetine 10mg tablets | 5 | 0 | 56 | 56 | 56 |
| Buspirone 5mg tablets (Mylan) | 4 | 0 | 20 | 20 | 20 |
| Fluoxetine 20mg/5ml oral solution | 4 | 0 | 122.5 | 70 | 140 |
| Lorazepam 500microgram tablets | 4 | 0 | 15.5 | 10 | 28 |
| Melatonin 1mg modified-release tablets | 4 | 0 | 60 | 60 | 60 |
| Mirtazapine 45mg orodispersible | 4 | 0 | 30 | 30 | 30 |
| Paroxetine 20mg tablets (Teva UK Ltd) | 4 | 0 | 60 | 60 | 60 |
| Sertraline 100mg tablets (Mylan) | 4 | 0 | 49 | 28 | 56 |
| Sertraline 100mg tablets (Sandoz Ltd) | 4 | 0 | 32.25 | 28 | 45 |
| Trazodone 150mg tablets (Actavis UK L.. | 4 | 0 | 28 | 28 | 28 |
| Trazodone 50mg capsules (Accord Health) | 4 | 0 | 22 | 4 | 56 |
| Ucerax 10mg/5ml syrup (UCB Pharma Ltd) | 4 | 0 | 175 | 100 | 200 |
| Zopiclone 7.5mg tablets | 4 | 0 | 17.5 | 7 | 28 |
| Citalopram 20mg tablets | 3 | 0 | 28 | 28 | 28 |
| Citalopram 40mg tablets (Ranbaxy (UK) | 3 | 0 | 28 | 28 | 28 |
| Cloral betaine 707mg tablets | 3 | 0 | 30 | 30 | 30 |
| Dosulepin 25mg capsules (Teva UK Ltd) | 3 | 0 | 56 | 56 | 56 |
| Fluoxetine 20mg capsules (Sandoz Ltd) | 3 | 0 | 17.3 | 30 | 60 |
| Lorazepam 1mg tablets | 3 | 0 | 7.33 | 4 | 11 |
| Mirtazapine 30mg tablets (Teva UK Ltd) | 3 | 0 | 28 | 28 | 28 |
| Paroxetine 10mg/5ml oral suspension | 3 | 0 | 150 | 150 | 150 |
| Trazodone 50mg capsules | 3 | 0 | 11.7 | 7 | 14 |
| Cipramil 10mg tablets (Lundbeck Ltd) | 2 | 0 | 2 | 56 | 56 |
| Citalopram 20mg tablets (Mylan) | 2 | 0 | 28 | 28 | 28 |
| Clomipramine 25mg capsules | 2 | 0 | 84 | 84 | 84 |
| Fluoxetine 20mg capsules | 2 | 0 | 30 | 30 | 30 |
| Imipramine 25mg/5ml oral solution | 2 | 0 | 150 | 150 | 150 |

| | | | | | |
|---|---|---|---|---|---|
| Melatonin 3mg modified-release capsules | 2 | 0 | 60 | 60 | 60 |
| Optimax 500mg tablets | 2 | 0 | 28 | 28 | 28 |
| Trazodone 150mg tablets | 2 | 0 | 14 | 14 | 14 |
| Trazodone 50mg capsules (Teva UK Ltd) | 2 | 0 | 28 | 28 | 28 |
| Zolpidem 5mg tablets (Teva UK Ltd) | 2 | 0 | 28 | 28 | 28 |
| Zopiclone 3.75mg tablets (Almus) | 2 | 0 | 4.5 | 4 | 5 |
| BUSPIRONE tablets 5mg [ACTAVIS] | 1 | 0 | 20 | 20 | 20 |
| Chlordiazepoxide 10mg tablets | 1 | 0 | 10 | 10 | 10 |
| Chlordiazepoxide 5mg tablets | 1 | 0 | 5 | 5 | 5 |
| Citalopram 10mg tablets (Mylan) | 1 | 0 | 28 | 28 | 28 |
| Citalopram 20mg tablets (Sandoz Ltd) | 1 | 0 | 28 | 28 | 28 |
| Citalopram 40mg tablets | 1 | 0 | 1 | 1 | 1 |
| Citalopram 40mg/ml oral drops sugar | 1 | 0 | 15 | 15 | 15 |
| Citalopram 40mg/ml oral drops sugar | 1 | 0 | 15 | 15 | 15 |
| Clomipramine 10mg capsules | 1 | 0 | 28 | 28 | 28 |
| Diazepam 5mg RecTubes | 1 | 0 | 5 | 5 | 5 |
| Diphenhydramine 10mg/5ml oral solution | 1 | 0 | 150 | 150 | 150 |
| Doxepin 50mg capsules | 1 | 0 | 28 | 28 | 28 |
| Duloxetine 20mg gastro-resistant capsules | 1 | 0 | 56 | 56 | 56 |
| Efexor XL 75mg capsules (Upjohn UK Ltd) | 1 | 0 | 1 | 3 | 3 |
| Escitalopram 20mg tablets (Teva UK Ltd) | 1 | 0 | 28 | 28 | 28 |
| Fluoxetine 20mg capsules | 1 | 0 | 60 | 60 | 60 |
| Fluoxetine 20mg capsules ( | 1 | 0 | 30 | 30 | 30 |
| Fluoxetine 30mg capsules (Medreich Plc) | 1 | 0 | 30 | 30 | 30 |
| Loprazolam 1mg tablets | 1 | 0 | 14 | 14 | 14 |
| Lorazepam 2.5mg tablets | 1 | 0 | 1 | 1 | 1 |
| Lormetazepam 1mg tablets | 1 | 0 | 10 | 10 | 10 |
| Melatonin 10mg/5ml oral solution | 1 | 0 | 100 | 100 | 100 |
| Melatonin 1mg capsules | 1 | 0 | 1 | 1 | 1 |
| Melatonin 5mg capsules | 1 | 0 | 1 | 1 | 1 |
| Mirtazapine 15mg orodispersible tablets | 1 | 0 | 30 | 30 | 30 |
| Mirtazapine 30mg tablets (A A H Pharm.. | 1 | 0 | 28 | 28 | 28 |
| Oxazepam 15mg tablets | 1 | 0 | 10 | 10 | 10 |

| | | | | | |
|---|---|---|---|---|---|
| Sertraline 50mg tablets (Arrow Generics) | 1 | 0 | 28 | 28 | 28 |
| Sertraline 50mg/5ml oral suspension | 1 | 0 | 150 | 150 | 150 |
| Trazodone 50mg tablets | 1 | 0 | 84 | 84 | 84 |
| Venlablue XL 37.5mg capsules (Zentiva) | 1 | 0 | 28 | 28 | 28 |
| Venlafaxine 37.5mg tablets (A A H Pharmacy) | 1 | 0 | 3 | 3 | 3 |
| Venlafaxine 37.5mg tablets (Almus Pharmacy) | 1 | 0 | 6 | 6 | 6 |
| Venlafaxine 75mg tablets (Almus Pharma) | 1 | 0 | 6 | 6 | 6 |
| Zaleplon 10mg capsules | 1 | 0 | 14 | 14 | 14 |
| Zolpidem 5mg tablets (A A H Pharmaceuticals) | 1 | 0 | 6 | 6 | 6 |
| Zopiclone 3.75mg tablets (Accord Heal.. | 1 | 0 | 14 | 14 | 14 |
| Zopiclone 3.75mg tablets (Mylan) | 1 | 0 | 10 | 10 | 10 |
| Zopiclone 3.75mg/5ml oral suspension | 1 | 0 | 70 | 70 | 70 |
| Zopiclone 7.5mg tablets (Almus Pharma) | 1 | 0 | 28 | 28 | 28 |
| Zopiclone 7.5mg tablets (Mylan) | 1 | 0 | 28 | 28 | 28 |

Figure A4.1: Trends in Sertraline prescription amongst resident of "Better Place" neighbourhoods, and the rest of Bradford

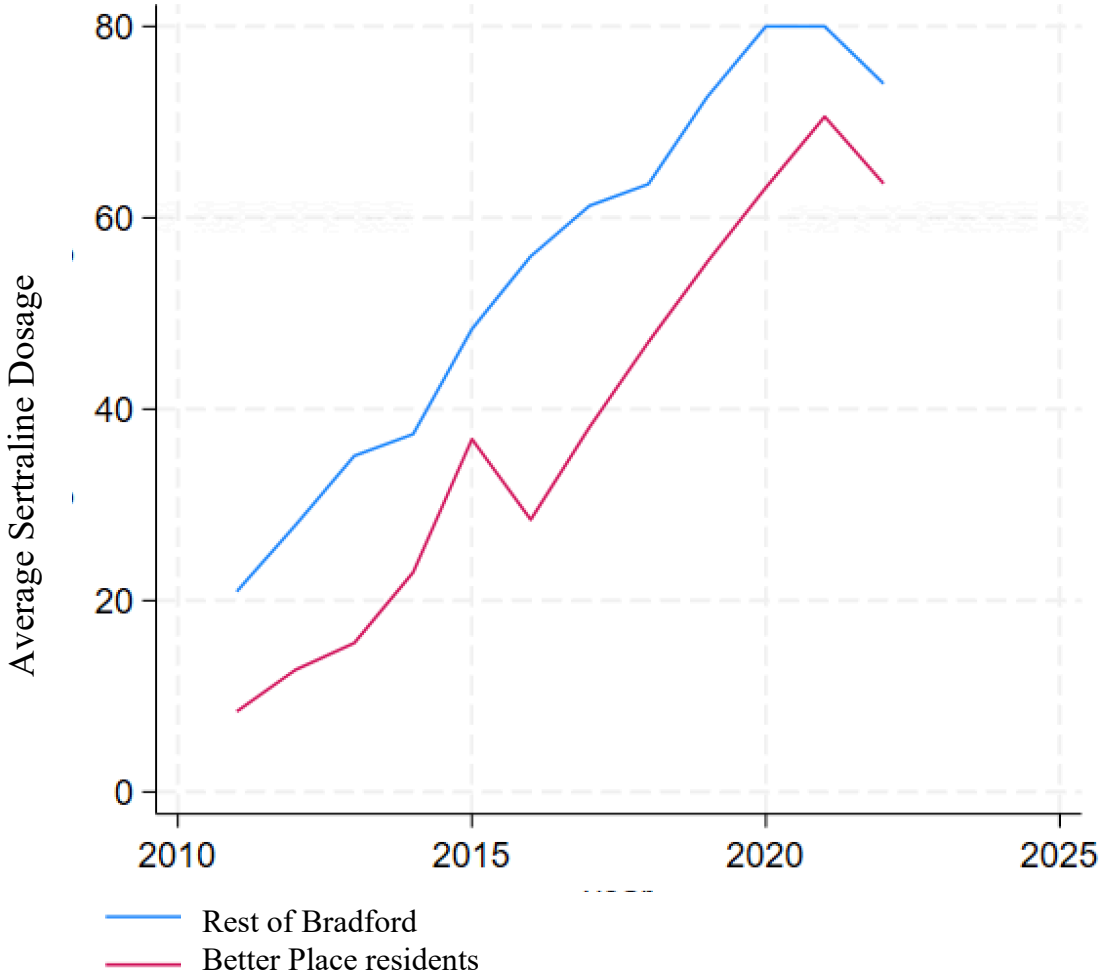
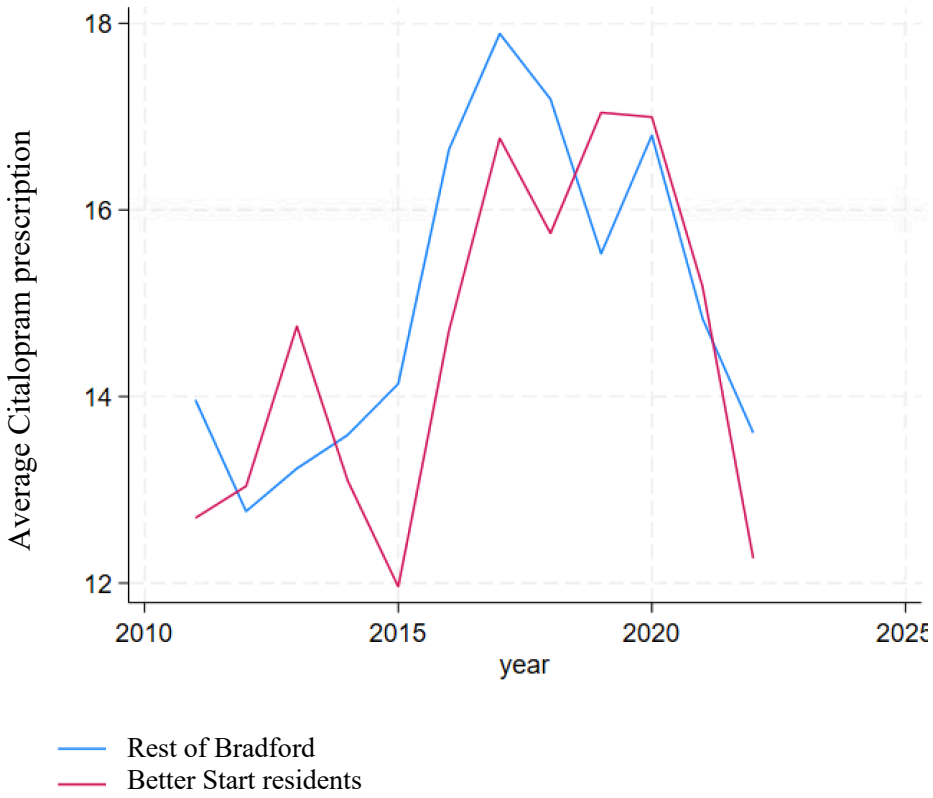


Figure A4.2: Trends in Citalopram prescription amongst resident of “Better Place” neighbourhoods, and the rest of Bradford



