Physical Activity in Green Space: A Mechanism for Reducing Health Inequalities?

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Abstract

Background: There is accumulating evidence that greater availability of neighbourhood green space is associated with better health. One mechanism proposed for this association is that green space provides a venue for, and therefore encourages, physical activity. It has also been suggested that socio-economic health inequalities may be narrower in greener areas because of the equalised opportunity for physical activity green spaces provide. However, research, exploring associations between availability of green space and physical activity has produced mixed results. Failure to account for the type and amount of physical activity which occurs specifically in green space may account for these mixed findings. This thesis therefore explored the extent to which green space is a venue for physical activity and whether this could account for better health and narrower socio-economic health inequalities in greener areas.

Methods: Secondary analyses were conducted on two cross-sectional surveys of adults (16+) living in urban areas across Scotland. The first survey included individual level health, total physical activity, physical activity specifically in green space and socio-demographic characteristics. These data were matched to an objective measure of neighbourhood green space availability. The second included self-reported data on green space availability, quality, green space use, health and socio-demographic characteristics. Objective and perceived measures of green space were assessed in relation to (a) health, (b) use of green space and (c) physical activity in green space using logistic regression models. Interactions between socio-economic position and each outcome were assessed.

Results: The objective availability of green space in a neighbourhood was not associated with health, total physical activity or that specifically in green space. The perceived availability and quality of green space was positively associated with more frequent use, but only perceived quality was associated with better population health. There was no evidence that socio-economic inequalities in health, use of green space or physical activity within green space were narrower in greener areas of Scotland.

Conclusion: There was no evidence that physical activity specifically in green space was associated with better health or narrower socio-economic health inequalities. Further research exploring green space characteristics over and above availability, may help determine whether green space is salutogenic in Scotland.

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Declaration

I declare that, except where acknowledged, all work presented within this thesis has been undertaken by myself.

Katherine L. Ord

Chapter 1 Introduction

This thesis is based on work I completed at the Institute of Health and Well-Being, College of Medical, Veterinary and Life Sciences, following the award of an advertised PhD Studentship. The studentship was proposed by my supervisors, Professor Rich Mitchell and Professor Jamie Pearce, and was funded by the Scottish Physical Activity Research Collaboration (SPARColl).

1.1 Thesis Aim and Objectives

The main aim of this thesis was to determine the role of physical activity as a mechanism by which green space may promote population health and narrow socio-economic health inequalities. The research questions were to explore whether:

1. Greater availability of green space is associated with better health in Scotland?
2. Socio-economic health inequalities are narrower in greener areas compared to less green areas in Scotland?
3. Greater availability of green space is associated with higher levels of physical activity participation in Scotland?
4. Socio-economic inequalities in physical activity are narrower in greener areas compared to less green areas in Scotland?
5. Greater equality in access to green space contributes to narrowing socio-economic inequalities in health by encouraging use of green space for physical activity in Scotland?

The overarching aim of this study stemmed from Mitchell and Popham's 2008 research paper titled "Effect of exposure to naturel environments on health inequalities: an observation population study"[1]; the first study to build upon the previous green space and health literature and explore whether income related health inequalities varied by exposure to green space. Below I will explore the aims, objectives and research findings of Mitchell and Popham's observational study, detailing the way in which their study influenced the research aims and objectives of this thesis.

1.1.1 Mitchell and Popham's Observational Population Study

Previous research has explored the relationship between green space and health, suggesting that greater availability of green space in an urban neighbourhood is associated with health benefits for the local population[2-6]. Green Spaces are defined as "land that consists predominantly of unsealed, permeable, soft structures such as soil, grass, shrubs and trees"[(7: P.97)]. Three plausible mechanisms have been proposed to explain the beneficial effect of green space. First, it has been suggested that contact with a green environment can promote restoration from stress and mental fatigue. Experimental studies have shown that contact with a natural environment can improve attention and positive feelings whilst reducing levels of stress and mental fatigue[8-10]. Second, research has shown that the availability of neighbourhood green space may encourage participation in physical activity. There is evidence, for example, that having access to neighbourhood green space is associated with an increase in walking and cycling behaviour[11, 12]. Third, it is plausible that green spaces may influence health by facilitating social interaction within the neighbourhood. Research has shown that greater availability of neighbourhood green space may provide greater opportunities for social interaction and strengthen neighbourhood social ties[13, 14]. Building upon this research, Mitchell and Popham[1] hypothesised that if these mechanisms correctly explain the pathway by which green spaces may impact health and health-related behaviour, there is the potential for access to green spaces to affect socio-economic health inequalities. This hypothesis was based on the author's suggestion that those living in areas with little green space may require higher material resources, such as transport to access usable green space, or entry fees to other spaces for physical activity or relaxation, which could, in turn, reinforce or produce socio-economic inequalities in health. Where green space is readily accessible, material resources are no longer a barrier for use of green space, everyone has access to a health promoting environment and thus, in theory, inequalities in health are narrowed.

Mitchell and Popham's[1] hypothesis was explored using an observational study on the entire English population. Individual mortality records on 366,348 deaths were matched with a neighbourhood level measure of green space availability. These included mortality records for all-cause mortality and cause-specific mortality (circulatory disease, lung cancer, intentional self-harm). Their results showed income-related health inequalities in all-cause mortality and mortality from circulatory disease were lower in the greenest areas compared to least green areas of England, but no association was shown for lung cancer or intentional self-harm. From these results the authors postulated a role for both physical activity and restoration from stress and mental fatigue as the mechanisms resulting in narrower socio-economic health inequalities in greener areas. This speculation was based on evidence which suggests that physical inactivity[15] and psychological stress[16] are risk factors of circulatory disease. Social contact was not included within the postulated mechanisms as there was no evidence that it was a risk factor of circulatory disease. Mitchell and Popham[1] highlight, however, that although research has shown that access to green space can promote recovery from stress and mental fatigue, no studies had yet connected the restorative aspect of green space to a reduced risk of circulatory disease. There was research, on the other hand, to suggest that participating in physical activity was protective against circulatory disease mortality[15]. This led the authors to suggest that the equalised opportunities that physical activity in green space could offer may be the key mechanism behind the narrower socio-economic health inequalities in greener areas. They hypothesised that where green space is plentiful, material resources are no longer a barrier to physical activity, and inequality in activity, and thus health, is narrowed.

It was the suggestion that physical activity may be the main mechanism explaining the salutogenic effects of green space which led to the overarching aim of this thesis; exploring the role of physical activity as a mechanism by which green space may promote population health and narrow socio-economic health inequalities.

1.2 Thesis Outline

The following sections will further explore Mitchell and Popham's hypothesis and the overarching aim of this thesis. The first chapter (Chapter 2) sets out the background of the thesis. It begins by providing a brief history of socio-economic health inequalities in the UK, going on to describe the extent of current socio-economic health inequalities in Scotland. It then goes on to explore the key explanations which have been proposed for why socio-economic health inequalities exist, stressing the potential role of the neighbourhood environment in influencing health inequalities. The second chapter (Chapter 3) explores the pathways by which the neighbourhood environment may influence health and health inequalities. It reviews the variations of the social ecological model which currently exist for understanding environmental influence on health and health-related behaviour and then goes on to propose a framework by which a social ecological model may be used to understand socio-economic health inequalities. The third chapter (Chapter 4) then examines the evidence to date on the association between neighbourhood green space and health and the mechanisms proposed to explain any health benefits that green space is thought to exert. This chapter concludes by describing the specific aims and objectives of this study and provides an overview of the structure of the remainder of the thesis.

Chapter 2 Inequalities in Health in Scotland

This chapter will explore the extent of socio-economic health inequalities in Scotland. It will begin by providing a brief historical review of the key literature on socio-economic health inequalities in the UK before focusing specifically on health inequalities within Scotland. It will conclude by reviewing the key explanations for the pattern of socio-economic health inequalities and explore the extent to which environmental factors have a role to play in explaining the socio-economic gradient in health.

2.1 Brief History

Concern with socio-economic health inequalities has a long tradition in Britain. As early as the first half of the 19th century, Edwin Chadwick's report on *The Sanitary Conditions of the Labouring Population in Great Britain,* demonstrated differences in life expectancy by social classes in many different areas across Britain [17]. The report found that average life expectancy for members of families across three social groups – gentry and professional; farmers and tradesmen; labourers and artisans – decreased as one moved down the social scale. Gentry and professional males living in Liverpool, for example, had a life expectancy of 35 years compared to only 15 years for labourers living in the same area. Nearly a century later, the Registrar General, Stevenson, produced a fivefold classification of father's occupation and applied this to adult and infant mortality rates around the 1921 census [18]. The results suggested that there was a clear socio-economic gradient in both adult and infant mortality, where rates incrementally increased as you moved down the social scale. Stevenson concluded that premature mortality was causally related to socio-economic grade. He suggested that at least 40% of present mortality could be avoided if the health conditions of the poorest could be met with those of the richest.

Dramatic improvements in public health have been achieved since the 19th century, notably, due to the passing of the Public Health Act in 1848[19] and the establishment of the National Health Service (NHS) in 1948. Whilst it was hoped that the introduction of the NHS would resolve any social class variations in health, an assessment in the mid 1970's, found that socio-economic health inequalities had persisted and that Britain was slipping behind other industrialised countries in terms of health improvements[20, 21]. This led to the Secretary of State for Social Services in the UK appointing a research working group in 1977 to assess the national and international evidence on health inequalities. The Black Report was published in 1980[22]. Using data from the 1970-72 decennial supplement on occupational mortality, the report found that crude death rates of both men and women in the lowest social class were two and half times those of men and women in the highest social class. Moreover, the report pointed to evidence that this socio-economic gradient in health existed for still births, infant mortality, childhood mortality and adult mortality, concluding that the poorer health experiences of lower occupational groups applied to all stages of the life course. Despite efforts to suppress the report by the UK government, renewed interest in socio-economic differences in health arose, resulting in a burgeoning body of new research into the study of health inequalities.

Three frequently cited British examples that were (and still are) of great importance in understanding the relationship between socio-economic grade and mortality are the Whitehall Study I [23], Whitehall Study II [24] and the Acheson Report [20]. The first Whitehall Study[23], set up in 1967, classified 18000 men in the civil service according to employment, and recorded mortality over a period of 10 years. The results demonstrated that mortality rates increased as socio-economic position decreased, indicating that the ‘health gap’ was not simply dichotomous (e.g. rich/poor) but, instead, a gradient in mortality was evident across all occupational groups. The Whitehall Study II[24], was set up in 1985, to investigate the reasons for this socio-economic gradient in mortality by following a new cohort of 10308 civil servants, of which two thirds were men and one third were women. The Acheson Report[20], published in 1998, was commissioned by the UK Government in order to summarise the growing body of evidence on health inequalities. The report found that although mortality had decreased during the last 50 years, inequalities in health had remained, and that these inequalities could be found across a wide range of health outcomes and determinants. The authors made 39 recommendations for addressing the socio-economic gradient in health. These recommendations were based on a social model of health and included a wide range of factors such as, education, employment, housing, transportation and nutrition.

In a renewed effort to tackle health inequalities, The National Health Strategy, the Programme for Action 2001[25], was announced. The main aim of this programme was, by 2010, to reduce the inequalities in health outcomes by 10% as measured by infant mortality and life expectancy at birth. In the most recent status report on the Programme for Action, however, inequalities as measured by both infant mortality and life expectancy at birth were shown not to be improving. The report highlighted the intrinsic difficulties in trying to tackle the complex issue of health inequalities[26, 27].

More recently, the UK Government published “Fair Society, Health Lives: A Strategic Review of Health Inequalities in England Post 2010” better known as the Marmot Review[28]. Like both the Black Report and Acheson Report, the Marmot Review summarises data on the extent of socio-economic health inequalities and reviews the available evidence in order to make a series of policy recommendations. These policy recommendations addressed the social determinants of health and stated: (1) give every child the best start in life, (2) enable all children, young people and adults to maximise their capabilities and have control over their lives, (3) create fair employment and good work for all, (4) ensure healthy standards of living for all, (5) create and develop healthy and sustainable places and communities and (6) strengthen the role and impact of ill health prevention. The Marmot Review differed from the previous reports as it had far greater research to base its recommendations and a more inclusive consultation process. This resulted in the review achieving a more in-depth evidenced based strategic framework. Moreover, the review recognised that if socio-economic health inequalities are to be reduced multi-disciplinary action would be required including central and local governments, the NHS, the third and private sector and community groups.