Appendix 4 – STATA code for cleaning and merging medicine database

```
Cleaning the medicines database*
gen drug_qty_revised=.
gen drug_type_revised=.

replace drug_qty_revised=1 if drug_quantity=="1 capsule"
replace drug_type_revised=1 if drug_quantity=="1 capsule"

replace drug_qty_revised=100 if drug_quantity=="1 pack of 100 mls"
replace drug_type_revised=2 if drug_quantity=="1 pack of 100 mls"

replace drug_qty_revised=100 if drug_quantity=="1 pack of 100 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 100 tablet(s)"

replace drug_qty_revised=14 if drug_quantity=="1 pack of 14 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 14 capsule(s)"

replace drug_qty_revised=15 if drug_quantity=="1 pack of 15 mls"
replace drug_type_revised=2 if drug_quantity=="1 pack of 15 mls"

replace drug_qty_revised=150 if drug_quantity=="1 pack of 150 mls"
replace drug_type_revised=3 if drug_quantity=="1 pack of 150 mls"

replace drug_qty_revised=16 if drug_quantity=="1 pack of 16 tablet(s)"
replace drug_type_revised=2 if drug_quantity=="1 pack of 16 tablet(s)"

replace drug_qty_revised=200 if drug_quantity=="1 pack of 200 mls"
replace drug_type_revised=2 if drug_quantity=="1 pack of 200 mls"

replace drug_qty_revised=25 if drug_quantity=="1 pack of 25 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 25 tablet(s)"

replace drug_qty_revised=28 if drug_quantity=="1 pack of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 28 capsule(s)"

replace drug_qty_revised=28 if drug_quantity=="1 pack of 28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 28 tablet(s)"

replace drug_qty_revised=30 if drug_quantity=="1 pack of 30 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 30 capsule(s)"

replace drug_qty_revised=30 if drug_quantity=="1 pack of 30 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 30 tablet(s)"

replace drug_qty_revised=5 if drug_quantity=="1 pack of 5 rectal tubes"
replace drug_type_revised=3 if drug_quantity=="1 pack of 5 rectal tubes"
```

```
replace drug_qty_revised=56 if drug_quantity=="1 pack of 56 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 56 capsule(s)"

replace drug_qty_revised=56 if drug_quantity=="1 pack of 56 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 56 tablet(s)"

replace drug_qty_revised=6 if drug_quantity=="1 pack of 6 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 6 tablet(s)"

replace drug_qty_revised=60 if drug_quantity=="1 pack of 60 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 60 capsule(s)"

replace drug_qty_revised=60 if drug_quantity=="1 pack of 60 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 60 tablet(s)"

replace drug_qty_revised=70 if drug_quantity=="1 pack of 70 mls"
replace drug_type_revised=2 if drug_quantity=="1 pack of 70 mls"

replace drug_qty_revised=8 if drug_quantity=="1 pack of 8 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 8 tablet(s)"

replace drug_qty_revised=84 if drug_quantity=="1 pack of 84 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="1 pack of 84 capsule(s)"

replace drug_qty_revised=1 if drug_quantity=="1 tablet"
replace drug_type_revised=1 if drug_quantity=="1 tablet"

replace drug_qty_revised=1 if drug_quantity=="1 tablets"
replace drug_type_revised=1 if drug_quantity=="1 tablets"

replace drug_qty_revised=10 if drug_quantity=="10 capsule"
replace drug_type_revised=1 if drug_quantity=="10 capsule"

replace drug_qty_revised=10 if drug_quantity=="10 capsules"
replace drug_type_revised=1 if drug_quantity=="10 capsules"

replace drug_qty_revised=280 if drug_quantity=="10 packs of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="10 packs of 28 capsule(s)"

replace drug_qty_revised=10 if drug_quantity=="10 tablet"
replace drug_type_revised=1 if drug_quantity=="10 tablet"

replace drug_qty_revised=10 if drug_quantity=="10 tablets"
replace drug_type_revised=1 if drug_quantity=="10 tablets"

replace drug_qty_revised=100 if drug_quantity=="100 capsule"
replace drug_type_revised=1 if drug_quantity=="100 capsule"

replace drug_qty_revised=100 if drug_quantity=="100 millilitres"
replace drug_type_revised=2 if drug_quantity=="100 millilitres"
```

```
replace drug_qty_revised=100 if drug_quantity=="100 ml"
replace drug_type_revised=2 if drug_quantity=="100 ml"

replace drug_qty_revised=100 if drug_quantity=="100 ml - 10 mg/5 ml"
replace drug_type_revised=2 if drug_quantity=="100 ml - 10 mg/5 ml"

replace drug_qty_revised=100 if drug_quantity=="100 tablet"
replace drug_type_revised=1 if drug_quantity=="100 tablet"

replace drug_qty_revised=100 if drug_quantity=="100 tablets"
replace drug_type_revised=1 if drug_quantity=="100 tablets"

replace drug_qty_revised=105 if drug_quantity=="105 capsule"
replace drug_type_revised=1 if drug_quantity=="105 capsule"

replace drug_qty_revised=105 if drug_quantity=="105 ml"
replace drug_type_revised=2 if drug_quantity=="105 ml"

replace drug_qty_revised=11 if drug_quantity=="11 capsule"
replace drug_type_revised=1 if drug_quantity=="11 capsule"

replace drug_qty_revised=11 if drug_quantity=="11 capsules"
replace drug_type_revised=1 if drug_quantity=="11 capsules"

replace drug_qty_revised=11 if drug_quantity=="11 tablet"
replace drug_type_revised=1 if drug_quantity=="11 tablet"

replace drug_qty_revised=11 if drug_quantity=="11 tablets"
replace drug_type_revised=1 if drug_quantity=="11 tablets"

replace drug_qty_revised=110 if drug_quantity=="110 tablets"
replace drug_type_revised=1 if drug_quantity=="110 tablets"

replace drug_qty_revised=112 if drug_quantity=="112 TABLET"
replace drug_type_revised=1 if drug_quantity=="112 TABLET"

replace drug_qty_revised=112 if drug_quantity=="112 capsule"
replace drug_type_revised=1 if drug_quantity=="112 capsule"

replace drug_qty_revised=112 if drug_quantity=="112 capsules"
replace drug_type_revised=1 if drug_quantity=="112 capsules"

replace drug_qty_revised=112 if drug_quantity=="112 tab"
replace drug_type_revised=1 if drug_quantity=="112 tab"

replace drug_qty_revised=112 if drug_quantity=="112 tablet"
replace drug_type_revised=1 if drug_quantity=="112 tablet"

replace drug_qty_revised=112 if drug_quantity=="112 tablets"
```

```
replace drug_type_revised=1 if drug_quantity=="112 tablets"

replace drug_qty_revised=12 if drug_quantity=="12 capsule"
replace drug_type_revised=1 if drug_quantity=="12 capsule"

replace drug_qty_revised=12 if drug_quantity=="12 capsules"
replace drug_type_revised=1 if drug_quantity=="12 capsules"

replace drug_qty_revised=12 if drug_quantity=="12 tablet"
replace drug_type_revised=1 if drug_quantity=="12 tablet"

replace drug_qty_revised=12 if drug_quantity=="12 tablets"
replace drug_type_revised=1 if drug_quantity=="12 tablets"

replace drug_qty_revised=120 if drug_quantity=="120 capsule"
replace drug_type_revised=1 if drug_quantity=="120 capsule"

replace drug_qty_revised=120 if drug_quantity=="120 capsule(s) - 20 mg"
replace drug_type_revised=1 if drug_quantity=="120 capsule(s) - 20 mg"

replace drug_qty_revised=120 if drug_quantity=="120 capsules"
replace drug_type_revised=1 if drug_quantity=="120 capsules"

replace drug_qty_revised=120 if drug_quantity=="120 ml"
replace drug_type_revised=2 if drug_quantity=="120 ml"

replace drug_qty_revised=120 if drug_quantity=="120 tablet"
replace drug_type_revised=1 if drug_quantity=="120 tablet"

replace drug_qty_revised=120 if drug_quantity=="120 tablets"
replace drug_type_revised=1 if drug_quantity=="120 tablets"

replace drug_qty_revised=124 if drug_quantity=="124 capsules"
replace drug_type_revised=1 if drug_quantity=="124 capsules"

replace drug_qty_revised=125 if drug_quantity=="125 ml"
replace drug_type_revised=2 if drug_quantity=="125 ml"

replace drug_qty_revised=126 if drug_quantity=="126 tablet"
replace drug_type_revised=1 if drug_quantity=="126 tablet"

replace drug_qty_revised=13 if drug_quantity=="13 tablet"
replace drug_type_revised=1 if drug_quantity=="13 tablet"

replace drug_qty_revised=14 if drug_quantity=="14"
replace drug_type_revised=1 if drug_quantity=="14"

replace drug_qty_revised=14 if drug_quantity=="14  cap"
replace drug_type_revised=1 if drug_quantity=="14  cap"
```

```
replace drug_qty_revised=14 if drug_quantity=="14  cap"
replace drug_type_revised=1 if drug_quantity=="14  cap"

replace drug_qty_revised=14 if drug_quantity=="14 capsule"
replace drug_type_revised=1 if drug_quantity=="14 capsule"

replace drug_qty_revised=14 if drug_quantity=="14 capsule - 20 mg"
replace drug_type_revised=1 if drug_quantity=="14 capsule - 20 mg"

replace drug_qty_revised=14 if drug_quantity=="14 capsules"
replace drug_type_revised=1 if drug_quantity=="14 capsules"

replace drug_qty_revised=392 if drug_quantity=="14 packs of 28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="14 packs of 28 tablet(s)"

replace drug_qty_revised=14 if drug_quantity=="14 tab"
replace drug_type_revised=1 if drug_quantity=="14 tab"

replace drug_qty_revised=14 if drug_quantity=="14 tablet"
replace drug_type_revised=1 if drug_quantity=="14 tablet"

replace drug_qty_revised=14 if drug_quantity=="14 tablet - 20 mg"
replace drug_type_revised=1 if drug_quantity=="14 tablet - 20 mg"

replace drug_qty_revised=14 if drug_quantity=="14 tablets"
replace drug_type_revised=1 if drug_quantity=="14 tablets"

replace drug_qty_revised=14 if drug_quantity=="14 tablets"
replace drug_type_revised=1 if drug_quantity=="14 tablets"

replace drug_qty_revised=140 if drug_quantity=="140 capsule"
replace drug_type_revised=1 if drug_quantity=="140 capsule"

replace drug_qty_revised=140 if drug_quantity=="140 millilitres"
replace drug_type_revised=2 if drug_quantity=="140 millilitres"

replace drug_qty_revised=140 if drug_quantity=="140 ml"
replace drug_type_revised=2 if drug_quantity=="140 ml"

replace drug_qty_revised=140 if drug_quantity=="140 ml - 20 mg/5 ml"
replace drug_type_revised=2 if drug_quantity=="140 ml - 20 mg/5 ml"

replace drug_qty_revised=140 if drug_quantity=="140 tablet"
replace drug_type_revised=1 if drug_quantity=="140 tablet"

replace drug_qty_revised=140 if drug_quantity=="140 tablets"
replace drug_type_revised=1 if drug_quantity=="140 tablets"

replace drug_qty_revised=1428 if drug_quantity=="1428 tablet"
replace drug_type_revised=1 if drug_quantity=="1428 tablet"
```

```
replace drug_qty_revised=15 if drug_quantity=="15 cap"
replace drug_type_revised=1 if drug_quantity=="15 cap"

replace drug_qty_revised=15 if drug_quantity=="15 capsule"
replace drug_type_revised=1 if drug_quantity=="15 capsule"

replace drug_qty_revised=15 if drug_quantity=="15 capsules"
replace drug_type_revised=1 if drug_quantity=="15 capsules"

replace drug_qty_revised=15 if drug_quantity=="15 millilitres"
replace drug_type_revised=2 if drug_quantity=="15 millilitres"

replace drug_qty_revised=15 if drug_quantity=="15 ml"
replace drug_type_revised=2 if drug_quantity=="15 ml"

replace drug_qty_revised=15 if drug_quantity=="15 tablet"
replace drug_type_revised=1 if drug_quantity=="15 tablet"

replace drug_qty_revised=15 if drug_quantity=="15 tablets"
replace drug_type_revised=1 if drug_quantity=="15 tablets"

replace drug_qty_revised=150 if drug_quantity=="150 millilitres"
replace drug_type_revised=2 if drug_quantity=="150 millilitres"

replace drug_qty_revised=150 if drug_quantity=="150 ml"
replace drug_type_revised=2 if drug_quantity=="150 ml"

replace drug_qty_revised=150 if drug_quantity=="150 tablet"
replace drug_type_revised=1 if drug_quantity=="150 tablet"

replace drug_qty_revised=150 if drug_quantity=="150 tablets"
replace drug_type_revised=1 if drug_quantity=="150 tablets"

replace drug_qty_revised=16 if drug_quantity=="16 capsules"
replace drug_type_revised=1 if drug_quantity=="16 capsules"

replace drug_qty_revised=16 if drug_quantity=="16 tablet"
replace drug_type_revised=1 if drug_quantity=="16 tablet"

replace drug_qty_revised=16 if drug_quantity=="16 tablets"
replace drug_type_revised=1 if drug_quantity=="16 tablets"

replace drug_qty_revised=16 if drug_quantity=="168  tab"
replace drug_type_revised=1 if drug_quantity=="168  tab"

replace drug_qty_revised=168 if drug_quantity=="168 capsule"
replace drug_type_revised=1 if drug_quantity=="168 capsule"

replace drug_qty_revised=168 if drug_quantity=="168 capsules"
```

```
replace drug_type_revised=1 if drug_quantity=="168 capsules"

replace drug_qty_revised=168 if drug_quantity=="168 tablet"
replace drug_type_revised=1 if drug_quantity=="168 tablet"

replace drug_qty_revised=17 if drug_quantity=="17 capsule"
replace drug_type_revised=1 if drug_quantity=="17 capsule"

replace drug_qty_revised=17 if drug_quantity=="17 tablet"
replace drug_type_revised=1 if drug_quantity=="17 tablet"

replace drug_qty_revised=175 if drug_quantity=="175 ml"
replace drug_type_revised=2 if drug_quantity=="175 ml"

replace drug_qty_revised=18 if drug_quantity=="18 capsule"
replace drug_type_revised=1 if drug_quantity=="18 capsule"

replace drug_qty_revised=18 if drug_quantity=="18 capsules"
replace drug_type_revised=1 if drug_quantity=="18 capsules"

replace drug_qty_revised=18 if drug_quantity=="18 tablet"
replace drug_type_revised=1 if drug_quantity=="18 tablet"

replace drug_qty_revised=18 if drug_quantity=="18 tablets"
replace drug_type_revised=1 if drug_quantity=="18 tablets"

replace drug_qty_revised=180 if drug_quantity=="180 capsule"
replace drug_type_revised=1 if drug_quantity=="180 capsule"

replace drug_qty_revised=180 if drug_quantity=="180 capsules"
replace drug_type_revised=1 if drug_quantity=="180 capsules"

replace drug_qty_revised=19 if drug_quantity=="19 tablet"
replace drug_type_revised=1 if drug_quantity=="19 tablet"

replace drug_qty_revised=196 if drug_quantity=="196 capsule"
replace drug_type_revised=1 if drug_quantity=="196 capsule"

replace drug_qty_revised=2 if drug_quantity=="2 capsules"
replace drug_type_revised=1 if drug_quantity=="2 capsules"

replace drug_qty_revised=2 if drug_quantity=="2 packs of 1 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 1 capsule(s)"

replace drug_qty_revised=200 if drug_quantity=="2 packs of 100 mls"
replace drug_type_revised=2 if drug_quantity=="2 packs of 100 mls"

replace drug_qty_revised=28 if drug_quantity=="2 packs of 14 capsule(s)"
replace drug_type_revised=2 if drug_quantity=="2 packs of 14 capsule(s)"
```

```
replace drug_qty_revised=30 if drug_quantity=="2 packs of 15 mls"
replace drug_type_revised=2 if drug_quantity=="2 packs of 15 mls"

replace drug_qty_revised=300 if drug_quantity=="2 packs of 150 mls"
replace drug_type_revised=2 if drug_quantity=="2 packs of 150 mls"

replace drug_qty_revised=32 if drug_quantity=="2 packs of 16 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 16 tablet(s)"

replace drug_qty_revised=400 if drug_quantity=="2 packs of 200 mls"
replace drug_type_revised=2 if drug_quantity=="2 packs of 200 mls"