2.2 Health Inequalities in Scotland: The Figures

It has long been recognised that substantial socio-economic health inequalities exist in Scotland[29]. Almost every physical and mental health indicator demonstrates differences between the rich and the poor, as well as gradients relating to both geographical location and social class[30]. In recent years, much attention has been given to the suggestion that health in Scotland is not only poorer than other countries within the UK and Western Europe; there is a marked variation in health between Local Authorities and Social Groups within Scotland[30, 31]. The following section is going to review this literature and explore the trend of Scotland's current socio-economic inequalities in health.

2.2.1 Scotland and Europe

Scotland's health, when compared to other Western European countries, is relatively poor[32]. Figure 2.1 shows the life expectancy at birth for the majority of countries that form the European Union. The Figure locates Scotland (in red) and shows that Scotland's life expectancy is among the lowest of the European Union 27 countries, falling behind the majority of Western European Countries and sitting more in line with that of Eastern European Nations. Making a comparison with the European Union country which has the highest life expectancy, Scottish men can expect to live four years less than Swedish men. In comparison to the UK, life expectancy in Scotland is lower than England, Wales and Northern Ireland[33]. For the period 2008-2010, Scottish life expectancy at birth was 75.8 years for men and 80.3 years for women. The corresponding figures for the UK as a whole were 78.1 for men and 82.1 for women, 2.3 years and 1.8 years higher than for Scottish men and women respectively[33].

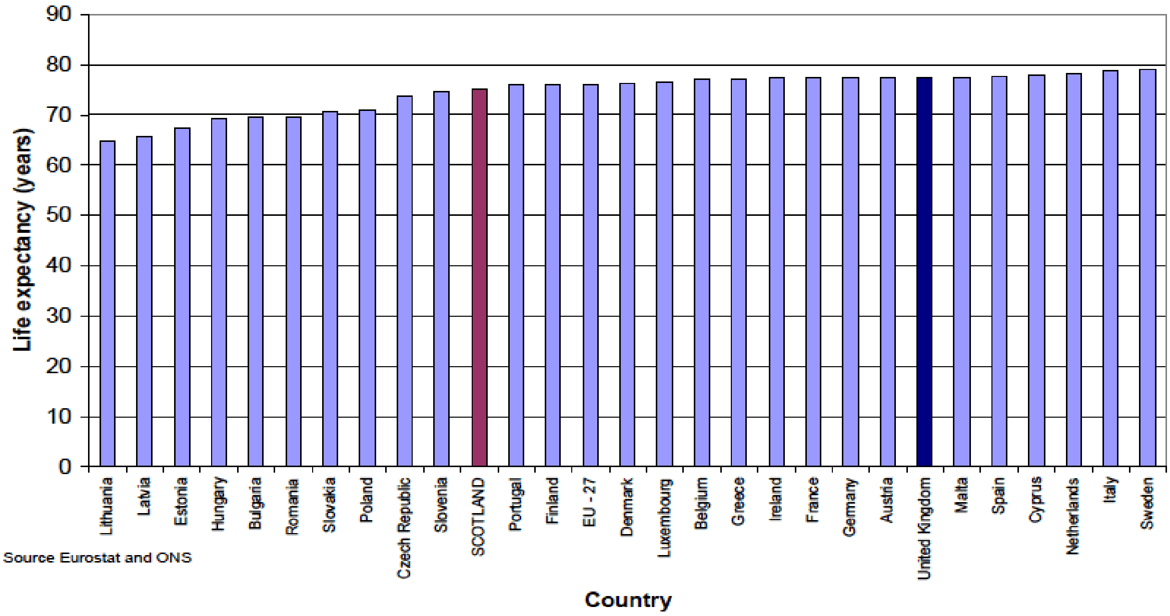


Figure 2.1 Life expectancy at birth, 2007, selected countries, males[32]

2.2.2 Differences by Area

Figure 2.2 highlights the extent of geographical health inequalities within Scotland. These geographical variations do not only occur between East and West or North and South, they occur between neighbouring authorities in the same regions of the country [32]. The most notable example can be seen between Glasgow City and its two neighbouring authorities; East Dunbartonshire and East Renfrewshire (See Figure 2.2). Life expectancy for Glasgow City is 71.1 years and 77.5 years for males and females, respectively [32]. In East Dunbartonshire, however, life expectancy is 7.2 years more for men and 5.6 years more for females than Glasgow City, and for East Renfrewshire 6.7 years and 4.5 years more for males and females, respectively [32]. If we classify areas by level of deprivation, and measure healthy life expectancy instead, we observe even greater inequalities in health[27]. For the period 2009-2010, men living in areas within the most deprived decile in Scotland spent 21.3 years in poor health, compared to only 12.1 years for men living in the least deprived areas; women spent 24.9 years and 11.6 years respectively[27]. It is important to understand the explanations behind these inequalities in health if they are to be reduced. An extensive volume of literature has reviewed both compositional (characteristics of the individual) and contextual (characteristics of the area) for explaining geographical variations in health[34-37]. Available evidence suggests that individual variables (e.g. age, sex, ethnicity and social class) are the strongest predictors of health but the neighbourhood in which you live also matters[37, 38]. This has been shown for a number of health outcomes and health-related behaviours[39-41].

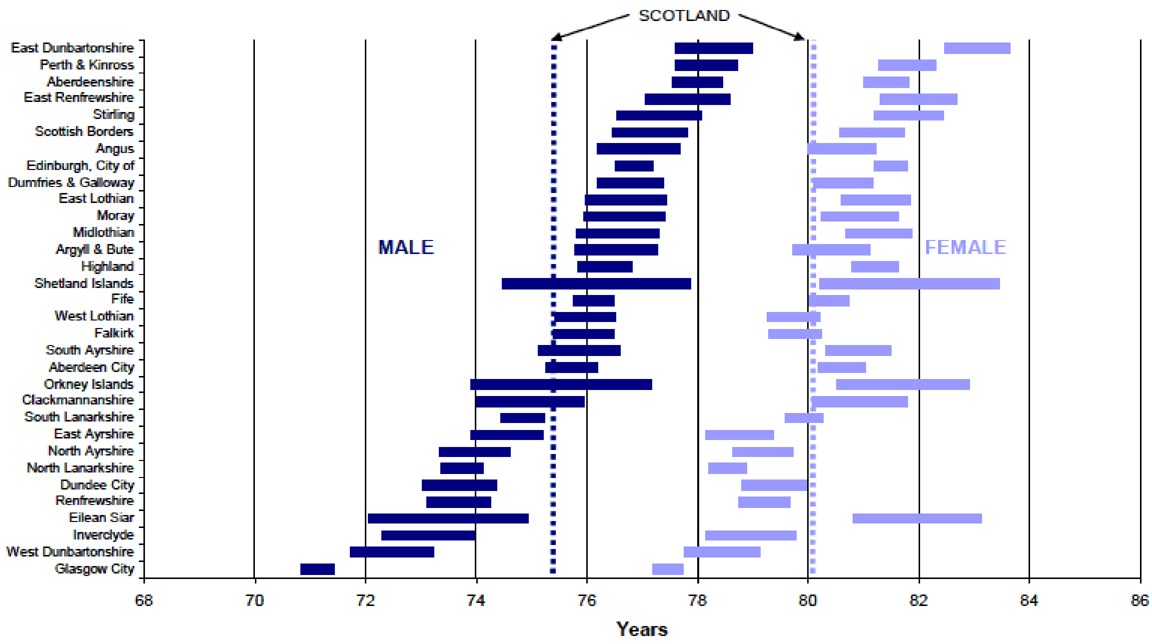


Figure 2.2 Life expectancy at birth, 95% confidence intervals for council areas, 2007-2009 ***(Source: General Register Office for Scotland [32]).***

2.2.3 Differences by Individual

Variation in health at an individual level can be seen across a number of measures of health and health-related behaviours[30]. Information on self-reported health, smoking and physical activity participation is presented below to demonstrate these links (Table 2.1). These data are based on the 2003 Scottish Health Survey[42]. The results show a clear socio-economic gradient in self-reported health and smoking behaviour among both males and females. Respondents classed in the highest income quintile, for example, are more likely to report ‘very good’ or ‘good’ health. These responses steadily decrease as you move down the income quintiles where respondents in the lowest quintile are less likely to report ‘very good’ or ‘good’ health. The percentage of respondents who met the recommended physical activity guidelines did not demonstrate quite as clear a socio-economic gradient, but the results did show that those in the bottom income quintile were less likely to meet the recommended guidelines than those in the top income quintile. A similar pattern of results was shown when socio-economic position was measured by occupational group.

Table 2.1 Distribution of selected health and health-related behaviours by individual level income quintiles

	Individual Level Income Quintiles				
	1st (Highest)	2nd	3rd	4th	5th (Lowest)
Men					
Very good/good self-reported health	88%	83%	74%	62%	58%
Current Smokers	15%	25%	28%	39%	51%
Meets Physical Activity Guidelines*	45%	49%	42%	37%	36%
Female					
Very good/good self-reported health	88%	84%	71%	64%	57%
Current Smokers	13%	22%	28%	35%	45%
Meets Physical Activity Guidelines*	33%	35%	30%	25%	26%

Source: Scottish Health Survey 2003[42], * to accumulate 150 minutes of moderate intensity physical activity, in bouts of 10 minutes or more, throughout the week

2.3 Explaining Scotland's Socio-Economic Gradient in Health

This literature shows that substantial socio-economic health inequalities exist in Scotland. The next section of this thesis will explore the body of research that has sought explanations for why this socio-economic gradient in health occurs. Due to the extent of research evidence that now exists on the topic of health inequalities, it is beyond the scope of this chapter to provide an in depth review; instead, it is going to draw on the key ideas and debates surrounding the current thinking on socio-economic health inequalities. This thesis will take the Black Report as a starting point, as it has been one of the most influential reports for furthering the understanding of socio-economic health inequalities.

2.4 Key Explanations for the Pattern of Socio-Economic Health Inequalities

The Black Report proposed four potential explanations for the socio-economic gradient in health [22]. The first explanation was that the social class variations in health are an artefact of the measurement process. The basis for this explanation was the concern that the size of the Registrar General's social classes had changed over time, thus, invalidating any over-time comparisons of occupational class death rates. This explanation was briefly considered by the Black Report but was later dismissed due to the strong evidence of a social class gradient in health, regardless of the measurement of socio-economic position[43, 44].

The second explanation was that inequalities in health could be due to natural or social selection. For the authors, this explanation placed greater emphasis on health as the cause of socio-economic position rather than the consequence, suggesting that socio-economic differences in health occur as a result of the healthy moving up and the unhealthy moving down the social scale. Research explaining the effects of social selection as an explanation for the socio-economic gradient in health has found mixed results. During the normal years of paid employment, the time when health is thought to influence social mobility the most, research suggests that the effect of social mobility plays little part in explaining the social class variations in health[45]. Using data from the office of population censuses and surveys, Fox et al.[46], found that health-related mobility between social classes did not contribute to differentials in mortality among men aged 15-64 years. The greatest amount of support for the social selection hypothesis has been found among young adults entering the labour market. This research suggests that health in childhood influences social mobility in early adulthood, but has little effect after mid-twenties and when adults move into middle-age[45]. Using the National Survey of Health and Development, among a cohort of 26 year old men, Wadsworth[47] found evidence to suggest that seriously ill children were somewhat less likely to be upwardly mobile when entering the labour market compared to healthy children. In general, research concludes that social selection does play a role in explaining social class gradients in health, but is insufficient an explanation to account for the entire socio-economic gradient in health.

The third explanation considered by the Black Report was that cultural and behavioural factors explains the variation in health, and the fourth explanation highlights the importance of material and structural factors. These two explanations have generated the greatest volume of research and debate and, within the context of this thesis, are the most relevant. These explanations are explored in detail below.

2.4.1 Cultural/Behavioural Explanation

The cultural/behavioural explanation focussed on the individual as the unit of analysis, emphasising that the socio-economic gradient in health is the result of social class variations in health related behaviour, because smoking, poor diet, lack of exercise and greater alcohol consumption are more prevalent in lower socio-economic groups[48]. In Britain, for example, smoking has shown a large socio-economic gradient since the 1970's. In the most recent General Lifestyle Survey, 29% of adults in 'routine and manual' occupational groups reported currently smoking compared to only 15% in the 'professional and managerial' group[49]. Several studies of diet have also demonstrated a pattern of poorer nutrition among lower socio-economic groups[50]. There is evidence to suggest that the consumption of whole grains, lean meats, fish, low fat dairy products and fresh fruit and vegetables is consistently associated with more advantaged socio-economic groups, whereas the consumption of fatty meats, refined grains and added fats is associated with lower socio-economic groups[50]. It is hard to dispute that some behaviours, such as smoking or diet, are major determinants of health or that these behaviours are socially patterned. The debate surrounding the 'cultural/behavioural' explanation is thus more focussed on the extent to which these behaviours constitute a complete explanation for health inequalities, or if there are 'causes' of these 'causes' of poor health.

Several studies have explored the contribution of health related behaviours to socio-economic differences in mortality[51-56]. The extent, however, to which these behaviours explain the socio-economic gradient in health, remains unclear. The estimated contribution of behavioural factors, for example, has been seen to range from 12% to 72% across various studies[51-56]. In the Whitehall Study I of civil servants, for example, only one third of the increased risk of coronary heart disease mortality between administrative and other grades could be attributed to lifestyle factors such as smoking, cholesterol and blood pressure[53]. A slightly larger explanatory role was found in a large nationwide study in Finland, where the results found that a wide range of health behaviours including smoking, physical activity and vegetable consumption, explained 54% of the risk of cardio-vascular disease mortality and 45% of all-cause mortality among men. The corresponding figures among women were 22% and 38%, respectively[51]. Despite this, a large proportion of the socio-economic variation in mortality remained unexplained. The largest explanatory role for the contribution of health behaviours has been found in a recent longitudinal study of the British Whitehall II cohort, where health behaviours explained 42% of all-cause mortality and 29% of cardio-vascular disease mortality at baseline and 72% of all-cause mortality and 45% of cardio-vascular mortality at follow up[56]. However, when results from this British Cohort were compared to a European Cohort, the French GAZEL, the finding that health behaviours explained most of the socio-economic gradient in health was not replicated. These results suggest that behavioural factors are only likely to be major contributors of socio-economic inequalities in health when social characteristics of health behaviours are high[57].

This mixed support for the autonomous role that lifestyle behaviours play in forming the socio-economic gradient in health has generated criticism about the extent to which the 'cultural/behavioural' explanation points towards solutions to address inequalities in health. One of the key criticisms concerns whether individuals' lifestyle behaviours can be separated from the social and material context in which people live[58, 59]. In other words, it is plausible that lifestyle behaviours are embedded in the environment through aspects such as material deprivation, living and working conditions. Such behaviours may simply be viewed as intervening variables between social structure and health. The Black Report illustrates several ways in which this may occur. Using the example of smoking, it explains that individuals' are more likely to give up smoking if they have the resources to 'find compensatory means of fulfilling the needs which smoking satisfies' and that smoking should be seen as 'an epiphenomenon, a secondary symptom of deeper underlying features of economic society' rather than the primary cause of ill-health[22]. This interrelationship between lifestyle behaviours and structural conditions has been evident in a great deal of research undertaken since. Graham[60], for example, suggests that higher smoking rates among women in lower social classes are associated with higher levels of material deprivation among these groups.

The importance of these variables is further underpinned by the results of intervention studies designed to improve lifestyle behaviours. Intervention studies found that increasing the public understanding of risk factors, and acceptance of norms of 'healthy behaviours' produced a reduction in cardiovascular disease [61, 62]. This reduction, however, had little effect on the socio-economic gradient in health[61, 62]. Moreover, some researchers believe that such intervention programmes might have had the effect of widening these inequalities in health as more advantaged social groups may be better able to adopt health promoting behaviours compared to more disadvantaged groups[63]. Although the effects of these intervention studies are still being debated[63], the results do raise questions about both the autonomous role and aetiological significance of lifestyle behaviours, such as smoking and poor diet, on reducing the socio-economic gradient in health.

2.4.2 Materialist/Structuralist Explanation

The materialist/structuralist explanation emphasised the role of economic and associated socio-economic factors in the distribution of health and well-being[22]. The Black Report recognised that along with other factors, poverty and income were important components of a material explanation. This explanation was originally formulated from a long tradition of research focussing on the effects various aspects of working and living conditions can have on health. Research has shown that the adverse working conditions of certain occupations can have health damaging effects [64-67]. In a review of the four major causes of death (cancer, coronary heart disease, accidents and chronic obstructive airways disease), Blane et al.[68] estimated that occupational factors may account for 10% of all deaths. This is because those in lower occupational groups are the section of the workforce that are most frequently exposed to physico-chemical hazards, such as, chemicals, dust and noise. Living and housing conditions have also been shown to affect the socio-economic gradient in health[69, 70]. Research has shown that living in poor housing conditions including homelessness, temporary accommodation, overcrowding and housing in poor physical condition has been associated with increased rates of death from respiratory disease, especially among children[69, 70]. Whilst the authors of the Black Report stated that they believed a material explanation was the most likely factor to explain the socio-economic gradient in health, it was later critiqued as it failed to fully account for why inequalities in health persist within countries where the material standard of living has increased significantly[67].

Since the publication of the Black Report two further theoretical explanations have been proposed to explain the way in which income may influence the socio-economic gradient in health. These are the neo-materialist explanation and the psycho-social explanation. The basic idea of these explanations is similar to the Black Report's material approach in that socio-economic variations in health are linked to the accumulation of material disadvantage (e.g. the physical aspects of the environment). The inclusion of both the additional explanations, however, broadens the context on the dimensions which need to be considered (e.g. the social and economic aspects of the environment). The neo-materialist explanation, proposed by Lynch et al.[71], builds upon the traditional materialist approach by recognising that economic circumstances have changed over time. In today's society the diseases of concern are mainly chronic diseases, such as heart disease, obesity and diabetes; a major shift from the 19th century where infectious diseases due to poor material conditions were the primary cause of premature mortality. The neo-materialism school of thought thus acknowledges that individual resources are also determined by the higher-level structural factors, such as access to private resources and public services, and social and economic policies. These factors shape social classes by influencing the distribution of resources and infrastructure and, as a result, affect health. In response to Lynch and colleagues[71] neo-materialist explanation of socio-economic health inequalities, Marmot[72] formed a role for a psycho-social explanation for the socio-economic variation in health. This explanation agreed that access to private resources and public services were key determinants of health but argued that it was a result of relative income inequality rather than absolute poverty. Central to this theory is the suggestion that perceptions of social status and social comparison to other people in society are the main psycho-social risk factors that lead to increased levels of stress and, consequently, poor health. A number of psycho-social risk factors have been proposed to cause 'stresses', such as, lack of control and autonomy at work and an imbalance between home and work[24].

It is quite evident, from the number of explanations, that there are several ways in which the materialist approach may explain the socio-economic gradient in health. The variety of proposed material factors, including physical, social, economic and psycho-social, and the suggestion that each factor may impact at different stages of the life course, have made it challenging to determine the precise causal pathways by which socio-economic position is thought to influence health. Research to date has examined the effect of one or two of the suggested material factors, but has largely ignored the 'black box' through which different types of socio-economic characteristics may influence health and health-related behaviour. More research is needed to illuminate this 'black box' in order to better understand the wide range of social, physical, economical and psycho-social factors that may interact and accumulate over the life span and how this may influence the distribution of health and well-being before the materialist/structuralist approach can be fully accepted as an explanation for socio-economic health inequalities.

2.5 Conclusion

This chapter has discussed the four potential explanations for the socio-economic gradient in health using the framework provided by the Black Report. The Black Report argued that the first two approaches (artefact and social selection) played a limited, if any, role in 'explaining away' the relationship between social class and health. Their argument centred on the latter explanations (cultural/behavioural and materialist/structuralist differences) as the main causes of the socio-economic gradient in health. Some support was shown for the cultural/behavioural explanation, but it was argued that behaviours cannot be easily separated from the social and material context in which people live, and that behaviours are often acting as intervening variables between social structure and health. The majority of support among the literature was shown for the materialist/structuralist explanation. Despite the volume of research that has gone into developing the material argument, identifying the precise causal pathways by which socio-economic position may influence health remains difficult. It recognised that understanding the complex array of material factors that are hypothesised to influence population health, and the way in which they may vary by social class and geographical location is no easy task. One way to begin to understand these factors and develop the materialist/structuralist explanation may be through the use of a social-ecological model. There are several different variations of the social ecological model, but the underlying assumption that health and health related behaviour is influenced by multiple facets at the individual, social and environmental level remains the same. The next chapter of this thesis will introduce some of the main ideas captured by social ecology. It will begin by tracing the development of social ecological models from their early roots in human development to the way in which they have evolved to include the application of health and health related behaviour. This chapter will conclude with a section on how social ecological models may be an appropriate framework to be applied to the study of socio-economic health inequalities.

Chapter 3 Social Ecological Models

During the 20th century attention in the field of epidemiology shifted from infectious diseases which were declining to the growing problem of chronic disease. As epidemiologists expanded their focus to include behavioural correlates of health there was also increased interest in the wide array of environmental factors (including social, physical, economical, cultural and political) thought to influence health and health-related behaviour[73]. As a result a burgeoning body of research began applying a social ecological framework to the field of health promotion[74]. A social ecological framework emphasises the interaction between an individual and their environment[73]. When these models are applied to the field of health they recognise that differences in health and health-related behaviour are a result of a reciprocal interaction between the individual, the behaviour and their environment [74-79]. Social ecological models allow the exploration of the complex interplay of factors that influence health as they go beyond the simple consideration that *either* individual characteristics (e.g. socio-economic position) *or* independent levels (e.g. environmental factors) influence health or health-related behaviour. This may have important implications for the study of socio-economic health inequalities as it could help gain a greater understanding of the multiple factors that are thought to influence the socio-economic gradient in health and, consequently, help guide the development of population health interventions that are aimed at reducing socio-economic health inequalities.

The following section will review some of the main ideas captured by a social ecological framework. It will begin by tracing the development of social ecological models from their early roots in human development to the way in which they have evolved to include the application of health and health related behaviour. The chapter will then conclude with a section on how social ecological models may be an appropriate framework to be applied to the study of socio-economic inequalities in health.

3.1 Foundations of Social Ecological Models

Modern ecological perspectives on health can trace their roots back to several earlier theories and models which recognised that the study of individual behaviour must involve consideration of the context or environment in which it takes place. Early theorising about the influence of the environment on individual behaviour was conducted by Kurt Lewin in 1935[80], who coined the term ecological psychology. Lewin posited that behaviour is a function of the person and environment, which he summarised in the equation B=F (P/E). The premise of this equation was that behaviour (B) was a function (F) of the interplay between a person (P) and the environment (E). In a later edition, Lewin introduced the element of time in his equation, Dt = f(t-p) (PE) (t-p), suggesting that the characteristics of a person at a given time in their life are a joint function of the characteristics of the environment over the life course. Despite introducing the interaction between the individual and the environment in understanding behaviour, the constructs of Lewin's Social Ecological Model were limited in scope as they relied exclusively on examining individuals' perceptions of their environment and failed to take into consideration objectively measured features of the environment. In 1968, the ecological perspective was further developed by Barker[81] who conducted field based studies to observe children in their everyday environment. Using naturalistic records of behaviour Barker explored the way in which the physical and social environment may affect individuals' behaviour, perceptions and feelings. His belief was that conditions of a behavioural setting were a greater predictor of child behaviour than their individual characteristics.