replace drug_qty_revised=50 if drug_quantity=="2 packs of 25 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 25 tablet(s)"

replace drug_qty_revised=56 if drug_quantity=="2 packs of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 28 capsule(s)"

replace drug_qty_revised=56 if drug_quantity=="2 packs of 28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 28 tablet(s)"

replace drug_qty_revised=60 if drug_quantity=="2 packs of 30 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 30 capsule(s)"

replace drug_qty_revised=60 if drug_quantity=="2 packs of 30 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 30 tablet(s)"

replace drug_qty_revised=112 if drug_quantity=="2 packs of 56 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 56 tablet(s)"

replace drug_qty_revised=120 if drug_quantity=="2 packs of 60 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 60 capsule(s)"

replace drug_qty_revised=120 if drug_quantity=="2 packs of 60 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 60 tablet(s)"

replace drug_qty_revised=140 if drug_quantity=="2 packs of 70 mls"
replace drug_type_revised=2 if drug_quantity=="2 packs of 70 mls"

replace drug_qty_revised=16 if drug_quantity=="2 packs of 8 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 8 tablet(s)"

replace drug_qty_revised=168 if drug_quantity=="2 packs of 84 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="2 packs of 84 capsule(s)"

replace drug_qty_revised=2 if drug_quantity=="2 tablet"
replace drug_type_revised=1 if drug_quantity=="2 tablet"

replace drug_qty_revised=2 if drug_quantity=="2 tablets"
replace drug_type_revised=1 if drug_quantity=="2 tablets"
```

```
replace drug_qty_revised=56 if drug_quantity=="2*28 capsule(s) - 150 mg"
replace drug_type_revised=1 if drug_quantity=="2*28 capsule(s) - 150 mg"

replace drug_qty_revised=56 if drug_quantity=="2*28 capsule(s) - 75 mg"
replace drug_type_revised=1 if drug_quantity=="2*28 capsule(s) - 75 mg"

replace drug_qty_revised=56 if drug_quantity=="2*28 tablet - 20 mg"
replace drug_type_revised=1 if drug_quantity=="2*28 tablet - 20 mg"

replace drug_qty_revised=56 if drug_quantity=="2*28 tablet - 50 mg"
replace drug_type_revised=1 if drug_quantity=="2*28 tablet - 50 mg"

replace drug_qty_revised=56 if drug_quantity=="2*28 tablets - 20 mg"
replace drug_type_revised=1 if drug_quantity=="2*28 tablets - 20 mg"

replace drug_qty_revised=60 if drug_quantity=="2*30 capsule - 20 mg"
replace drug_type_revised=1 if drug_quantity=="2*30 capsule - 20 mg"

replace drug_qty_revised=20 if drug_quantity=="20 capsule"
replace drug_type_revised=1 if drug_quantity=="20 capsule"

replace drug_qty_revised=20 if drug_quantity=="20 capsules"
replace drug_type_revised=1 if drug_quantity=="20 capsules"

replace drug_qty_revised=20 if drug_quantity=="20 tablet"
replace drug_type_revised=1 if drug_quantity=="20 tablet"

replace drug_qty_revised=20 if drug_quantity=="20 tablet - 2 mg"
replace drug_type_revised=1 if drug_quantity=="20 tablet - 2 mg"

replace drug_qty_revised=20 if drug_quantity=="20 tablet - 7.5 mg"
replace drug_type_revised=1 if drug_quantity=="20 tablet - 7.5 mg"

replace drug_qty_revised=20 if drug_quantity=="20 tablets"
replace drug_type_revised=1 if drug_quantity=="20 tablets"

replace drug_qty_revised=20 if drug_quantity=="20 tablets"
replace drug_type_revised=1 if drug_quantity=="20 tablets"

replace drug_qty_revised=200 if drug_quantity=="200 millilitres"
replace drug_type_revised=2 if drug_quantity=="200 millilitres"

replace drug_qty_revised=200 if drug_quantity=="200 ml"
replace drug_type_revised=2 if drug_quantity=="200 ml"

replace drug_qty_revised=200 if drug_quantity=="200 tablet"
replace drug_type_revised=1 if drug_quantity=="200 tablet"

replace drug_qty_revised=201 if drug_quantity=="201 millilitres"
```

```
replace drug_type_revised=2 if drug_quantity=="201 millilitres"

replace drug_qty_revised=21 if drug_quantity=="21 capsule"
replace drug_type_revised=1 if drug_quantity=="21 capsule"

replace drug_qty_revised=21 if drug_quantity=="21 capsules"
replace drug_type_revised=1 if drug_quantity=="21 capsules"

replace drug_qty_revised=21 if drug_quantity=="21 tablet"
replace drug_type_revised=1 if drug_quantity=="21 tablet"

replace drug_qty_revised=21 if drug_quantity=="21 tablets"
replace drug_type_revised=1 if drug_quantity=="21 tablets"

replace drug_qty_revised=21 if drug_quantity=="21 tablets"
replace drug_type_revised=1 if drug_quantity=="21 tablets"

replace drug_qty_revised=210 if drug_quantity=="210 ml"
replace drug_type_revised=2 if drug_quantity=="210 ml"

replace drug_qty_revised=22 if drug_quantity=="22 capsule"
replace drug_type_revised=1 if drug_quantity=="22 capsule"

replace drug_qty_revised=22 if drug_quantity=="22 tablet"
replace drug_type_revised=1 if drug_quantity=="22 tablet"

replace drug_qty_revised=224 if drug_quantity=="224 CAPSULE(S)"
replace drug_type_revised=1 if drug_quantity=="224 CAPSULE(S)"

replace drug_qty_revised=224 if drug_quantity=="224 capsule"
replace drug_type_revised=1 if drug_quantity=="224 capsule"

replace drug_qty_revised=224 if drug_quantity=="224 ml"
replace drug_type_revised=2 if drug_quantity=="224 ml"

replace drug_qty_revised=224 if drug_quantity=="224 tablet"
replace drug_type_revised=1 if drug_quantity=="224 tablet"

replace drug_qty_revised=23 if drug_quantity=="23 tablet"
replace drug_type_revised=1 if drug_quantity=="23 tablet"

replace drug_qty_revised=24 if drug_quantity=="24 tablet"
replace drug_type_revised=1 if drug_quantity=="24 tablet"

replace drug_qty_revised=24 if drug_quantity=="24 tablets"
replace drug_type_revised=1 if drug_quantity=="24 tablets"

replace drug_qty_revised=240 if drug_quantity=="240 ml"
replace drug_type_revised=2 if drug_quantity=="240 ml"
```

```
replace drug_qty_revised=25 if drug_quantity=="25 tab"
replace drug_type_revised=1 if drug_quantity=="25 tab"

replace drug_qty_revised=25 if drug_quantity=="25 tablet"
replace drug_type_revised=1 if drug_quantity=="25 tablet"

replace drug_qty_revised=25 if drug_quantity=="25 tablets"
replace drug_type_revised=1 if drug_quantity=="25 tablets"

replace drug_qty_revised=250 if drug_quantity=="250ml"
replace drug_type_revised=1 if drug_quantity=="250ml"

replace drug_qty_revised=26 if drug_quantity=="26 tablet"
replace drug_type_revised=1 if drug_quantity=="26 tablet"

replace drug_qty_revised=27 if drug_quantity=="27 capsules"
replace drug_type_revised=1 if drug_quantity=="27 capsules"

replace drug_qty_revised=27 if drug_quantity=="27 tablets"
replace drug_type_revised=1 if drug_quantity=="27 tablets"

replace drug_qty_revised=270 if drug_quantity=="270 capsule"
replace drug_type_revised=1 if drug_quantity=="270 capsule"

replace drug_qty_revised=28 if drug_quantity=="28 CAPSULE"
replace drug_type_revised=1 if drug_quantity=="28 CAPSULE"

replace drug_qty_revised=28 if drug_quantity=="28 CAPSULE(S)"
replace drug_type_revised=1 if drug_quantity=="28 CAPSULE(S)"

replace drug_qty_revised=28 if drug_quantity=="28 TABLET(S)"
replace drug_type_revised=1 if drug_quantity=="28 TABLET(S)"

replace drug_qty_revised=28 if drug_quantity=="28 capsule"
replace drug_type_revised=1 if drug_quantity=="28 capsule"

replace drug_qty_revised=28 if drug_quantity=="28 capsule - 25 mg"
replace drug_type_revised=1 if drug_quantity=="28 capsule - 25 mg"

replace drug_qty_revised=28 if drug_quantity=="28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="28 capsule(s)"

replace drug_qty_revised=28 if drug_quantity=="28 capsules"
replace drug_type_revised=1 if drug_quantity=="28 capsules"

replace drug_qty_revised=28 if drug_quantity=="28 capsules - 100 mg"
replace drug_type_revised=1 if drug_quantity=="28 capsules - 100 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tab"
replace drug_type_revised=1 if drug_quantity=="28 tab"
```

```
replace drug_qty_revised=28 if drug_quantity=="28 tablet"
replace drug_type_revised=1 if drug_quantity=="28 tablet"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 10 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 10 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 15 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 15 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 2 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 2 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 20 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 20 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 25 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 25 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 3.75 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 3.75 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 40 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 40 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 5 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 5 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 50 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 50 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 7.5 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 7.5 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet - 75 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet - 75 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="28 tablet(s)"

replace drug_qty_revised=28 if drug_quantity=="28 tablet(s) - 10 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet(s) - 10 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet(s) - 20 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet(s) - 20 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablet(s) - 50 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablet(s) - 50 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tablets"
```

```
replace drug_type_revised=1 if drug_quantity=="28 tablets"

replace drug_qty_revised=28 if drug_quantity=="28 tablets - 20 mg"
replace drug_type_revised=1 if drug_quantity=="28 tablets - 20 mg"

replace drug_qty_revised=28 if drug_quantity=="28 tabs"
replace drug_type_revised=1 if drug_quantity=="28 tabs"

replace drug_qty_revised=280 if drug_quantity=="280 capsule"
replace drug_type_revised=1 if drug_quantity=="280 capsule"

replace drug_qty_revised=280 if drug_quantity=="280 ml"
replace drug_type_revised=1 if drug_quantity=="280 ml"

replace drug_qty_revised=29 if drug_quantity=="29 tablet"
replace drug_type_revised=1 if drug_quantity=="29 tablet"

replace drug_qty_revised=56 if drug_quantity=="2x28 tablet"
replace drug_type_revised=1 if drug_quantity=="2x28 tablet"

replace drug_qty_revised=3 if drug_quantity=="3 capsule"
replace drug_type_revised=1 if drug_quantity=="3 capsule"

replace drug_qty_revised=3 if drug_quantity=="3 capsules"
replace drug_type_revised=1 if drug_quantity=="3 capsules"

replace drug_qty_revised=300 if drug_quantity=="3 packs of 100 mls"
replace drug_type_revised=2 if drug_quantity=="3 packs of 100 mls"

replace drug_qty_revised=450 if drug_quantity=="3 packs of 150 mls"
replace drug_type_revised=2 if drug_quantity=="3 packs of 150 mls"

replace drug_qty_revised=600 if drug_quantity=="3 packs of 200 mls"
replace drug_type_revised=2 if drug_quantity=="3 packs of 200 mls"

replace drug_qty_revised=84 if drug_quantity=="3 packs of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="3 packs of 28 capsule(s)"

replace drug_qty_revised=84 if drug_quantity=="3 packs of 28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="3 packs of 28 tablet(s)"

replace drug_qty_revised=90 if drug_quantity=="3 packs of 30 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="3 packs of 30 capsule(s)"

replace drug_qty_revised=90 if drug_quantity=="3 packs of 30 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="3 packs of 30 tablet(s)"

replace drug_qty_revised=168 if drug_quantity=="3 packs of 56 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="3 packs of 56 tablet(s)"
```

```
replace drug_qty_revised=18 if drug_quantity=="3 packs of 6 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="3 packs of 6 tablet(s)"

replace drug_qty_revised=210 if drug_quantity=="3 packs of 70 mls"
replace drug_type_revised=2 if drug_quantity=="3 packs of 70 mls"

replace drug_qty_revised=3 if drug_quantity=="3 tablet"
replace drug_type_revised=1 if drug_quantity=="3 tablet"

replace drug_qty_revised=3 if drug_quantity=="3 tablets"
replace drug_type_revised=1 if drug_quantity=="3 tablets"

replace drug_qty_revised=84 if drug_quantity=="3*28 tablet - 20 mg"
replace drug_type_revised=1 if drug_quantity=="3*28 tablet - 20 mg"

replace drug_qty_revised=30 if drug_quantity=="30 - capsule(s)"
replace drug_type_revised=1 if drug_quantity=="30 - capsule(s)"

replace drug_qty_revised=30 if drug_quantity=="30 cap"
replace drug_type_revised=1 if drug_quantity=="30 cap"

replace drug_qty_revised=30 if drug_quantity=="30 capsule"
replace drug_type_revised=1 if drug_quantity=="30 capsule"

replace drug_qty_revised=30 if drug_quantity=="30 capsule - 20 mg"
replace drug_type_revised=1 if drug_quantity=="30 capsule - 20 mg"

replace drug_qty_revised=30 if drug_quantity=="30 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="30 capsule(s)"

replace drug_qty_revised=30 if drug_quantity=="30 capsule(s) - 20 mg"
replace drug_type_revised=1 if drug_quantity=="30 capsule(s) - 20 mg"

replace drug_qty_revised=30 if drug_quantity=="30 capsules"
replace drug_type_revised=1 if drug_quantity=="30 capsules"

replace drug_qty_revised=30 if drug_quantity=="30 capsules - 20 mg"
replace drug_type_revised=1 if drug_quantity=="30 capsules - 20 mg"

replace drug_qty_revised=30 if drug_quantity=="30 ml"
replace drug_type_revised=2 if drug_quantity=="30 ml"

replace drug_qty_revised=30 if drug_quantity=="30 tab"
replace drug_type_revised=1 if drug_quantity=="30 tab"

replace drug_qty_revised=30 if drug_quantity=="30 tablet"
replace drug_type_revised=1 if drug_quantity=="30 tablet"

replace drug_qty_revised=30 if drug_quantity=="30 tablet - 10 mg"
replace drug_type_revised=1 if drug_quantity=="30 tablet - 10 mg"
```

```
replace drug_qty_revised=30 if drug_quantity=="30 tablet - 2 mg"
replace drug_type_revised=1 if drug_quantity=="30 tablet - 2 mg"

replace drug_qty_revised=30 if drug_quantity=="30 tablet - 20 mg"
replace drug_type_revised=1 if drug_quantity=="30 tablet - 20 mg"

replace drug_qty_revised=30 if drug_quantity=="30 tablet - 30 mg"
replace drug_type_revised=1 if drug_quantity=="30 tablet - 30 mg"

replace drug_qty_revised=30 if drug_quantity=="30 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="30 tablet(s)"

replace drug_qty_revised=30 if drug_quantity=="30 tablets"
replace drug_type_revised=1 if drug_quantity=="30 tablets"

replace drug_qty_revised=30 if drug_quantity=="30 tablets - 2 mg"
replace drug_type_revised=1 if drug_quantity=="30 tablets - 2 mg"