One of the most influential models that have helped shape the current ecological perspective is Urie Bronfenbrenner's (1979) ecological model of human development [75]. Bronfenbrenner's work described the influences of behaviour as a series of overlapping circles, where each circle has an impact on the next (Figure 3.1). He described these circles as being like a set of Russian dolls, where the innermost circle represents the individual, which is then surrounded by differing circles of environmental influences. Bronfenbrenner's theory posits that the individual is surrounded by four environmental levels of influence, consisting of the microsystem, mesosystem, exosystem and macrosystem [75]. The microsystem is viewed as the immediate setting in which the individual lives. These settings include the person's family, school or neighbourhood. It is in these settings where the most direct interactions with social agents, such as families, peers or work groups occur. The next level is the mesosystem which refers to the interaction between two or more microsystems in which an individual is involved. These may include family, peer or church groups. The third level of influence is the exosystem. The exosystem links "settings that a person may or may not directly participate in, but are nonetheless relevant because of their impact on his or her immediate environment" [(82:P.10)]. Examples of a child's exosystem may include a parent's place of work, neighbourhood associations and the local school board. Finally, the outer layer of the individual's environment, the macrosystem, is composed of cultural values, customs and laws that influence all the other systems within the model.

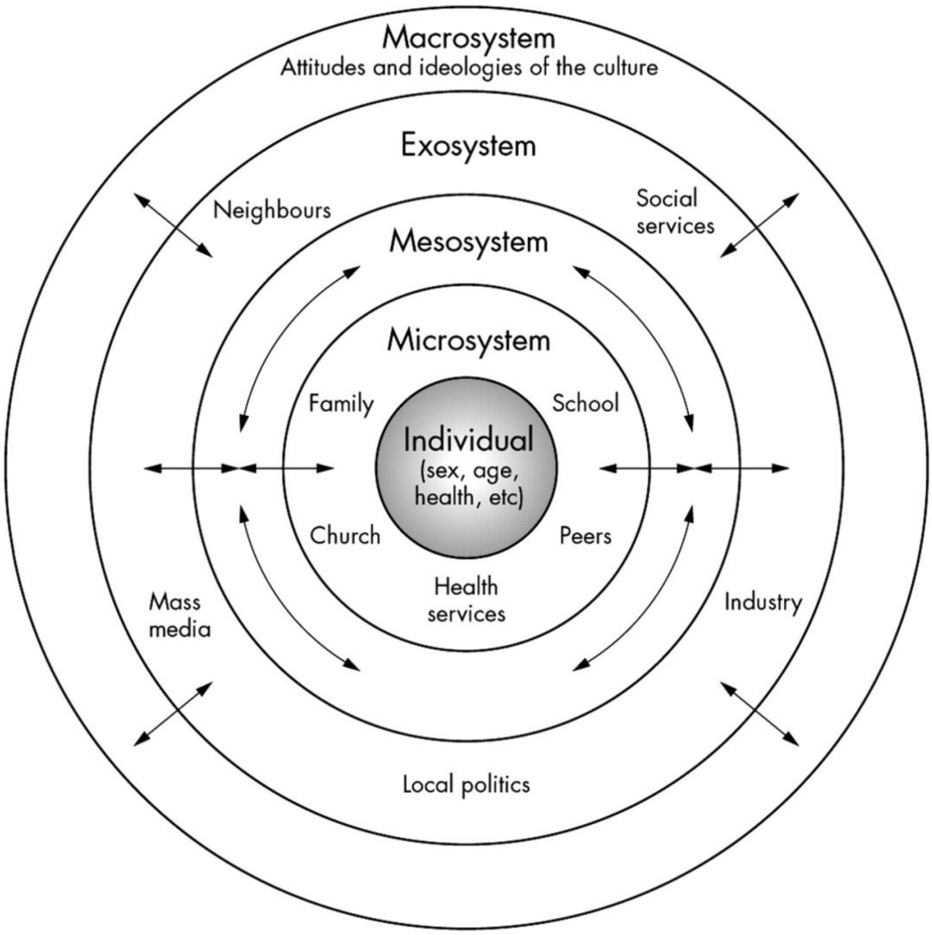


Figure 3.1 Bronfenbrenner's ecological model of human development (Source: McLaren & Hawe [82])

3.2 Social Ecological Models for understanding Health

McLeroy et al. [74] built on Bronfenbrenner's conceptual framework and proposed the way in which a social ecological model may be applied to the study of health and health-related behaviour. According to their model of health promotion, behaviour is regarded as being influenced by five classes of factors: (i) intrapersonal, (ii) interpersonal, (iii) institutional, (iv) community and (v) public policy.

(i) Intrapersonal factors include the knowledge, attitudes, behaviours and skill set of potential participants. Interventions at the intrapersonal level use a variety of strategies to modify health related behaviour such as educational programs, mass media campaigns and peer support groups. These interventions are delivered at a population level, but are designed to target individual characteristics and evoke the desired behavioural change.

(ii) Interpersonal factors include the relationship between family members, acquaintances, co-workers and neighbours. The opinions and support of these people have been shown to influence health and health related behaviour. Participating in physical activity with someone such as a friend, family member or work colleague, for example, can increase physical activity behaviour[83]. Health promotion interventions that use interpersonal strategies have focussed on changing individuals' behaviour through social influences such as peer pressure, instead of changing the norms of social groups to which these individuals belong [74].

(iii) Organisation structures including schools, work settings and day care facilities are important sites for health promotion interventions, as they provide an opportunity to gain access to large groups of people. There are numerous examples of worksite and school based interventions that exist in the literature. For example, work based incentives have been used to decrease smoking rates among employees [84] and food served in canteens has been modified to support healthy eating behaviours [85, 86].

(iv) Community factors such as the relationships between organisations, institutions and informal networks have historically occupied a central role in public health. McLeroy and colleagues [74] propose that the term 'community' should be viewed as having three distinct meanings. Firstly, an important attribute of communities includes what McLeroy et al. [74] describe as "mediating structures". These structures can be seen as playing an important role in influencing a variety of health related behaviours. The authors argue that changing individual behaviour without the support of these structures will be difficult to achieve due to their importance. Secondly, communities can be thought of as the relationships among organisations and groups within a political or geographical area. If the resources for health and health services are limited in certain communities, resource competition may result in inefficient use of health services. Thirdly, communities can impact health and health related behaviour through the exertion of power. One of the most important roles played by community power structures is in exerting formal or informal control over the behaviour of individual members within those communities. This can prevent some populations (e.g. the poor, uneducated or unemployed) from accessing health promoting interventions as they are often cut off from power structures[82].

(iv) Public policy plays a critical role in maintaining the health of the population, rather than the health of individuals, by using laws and policies at both the local state and national level to protect its health. Public policies may restrict detrimental behaviours through both positive and negative actions. Policies to reduce smoking rates, for example, have increased taxes on cigarettes and banned smoking from public places [87]. Similarly, public policies may promote a positive behaviour, such as physical activity, through increasing access to recreational facilities, while also discouraging it through other regulations such as reducing parking facilities.

3.3 Variations of the Social Ecological Model

Several variations of the social ecological model now exist. Stokols [79] has, for example, built on McLeroy's [74] model of health promotion by acknowledging that health related behaviour is influenced by both the physical environment (e.g.

geography, architecture and technology) and the social environment (e.g. culture, economics and politics), whilst still recognising that health promotion initiatives are enhanced through multilevel interventions. Similarly, Morris and colleagues [88] developed a conceptual framework to consider the ways in which certain aspects of the environment may influence health outcomes. The premise of this model was to provide a simple framework that not only represented the causal processes that influence health but which also took into consideration interventions in the form of policies and actions which may help deliver better health outcomes. What is useful about this model is that it recognises developing interventions require an understanding of local context as research has shown that health and health related behaviour vary by population group and geographical location. It recognises, for example, that the prevalence of smoking may differ by both social economic group and neighbourhood of residence. This model is designed so that it can be applied at different geographical and administrative levels.

Social ecological models have also been developed which focus on specific health related behaviours; the most popular being the use of a social ecological model to understand physical activity. Spencer and Lee [78], have developed a structural model of the environment to explore environmental influences on physical activity behaviour. Based on Bronfenbrenner's ecological systems theory, Spencer and Lee recognise that physical activity behaviour is influenced by four environmental levels: the microsystem, mesosystem, exosystem and macrosystem (See Section 3.1). They further proposed that four additional factors need to be taken into consideration to understand physical activity. These consisted of clarifying the roles of biological processes, higher level mediators, physical ecology and highlighting the direct and indirect influences of the environment. The authors pointed to evidence to suggest that biological factors (e.g. body composition and physical fitness) influenced the type and extent of physical activity, but it was the higher level mediators (e.g. psychological factors including self-efficacy, social support, enjoyment of activity and perceived benefits) that produced the reasons for being physically active. Physical ecology (e.g. climate and air pollution) was seen as having a direct influence on both these biological and psychological factors. Spencer and Lee also recognised that their ecological model of physical activity should include a role for objective and subjective assessments of individual and environmental characteristics. Both objective and subjective measurements are important in research as physical activity behaviour may not only depend on the objective environment but also on how a person perceives that environment. Research has shown that increasing proximity to recreational facilities such as public parks may not be sufficient for promoting physical activity participation, factors such as perceived safety and aesthetics may also need to be taken into consideration [89, 90].

Sallis et al[91], building on previous ecological models of physical activity, developed a multi-level model which identified the potential environmental and policy influences on the four domains of active living: active transport, occupational activities, household activities and active recreation. They suggested that the ambitious research agenda set out by their ecological model of active living would require the combined efforts of investigators from a variety of disciplines. Creating this trans-disciplinary approach would expand the way in which (i) the environment is conceptualised, (ii) physical activity is measured, (iii) interventions are implemented and (iv) study designs and statistical methods are used. The authors concluded that involving numerous disciplines would improve understanding of the way in which individual and environmental characteristics interact and improve the likelihood of translating research findings into changes in environments, policies and practises.

This section illustrates that there are several variations of the social ecological model, each of which emphasises a different aspect of earlier social ecological models of human behaviour. Consequently, the social ecological model is best viewed as a broad framework to guide thinking and research about health and related behaviour, and the model selected may need to be adapted to suit specific health research endeavours.

3.4 Applying the Social Ecological Framework to Health Inequalities

Despite the volume of research that has gone into developing the behavioural/cultural and material/structural explanations for socio-economic health inequalities, identifying the precise causal pathways by which socio-economic position may influence health remains difficult. In Chapter 2, I argued that this was because research had focussed on one or two material factors, largely ignoring the 'black box' through which different types of socio-economic characteristics may influence health and health-related behaviour. I suggested that one way to understand these factors was through the use of a social ecological model. The suggestion was based on the fact that the primary component of social ecological models is recognition that health and health-related behaviour is influenced by multiple factors at the individual, social and environmental level. Social ecological models, thus, acknowledge that to reduce socio-economic health inequalities research needs to develop an understanding of the reciprocal relationship between individuals and their environments and how these may interact and change over the life course. Despite the promise of social ecological models in addressing socio-economic variations in health[92], little research has actually explored how a social ecological model could be applied specifically to the study of socio-economic health inequalities. In this section I am, therefore, going to discuss one way in which a social ecological model could be adapted to further our understanding of socio-economic health inequalities. I am going to focus specifically on the role of the natural environment in influencing physical activity, as investigating this association is central to the thesis.

3.4.1 Current Social Ecological Approach for Understanding Health

Figure 3.2 (a) shows my social ecological model that has been designed to explore the way in which the characteristics of both a natural environment and an individual may influence health and health-related behaviour. Using physical activity as an example, the model recognises that behaviour is influenced by the reciprocal interaction between an individual's characteristics (e.g. demographic, socio-economic, lifestyle and cultural) and that of their natural environment. Research has shown that the availability of neighbourhood green space has been associated with meeting the recommended physical activity guidelines and walking for recreation, independently of an individual's demographic and socio-economic characteristics[11, 12]. The limitation with this current social ecological approach for the study of socio-economic health inequalities is that research, to date, has recognised the contribution of an individuals' socio-economic position by simply adjusting for their socio-economic characteristics as confounding variables. Adjusting for socio-economic characteristics is necessary as both physical activity and access to green space are associated with the socio-economic position of an individual. It does not, however, allow the exploration of whether the association between a natural environment and physical activity is stronger for a particular socio-economic group, and as a result, you are limited in the understanding of whether particular aspects of a natural environment are factors that may help address the socio-economic gradient in health. It could be hypothesised, for example, that access to a neighbourhood green space is of particular value to lower socio-economic groups as it provides an opportunity to be physically active that is close to the home and free to use.