replace drug_qty_revised=30 if drug_quantity=="30.00 caps"
replace drug_type_revised=1 if drug_quantity=="30.00 caps"

replace drug_qty_revised=30 if drug_quantity=="30.00 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="30.00 tablet(s)"

replace drug_qty_revised=300 if drug_quantity=="300 millilitres"
replace drug_type_revised=2 if drug_quantity=="300 millilitres"

replace drug_qty_revised=300 if drug_quantity=="300 ml"
replace drug_type_revised=2 if drug_quantity=="300 ml"

replace drug_qty_revised=32 if drug_quantity=="32 capsule"
replace drug_type_revised=1 if drug_quantity=="32 capsule"

replace drug_qty_revised=32 if drug_quantity=="32 tablet"
replace drug_type_revised=1 if drug_quantity=="32 tablet"

replace drug_qty_revised=32 if drug_quantity=="32 tablets"
replace drug_type_revised=1 if drug_quantity=="32 tablets"

replace drug_qty_revised=33 if drug_quantity=="33 tablet"
replace drug_type_revised=1 if drug_quantity=="33 tablet"

replace drug_qty_revised=336 if drug_quantity=="336 capsule"
replace drug_type_revised=1 if drug_quantity=="336 capsule"

replace drug_qty_revised=34 if drug_quantity=="34 capsule"
replace drug_type_revised=1 if drug_quantity=="34 capsule"

replace drug_qty_revised=34 if drug_quantity=="34 tablet"
```

```
replace drug_type_revised=1 if drug_quantity=="34 tablet"

replace drug_qty_revised=340 if drug_quantity=="340 tablet"
replace drug_type_revised=1 if drug_quantity=="340 tablet"

replace drug_qty_revised=35 if drug_quantity=="35 capsules"
replace drug_type_revised=1 if drug_quantity=="35 capsules"

replace drug_qty_revised=35 if drug_quantity=="35 millilitres"
replace drug_type_revised=2 if drug_quantity=="35 millilitres"

replace drug_qty_revised=35 if drug_quantity=="35 tablet"
replace drug_type_revised=1 if drug_quantity=="35 tablet"

replace drug_qty_revised=35 if drug_quantity=="35 tablets"
replace drug_type_revised=1 if drug_quantity=="35 tablets"

replace drug_qty_revised=350 if drug_quantity=="350 ml"
replace drug_type_revised=2 if drug_quantity=="350 ml"

replace drug_qty_revised=36 if drug_quantity=="36 capsule"
replace drug_type_revised=1 if drug_quantity=="36 capsule"

replace drug_qty_revised=36 if drug_quantity=="36 tablet"
replace drug_type_revised=1 if drug_quantity=="36 tablet"

replace drug_qty_revised=39 if drug_quantity=="39 tablet"
replace drug_type_revised=1 if drug_quantity=="39 tablet"

replace drug_qty_revised=392 if drug_quantity=="392 tablet"
replace drug_type_revised=392 if drug_quantity=="392 tablet"

replace drug_qty_revised=90 if drug_quantity=="3x30 capsule"
replace drug_type_revised=1 if drug_quantity=="3x30 capsule"

replace drug_qty_revised=4 if drug_quantity=="4 capsule"
replace drug_type_revised=1 if drug_quantity=="4 capsule"

replace drug_qty_revised=4 if drug_quantity=="4 capsules"
replace drug_type_revised=1 if drug_quantity=="4 capsules"

replace drug_qty_revised=600 if drug_quantity=="4 packs of 150 mls"
replace drug_type_revised=2 if drug_quantity=="4 packs of 150 mls"

replace drug_qty_revised=112 if drug_quantity=="4 packs of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="4 packs of 28 capsule(s)"

replace drug_qty_revised=112 if drug_quantity=="4 packs of 28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="4 packs of 28 tablet(s)"
```

```
replace drug_qty_revised=120 if drug_quantity=="4 packs of 30 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="4 packs of 30 capsule(s)"

replace drug_qty_revised=120 if drug_quantity=="4 packs of 30 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="4 packs of 30 tablet(s)"

replace drug_qty_revised=4 if drug_quantity=="4 tab"
replace drug_type_revised=1 if drug_quantity=="4 tab"

replace drug_qty_revised=4 if drug_quantity=="4 tablet"
replace drug_type_revised=1 if drug_quantity=="4 tablet"

replace drug_qty_revised=4 if drug_quantity=="4 tablets"
replace drug_type_revised=1 if drug_quantity=="4 tablets"

replace drug_qty_revised=40 if drug_quantity=="40 capsule"
replace drug_type_revised=1 if drug_quantity=="40 capsule"

replace drug_qty_revised=40 if drug_quantity=="40 capsules"
replace drug_type_revised=1 if drug_quantity=="40 capsules"

replace drug_qty_revised=40 if drug_quantity=="40 tablet"
replace drug_type_revised=1 if drug_quantity=="40 tablet"

replace drug_qty_revised=40 if drug_quantity=="40 tablets"
replace drug_type_revised=1 if drug_quantity=="40 tablets"

replace drug_qty_revised=400 if drug_quantity=="400 millilitres"
replace drug_type_revised=2 if drug_quantity=="400 millilitres"

replace drug_qty_revised=400 if drug_quantity=="400 ml"
replace drug_type_revised=2 if drug_quantity=="400 ml"

replace drug_qty_revised=41 if drug_quantity=="41 tablet"
replace drug_type_revised=1 if drug_quantity=="41 tablet"

replace drug_qty_revised=42 if drug_quantity=="42 capsule"
replace drug_type_revised=1 if drug_quantity=="42 capsule"

replace drug_qty_revised=42 if drug_quantity=="42 capsules"
replace drug_type_revised=1 if drug_quantity=="42 capsules"

replace drug_qty_revised=42 if drug_quantity=="42 tablet"
replace drug_type_revised=1 if drug_quantity=="42 tablet"

replace drug_qty_revised=42 if drug_quantity=="42 tablet(s) - 50 mg"
replace drug_type_revised=1 if drug_quantity=="42 tablet(s) - 50 mg"

replace drug_qty_revised=42 if drug_quantity=="42 tablets"
replace drug_type_revised=1 if drug_quantity=="42 tablets"
```

```
replace drug_qty_revised=420 if drug_quantity=="420 millilitres"
replace drug_type_revised=2 if drug_quantity=="420 millilitres"

replace drug_qty_revised=420 if drug_quantity=="420 ml"
replace drug_type_revised=2 if drug_quantity=="420 ml"

replace drug_qty_revised=43 if drug_quantity=="43 tablet"
replace drug_type_revised=1 if drug_quantity=="43 tablet"

replace drug_qty_revised=45 if drug_quantity=="45 capsule"
replace drug_type_revised=1 if drug_quantity=="45 capsule"

replace drug_qty_revised=45 if drug_quantity=="45 capsules"
replace drug_type_revised=1 if drug_quantity=="45 capsules"

replace drug_qty_revised=45 if drug_quantity=="45 ml"
replace drug_type_revised=2 if drug_quantity=="45 ml"

replace drug_qty_revised=45 if drug_quantity=="45 tablet"
replace drug_type_revised=1 if drug_quantity=="45 tablet"

replace drug_qty_revised=45 if drug_quantity=="45 tablets"
replace drug_type_revised=1 if drug_quantity=="45 tablets"

replace drug_qty_revised=450 if drug_quantity=="450 ml"
replace drug_type_revised=2 if drug_quantity=="450 ml"

replace drug_qty_revised=46 if drug_quantity=="46 tablet"
replace drug_type_revised=1 if drug_quantity=="46 tablet"

replace drug_qty_revised=47 if drug_quantity=="47 tablet"
replace drug_type_revised=1 if drug_quantity=="47 tablet"

replace drug_qty_revised=48 if drug_quantity=="48 tablet"
replace drug_type_revised=1 if drug_quantity=="48 tablet"

replace drug_qty_revised=48 if drug_quantity=="48 tablets"
replace drug_type_revised=1 if drug_quantity=="48 tablets"

replace drug_qty_revised=49 if drug_quantity=="49 tablet"
replace drug_type_revised=1 if drug_quantity=="49 tablet"

replace drug_qty_revised=49 if drug_quantity=="49 tablets"
replace drug_type_revised=1 if drug_quantity=="49 tablets"

replace drug_qty_revised=5 if drug_quantity=="5 capsule"
replace drug_type_revised=1 if drug_quantity=="5 capsule"

replace drug_qty_revised=5 if drug_quantity=="5 capsules"
```

```
replace drug_type_revised=1 if drug_quantity=="5 capsules"

replace drug_qty_revised=750 if drug_quantity=="5 packs of 150 mls"
replace drug_type_revised=2 if drug_quantity=="5 packs of 150 mls"

replace drug_qty_revised=140 if drug_quantity=="5 packs of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="5 packs of 28 capsule(s)"

replace drug_qty_revised=150 if drug_quantity=="5 packs of 30 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="5 packs of 30 capsule(s)"

replace drug_qty_revised=150 if drug_quantity=="5 packs of 30 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="5 packs of 30 tablet(s)"

replace drug_qty_revised=5 if drug_quantity=="5 tablet"
replace drug_type_revised=1 if drug_quantity=="5 tablet"

replace drug_qty_revised=5 if drug_quantity=="5 tablet - 2 mg"
replace drug_type_revised=1 if drug_quantity=="5 tablet - 2 mg"

replace drug_qty_revised=5 if drug_quantity=="5 tablets"
replace drug_type_revised=1 if drug_quantity=="5 tablets"

replace drug_qty_revised=50 if drug_quantity=="50 capsule"
replace drug_type_revised=1 if drug_quantity=="50 capsule"

replace drug_qty_revised=50 if drug_quantity=="50 millilitres"
replace drug_type_revised=2 if drug_quantity=="50 millilitres"

replace drug_qty_revised=50 if drug_quantity=="50 ml - 10 mg/5 ml"
replace drug_type_revised=2 if drug_quantity=="50 ml - 10 mg/5 ml"

replace drug_qty_revised=50 if drug_quantity=="50 tablet"
replace drug_type_revised=1 if drug_quantity=="50 tablet"

replace drug_qty_revised=500 if drug_quantity=="500 millilitres"
replace drug_type_revised=2 if drug_quantity=="500 millilitres"

replace drug_qty_revised=500 if drug_quantity=="500 ml"
replace drug_type_revised=2 if drug_quantity=="500 ml"

replace drug_qty_revised=53 if drug_quantity=="53 tablets"
replace drug_type_revised=1 if drug_quantity=="53 tablets"

replace drug_qty_revised=54 if drug_quantity=="54 capsule"
replace drug_type_revised=1 if drug_quantity=="54 capsule"

replace drug_qty_revised=54 if drug_quantity=="54 tablet"
replace drug_type_revised=1 if drug_quantity=="54 tablet"
```

```
replace drug_qty_revised=55 if drug_quantity=="55 ml"
replace drug_type_revised=2 if drug_quantity=="55 ml"

replace drug_qty_revised=56 if drug_quantity=="56  tabs"
replace drug_type_revised=1 if drug_quantity=="56  tabs"

replace drug_qty_revised=56 if drug_quantity=="56  tabs"
replace drug_type_revised=1 if drug_quantity=="56  tabs"

replace drug_qty_revised=56 if drug_quantity=="56 - tablet(s)"
replace drug_type_revised=1 if drug_quantity=="56 - tablet(s)"

replace drug_qty_revised=56 if drug_quantity=="56 CAPSULE"
replace drug_type_revised=1 if drug_quantity=="56 CAPSULE"

replace drug_qty_revised=56 if drug_quantity=="56 CAPSULE(S)"
replace drug_type_revised=1 if drug_quantity=="56 CAPSULE(S)"

replace drug_qty_revised=56 if drug_quantity=="56 TABLET"
replace drug_type_revised=1 if drug_quantity=="56 TABLET"

replace drug_qty_revised=56 if drug_quantity=="56 capsule"
replace drug_type_revised=1 if drug_quantity=="56 capsule"

replace drug_qty_revised=56 if drug_quantity=="56 capsule   Temp. - 20 mg"
replace drug_type_revised=1 if drug_quantity=="56 capsule   Temp. - 20 mg"

replace drug_qty_revised=56 if drug_quantity=="56 capsule - 100 mg"
replace drug_type_revised=1 if drug_quantity=="56 capsule - 100 mg"

replace drug_qty_revised=56 if drug_quantity=="56 capsule - 20 mg"
replace drug_type_revised=1 if drug_quantity=="56 capsule - 20 mg"

replace drug_qty_revised=56 if drug_quantity=="56 capsule - 25 mg"
replace drug_type_revised=1 if drug_quantity=="56 capsule - 25 mg"

replace drug_qty_revised=56 if drug_quantity=="56 capsule(s) - 25 mg"
replace drug_type_revised=1 if drug_quantity=="56 capsule(s) - 25 mg"

replace drug_qty_revised=56 if drug_quantity=="56 capsules"
replace drug_type_revised=1 if drug_quantity=="56 capsules"

replace drug_qty_revised=56 if drug_quantity=="56 tab"
replace drug_type_revised=1 if drug_quantity=="56 tab"

replace drug_qty_revised=56 if drug_quantity=="56 tablet"
replace drug_type_revised=1 if drug_quantity=="56 tablet"

replace drug_qty_revised=56 if drug_quantity=="56 tablet - 10 mg"
replace drug_type_revised=1 if drug_quantity=="56 tablet - 10 mg"
```

```
replace drug_qty_revised=56 if drug_quantity=="56 tablet - 100 mg"
replace drug_type_revised=1 if drug_quantity=="56 tablet - 100 mg"

replace drug_qty_revised=56 if drug_quantity=="56 tablet - 20 mg"
replace drug_type_revised=1 if drug_quantity=="56 tablet - 20 mg"

replace drug_qty_revised=56 if drug_quantity=="56 tablet - 37.5 mg"
replace drug_type_revised=1 if drug_quantity=="56 tablet - 37.5 mg"

replace drug_qty_revised=56 if drug_quantity=="56 tablet - 50 mg"
replace drug_type_revised=1 if drug_quantity=="56 tablet - 50 mg"

replace drug_qty_revised=56 if drug_quantity=="56 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="56 tablet(s)"

replace drug_qty_revised=56 if drug_quantity=="56 tablets"
replace drug_type_revised=1 if drug_quantity=="56 tablets"

replace drug_qty_revised=56 if drug_quantity=="56 tablets - 20 mg"
replace drug_type_revised=1 if drug_quantity=="56 tablets - 20 mg"

replace drug_qty_revised=6 if drug_quantity=="6 capsule"
replace drug_type_revised=1 if drug_quantity=="6 capsule"

replace drug_qty_revised=6 if drug_quantity=="6 capsules"
replace drug_type_revised=1 if drug_quantity=="6 capsules"

replace drug_qty_revised=168 if drug_quantity=="6 packs of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="6 packs of 28 capsule(s)"

replace drug_qty_revised=168 if drug_quantity=="6 packs of 28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="6 packs of 28 tablet(s)"

replace drug_qty_revised=180 if drug_quantity=="6 packs of 30 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="6 packs of 30 capsule(s)"

replace drug_qty_revised=180 if drug_quantity=="6 packs of 30 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="6 packs of 30 tablet(s)"

replace drug_qty_revised=6 if drug_quantity=="6 tablet"
replace drug_type_revised=1 if drug_quantity=="6 tablet"

replace drug_qty_revised=6 if drug_quantity=="6 tablets"
replace drug_type_revised=1 if drug_quantity=="6 tablets"

replace drug_qty_revised=60 if drug_quantity=="60  cap"
replace drug_type_revised=1 if drug_quantity=="60  cap"

replace drug_qty_revised=60 if drug_quantity=="60 - tablet(s)"
```

```
replace drug_type_revised=1 if drug_quantity=="60 - tablet(s)"

replace drug_qty_revised=60 if drug_quantity=="60 CAPSULE"
replace drug_type_revised=1 if drug_quantity=="60 CAPSULE"

replace drug_qty_revised=60 if drug_quantity=="60 capsule"
replace drug_type_revised=1 if drug_quantity=="60 capsule"

replace drug_qty_revised=60 if drug_quantity=="60 capsule"
replace drug_type_revised=1 if drug_quantity=="60 capsule"

replace drug_qty_revised=60 if drug_quantity=="60 capsule - 20 mg"
replace drug_type_revised=1 if drug_quantity=="60 capsule - 20 mg"

replace drug_qty_revised=60 if drug_quantity=="60 capsules"
replace drug_type_revised=1 if drug_quantity=="60 capsules"

replace drug_qty_revised=60 if drug_quantity=="60 tablet"
replace drug_type_revised=1 if drug_quantity=="60 tablet"

replace drug_qty_revised=60 if drug_quantity=="60 tablets"
replace drug_type_revised=1 if drug_quantity=="60 tablets"

replace drug_qty_revised=600 if drug_quantity=="600 ml"
replace drug_type_revised=2 if drug_quantity=="600 ml"

replace drug_qty_revised=63 if drug_quantity=="63 capsule"
replace drug_type_revised=1 if drug_quantity=="63 capsule"

replace drug_qty_revised=63 if drug_quantity=="63 tablet"
replace drug_type_revised=1 if drug_quantity=="63 tablet"

replace drug_qty_revised=7 if drug_quantity=="7 capsule"
replace drug_type_revised=1 if drug_quantity=="7 capsule"

replace drug_qty_revised=7 if drug_quantity=="7 capsules"
replace drug_type_revised=1 if drug_quantity=="7 capsules"

replace drug_qty_revised=196 if drug_quantity=="7 packs of 28 tablet(s)"
replace drug_type_revised=1 if drug_quantity=="7 packs of 28 tablet(s)"

replace drug_qty_revised=7 if drug_quantity=="7 tab"
replace drug_type_revised=1 if drug_quantity=="7 tab"

replace drug_qty_revised=7 if drug_quantity=="7 tablet"
replace drug_type_revised=1 if drug_quantity=="7 tablet"

replace drug_qty_revised=7 if drug_quantity=="7 tablet - 2 mg"
replace drug_type_revised=1 if drug_quantity=="7 tablet - 2 mg"
```

```
replace drug_qty_revised=7 if drug_quantity=="7 tablets"
replace drug_type_revised=1 if drug_quantity=="7 tablets"

replace drug_qty_revised=7 if drug_quantity=="7 tabs"
replace drug_type_revised=1 if drug_quantity=="7 tabs"

replace drug_qty_revised=70 if drug_quantity=="70 millilitres"
replace drug_type_revised=2 if drug_quantity=="70 millilitres"

replace drug_qty_revised=70 if drug_quantity=="70 ml"
replace drug_type_revised=2 if drug_quantity=="70 ml"

replace drug_qty_revised=70 if drug_quantity=="70 ml - 20 mg/5 ml"
replace drug_type_revised=2 if drug_quantity=="70 ml - 20 mg/5 ml"

replace drug_qty_revised=70 if drug_quantity=="70 tablet"
replace drug_type_revised=1 if drug_quantity=="70 tablet"

replace drug_qty_revised=70 if drug_quantity=="70 tablets"
replace drug_type_revised=1 if drug_quantity=="70 tablets"

replace drug_qty_revised=700 if drug_quantity=="700 ml"
replace drug_type_revised=2 if drug_quantity=="700 ml"

replace drug_qty_revised=72 if drug_quantity=="72 tablet"
replace drug_type_revised=1 if drug_quantity=="72 tablet"

replace drug_qty_revised=8 if drug_quantity=="8 capsule"
replace drug_type_revised=1 if drug_quantity=="8 capsule"

replace drug_qty_revised=8 if drug_quantity=="8 capsules"
replace drug_type_revised=1 if drug_quantity=="8 capsules"

replace drug_qty_revised=224 if drug_quantity=="8 packs of 28 capsule(s)"
replace drug_type_revised=1 if drug_quantity=="8 packs of 28 capsule(s)"

replace drug_qty_revised=560 if drug_quantity=="8 packs of 70 mls"
replace drug_type_revised=2 if drug_quantity=="8 packs of 70 mls"

replace drug_qty_revised=8 if drug_quantity=="8 tablet"
replace drug_type_revised=1 if drug_quantity=="8 tablet"

replace drug_qty_revised=8 if drug_quantity=="8 tablet - 2 mg"
replace drug_type_revised=1 if drug_quantity=="8 tablet - 2 mg"

replace drug_qty_revised=8 if drug_quantity=="8 tablets"
replace drug_type_revised=1 if drug_quantity=="8 tablets"

replace drug_qty_revised=80 if drug_quantity=="80 capsule"
replace drug_type_revised=1 if drug_quantity=="80 capsule"
```

```
replace drug_qty_revised=80 if drug_quantity=="80 tablet"
replace drug_type_revised=1 if drug_quantity=="80 tablet"

replace drug_qty_revised=800 if drug_quantity=="800 ml"
replace drug_type_revised=2 if drug_quantity=="800 ml"

replace drug_qty_revised=83 if drug_quantity=="83 tablet"
replace drug_type_revised=1 if drug_quantity=="83 tablet"

replace drug_qty_revised=84 if drug_quantity=="84 capsule"
replace drug_type_revised=1 if drug_quantity=="84 capsule"

replace drug_qty_revised=84 if drug_quantity=="84 capsules"
replace drug_type_revised=1 if drug_quantity=="84 capsules"

replace drug_qty_revised=84 if drug_quantity=="84 tablet"
replace drug_type_revised=1 if drug_quantity=="84 tablet"

replace drug_qty_revised=84 if drug_quantity=="84 tablet - 20 mg"
replace drug_type_revised=1 if drug_quantity=="84 tablet - 20 mg"

replace drug_qty_revised=84 if drug_quantity=="84 tablets"
replace drug_type_revised=1 if drug_quantity=="84 tablets"

replace drug_qty_revised=840 if drug_quantity=="840 ml"
replace drug_type_revised=2 if drug_quantity=="840 ml"

replace drug_qty_revised=86 if drug_quantity=="86 capsule"
replace drug_type_revised=1 if drug_quantity=="86 capsule"

replace drug_qty_revised=87 if drug_quantity=="87 tablet"
replace drug_type_revised=1 if drug_quantity=="87 tablet"

replace drug_qty_revised=9 if drug_quantity=="9 capsule"
replace drug_type_revised=1 if drug_quantity=="9 capsule"

replace drug_qty_revised=9 if drug_quantity=="9 capsules"
replace drug_type_revised=1 if drug_quantity=="9 capsules"

replace drug_qty_revised=9 if drug_quantity=="9 tablet"
replace drug_type_revised=1 if drug_quantity=="9 tablet"

replace drug_qty_revised=9 if drug_quantity=="9 tablets"
replace drug_type_revised=1 if drug_quantity=="9 tablets"

replace drug_qty_revised=90 if drug_quantity=="90 capsule"
replace drug_type_revised=1 if drug_quantity=="90 capsule"

replace drug_qty_revised=90 if drug_quantity=="90 capsules"
```

```
replace drug_type_revised=1 if drug_quantity=="90 capsules"

replace drug_qty_revised=90 if drug_quantity=="90 millilitres"
replace drug_type_revised=2 if drug_quantity=="90 millilitres"

replace drug_qty_revised=90 if drug_quantity=="90 tablet"
replace drug_type_revised=1 if drug_quantity=="90 tablet"

replace drug_qty_revised=90 if drug_quantity=="90 tablets"
replace drug_type_revised=1 if drug_quantity=="90 tablets"

replace drug_qty_revised=98 if drug_quantity=="98 tablet"
replace drug_type_revised=1 if drug_quantity=="98 tablet"

**Adding drug price**
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"

gen drug_name_revised = "Amitriptyline 50mg/5ml oral solution" if
strpos(drug_name,"Amitriptyline 50mg/5ml")
gen drug_price = 0.128 if strpos(drug_name,"Amitriptyline 50mg/5ml")

replace drug_name_revised = "Buspirone 5mg" if strpos(drug_name, "BUSPIRONE")
replace drug_price = 0.18067 if strpos(drug_name, "BUSPIRONE")

replace drug_name_revised = "Buspirone 5mg" if strpos(drug_name, "Buspirone 5mg")
replace drug_price = 0.18067 if strpos(drug_name, "Buspirone 5mg")

replace drug_name_revised = "Buspirone 10mg" if strpos(drug_name, "Buspirone 10mg")
replace drug_price =0.291666667 if strpos(drug_name, "Buspirone 10mg")

replace drug_name_revised = "chloral hydrate 500mg/5ml" if strpos(drug_name,
"CHLORAL")
replace drug_price = 1.62833 if strpos(drug_name, "CHLORAL")

replace drug_name_revised = "chloral hydrate 500mg/5ml" if strpos(drug_name, "Chloral
hydrate")
replace drug_price = 1.62833 if strpos(drug_name, "Chloral hydrate")

replace drug_name_revised = "Chlordiazepoxide 10mg" if strpos(drug_name,
"Chlordiazepoxide 10mg")
replace drug_price =0.251  if strpos(drug_name, "Chlordiazepoxide 10mg")

replace drug_name_revised = "Chlordiazepoxide 5mg" if strpos(drug_name,
"Chlordiazepoxide 5mg")
replace drug_price =0.194  if strpos(drug_name, "Chlordiazepoxide 5mg")

replace drug_name_revised = "Circadin 2mg" if strpos(drug_name, "Circadin 2mg")
replace drug_price =0.513 if strpos(drug_name, "Circadin 2mg")
```

```
replace drug_name_revised = "Citalopram 10mg" if strpos(drug_name, "Citalopram 10mg")
replace drug_price = 0.0443  if strpos(drug_name, "Citalopram 10mg")

replace drug_name_revised = "Citalopram 20mg" if strpos(drug_name, "Citalopram 20mg")
replace drug_price = 0.0575  if strpos(drug_name, "Citalopram 20mg")

replace drug_name_revised = "Citalopram 20mg" if strpos(drug_name, "Citalopram 20mg")
replace drug_price =0.0575 if strpos(drug_name, "Citalopram 20mg")

replace drug_name_revised = "Citalopram 40mg" if strpos(drug_name, "Citalopram 40mg
tablets")
replace drug_price =0.045714286  if strpos(drug_name, "Citalopram 40mg tablets")

replace drug_name_revised = "Citalopram 40mg/ml" if strpos(drug_name, "Citalopram
40mg/ml")
replace drug_price =0.515333333 if strpos(drug_name, "Citalopram 40mg/ml")

replace drug_name_revised = "Clobazam 10mg tablets" if strpos(drug_name, "Clobazam
10mg tablets")
replace drug_price =0.215333333 if strpos(drug_name, "Clobazam 10mg tablets")

replace drug_name_revised = "Clobazam 5mg/5ml" if strpos(drug_name, "Clobazam
5mg/5ml")
replace drug_price =0.499533333 if strpos(drug_name, "Clobazam 5mg/5ml")

replace drug_name_revised = "Clomipramine 10mg" if strpos(drug_name, "Clomipramine
10mg")
replace drug_price =0.124285714 if strpos(drug_name, "Clomipramine 10mg")

replace drug_name_revised = "Clomipramine 25mg" if strpos(drug_name, "Clomipramine
25mg capsules")
replace drug_price =0.180714286 if strpos(drug_name, "Clomipramine 25mg capsules")

replace drug_name_revised = "Clomipramine 50mg" if strpos(drug_name, "Clomipramine
50mg")
replace drug_price =0.335357143  if strpos(drug_name, "Clomipramine 50mg")

replace drug_name_revised = "Dapoxetine 30mg" if strpos(drug_name, "Dapoxetine 30mg
tablets")
replace drug_price =4.903333333  if strpos(drug_name, "Dapoxetine 30mg tablets")

replace drug_name_revised = "Diazepam 2mg tablets" if strpos(drug_name, "Diazepam 2mg
tablets")
replace drug_price =0.027857143 if strpos(drug_name, "Diazepam 2mg tablets")

replace drug_name_revised = "Diazepam 2mg/5ml oral solution" if strpos(drug_name,
"Diazepam 2mg/5ml oral solution")
replace drug_price =0.6498 if strpos(drug_name, "Diazepam 2mg/5ml oral solution")
```

```
replace drug_name_revised = "Diazepam 2mg/5ml oral suspension" if strpos(drug_name, "Diazepam 2mg/5ml oral suspension")
replace drug_price =0.6031 if strpos(drug_name, "Diazepam 2mg/5ml oral suspension")

replace drug_name_revised = "Diazepam 5mg RecTubes" if strpos(drug_name, "Diazepam 5mg RecTubes")
replace drug_price =1.17 if strpos(drug_name, "Diazepam 5mg RecTubes")

replace drug_name_revised = "Dosulepin 25mg" if strpos(drug_name, "Dosulepin 25mg")
replace drug_price =0.059642857 if strpos(drug_name, "Dosulepin 25mg")

replace drug_name_revised = "Dosulepin 75mg" if strpos(drug_name, "Dosulepin 75mg")
replace drug_price =0.363928571 if strpos(drug_name, "Dosulepin 75mg")

replace drug_name_revised = "Doxepin 50mg" if strpos(drug_name, "Doxepin 50mg")
replace drug_price =5.5 if strpos(drug_name, "Doxepin 50mg")

replace drug_name_revised = "Duloxetine 20mg" if strpos(drug_name, "Duloxetine 20mg")
replace drug_price =0.081071429 if strpos(drug_name, "Duloxetine 20mg")

replace drug_name_revised = "Duloxetine 60mg" if strpos(drug_name, "Duloxetine 60mg")
replace drug_price =0.112142857 if strpos(drug_name, "Duloxetine 60mg")

replace drug_name_revised = "Escitalopram 10mg" if strpos(drug_name, "Escitalopram 10mg")
replace drug_price =0.048214286 if strpos(drug_name, "Escitalopram 10mg")

replace drug_name_revised = "Escitalopram 20mg" if strpos(drug_name, "Escitalopram 20mg")
replace drug_price =0.055357143 if strpos(drug_name, "Escitalopram 20mg")

replace drug_name_revised = "Escitalopram 5mg" if strpos(drug_name, "Escitalopram 5mg")
replace drug_price =0.041071429 if strpos(drug_name, "Escitalopram 5mg")

replace drug_name_revised = "Fluoxetine 10mg" if strpos(drug_name, "Fluoxetine 10mg")
replace drug_price =0.935333333 if strpos(drug_name, "Fluoxetine 10mg")

replace drug_name_revised = "Fluoxetine 20mg capsules" if strpos(drug_name, "Fluoxetine 20mg capsules")
replace drug_price =0.041666667 if strpos(drug_name, "Fluoxetine 20mg capsules")

replace drug_name_revised = "Fluoxetine 20mg dispersible tablets" if strpos(drug_name, "Fluoxetine 20mg dispersible tablets")
replace drug_price =0.122857143 if strpos(drug_name, "Fluoxetine 20mg dispersible tablets")

replace drug_name_revised = "Fluoxetine 20mg/5m" if strpos(drug_name, "Fluoxetine 20mg/5m")
replace drug_price =0.065285714 if strpos(drug_name, "Fluoxetine 20mg/5m")
```

```
replace drug_name_revised = "Fluoxetine 30mg capsules" if strpos(drug_name, "Fluoxetine 30mg capsules")
replace drug_price =0.104333333 if strpos(drug_name, "Fluoxetine 30mg capsules")

replace drug_name_revised = "Fluoxetine 40mg" if strpos(drug_name, "Fluoxetine 40mg")
replace drug_price =0.06 if strpos(drug_name, "Fluoxetine 40mg")

replace drug_name_revised = "Fluoxetine 60mg" if strpos(drug_name, "Fluoxetine 60mg")
replace drug_price =0.073 if strpos(drug_name, "Fluoxetine 60mg")

replace drug_name_revised = "Flupentixol 1mg" if strpos(drug_name, "Flupentixol 1mg")
replace drug_price =0.081 if strpos(drug_name, "Flupentixol 1mg")

replace drug_name_revised = "Flupentixol 500microgram" if strpos(drug_name, "Flupentixol 500microgram")
replace drug_price =0.048 if strpos(drug_name, "Flupentixol 500microgram")

replace drug_name_revised = "Fluvoxamine 100mg" if strpos(drug_name, "Fluvoxamine 100mg")
replace drug_price =0.699333333 if strpos(drug_name, "Fluvoxamine 100mg")

replace drug_name_revised = "Fluvoxamine 50mg" if strpos(drug_name, "Fluvoxamine 50mg")
replace drug_price =0.285 if strpos(drug_name, "Fluvoxamine 50mg")

replace drug_name_revised = "Hydroxyzine 25mg" if strpos(drug_name, "Hydroxyzine 25mg")
replace drug_price =0.039285714 if strpos(drug_name, "Hydroxyzine 25mg")

replace drug_name_revised = "Imipramine 25mg tablets" if strpos(drug_name, "Imipramine 25mg tablets")
replace drug_price =0.058571429 if strpos(drug_name, "Imipramine 25mg tablets")

replace drug_name_revised = "Imipramine 25mg/5ml" if strpos(drug_name, "Imipramine 25mg/5ml")
replace drug_price =1.666666667 if strpos(drug_name, "Imipramine 25mg/5ml")

replace drug_name_revised = "Lorazepam 1mg" if strpos(drug_name, "LORAZEPAM")
replace drug_price =0.061071429 if strpos(drug_name, "LORAZEPAM")

replace drug_name_revised = "Lofepramine 70mg" if strpos(drug_name, "Lofepramine 70mg")
replace drug_price =0.226785714 if strpos(drug_name, "Lofepramine 70mg")

replace drug_name_revised = "Loprazolam 1mg" if strpos(drug_name, "Loprazolam 1mg")
replace drug_price =0.883928571 if strpos(drug_name, "Loprazolam 1mg")

replace drug_name_revised = "Lorazepam 1mg" if strpos(drug_name, "Lorazepam 1mg")
replace drug_price =0.061071429 if strpos(drug_name, "Lorazepam 1mg")
```

```
replace drug_name_revised = "Lorazepam 2.5mg" if strpos(drug_name, "Lorazepam 2.5mg")
replace drug_price =0.106785714 if strpos(drug_name, "Lorazepam 2.5mg")

replace drug_name_revised = "Lorazepam 0.5mg" if strpos(drug_name, "Lorazepam
500microgram")
replace drug_price =1.234642857 if strpos(drug_name, "Lorazepam 500microgram")

replace drug_name_revised = "Lormetazepam 1mg" if strpos(drug_name, "Lormetazepam
1mg")
replace drug_price =0.592333333 if strpos(drug_name, "Lormetazepam 1mg")

replace drug_name_revised = "Melatonin 1mg" if strpos(drug_name, "MELATONIN")
replace drug_price =1 if strpos(drug_name, "MELATONIN ")

replace drug_name_revised = "MIRTAZAPINE tablets 30mg" if strpos(drug_name,
"MIRTAZAPINE tablets 30mg")
replace drug_price =0.037857143 if strpos(drug_name, "MIRTAZAPINE tablets 30mg")

replace drug_name_revised = "Melatonin 1mg capsules" if strpos(drug_name, "Melatonin