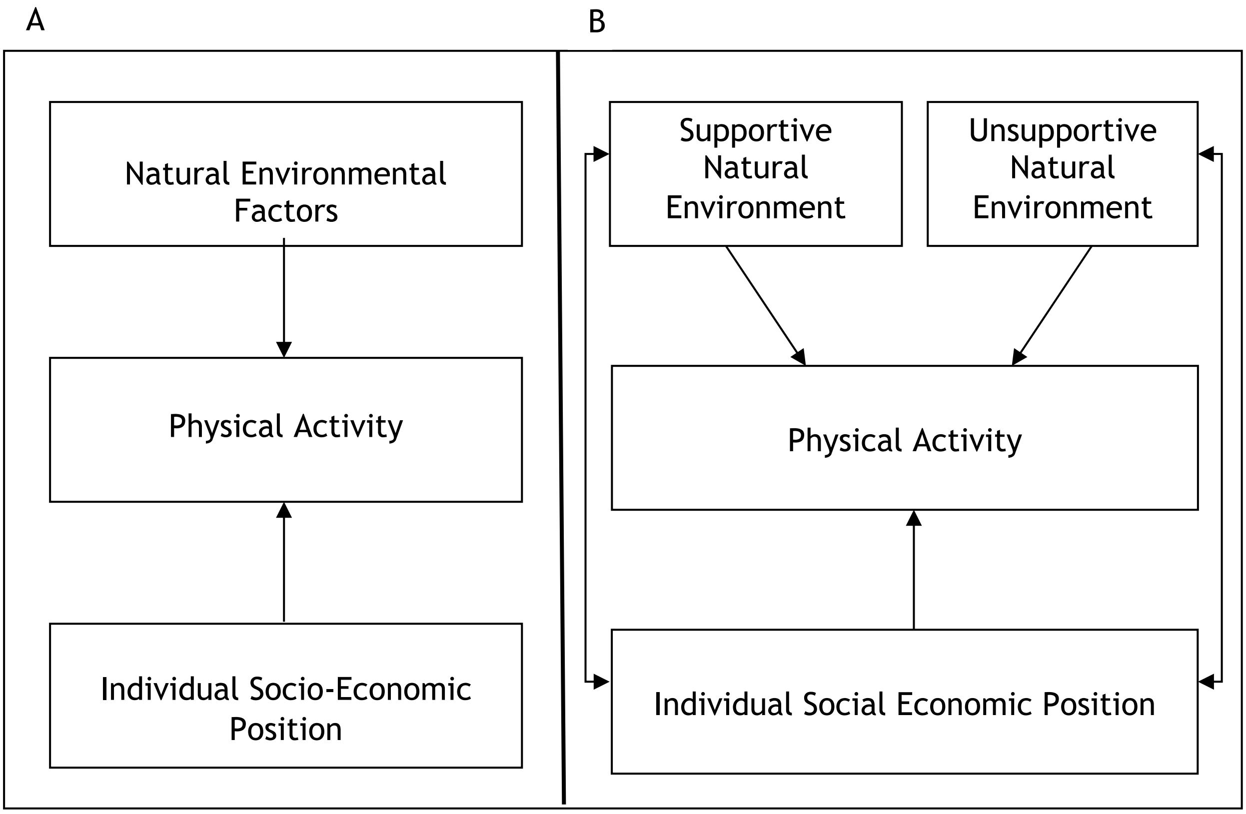


Figure 3.2 (a): A current social ecological model used to understand the way in which a natural environment may influence physical activity and (b) an adapted social ecological model used to understand the way in which a natural environment may create inequalities in health

3.4.2 Adapted Social Ecological Approach for Understanding Health Inequalities

Figure 3.2 (b) shows that by taking the current social ecological approach further it is possible to explore the potential for access to a supportive, health promoting natural environment to affect social ecological health inequalities. Beginning at the individual level, research has shown that people of low socio-economic position have poorer health and are less likely to participate in physical activity[93, 94]. It could be hypothesised that this is partly because the environment in which they live is not conducive to it. There is research to suggest that disadvantaged areas have poorer access to health-promoting facilities[35, 95, 96]. In order for these individuals to access a suitable environment for physical activity they would have to travel outwith their area of residence. From the social ecological model it could be proposed that inequalities in physical activity would be wider in a less supportive natural environment as accessing a health-promoting environment would require higher material resources to be physically active. This could include factors such as transport or admission fees. In a more supportive natural environment, material resources are not needed to access a more health-promoting environment, providing more equalised opportunities for physical activity and other health-related behaviour. There is research to show, for example, that socio-economic position does not independently affect use of a natural environment if it is readily available[97]. Consequently, lower socio-economic groups may use their natural environment for physical activity, and as result, gain greater health benefits than those of a similar level of deprivation living in a less supportive natural environment. From the social ecological model it could be suggested that having access to a supportive natural environment would narrow inequalities in physical activity. As physical activity is associated with health this would in turn narrow socio-economic inequalities in health.

This provides one example of the way in which a social ecological model could be adapted to include the study of socio-economic health inequalities. It was specific to the application of this thesis in that it provided a theoretical background to the way in which Mitchell and Popham's hypothesis[1], that physical activity is a mechanism by which green space may narrow socio-economic health inequalities, may actually occur. A similar approach could also be taken to explore the way in which other aspects of the social and physical environment may vary by socio-economic position and the potential this may have to reduce or exacerbate the socio-economic gradient in health.

3.5 Challenges of Implementing a Social Ecological Model to the Study of Socio-Economic Health Inequalities

This chapter suggests that there are numerous benefits of applying a social ecological model to the study of health-related behaviour and socio-economic health inequalities. Despite this, there are a number of challenges in conducting research based on a social ecological approach. Firstly, applying a social ecological perspective to the study of health inequalities involves generating a comprehensive understanding of the multiple factors that are thought to influence health and health related behaviour, and the way in which they may interact. This creates a daunting research agenda as identifying and understanding these factors is complex which, in turn, results in ever more complex social ecological models. Identifying the variables thought to influence individual behaviour is made even more challenging as the application of social ecological models to the study of health related behaviour is a relatively new area of inquiry and there is, thus, a lack of information surrounding the wide range of factors that are hypothesised to influence health and health related behaviour. A good example to illustrate the potential complexity of social ecological models is the Foresight Obesity Systems map (Figure 3.3) [98]. This map reveals that the causes of obesity are embedded in an extremely complex biological system, set within an equally complex societal framework. It is divided into seven subsystems to illustrate the interplay between causative factors: individual biology, individual activity, environmental activity, individual psychology, societal influences, food consumption and food production. Using this complex system to actually tackle obesity is far from straight forward. Policy makers using this systems map will have to understand that success in any one intervention will depend on a multiplicity of factors and that intervening at one segment of the systems map may have a likely impact across other segments. This complexity of social ecological models illustrates the challenges associated with understanding the social class variations in health and health related behaviour. In order to begin to understand the mechanisms by which these multitude of factors may vary among different social economic groups and areas of deprivation, researchers and policy makers will have to begin to prioritise a few of the many research questions, which is no easy task.

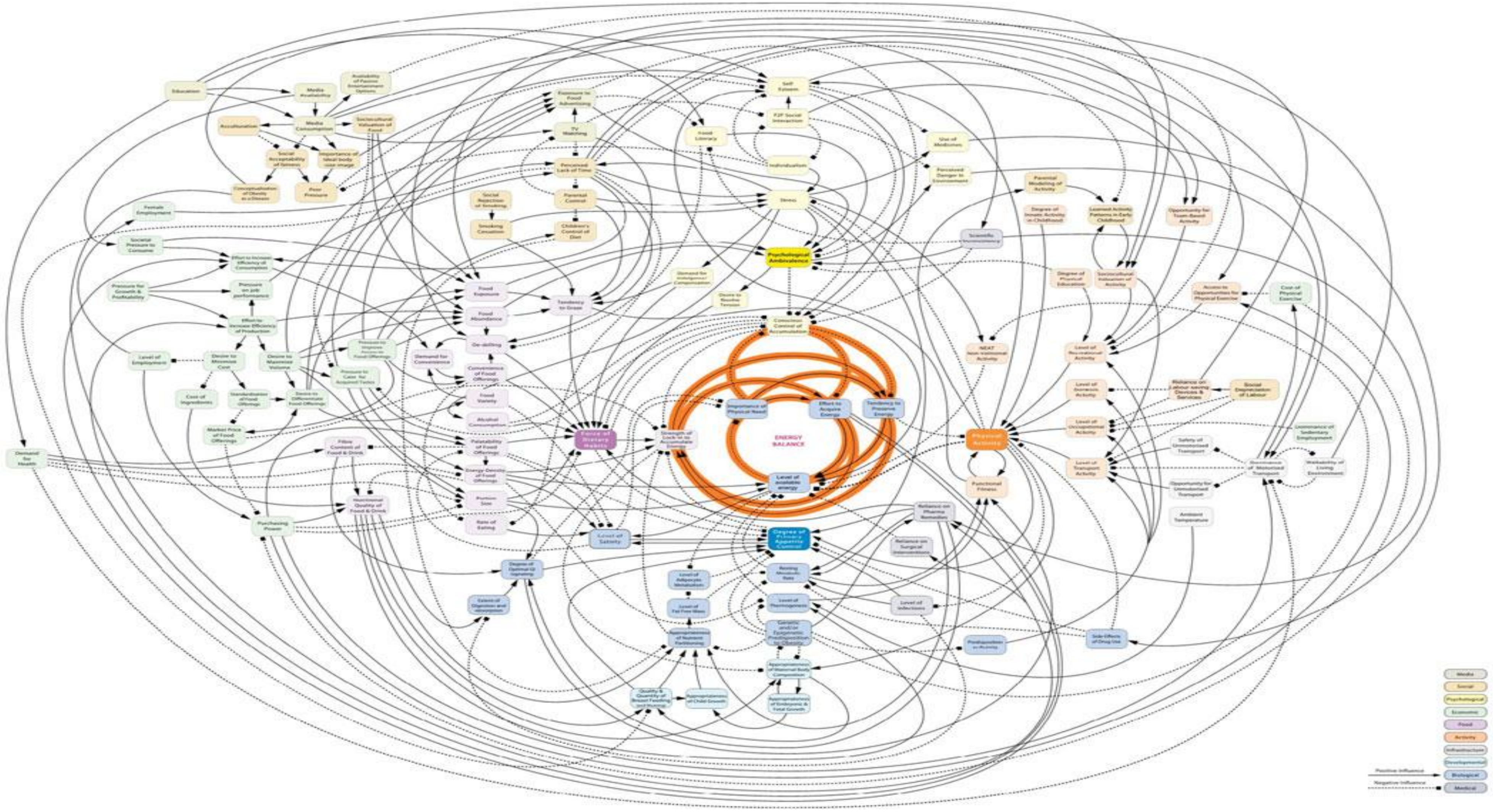


Figure 3.3 Foresight obesity systems map[96]

Secondly, exploring a social ecological model of health and health related behaviour is methodologically challenging at it requires data to be integrated at a number of different levels. If we look back at the Foresight Obesity Systems map we can see that interventions designed to tackle obesity must involve a whole systems approach. Evaluating the effectiveness of these interventions will include integrating data at an individual, biological, environmental, societal and political level. In order to adopt an inequality perspective these data will need to be matched with individual health and health related behaviour to examine whether differences within the systems affect the social economic gradient of health. This process will involve utilising innovative methodological designs as researchers will need to gain access to data at each level of the model and deal with multicollinearity. Moreover, analysing this data will require sophisticated statistical strategies. Researchers will need to consider techniques which can account for the interrelationships between different levels of the social ecological framework while explaining the variance in health and health related behaviour.