1mg capsules")
replace drug_price =0.590666667 if strpos(drug_name, "Melatonin 1mg capsules")

replace drug_name_revised = "Melatonin 1mg modified-release" if strpos(drug_name,
"Melatonin 1mg modified-release")
replace drug_price =0.686666667 if strpos(drug_name, "Melatonin 1mg modified-release")

replace drug_name_revised = "Melatonin 1mg/ml" if strpos(drug_name, "Melatonin
1mg/ml")
replace drug_price =1.1852 if strpos(drug_name, "Melatonin 1mg/ml")

replace drug_name_revised = "Melatonin 2mg capsules" if strpos(drug_name, "Melatonin
2mg capsules")
replace drug_price =1.916666667 if strpos(drug_name, "Melatonin 2mg capsules")

replace drug_name_revised = "Melatonin 2mg modified-release" if strpos(drug_name,
"Melatonin 2mg modified-release")
replace drug_price =0.513 if strpos(drug_name, "Melatonin 2mg modified-release")

replace drug_name_revised = "Melatonin 3mg capsules" if strpos(drug_name, "Melatonin
3mg capsules")
replace drug_price =2.083333333 if strpos(drug_name, "Melatonin 3mg capsules")

replace drug_name_revised = "Melatonin 3mg modified-release " if strpos(drug_name,
"Melatonin 3mg modified-release ")
replace drug_price =3.433333333 if strpos(drug_name, "Melatonin 3mg modified-release ")

replace drug_name_revised = "Melatonin 5mg" if strpos(drug_name, "Melatonin 5mg")
replace drug_price =3.5 if strpos(drug_name, "Melatonin 5mg")
```

```
replace drug_name_revised = "Mirtazapine 15mg orodispersible" if strpos(drug_name, "Mirtazapine 15mg orodispersible")
replace drug_price =0.063333333 if strpos(drug_name, "Mirtazapine 15mg orodispersible")

replace drug_name_revised = "Mirtazapine 15mg tablets" if strpos(drug_name, "Mirtazapine 15mg tablets")
replace drug_price =0.0375 if strpos(drug_name, "Mirtazapine 15mg tablets")

replace drug_name_revised = "Mirtazapine 30mg orodispersible" if strpos(drug_name, "Mirtazapine 30mg orodispersible")
replace drug_price =0.067333333 if strpos(drug_name, "Mirtazapine 30mg orodispersible")

replace drug_name_revised = "Mirtazapine 30mg tablets" if strpos(drug_name, "Mirtazapine 30mg tablets")
replace drug_price =0.037857143 if strpos(drug_name, "Mirtazapine 30mg tablets")

replace drug_name_revised = "Mirtazapine 45mg orodispersible" if strpos(drug_name, "Mirtazapine 45mg orodispersible")
replace drug_price =0.075666667 if strpos(drug_name, "Mirtazapine 45mg orodispersible")

replace drug_name_revised = "Mirtazapine 45mg tablets" if strpos(drug_name, "Mirtazapine 45mg tablets")
replace drug_price =0.048571429 if strpos(drug_name, "Mirtazapine 45mg tablets")

replace drug_name_revised = "Moclobemide 150mg tablets" if strpos(drug_name, "Moclobemide 150mg tablets")
replace drug_price =0.311 if strpos(drug_name, "Moclobemide 150mg tablets")

replace drug_name_revised = "Nitrazepam 5mg tablets" if strpos(drug_name, "Nitrazepam 5mg tablets")
replace drug_price =0.094285714 if strpos(drug_name, "Nitrazepam 5mg tablets")

replace drug_name_revised = "Nortriptyline 10mg" if strpos(drug_name, "Nortriptyline 10mg")
replace drug_price =0.0206 if strpos(drug_name, "Nortriptyline 10mg")

replace drug_name_revised = "Nortriptyline 25mg" if strpos(drug_name, "Nortriptyline 25mg")
replace drug_price =0.0253 if strpos(drug_name, "Nortriptyline 25mg")

replace drug_name_revised = "Oxazepam 10mg" if strpos(drug_name, "Oxazepam 10mg")
replace drug_price =0.164285714 if strpos(drug_name, "Oxazepam 10mg")

replace drug_name_revised = "Oxazepam 15mg" if strpos(drug_name, "Oxazepam 15mg")
replace drug_price =0.108214286 if strpos(drug_name, "Oxazepam 15mg")

replace drug_name_revised = "Paroxetine 10mg" if strpos(drug_name, "PAROXETINE tablets 10mg")
replace drug_price =0.069642857 if strpos(drug_name, "PAROXETINE tablets 10mg")
```

```
replace drug_name_revised = "Paroxetine 10mg" if strpos(drug_name, "Paroxetine 10mg")
replace drug_price =0.069642857 if strpos(drug_name, "Paroxetine 10mg")

replace drug_name_revised = "Paroxetine 20mg" if strpos(drug_name, "Paroxetine 20mg")
replace drug_price =0.048 if strpos(drug_name, "Paroxetine 20mg")

replace drug_name_revised = "Paroxetine 30mg" if strpos(drug_name, "Paroxetine 30mg")
replace drug_price =0.053666667 if strpos(drug_name, "Paroxetine 30mg")

replace drug_name_revised = "Paroxetine 40mg" if strpos(drug_name, "Paroxetine 40mg")
replace drug_price =0.518 if strpos(drug_name, "Paroxetine 40mg")

replace drug_name_revised = "Promethazine hydrochloride 10mg" if strpos(drug_name,
"Promethazine hydrochloride 10mg")
replace drug_price =0.488571429 if strpos(drug_name, "Promethazine hydrochloride 10mg")

replace drug_name_revised = "Prothiaden 25mg" if strpos(drug_name, "Prothiaden 25mg")
replace drug_price =0.059642857 if strpos(drug_name, "Prothiaden 25mg")

replace drug_name_revised = "Sertraline 100mg" if strpos(drug_name, "Sertraline 100mg")
replace drug_price =0.046071429 if strpos(drug_name, "Sertraline 100mg")

replace drug_name_revised = "Sertraline 25mg" if strpos(drug_name, "Sertraline 25mg")
replace drug_price =0.599285714 if strpos(drug_name, "Sertraline 25mg")

replace drug_name_revised = "Sertraline 50mg tablets" if strpos(drug_name, "Sertraline
50mg tablets")
replace drug_price =0.038928571 if strpos(drug_name, "Sertraline 50mg tablets")

replace drug_name_revised = "Sertraline 50mg/5ml" if strpos(drug_name, "Sertraline
50mg/5ml")
replace drug_price =0.038928571 if strpos(drug_name, "Sertraline 50mg/5ml")

replace drug_name_revised = "Slenyto 1mg" if strpos(drug_name, "Slenyto 1mg")
replace drug_price =0.686666667 if strpos(drug_name, "Slenyto 1mg")

replace drug_name_revised = "Trazodone 100mg" if strpos(drug_name, "Trazodone 100mg")
replace drug_price =0.477678571 if strpos(drug_name, "Trazodone 100mg")

replace drug_name_revised = "Trazodone 150mg tablets" if strpos(drug_name, "Trazodone
150mg tablets")
replace drug_price =0.080357143 if strpos(drug_name, "Trazodone 150mg tablets")

replace drug_name_revised = "Trazodone 50mg" if strpos(drug_name, "Trazodone 50mg")
replace drug_price =0.278928571 if strpos(drug_name, "Trazodone 50mg")

replace drug_name_revised = "Trazodone 50mg/5ml" if strpos(drug_name, "Trazodone
50mg/5ml")
replace drug_price =0.088083333 if strpos(drug_name, "Trazodone 50mg/5ml")
```

```
replace drug_name_revised = "Venlafaxine 150mg modified-release" if strpos(drug_name, "Venlafaxine 150mg modified-release")
replace drug_price =0.667857143 if strpos(drug_name, "Venlafaxine 150mg modified-release")

replace drug_name_revised = "Venlafaxine 225mg modified-release" if strpos(drug_name, "Venlafaxine 225mg modified-release")
replace drug_price =1.12 if strpos(drug_name, "Venlafaxine 225mg modified-release")

replace drug_name_revised = "Venlafaxine 300mg modified-release" if strpos(drug_name, "Venlafaxine 300mg modified-release")
replace drug_price =1.25 if strpos(drug_name, "Venlafaxine 300mg modified-release")

replace drug_name_revised = "Venlafaxine 37.5mg modified-release" if strpos(drug_name, "Venlafaxine 37.5mg modified-release")
replace drug_price =0.22 if strpos(drug_name, "Venlafaxine 37.5mg modified-release")

replace drug_name_revised = "Venlafaxine 37.5mg tablets" if strpos(drug_name, "Venlafaxine 37.5mg tablets")
replace drug_price =0.032857143 if strpos(drug_name, "Venlafaxine 37.5mg tablets")

replace drug_name_revised = "Venlafaxine 75mg modified-release" if strpos(drug_name, "Venlafaxine 75mg modified")
replace drug_price= 0.086 if strpos(drug_name, "Venlafaxine 75mg modified")


replace drug_name_revised = "Venlafaxine 75mg tablets" if strpos(drug_name, "Venlafaxine 75mg tablets")
replace drug_price =0.133214286 if strpos(drug_name, "Venlafaxine 75mg tablets")

replace drug_name_revised = "xx" if strpos(drug_name, "Venlalic XL 150mg")
replace drug_price =0.13 if strpos(drug_name, "Venlalic XL 150mg")

replace drug_name_revised = "Venlalic XL 75mg tablets" if strpos(drug_name, "Venlalic XL 75mg tablets")
replace drug_price =0.133214286 if strpos(drug_name, "Venlalic XL 75mg tablets")

replace drug_name_revised = "Vensir XL 150mg" if strpos(drug_name, "Vensir XL 150mg")
replace drug_price =0.13 if strpos(drug_name, "Vensir XL 150mg")

replace drug_name_revised = "Vensir XL 225mg" if strpos(drug_name, "Vensir XL 225mg")
replace drug_price =1.12 if strpos(drug_name, "Vensir XL 225mg")

replace drug_name_revised = "Vensir XL 75mg capsules" if strpos(drug_name, "Vensir XL 75mg capsules")
replace drug_price =0.102142857 if strpos(drug_name, "Vensir XL 75mg capsules")

replace drug_name_revised = "Zolpidem 10mg" if strpos(drug_name, "Zolpidem 10mg")
replace drug_price =0.044285714 if strpos(drug_name, "Zolpidem 10mg")
```

```
replace drug_name_revised = "Zolpidem 5mg" if strpos(drug_name, "Zolpidem 5mg")
replace drug_price =0.044285714 if strpos(drug_name, "Zolpidem 5mg")

replace drug_name_revised = "Zopiclone 3.75mg tablets" if strpos(drug_name, "Zopiclone
3.75mg tablets")
replace drug_price =0.025 if strpos(drug_name, "Zopiclone 3.75mg tablets")

replace drug_name_revised = "Zopiclone 7.5mg tablets" if strpos(drug_name, "Zopiclone
7.5mg tablets")
replace drug_price =0.032857143 if strpos(drug_name, "Zopiclone 7.5mg tablets")

replace drug_name_revised = "chloral hydrate mixture 500mg/5ml" if strpos(drug_name,
"chloral hydrate mixture 500mg/5ml")
replace drug_price =1.628333333 if strpos(drug_name, "chloral hydrate mixture
500mg/5ml")

replace drug_name_revised = "melatonin oral liquid sugar-free" if strpos(drug_name,
"melatonin oral liquid sugar-free")
replace drug_price =1 if strpos(drug_name, "melatonin oral liquid sugar-free")

**Calculating the total cost**
gen total_drug_cost= drug_price* drug_qty_revised

**Generating variables for the total cost per person by year**
bysort id: gen sum_2010=sum(total_drug_cost) if yr==2010
bysort id: gen sum_2011=sum(total_drug_cost) if yr==2011
bysort id: gen sum_2012=sum(total_drug_cost) if yr==2012
bysort id: gen sum_2013=sum(total_drug_cost) if yr==2013
bysort id: gen sum_2014=sum(total_drug_cost) if yr==2014
bysort id: gen sum_2015=sum(total_drug_cost) if yr==2015
bysort id: gen sum_2016=sum(total_drug_cost) if yr==2016
bysort id: gen sum_2017=sum(total_drug_cost) if yr==2017
bysort id: gen sum_2018=sum(total_drug_cost) if yr==2018
bysort id: gen sum_2019=sum(total_drug_cost) if yr==2019
bysort id: gen sum_2020=sum(total_drug_cost) if yr==2020
bysort id: gen sum_2021=sum(total_drug_cost) if yr==2021

drop dup
quietly by id: gen dup = cond(_N==1,0,_n)

*That code was giving me the sum in different rows, and each year for each person had
multiple values because it was summing at different levels.
*I'm now creating multiple datasets for each year, keeping the max value for the sum and
dropping duplicates.*

*2010*
keep if yr==2010
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2010.dta"
bysort id: egen sum_2010_revised = max(sum_2010)
```

```
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2010_revised==sum_2010
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2010.dta", replace
clear

*2011*
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2011
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2011.dta"
bysort id: egen sum_2011_revised = max(sum_2011)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2011_revised==sum_2011
keep if maxvaluecheckr==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2011.dta", replace
clear

*2012*
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2012
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2012.dta"
bysort id: egen sum_2012_revised = max(sum_2012)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2012_revised==sum_2012
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2012.dta", replace

*2013
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2013
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2013.dta"
bysort id: egen sum_2013_revised = max(sum_2013)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2013_revised==sum_2013
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2013.dta", replace
```

```
clear

*2014
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2014
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2014.dta"
bysort id: egen sum_2014_revised = max(sum_2014)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2014_revised==sum_2014
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2014.dta", replace
clear

*2015
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2015
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2015.dta"
bysort id: egen sum_2015_revised = max(sum_2015)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2015_revised==sum_2015
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2015.dta", replace
clear


*2016
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2016
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2016.dta"
bysort id: egen sum_2016_revised = max(sum_2016)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2016_revised==sum_2016
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2016.dta", replace
clear

*2017
```

```
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2017
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2017.dta"
bysort id: egen sum_2017_revised = max(sum_2017)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2017_revised==sum_2017
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2017.dta", replace
clear

*2018
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2018
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2018.dta"
bysort id: egen sum_2018_revised = max(sum_2018)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2018_revised==sum_2018
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2018.dta", replace
clear

*2019
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2019
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2019.dta"
bysort id: egen sum_2019_revised = max(sum_2019)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2019_revised==sum_2019
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2019.dta", replace
clear

*2020
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2020
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2020.dta"
```

```
bysort id: egen sum_2020_revised = max(sum_2020)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2020_revised==sum_2020
keep if maxvaluecheck==1
duplicates drop id, force

save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2020.dta", replace
clear

*2021
use
"X:\Projects\BiB_BetterPlace_eval\1898_Green_Space_cohort_PrimaryCare_BNFcodes_cle
aned.dta"
keep if yr==2021
save "X:\Projects\BiB_BetterPlace_eval\Drugprices_byyear\Drug prices 2021.dta"
bysort id: egen sum_2021_revised = max(sum_2021)
gen maxvaluecheck=.
recode maxvaluecheck .=1 if sum_2021_revised==sum_2021
keep if maxvaluecheck==1
duplicates drop id, force
```