Finally, implementing multi-level interventions is a major task as strategies have to be targeted across multiple levels. This creates several challenges. Firstly, researchers and health professionals are more familiar with targeting interventions at the individual level in order to implement interventions also at environmental and policy levels, researchers and health professionals will need to work with those who have influence at those levels. Secondly, specific challenges can be expected at each level of the intervention. Interventions designed to modify health related behaviour at the intrapersonal level, for example, will require trained staff and supportive policies that provide physician counselling, education programs, peer support groups and mass media campaigns. Interventions at the environmental level will require both public and political will to build new facilities that will support healthy lifestyle behaviours. Thirdly, care will have to be taken when implementing government policies to ensure that interventions do not potentially exacerbate rather than alleviate socio-economic differences in health. Government policies will, therefore, have to be accompanied by on-going evaluation and assessment. Modifying health related behaviour across multiple levels will take considerable time and funding, and will require the health of the population to be seen as a priority by both government and society at large.

Despite these research challenges, social ecological models can provide a useful theoretical framework that could allow us to expand our current thinking surrounding the Materialist/Structuralist explanation for health inequalities. Although the current materialist explanation recognises that a wide range of social, physical and economic factors influence the distribution of health and well-being, it fails to conceptualise the way in which these multiple factors may interact to influence specific health outcomes and individual behaviour. Adopting a social ecological framework would allow us to increase our understanding of the complex array of factors that are hypothesised to influence health and health related behaviour, and the way in which they may vary by population group and geographical location. This has important implications for tackling health inequalities, as if we can gain a greater understanding of these factors and the way in which they interact we can begin to design and implement effective intervention strategies which support both environmental and policy change but are tailored to specific population groups and geographical locations.

3.6 Conclusion

Social ecological models provide a theoretical framework that may allow us to increase our understanding of the multiple factors that influence socio-economic inequalities in health. Adopting this framework creates an ambitious research agenda as research will need to conceptualise the complex array of factors that influence health inequalities, develop specific hypotheses and prioritise the factors that need to be measured and studied. If these challenges can be overcome research will be better able to be translated into effective intervention strategies tailored to reducing the socio-economic gradient in health.

In this chapter, I illustrated one way in which current studies exploring the association between the natural environment and physical activity using a social ecological approach could be adapted to include the study of socio-economic health inequalities. In the next chapter I will expand this literature and explore what particular aspects of the natural environment are associated with health and whether physical activity is a mechanism by which green space may be associated with better health and narrower socio-economic health inequalities.

Chapter 4 The Relationship between Green Space and Health: A Review

In this chapter I will review the literature investigating the mechanisms by which green space is thought to influence health. This will allow me to explore Mitchell and Popham's[1] hypothesis that physical activity in green space is the main mechanism explaining the salutogenic effects of green space. This review will be conducted in four parts. The first part will provide a definition of green space and outline the three mechanisms that have been proposed to explain the beneficial effect that green space exerts on health. The second part will detail the methods used to conduct the literature review. The third part will explore the results of the review. This will cover both evidence for the relationship between green space and health and evidence for the three mechanisms proposed to explain the way in which green space may be associated with health. The final part will summarise these results and address the key methodological limitations of the existing literature. The chapter will conclude by outlining the overarching aim and specific research questions of this thesis.

4.1 Introduction

One domain of the neighbourhood environment that is thought to influence the health and well-being of residents is green space[99]. Green spaces are defined as "land that consists predominantly of unsealed, permeable, soft structures such as soil, grass, shrubs and trees"([7]: P.97), and includes: recreational, incidental, private and productive green space; burial and institutional grounds; wetland, woodland, other habitats and linear green space (See Swanwick et al.[7] for a full definition of green space). Three plausible mechanisms have been proposed to explain the way in which green space may exert a beneficial effect on health. Firstly, it has been suggested that contact with nature can have a positive impact on health and well-being by providing restoration from stress and mental fatigue [8, 10]. Experimental studies have shown that contact with a natural environment can improve attention, positive feelings and psychological restoration whilst reducing levels of stress and mental fatigue[8, 97, 100, 101]. These effects have been shown among respondents visiting a natural environment as well as those simply viewing elements of nature from within a building[102, 103].

Secondly, exposure to green space can encourage individuals to engage in physical activity. There is research to show that having access to neighbourhood green space is associated with an increase in walking and cycling behaviour[11, 12]. Thirdly, green space may potentially influence health by facilitating social coherence and social interaction among neighbours. Evidence has shown that greater availability of neighbourhood green space can enhance social interaction or participation in group activities[13, 14], which has been shown to be conducive to better health[104].

A burgeoning body of research has begun to explore the way in which green space may influence health. Contributions to this research have been made from a broad range of disciplines, resulting in current studies varying widely in their study population, geographical location and the way in which they categorise and define green space characteristics, health and health-related behaviour. Despite widespread discussion of this topic, research systematically reviewing both the association between green space and health and the causal mechanisms by which green space may impact health has yet to be undertaken. Previous systematic reviews have been limited to a specific green space characteristic[105], health outcome[105] or health-related behaviour[12, 106]. Lachowycz and Jones'[105] review, for example, explored whether objective green space accessibility was associated with obesity, whereas, Kaczynski and Hendersons'[12] review explored whether greater availability of green space was associated with increased physical activity participation. The most wide-ranging review was conducted by Lees et al.[107] who explored the impact green space may have on aspects of both physical and mental health. This review, however, largely ignored the underlying mechanisms by which green space has been proposed to exert a beneficial effect on health. Previous literature reviews have also been limited in their reporting of the way in which the association between green space and health may differ by population sub groups. Without a clear understanding of the mechanisms by which green space may impact health and the potential for them to differ by population sub-group, it is difficult to reach a conclusion as to whether interacting with green space is beneficial to population health and socio-economic health inequalities.

The purpose of this review was to synthesise the literature and explore (1) the association between green space and health, (2) the mechanisms by which green space may impact health and (3) the way in which the relationship between green space and health may differ by population sub-group. To expand on previous reviews, I included a large number of studies from multiple disciplines, employed a systematic literature search and included studies that explored any characteristic of green space, health outcome or measurement of the three proposed underlying mechanisms.

4.2 Methods

To fully explore the association between neighbourhood green space and health, this review focussed on five classifications of health and health-related behaviour: (1) physical health, (2) mental health, (3) physical activity, (4) restoration from stress and (5) social interaction.

4.2.1 Literature Search

A search of major electronic databases (Medline, PsycInfo and Web of Science) was conducted during November to December 2009. As a burgeoning body of studies continue to explore this field of study, a supplementary search was conducted in February 2013. This enabled any recent research articles to be examined producing an up-to-date account of the way in which green space may impact health. This search strategy consisted of five sections. The first section searched for green space definitions from urban planning and health research. This included terms such as green space, open space, public park and natural environment. The second section searched for aspects of physical and mental health. The third, fourth and fifth section searched for the underlying mechanisms: physical activity, restoration from stress and mental fatigue and social interaction. Each section was independently searched, then grouped together using the Boolean operator terms OR or AND. Manual searches using internet sources and the reference sections of retrieved articles were also performed. A full description of the search terms and strategy can be seen in a supplementary table located in the Appendix A.

4.2.2 Inclusion Criteria

Articles were included in the review if they met the criteria listed in Table 4.1. As this literature review was conducted as part of my thesis, I was the only person to select potentially relevant papers and determine their suitability for review.

4.2.3 Classification of Evidence

From all articles that meet the inclusion criteria information was extracted on the author, year of study, country, design, subjects and the outcome under investigation (See Appendix B and C). The direction of association will be described in the results using three classifications: positive (+) indicating that greater green space availability was significantly associated with better health or health-related behaviour; negative (-) indicating that greater green space availability was significantly associated with a decrease in health or health-related behaviour or no significant association (o) indicating that there was no significant association between green space and health or health-related behaviour. A meta-analysis could not be conducted as studies had too great a variability in their method of capturing and reporting green space, health and health-related behaviour. Multiple entries for an association may be reported from one study as a result of different definitions of health and health-related behaviour being explored. Where this occurs the relevant section will detail both the total number of studies and the total number of observations being reviewed. The statistical level of significance will be defined as $p<0.05$ throughout.

Table 4.1 Inclusion criteria used to select studies

1)	Use of empirical data to explore the association neighbourhood green space has on health and health-related behaviour. Studies exploring the impact of green space on other topics, such as air pollution, were excluded.
2)	Measurement of one or more aspect of green space as the independent variable. This could include perceived or objective measurements of green space but excluded studies that examined green space within a composite environmental score.
3)	Categorisation of green space based on a respondent's residential environment. Could include definitions such as distance to or quality of neighbourhood green space but excluded studies that compared pictures, views or slides of green space as this could not be regarded as neighbourhood green space.
4)	Measurement of health status (individual or neighbourhood level) or health related behaviour as the outcome variable. Could be either self-reported or objectively measured
5)	Original studies printed in English in peer reviewed journals before February 2013 (review articles were excluded).
6)	Adult population (16+)

4.3 Results

The database search produced 948 hits in Medline, 506 hits in PsychInfo and 6492 hits in Web of Knowledge, giving a total of 7496. This large number of studies reflects the widespread discussion on the relationship between green space and health. Initial screening by article title rejected 7371 studies. Reasons included irrelevant studies, conducted on children or concerned with a general discussion on the relationship between green space and health. This left 125 studies of potential relevance. After reviewing these studies abstracts against the inclusion criteria, 70 articles were included. After full-text viewing, a final list of 63 articles was included in the review. Figure 4.1 illustrates the total number of articles identified and the number rejected at each stage of the inclusion criteria.

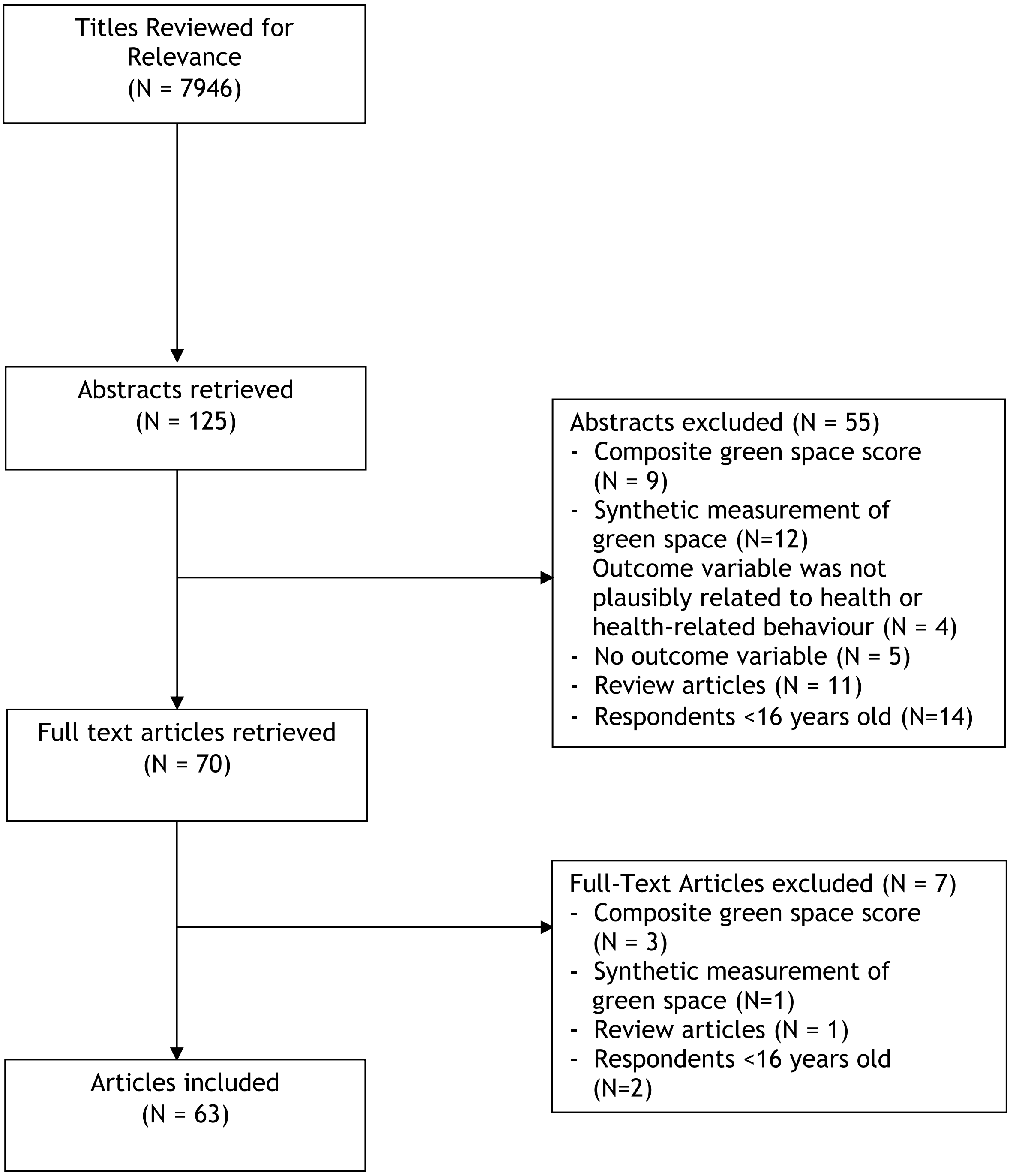


Figure 4.1 The total number of articles identified by the database search and the total number of articles rejected at each stage of the inclusion criteria

4.3.1 Green Space and Physical Health

The search identified 14 studies that examined the relationship between green space and physical health. Due to some studies reporting multiple entries, a total of 24 measurements of physical health were explored, categorised into general health *(n=7)*, health-related complaints *(n=4)*, body mass index (BMI) *(n=4)* and mortality *(n=9)*. More results involved objective measurements of green space availability *(n=18)* than perceived *(n=4),* with very few studies using either objective *(n=2)* or perceived *(n=0)* measurements of green space quality. These studies were conducted in Netherlands (4), England (3), Denmark (2), Australia (1), New Zealand (1), Japan (1), UK-Wide (1) and Europe-Wide (1). The observed relationships between green space and physical health are shown in Figure 4.2. Defining health into general health, health-related complaints, BMI and mortality, Figure 4.2 illustrates the number of observations that reported a positive (+), negative (-) or non-significant associations (0) for each categorisation of objective and perceived green space availability or quality. The superscript numbers listed within each bar refers to the specific studies on which this total was based. The following sections will review these studies in more detail.

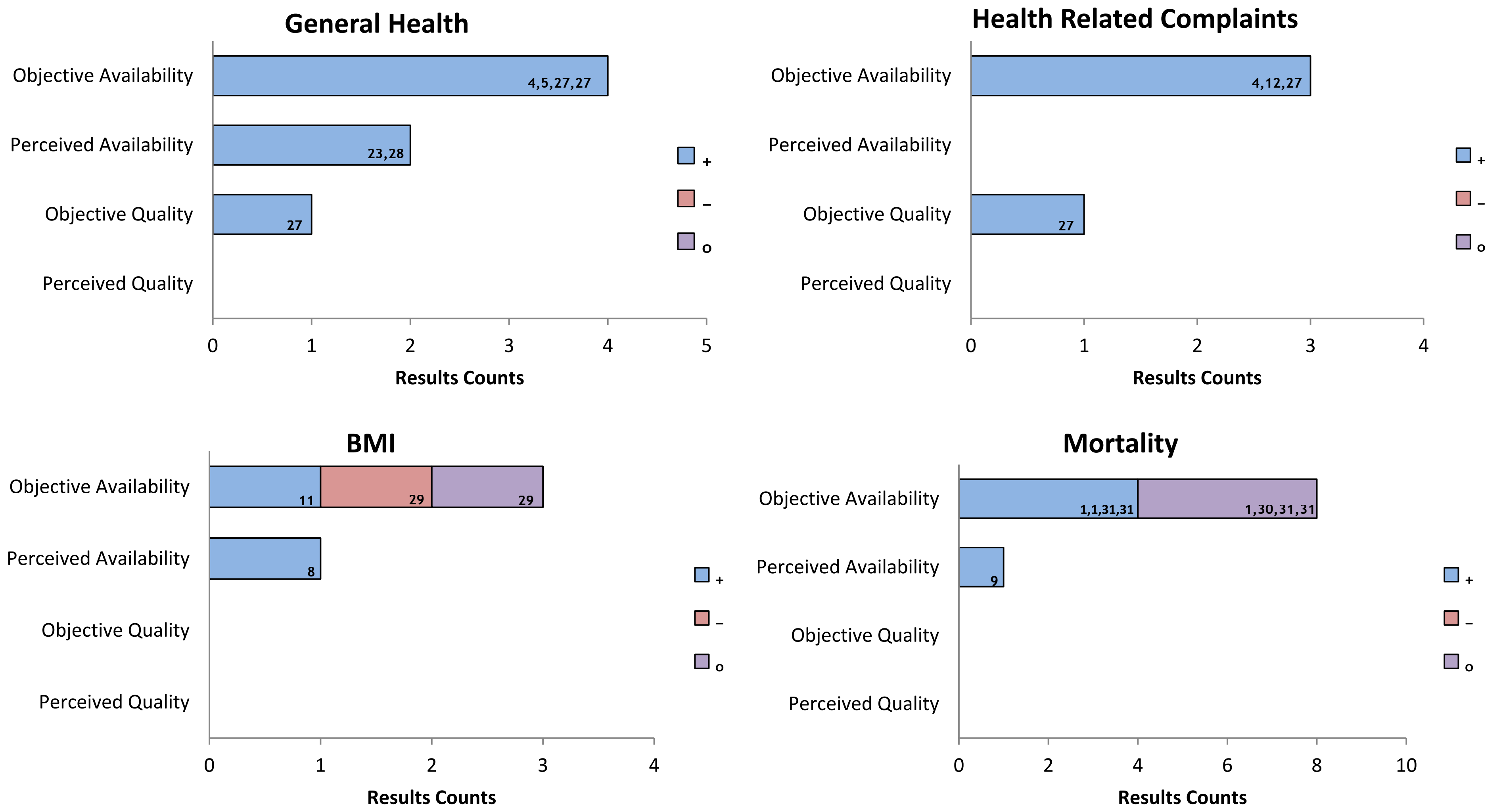


Figure 4.2 The number of articles and the evidence they provide for the association between green space and (a) general health (b) health related complaints (c) BMI and (d) mortality. Numbers in superscript corresponds to relevant article reference

4.3.1.1 General Health

All seven studies exploring the relationship between green space and general health reported a positive association. These studies typically captured general health by asking respondents to rate their health on a five point scale running from 'very good' to 'very poor'. Four of the studies used objective measurements of green space availability[3, 4, 6, 108], of which three studies captured green space by calculating the overall percentage of green space within a defined area[3, 4, 108] and one study capturing the number of square metres available within a set distance[6]. Two studies explored the association between perceived green space availability and general health using two different measurements of green space [104, 109]. Sugiyama et al.[104] measured the perceived greenness of a respondent's neighbourhood using five questions from the Neighbourhood Environment Walkability Scale. Items included access to a park or nature reserve; access to a bicycle or walking path; presence of greenery; presence of tree cover or canopy along footpaths and presence of pleasant natural features. Stigsdotter et al. [109], on the other hand, used respondents' self-reported distance from their home to their nearest green space. Only one study explored the effects of green space quality[6]. In this study quality was assessed objectively by the research team using a 10 item audit tool, which included information on the accessibility, maintenance, variation, naturalness, colourfulness, arrangements, shelter, litter, safety and general impression.

Several of these studies examined how the association between green space access and general health varied by population sub-groups. Research in the Netherlands found that the relationship between green space and health was stronger for lower socio-economic groups compared to higher socio-economic groups, and was stronger for the youth and elderly compared to adults aged 25-64 years[3], whilst, research in England found that the association between green space and general health was weaker in higher income suburban areas[4]. These findings provide preliminary evidence to suggest that the proposed benefits of green space may not be uniform across all population groups.

4.3.1.2 Health Related Complaints

Four studies examined the association between green space and health-related complaints. These studies were all conducted in the Netherlands. Three matched individual level data on the number of health-related complaints to an objective measurement of green space availability [6, 108, 110] and one matched it to an objective measurement of quality [6]. De-Vries et al.[108] and Van Dillan et al.[6], for example, explored the association between the availability of green space within a respondent's neighbourhood and the number of acute health-related complaints experienced during the last 14 days, including headaches, nausea, dizziness, listlessness etc. Both studies found consistent results, indicating that respondents living in a greener environment compared to a less green environment were more likely to report fewer health-related complaints. Maas et al.[110], on the other hand, investigated the association between green space availability and health-related complaints using a measurement of the annual prevalence of disease, derived from electronic medical records of GPs. The most frequent recorded episodes were combined into 24 disease clusters, distributed over seven disease categories which included cardio-vascular disease, musculoskeletal disease, mental diseases, respiratory diseases, neurological diseases, digestive diseases and miscellaneous. The results found that the annual prevalence rate of 15 out of the 24 disease clusters were lower in neighbourhoods with greater availability of green space within a 1km radius. This relationship was apparent for complaints in all seven disease categories, with the strongest association being shown for anxiety disorders and depression. Only one study explored the way in which green space quality may be associated with health-related complaints[6]. Using the number of acute health-related complaints experienced during the last 14 days the results found that living in a neighbourhood with better quality green space was associated with fewer health-related complaints. The main critique with all four of these studies is that it is difficult to understand why the prevalence of some of the health-related complaints investigated would be positively related to the availability of neighbourhood green space. If the causal pathways by which green space and each health-related complaint cannot be understood, it is plausible that many of the positive associations reported in these studies may not be a function of neighbourhood green space.

4.3.1.3 BMI

Three studies, which produced four observations, investigated the association between green space and BMI. Two studies used objective measurements of green space availability[111, 112]. Among a sample of 6919 adults living across eight European cities, Ellaway et al.[112] found that residents living in neighbourhoods containing a high level of greenery were 40% less likely to report being overweight or obese. In contrast, Cummins et al.[111], using information from the Health Survey of England and analysis over two time periods: 2000-2003 and 2004-2007, found that in 2000-2003 there was a negative association between green space and BMI whilst in 2004-2007 there was a weak protective effect of green space for those residing in the greenest neighbourhoods but this did not reach statistical significance. The advantage of Cummins and colleagues[111] study was that it was conducted on a large nationally representative study using both objective measurements of green space availability and BMI. Ellaway and colleagues[112] study, on the other hand, was conducted on a smaller population and used self-reported measurements of BMI. The limitations of self-reported measures include misunderstanding of survey questions, inaccurate recall or response bias e.g. social desirability. In the case of Ellaway et al.[112] this limitation may be particularly pertinent as the study drew upon data from eight different European countries where differences in the interpretation and reporting of height and weight between each country may occur. Cummins et al.[111] study was also strengthened by the fact that it adjusted for each respondent's total levels of physical activity behaviour. This is important to take into consideration as any reported association between green space and BMI may be due to levels of physical activity being higher or lower in greener areas. As Ellaway et al.[112] did not control for physical activity, it is plausible that the negative association between green space and BMI was strengthened due to respondents being more physically active in greener areas. Only one study explored the association between green space and BMI using a perceived measurement of green space availability. The results found that living within a short distance to green space was associated with a lower likelihood of reporting overweight and obesity[113]. This study was again limited by its small sample size, self-reported measurement of physical activity and its failure to adjust for total level of physical activity.

4.3.1.4 Mortality

Four studies, which produced nine observations, examined the relationship between green space and mortality. Two of these observations explored all-cause mortality[1, 5] and seven explored cause-specific mortality[1, 114, 115]. Three of the studies[1, 114, 115], totalling eight observations, used objective measurements of green space availability and one study used perceived measurements[5]. Study locations were the UK, Japan and New Zealand. Both studies exploring the association between green space availability and all-cause mortality reported a positive association[1, 5]. Takano et al.[5] used a longitudinal design to explore the association between neighbourhood green space walkability and longevity among 3144 senior citizens. The results were conducted over a five year period suggesting that neighbourhoods with walkable green space positively influenced longevity independent of respondents' demographic and socio-economic characteristics. Despite the strengths of using a longitudinal design, this study was limited by its sample population as it was a regional study conducted in Tokyo, Japan on a population of senior citizens. Similar results, however, have been found among a larger more representative study population. In England, Mitchell and Popham[1] found a lower risk of all-cause mortality among populations living in areas with greater green space availability. This study was limited by its use of a cross-sectional design.