Additional File 1: Estimating the impact of a green space intervention on generalised anxiety disorder (GAD), and the patient health questionnaire (PHQ), and the expected net monetary benefit from the intervention

1. Introduction

This file presents the results of an additional analysis on mapping the mental health prescription data with generalised anxiety disorder (GAD), and the patient health questionnaire (PHQ) and subsequently its impact on net monetary benefit using existing mapping of GAD, and PHQ and QALYs. This analysis was originally included in an initial draft for chapter 4/ paper 3. However, it was eventually removed from the final thesis as the dataset only included mothers of a specific age, and did not include other relevant control variables. This meant that the analysis was deemed underpowered and not sufficiently reliable to be included for publication.

The methods and results of the analysis have been included in this additional file.

2. Methods

The intervention, the survey including all socio-economic variables, and mental health prescription data have been described in detail in chapter 4. The methods for the additional analysis in this supplement are described below:

2.1 Mental health status

The study estimates baseline data on common mental health disorders using baseline data on depression and anxiety from for 4475 women from the Born in Bradford Growing Up survey. The model uses self-reported results from two commonly used measures for depression and anxiety: the Patient Health Questionnaire (PHQ) tool and the Generalised Anxiety Disorder (GAD) tool. Both are widely used self-reported survey tools used to assess depression, and anxiety respectively.

The PHQ-9 captures the frequency of nine criteria for major depressive disorder over the previous two weeks (Kroenke, Spitzer and Williams, 2001). Responses are scored from 0 ("not at all") to 3 ("nearly every day"), generating a total score ranging from 0–27, that can be coverted to a four point scale of mild, moderate, moderately severe, and severe depressive symptoms (Kroenke, Spitzer and Williams, 2001). The GAD-7 assesses seven core symptoms of generalised anxiety disorder, also over the preceding two weeks (Spitzer et al., 2006). Items are rated on the same 0–3 scale, producing a total score from 0–21. Scores of 5, 10, and 15 indicate mild, moderate, and severe anxiety (Spitzer et al., 2006).

2.2 Estimating the relationship between PHQ, GAD scores and mental health prescriptions

The analysis used a generalised linear model with log-link and gamma distribution to estimate the correlation between PHQ scores and the cost of prescriptions for depression and anxiety, and GAD scores with the cost of prescriptions for depression and anxiety. The type of regression was considered appropriate because the independent variable (mental

health prescriptions from 2019) was negatively skewed with many zero values. A two-part model was not considered appropriate for this section, as here we were investigating the average change in PHQ or GAD, for a one unit change in the cost of mental health prescriptions.

The analysis uses mental health prescriptions from 2019, as the values for PHQ and GAD were collected in this year. For both PHQ and GAD, three separate models were run: (1) Unadjusted, (2) Adjusted for socio-economic covariates, (3) adjusted for socio-economic and behavioural factors. Model (2) includes additional covariates for age, ethnicity, IMD, and relationship status, and model (3) uses all the covariates from model (2) and an additional variable on physical activity.

This step was only run for women, as there were very few men (289 individuals) compared to 4,475 women.

2.3 Estimating the net monetary benefit.

The third step in the analysis was estimating the cost-effectiveness of the intervention using net monetary benefit. The incremental net monetary benefit (INMB) is defined as:

$$INMB = \lambda \times \Delta E - \Delta C$$

where $\Delta E$ is the incremental effect (i.e., change in QALYs over a one-year period) and $\Delta C$ is the cost of the intervention per person. According to NICE, an intervention is considered to be cost effective against the reference scenario (in this case, no intervention) if $INMB > 0$. In England and Wales, NICE states that $\lambda$ (the cost effectiveness threshold) falls between £20,000 – £30,000 per QALY gain (National Institute for Health and Care Excellence, 2022). This analysis presents the INMB for a range of cost-effectiveness thresholds between £10,000 – £50,000.

The $\Delta E$ was calculated by mapping the age-specific QALY for each individual using their PHQ and GAD scores, using the mapping conducted by (Mukuria et al., 2024). Expected changes in PHQ and GAD were calculated using the expected change in the cost of a mental health prescription in step 1, and translating this to an expected change in PHQ and GAD using the relationship between GAD, PHQ and mental health prescrptions established in step 2.

The NMB analysis uses a one year time-horizon and uses a provider perspective. As the time horizon is only one year, no discounting was applied.

3. Results

3.1 Expected change in PHQ and QALY

Table AF1.1 outlines the three models used to predict the relationship between mental health prescriptions with PHQ and GAD ; (1) no covariates, (2) with socio-economic covariates, and with (3) socio-economic and lifestyle covariates. From the three models, it was estimated that a one unit change in PHQ is expected to increase the cost of a

prescription for mental health by £0.85-1.09, and a one unit change in GAD is expected to increase the cost of a prescription for mental health by £0.77-0.95. The results from the first part of the analysis presented in chapter 4 found that for those who have a prescription, there will be a yearly reduction of £2.76 in mental health prescriptions, which would translate to between a 2-3 unit improvements in GAD, and a 2-3 unit improvements in PHQ.

| | Model 1: Unadjusted | Model 2: Adjusted for socio-economic factors | Model 3: Adjusted for socio-economic and lifestyle factors |
|---|---|---|---|
| Coefficient for PHQ | 0.853* | 0.912* | 1.09* |
| Coefficient for GAD | 0.767* | 0.797* | 0.954* |
| Expected change in PHQ | 3.23 | 3.03 | 2.53 |
| Expected change in GAD | 3.60 | 3.46 | 2.89 |

Table AF1.1: Regression analysis results, and expected change in PHQ and GAD from intervention
*Statistically significant at a 5% margin

3.2 Net Monetary Benefit (NMB)

Figure AF1.1 demonstrates the expected net monetary benefit of the intervention per capita over a range of values for the CEA threhold. The NMB was estimated for four scenarios based on the mapping of PHQ and GAD scores with mental health prescriptions in section 3.1. The resuls from section 3.1 find that PHQ and GAD are expected to change by 2-3 points each. This step estimates the QALY changes from the changes in GAD, and PHQ in four different scenarios outlines in figure 1. Scenario 1 and 2 shows the impact of a more conservative decrease of two points for PHQ and GAD respectively for those with a mental health prescription. Scenarios 3 and 4 represent a less conservative three point decrease in PHQ and GAD scores respectively. Each of the four scenarios represent cost-effective options for a cost-effectiveness threshold of over £15,000. For thresholds below £13,000 , scenario 2 was the only one that was not found to be cost-effective. The NMB values range from £-5 to £130 per person depending on the scenario and cost-effectiveness threshold.

For Bradford, a threshold of £20,000 - £30,000 may be considered appropriate as this is the recommended threshold used by NICE in England. This threshold would represent a NMB of between £12-£99 depending on the scenario for whether we use GAD or PHQ, and whether we use a conservative estimate.

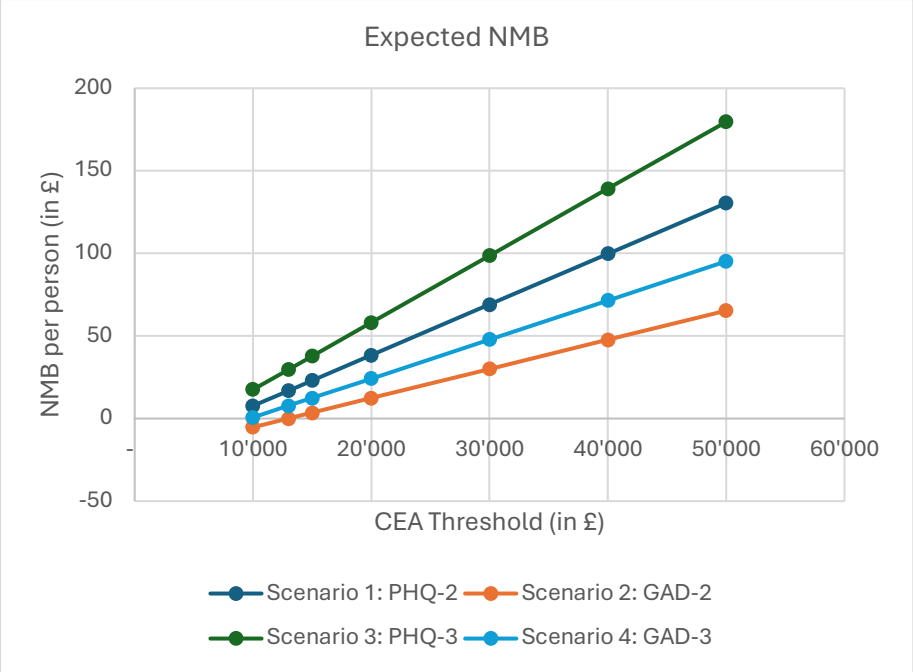



Figure AF1.1: Expected Net Monetary Benefit across a range of CEA thresholds

Additional File 2: Estimating the impact of urban green spaces on mental health prescriptions in Bradford UK

## Introduction

This file briefly describes the results of an analysis using a two-part model to evaluate the association between the number of green spaces within a 1000 metre radius and mental health prescriptions. This is similar to some existing studies on green spaces and mental health prescriptions, which have found mixed results (Aerts et al., 2022; Helbich et al., 2018). This analysis investigates the associational effect an additional urban green space to the probability of requiring a mental health prescription, and the expected cost of the prescription.

## Methods

This analysis uses variables on gender and IMD from the Born in Bradford dataset and linked mental health statistics described in detail in Chapter 4 of this thesis. This analysis also uses variables on the count of green spaces which measures all the green spaces within a distance of 1000 metres radius

The analysis also uses a two-part model decribed in more detail in Chapter 4 of this thesis. The regression model used in this analysis is described below:

Part 1:

$$Binary\ value\ indicating\ whether\ there\ was\ a\ prescription\ in\ a\ given\ year = \beta o + \beta 1 countof greenspaces + \beta 2.IMDscore + \beta 3 gender$$

Part 2:

$$Cost\ of\ a\ prescription\ in\ a\ given\ year = \beta o + \beta 1 countof greenspaces + \beta 2.IMDscore + \beta 3 gender$$

## Results & Discussion

Table AF2.1 reports the marginal effects from part 1 of the two-part model which exames the probability of requiring a prescription. Greater availability of green space within a one-kilometre buffer was associated with a statistically significant reduction in the likelihood of receiving a prescription. Each additional green space reduced the probability by 4.6 percentage points ($p<0.001$). Socioeconomic deprivation (IMD 2019 score) was positively signed but not statistically significant. Being male was associated with a 9.2 percentage point lower probability of requiring a prescription ($p<0.001$).

Table AF2.1. Marginal effects on the probability of requiring a prescription

| Variable | Coef. | Std.Err. | z | P>\|z\| | 95% CI Lower | 95% CI Upper |
|---|---|---|---|---|---|---|
| Green space count (2km) | -0.046 | 0.0068 | -6.76 | 0.0 | -0.06 | -0.033 |
| IMD 2019 score | 0.003 | 0.0021 | 1.46 | 0.144 | -0.001 | 0.007 |
| Male | -0.916 | 0.0806 | -11.37 | 0.0 | -1.074 | -0.758 |
| Constant | -3.168 | 0.106 | -29.92 | 0.0 | -3.375 | -2.96 |
| | | | | | | |

Table AF2.2 presents part two of the model, which estimates the expected change in prescription costs. In comparison to the previous model, green space availability was not significantly related to prescription expenditure (p=0.661). Neither deprivation nor gender differences were statistically significant.

Table AF2.2. Marginal effects on expected prescription costs

| Variable | Coef. | Std.Err. | z | P>\|z\| | 95% CI Lower | 95% CI Upper |
|---|---|---|---|---|---|---|
| Green space count (2km) | -0.006 | 0.0142 | -0.44 | 0.661 | -0.034 | 0.022 |
| IMD 2019 score | 0.0004 | 0.0041 | 0.11 | 0.914 | -0.0076 | 0.0085 |
| Male | 0.072 | 0.174 | 0.42 | 0.678 | -0.269 | 0.413 |
| Constant | 2.489 | 0.217 | 11.48 | 0.0 | 2.064 | 2.913 |

The results from this analysis suggest that increasing the number of green spaces would reduce depression and anxiety prescriptions, and would lead to a marginal improvement in the mental health of the residents in the area.

Additional File 3: Exploratory analysis of Born in Bradford Growing Up

This file provides some of the additional exploratory analysis done for chapter 4. This includes descriptive analysis, simple correlations and basic regressions. This tables presented in this file informed some of the broader understanding about the dataset, including the correlations between mental health and physical activity.

Since, this is a journal-style thesis, only the tables directly linked to the final analysis were included in chapter 4. All additional tables are included here in this additional file.

**Table AF3.1. Economic variables of the study sample (n=5404)**

| | n | (%) |
|---|---|---|
| **Currently employed** | | |
| Yes | 2711 | 50.5% |
| No | 2660 | 49.5% |
| | | |
| **Respondent profession** | | |
| Managerial, administrative and professional | 1324 | 33.9% |
| Intermediate occupations | 854 | 21.9% |
| Small employers and own account workers | 404 | 10.4% |
| Lower supervsiory and technical occupations | 307 | 2.9% |
| Semi-routine and routine occupations | 1012 | 25.9% |
| | | |
| **Partner employment** | | |
| Yes | 3722 | 79.5% |
| No | 419 | 9.0% |
| I don't have a partner | 543 | 11.6% |
| | | |
| **Partner profession** | | |
| Managerial, administrative and professional | 1014 | 26.7% |
| Intermediate occupations | 194 | 5.1% |
| Small employers and own account workers | 1076 | 28.4% |
| Lower supervsiory and technical occupations | 666 | 17.6% |
| Semi-routine and routine occupations | 844 | 22.3% |
| | | |
| **Self-reported financial wellbeing** | | |
| Living comfortably | 1245 | 26.2% |
| Doing alright | 1966 | 41.4% |
| Just about getting by | 1110 | 23.4% |
| Finding it quite difficult | 246 | 5.2% |
| Finding very difficult | 100 | 2.1% |
| Do not wish to answer | 83 | 1.8% |
| | | |
| **IMD 2019 decile** | | |
| 1 | 2'339 | 46.58 |
| 2 | 842 | 16.77 |
| 3 | 891 | 17.75 |
| 4 | 288 | 5.74 |
| 5 | 169 | 3.37 |
| 6 | 192 | 3.82 |
| 7 | 115 | 2.29 |
| 8 | 97 | 1.93 |
| 9 | 58 | 1.16 |
| 10 | 30 | 0.6 |
| Total | 5'021 | 100 |

**Table AF3.2. Partner employment and profession of respondents**

| | n | (%) |
|---|---|---|
| **Mental health values (n=5,404)** | | |
| | | |
| **PHQ severity (0-27 score)** | | |
| No significant symptoms (score 0-4) | 3793 | 70.8% |
| Mild symptoms (score 5- 9) | 961 | 17.9% |
| Moderate symptoms (score 10-14) | 354 | 6.6% |
| Moderately severe symptoms (score 15-19) | 172 | 3% |
| Severe symptoms (score 20-27) | 77 | 1% |
| | | |
| **GAD categories** | | |
| Minimal anxiety | 4052 | 75.5% |
| Mild anxiety | 792 | 14.8% |
| Moderate anxiety | 297 | 5.5% |
| Severe anxiety | 225 | 4.2% |

**Table AF3.3: Physical activity levels of respondents**

| **Time categories for moderate to vigorous physical activity** | | | |
|---|---|---|---|
| | N | % | Cum % |
| Less than 30 mins | 261 | 7.52 | 7.52 |
| 30 to 90 mins | 1117 | 32.2 | 39.72 |
| 91 mins to 3 hours | 1039 | 29.95 | 69.67 |
| 151 min to 5 hours | 593 | 17.09 | 86.77 |
| More than 5 hours | 459 | 13.23 | 100 |
| Total | 3'469 | 100 | |
| | | | |
| **Time categories for Vigorous physical activity** | | | |
| less than 60 mins | 481 | 26.86 | 26.86 |
| More than 1 hour to 3 hours | 1'025 | 57.23 | 84.09 |
| More than 3 hours to 5 hours | 155 | 8.65 | 92.74 |
| More than 5 hours | 130 | 7.26 | 100 |
| Total | 1'791 | 100 | |
| | | | |
| **Time categories for moderate physical activity** | | | |
| less than 60 mins | 874 | 27.98 | 27.98 |
| More than 1 hour to 3 hours | 1'670 | 53.46 | 81.43 |
| More than 3 hours to 5 hours | 355 | 11.36 | 92.8 |
| More than 5 hours | 225 | 7.2 | 100 |
| Total | 3124 | 100 | |
| | | | |
| **Days spent in Vigorous PA** | | | |
| 0 days per week | 3216 | 59.9% | |
| 1 days per week | 334 | 6.2% | |
| 2 days per week | 399 | 7.4% | |
| 3 days per week | 425 | 7.9% | |
| 4 days per week | 233 | 4.3% | |
| 5 days per week | 281 | 5.2% | |
| 6 days per week | 62 | 1.2% | |
| 7 days per week | 239 | 4.5% | |
| Don't wish to answer | 49 | 0.9% | |
| Not applicable | 46 | 0.9% | |
| Don't know | 85 | 1.6% | |

**Table AF3.4: Satisfaction with green spaces in their area**

| | n | (%) |
|---|---|---|
| **Characteristics of the study sample (n=5,404)** | | |
| | | |
| **How do you feel about parks in the area** | | |
| Very satisfied | 1942 | 36.1% |
| Fairly satisfied | 2194 | 40.7% |
| Neither satisfied nor dissatisfied | 624 | 11.6% |
| Fairly dissastisfied | 298 | 55.3% |
| Very dissatisfied | 329 | 61.1% |
| | | |
| **How often do you visit parks in your area in winter (Sep-March)** | | |
| 5 times a week or more | 225 | 4.2% |
| 2 to 4 times a week | 408 | 7.6% |
| Once a week | 715 | 13.3% |
| 1 to 3 times a month | 1210 | 22.5% |
| Less than once a month | 2832 | 52.5% |
| | | |
| **How often do you visit parks in your area in spring (April-Aug)** | | |
| 5 times a week or more | 854 | 15.9% |
| 2 to 4 times a week | 1945 | 36.1% |
| Once a week | 1329 | 24.7% |
| 1 to 3 times a month | 905 | 16.8% |
| Less than once a month | 355 | 6.6% |

**Table AF3.5: IMD status, PHQ scores and GAD scores for intervention and control group**

| | n (Intervention) | n (control) | Total |
|---|---|---|---|
| **Better Place vs non better place population** | | | |
| | | | |
| **IMD 2019 decile** | | | |
| 1 | 883 | 1456 | 2339 |
| % | 84.02 | 36.68 | 46.58 |
| 2 | 168 | 674 | 842 |
| % | 15.98 | 16.98 | 16.77 |
| 3 | 0 | 891 | 891 |
| % | 0 | 22.44 | 17.75 |
| 4 | 0 | 288 | 288 |
| % | 0 | 7.25 | 5.74 |
| 5 | 0 | 169 | 169 |
| % | 0 | 4.26 | 3.37 |
| 6 | 0 | 192 | 192 |
| % | 0 | 4.84 | 3.82 |
| 7 | 0 | 115 | 115 |
| % | 0 | 2.9 | 2.29 |
| 8 | 0 | 97 | 97 |
| % | 0 | 2.44 | 1.93 |
| 9 | 0 | 58 | 58 |
| % | 0 | 1.46 | 1.16 |
| 10 | 0 | 30 | 30 |
| % | 0 | 0.76 | 0.6 |
| Total | 1,051 | 3,970 | 5,021 |
| | 100 | 100 | 100 |
| **PHQ severity category** | | | |
| No significant symptoms (score 0-4) | 734 | 2'768 | 3'502 |
| % | 70.24 | 70.2 | 70.21 |
| Mild symptoms (score 5- 9) | 188 | 729 | 917 |
| % | 17.99 | 18.49 | 18.38 |
| Moderate symptoms (score 10-14) | 74 | 254 | 328 |
| % | 7.08 | 6.44 | 6.58 |
| Moderately severe symptoms (score 15-19) | 30 | 137 | 167 |
| % | 2.87 | 3.47 | 3.35 |
| Severe symptoms (score 20-27) | 19 | 55 | 74 |
| % | 1.82 | 1.39 | 1.48 |
| Total | 1,045 | 3,943 | 4,988 |

| **GAD severity category** | | | |
|---|---|---|---|
| Minimal anxiety | 797 | 2,944 | 3,741 |
| % | 76.2 | 74.53 | 74.88 |
| Mild anxiety | 144 | 614 | 758 |
| % | 13.77 | 15.54 | 15.17 |
| Moderate anxiety | 62 | 220 | 282 |
| % | 5.93 | 5.57 | 5.64 |
| Severe anxiety | 43 | 172 | 215 |
| % | 4.11 | 4.35 | 4.3 |
| Total | 1046 | 3950 | 4996 |
| | 100 | 100 | 100 |

**Table AF3.6: Correlation between IMD and outcomes of interest**

| **Predictor** | **Outcome** | **Correlation (r)** | **p-value** |
|---|---|---|---|
| IMD (2019) | MVPA category | 0.0238 | 0.175 |
| IMD (2019) | PHQ score | –0.0725 | 0.0000** |
| IMD (2019) | GAD score | –0.0506 | 0.0003** |

**Significant at 5%

**Table AF3.7: Determinants of GAD using simple OLS regression**

| | Coefficient | Std. err. | t | P>\|t\| | 95% confidence interval | |
|---|---|---|---|---|---|---|
| **Age** | 0.00 | 0.00 | -0.50 | 0.62 | -0.01 | 0.00 |
| | | | | | | |
| **Relationship status** | | | | | | |
| Not married and living with partner | 0.17 | 0.05 | 3.26 | 0.00 | 0.07 | 0.27 |
| Not living with partner | 0.31 | 0.04 | 7.70 | 0.00 | 0.23 | 0.39 |
| | | | | | | |
| **Ethnicity** | | | | | | |
| Mixed | 0.12 | 0.10 | 1.22 | 0.22 | -0.07 | 0.32 |
| Asian | -0.09 | 0.03 | -2.70 | 0.01 | -0.16 | -0.03 |
| Black | -0.30 | 0.10 | -2.85 | 0.00 | -0.50 | -0.09 |
| Other | -0.19 | 0.14 | -1.34 | 0.18 | -0.46 | 0.09 |
| | | | | | | |
| **IMD score** | | | | | | |
| 2 | 0.02 | 0.04 | 0.43 | 0.67 | -0.06 | 0.09 |
| 3 | 0.02 | 0.04 | 0.50 | 0.62 | -0.05 | 0.09 |
| 4 | -0.05 | 0.06 | -0.95 | 0.34 | -0.17 | 0.06 |
| 5 | -0.16 | 0.08 | -2.10 | 0.04 | -0.30 | -0.01 |
| 6 | -0.15 | 0.07 | -2.23 | 0.03 | -0.29 | -0.02 |
| 7 | -0.04 | 0.09 | -0.49 | 0.62 | -0.22 | 0.13 |
| 8 | -0.29 | 0.09 | -3.22 | 0.00 | -0.47 | -0.11 |
| 9 | -0.18 | 0.12 | -1.57 | 0.12 | -0.41 | 0.05 |
| 10 | -0.09 | 0.16 | -0.55 | 0.58 | -0.40 | 0.22 |
| | | | | | | |
| **Physical activity** | | | | | | |
| 30 to 90 mins | -0.08 | 0.05 | -1.53 | 0.13 | -0.18 | 0.02 |
| 90 mins to 3 hours | -0.06 | 0.05 | -1.21 | 0.23 | -0.17 | 0.04 |
| 3 to 5 hours | -0.06 | 0.06 | -1.04 | 0.30 | -0.17 | 0.05 |
| More than 5 hours | -0.03 | 0.06 | -0.51 | 0.61 | -0.15 | 0.09 |

**Table AF3.8: Determinants of PHQ using simple OLS regression**

| **Determinants of PHQ** | Coefficient | Std. err. | t | P>\|t\| | 95% confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Age** | 0.00 | 0.00 | -0.24 | 0.81 | -0.01 | 0.00 |
| | | | | | | |
| **Relationship Status** | | | | | | |
| Not married and living with partner | 0.20 | 0.06 | 3.39 | 0.00 | 0.08 | 0.31 |
| Not living with partner | 0.40 | 0.05 | 8.72 | 0.00 | 0.31 | 0.49 |
| | | | | | | |
| **Ethnicity** | | | | | | |
| Mixed | 0.20 | 0.11 | 1.79 | 0.07 | -0.02 | 0.42 |
| Asian | -0.14 | 0.04 | -3.49 | 0.00 | -0.21 | -0.06 |
| Black | -0.27 | 0.12 | -2.32 | 0.02 | -0.50 | -0.04 |
| Other | -0.23 | 0.16 | -1.49 | 0.14 | -0.54 | 0.07 |
| | | | | | | |
| **IMD** | | | | | | |
| 2 | -0.01 | 0.04 | -0.16 | 0.88 | -0.09 | 0.08 |
| 3 | 0.00 | 0.04 | 0.07 | 0.94 | -0.08 | 0.09 |
| 4 | -0.11 | 0.06 | -1.72 | 0.09 | -0.24 | 0.02 |
| 5 | -0.29 | 0.08 | -3.52 | 0.00 | -0.46 | -0.13 |
| 6 | -0.23 | 0.08 | -2.95 | 0.00 | -0.38 | -0.08 |
| 7 | -0.30 | 0.10 | -2.91 | 0.00 | -0.50 | -0.10 |
| 8 | -0.36 | 0.10 | -3.59 | 0.00 | -0.56 | -0.16 |
| 9 | -0.35 | 0.13 | -2.68 | 0.01 | -0.61 | -0.09 |
| 10 | -0.18 | 0.18 | -1.01 | 0.31 | -0.52 | 0.17 |
| | | | | | | |
| **Physical activity** | | | | | | |
| 30 to 90 mins | -0.02 | 0.06 | -0.40 | 0.69 | -0.14 | 0.09 |
| 90 mins to 3 hours | -0.09 | 0.06 | -1.44 | 0.15 | -0.20 | 0.03 |
| 3 to 5 hours | 0.00 | 0.06 | -0.03 | 0.98 | -0.13 | 0.12 |
| More than 5 hours | -0.07 | 0.07 | -1.05 | 0.29 | -0.20 | 0.06 |

**Table AF3.9: Determinants of physical activity using simple OLS regression**

| **Determinants of Moderate to Vigorous Physical activity** | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Age** | -0.75 | 0.91 | -0.83 | 0.41 | -2.54 | 1.03 |
| | | | | | | |
| **Relationship status** | | | | | | |
| Not married and living with partner | 59.23 | 19.70 | 3.01 | 0.00 | 20.61 | 97.85 |
| Not living with partner | 22.63 | 15.72 | 1.44 | 0.15 | -8.20 | 53.46 |
| | | | | | | |
| **Ethnicity** | | | | | | |
| Mixed | -30.52 | 38.09 | -0.80 | 0.42 | -105.20 | 44.17 |
| Asian | -4.06 | 13.15 | -0.31 | 0.76 | -29.84 | 21.71 |
| Black | 41.32 | 39.69 | 1.04 | 0.30 | -36.49 | 119.14 |
| Other | 0.39 | 53.13 | 0.01 | 0.99 | -103.77 | 104.56 |
| | | | | | | |
| **IMD** | | | | | | |
| 2 | 11.92 | 14.53 | 0.82 | 0.41 | -16.57 | 40.42 |
| 3 | 3.28 | 14.22 | 0.23 | 0.82 | -24.60 | 31.16 |
| 4 | -12.98 | 21.82 | -0.59 | 0.55 | -55.77 | 29.81 |
| 5 | 27.14 | 28.50 | 0.95 | 0.34 | -28.74 | 83.03 |
| 6 | 31.01 | 26.21 | 1.18 | 0.24 | -20.37 | 82.39 |
| 7 | 27.39 | 34.66 | 0.79 | 0.43 | -40.58 | 95.36 |
| 8 | 9.12 | 34.51 | 0.26 | 0.79 | -58.55 | 76.80 |
| 9 | -51.17 | 44.42 | -1.15 | 0.25 | -138.26 | 35.92 |
| 10 | -35.40 | 59.98 | -0.59 | 0.56 | -153.01 | 82.20 |
| | | | | | | |
| **PHQ severity** | | | | | | |
| Mild symptoms | 14.97 | 13.00 | 1.15 | 0.25 | -10.53 | 40.47 |
| Moderate symptoms | 25.93 | 21.04 | 1.23 | 0.22 | -15.32 | 67.19 |
| Moderately severe symptoms | -11.09 | 30.15 | -0.37 | 0.71 | -70.20 | 48.03 |
| Severe symptoms | -23.97 | 44.09 | -0.54 | 0.59 | -110.42 | 62.49 |

Additional file 4: Expanded analysis for Difference-in-difference

**Table X. Adjusted marginal effects of the additional covariates on the probability of a prescription for depression or anxiety and on prescription cost, women**

| | Probability of a prescription | | | | Prescription cost (£) | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** | **Coeff** | **P-value** | **95% CI lower** | **95% CI upper** |
| Y.2021/22 | 0.024 | <0.001 | 0.020 | 0.028 | 2.88 | <0.001 | 2.03 | 3.73 |
| Lives in BP area | -0.009 | 0.028 | -0.017 | -0.001 | -0.94 | 0.234 | -2.48 | 0.61 |
| Y.2021/22 x Lives in BP area | 0.018 | 0.002 | 0.006 | 0.029 | -0.07 | 0.949 | -2.24 | 2.10 |
| Ethnicity – Pakistani origin | -0.092 | <0.001 | -0.105 | -0.080 | -3.63 | <0.001 | -5.53 | -1.73 |
| Ethnicity – Other | -0.102 | <0.001 | -0.115 | -0.088 | -4.19 | <0.001 | -6.47 | -1.91 |
| IMD 2019 score | 0.001 | <0.001 | 0.000 | 0.001 | 0.01 | 0.562 | -0.03 | 0.06 |
| Body mass index | 0.002 | <0.001 | 0.002 | 0.003 | 0.10 | 0.106 | -0.02 | 0.23 |
| Education – GCSE equivalent | -0.014 | 0.027 | -0.027 | -0.002 | -0.97 | 0.351 | -3.01 | 1.07 |
| Education – A-level equivalent | -0.027 | <0.001 | -0.042 | -0.012 | -1.06 | 0.406 | -3.56 | 1.44 |
| Education – Higher than A-level | -0.051 | <0.001 | -0.064 | -0.038 | -1.85 | 0.124 | -4.21 | 0.51 |
| Education – Other | -0.016 | 0.134 | -0.036 | 0.005 | -0.10 | 0.957 | -3.60 | 3.40 |
| Education – Don't know | -0.045 | 0.012 | -0.081 | -0.010 | -4.13 | 0.115 | -9.25 | 1.00 |
| Education – Foreign/Unknown | -0.101 | <0.001 | -0.129 | -0.073 | -5.36 | 0.085 | -11.46 | 0.74 |
| Living arrangement – Not married, living with partner | 0.022 | 0.001 | 0.009 | 0.036 | -0.57 | 0.602 | -2.72 | 1.57 |
| Living arrangement – Not living with partner | 0.049 | <0.001 | 0.035 | 0.064 | 0.82 | 0.473 | -1.42 | 3.07 |

Coefficients are average marginal effects from the two-part model, estimated with the full set of covariates. The probability columns give the change in the probability of receiving a prescription; the cost columns give the change in prescription cost, in pounds, among women with a prescription. Reference categories are White British for ethnicity, no formal qualification for maternal education, and married or living with a partner for living arrangement.

For the probability of a prescription, several characteristics were associated with prescribing after adjustment. Women of Pakistani origin were 0.092 less likely to receive a prescription than White British women, and women in the Other ethnic group were 0.102 less likely (both p<0.001). Higher area-level deprivation and higher body mass index were each associated with a small increase in probability (p<0.001). Maternal education showed a gradient, with women educated above A-level 0.051 less likely to receive a prescription than those with no formal qualification (p<0.001). Women

not living with a partner were 0.049 more likely to receive a prescription than married women or those living with a partner ($p<0.001$).

For prescription cost, only ethnicity remained significant. Women of Pakistani origin and women in the Other group had lower costs than White British women (both $p<0.001$). Deprivation, body mass index, education and living arrangement were not significantly associated with cost.

After adjustment for this wider set of characteristics, the intervention effect on the probability of a prescription remained positive and significant, at 0.018 ($p=0.002$). The intervention effect on cost was close to zero and no longer significant, at −£0.07 ($p=0.949$).