The association between green space availability and cause-specific mortality has been explored for cardio-vascular disease, respiratory disease and lung cancer. Cardio-vascular disease and respiratory disease mortality were selected in the literature as they have certain risk factors (inactivity and stress) which may be partly ameliorated by the availability of neighbourhood green space. Lung cancer, on the other hand, was purposefully selected as a control disease as the pathway by which the availability of neighbourhood green space may be associated with lung cancer mortality is difficult to establish. The studies exploring the association between green space availability and cause-specific mortality have found mixed results. Mitchell and Popham[1] found a positive association between green space availability and mortality from cardio-vascular disease, but, as expected, no significant association was shown for mortality from lung cancer. In New Zealand, however, no association between the availability of green space and cause specific mortality was shown for either cardiovascular disease or lung cancer mortality[114]. In this study green space availability was captured by aggregating three data sets, thereby, producing a high resolution classification that distinguished usable from non-usable green space. It could be plausible that the difference in results between both studies was due to the New Zealand study having greater sensitivity to green space accessibility. Alternatively the results suggest that the relationship between green space and health may differ by country.

Two studies investigated whether the relationship between green space and mortality differed by population sub group[1, 115]. Richardson and Mitchell[115] explored the effect of gender, whereas, Mitchell and Popham[1] explored the effects green space may have on socio-economic health inequalities. The results suggest both gender and socio-economic differences in the association between green space and mortality. Increasing green space availability was associated with a decrease in male cardio-vascular disease and respiratory disease mortality but no significant associations were shown for females[115]. No significant effect for lung cancer mortality was shown for either males or females[115]. In terms of socio-economic differences, the results found that income-related health inequalities for cardio-vascular disease were narrower among populations living in the greenest areas of England, compared to the least green areas, but no association was shown for lung cancer[1]. These results lend weight to the argument that the salutogenic effects of green space cannot be uniformly assumed across all population sub groups.

4.3.2 Green Space and Mental Health

Five studies, which produced eight observations, investigated the association between green space and mental health. Four of these observations used objective measurements of green space availability[6, 108, 116, 117] and one used a perceived measurement[104, 104, 117]. Only three observations explored the effects of either objective *(n=2)* or perceived *(n=1)* measurements of green space quality. Out of the five studies, three were conducted in the Netherlands and two in Australia. The number of observations that reported a positive (+), negative (-) or non-significant (o) association is shown in Figure 4.3. The results indicate that on a whole the association between green space and mental health was mixed. Below the results of these studies will be reviewed in more detail.

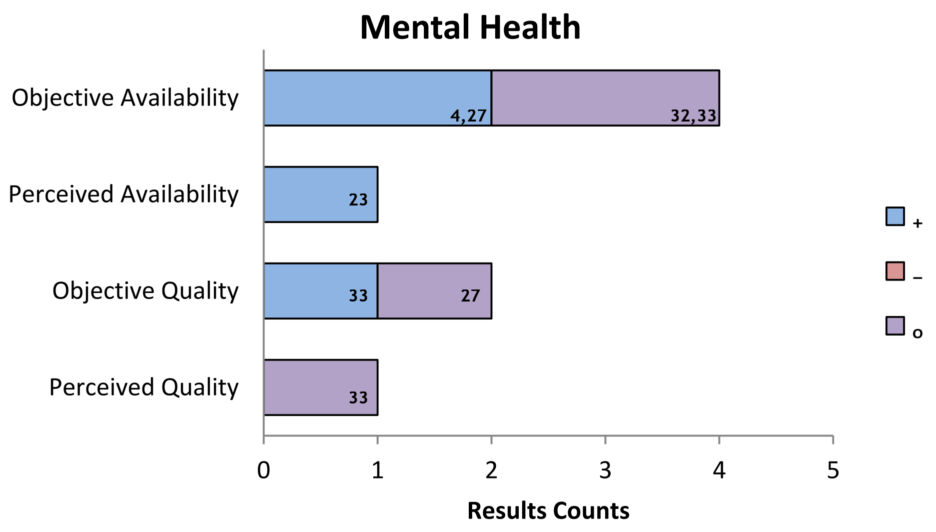


Figure 4.3 The number of articles and the evidence they provide for the association between green space and mental health. Numbers in superscript refer to the relevant article reference

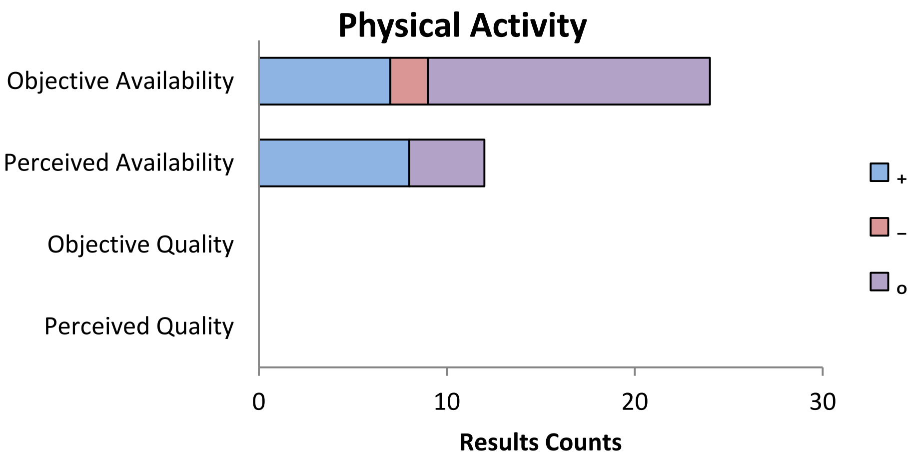
In the Netherlands, both De Vries et al.[108] and Van Dillen et al.[6], using objective measurements of green space availability, found that having access to a greater quantity of neighbourhood green space was associated with better self-reported mental health. Van den Berg et al.[116], however, found no significant association. Explanation for the differences in these results is difficult to establish as all studies were conducted in the same country using a similar methodological approach. They all used comparable measures of green space availability, mental health and statistical techniques; the only difference that could be noted was that of the study population. Van Dillen et al.[6] recruited their population by selecting neighbourhoods from four large Dutch cities, resulting in a sample that was not representative of the Dutch population. De Vries et al.[108] and Van Den Berg et al.[116] recruited their study population using data from 103 general practices in the Netherlands, ensuring a much more representative sample. De Vries and colleagues[108] study included children and adults, whereas, Van den berg et al.[116] included only adults. As the relationship between green space and health appears to be more sensitive for particular population sub-groups then it is plausible that these differences in the study population may account for the differences in results.

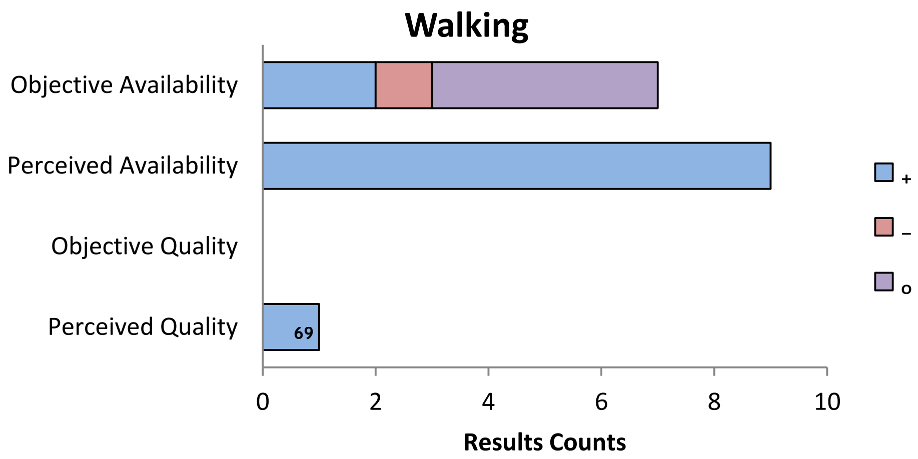
In Australia, Sugiyama et al.[104] found that the availability of green space was positively associated with self-reported mental health but no association was shown by Francis and colleagues[117]. Unlike the studies conducted in the Netherlands these studies used distinct methodological approaches. Sugiyama et al.[104] relied solely on self-reported data for both green space availability and mental health, whereas, Francis et al. used an objective measurement of green space availability. Due to the contrasting methodological designs it is difficult to determine the strength of the association between green space availability and mental health in Australia.

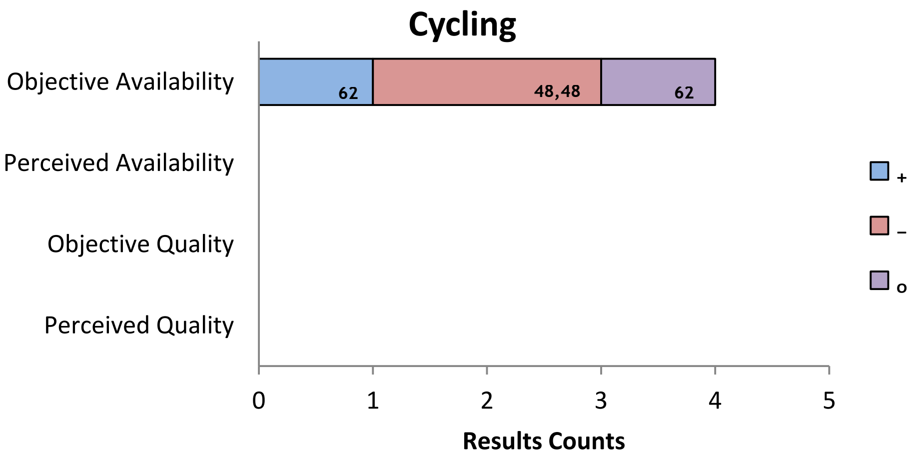
Two studies explored the association between green space quality and mental health. The results were mixed. Using an objective measurement of green space availability Van Dillan et al.[6] found no association between the quality of green space and self-reported mental health. In contrast, Francis et al.[117] found, that when green space quality was measured objectively, residents living in neighbourhoods with a higher quality green space were more likely to have better mental health than residents living in neighbourhoods with a lower quality green space. When green space quality was measured subjectively no significant associations were found. One explanation for these contrasting results is the way in which green space quality was defined. Both studies captured objective measurements of green space quality by developing audit tools that assessed green space quality across ten constructs. These 10 constructs, however, differed between studies. Francis et al.[117], defined green space quality by including attributes such as walking paths, shade, water features, irrigated lawn, birdlife, lighting, sporting facilities, playgrounds, type of surrounding roads and presence of nearby water. Van Dillan et al.[6], on the other hand, defined green space quality by including attributes such as accessibility, maintenance, variation, naturalness, colourfulness, clear arrangement, shelter, absence of litter and general impression. These more subjectively measured qualities of green space may explain why the finding of this study was more consistent with Francis and colleagues[117] self-reported measurement of green space quality.

4.3.3 Green Space and Physical Activity

The search identified 37 studies which examined the relationship between green space and physical activity. From these studies a total of 56 observations were made. These observations were categorised into general activity *(n=36),* walking *(n=16)* and cycling *(n=4).* A greater number of observations involved objective measurements of green space availability *(n=34)* than perceived *(n=23).* Only one study, using a perceived measurement, explored the effects of green space quality on physical activity. The study locations ranged from the United States *(n=14),* Australia *(n=10),* England *(n=5),* Denmark *(n=3),* Canada *(n=2),* New Zealand *(n=2)* and The Netherlands *(n=1).* The observed relationships are shown in Figure 4.4 with more detail in the following paragraphs.







Relevant Article References	Physical Activity	Walking
Objective Availability		
+	35,40,41,41,42,43,44	52,54
-	45,46	48
o	39,39,47,42,49,50,50,50 51,46,48,52,53,54,55	37,54,61,62
Perceived Availability		
+	35,36,37,45,56,57,58,59	23,57,58,61,63,64,65,66,67
-		
o	45,47,49,46	

Figure 4.4 The number of articles and the evidence they provide for the association between green space and (a) general physical activity, (b) walking and (c) cycling. Numbers in superscript refer to the relevant article reference. Where there was too many to fit in the graphs they are provided in the appropriate section of table

4.3.3.1 General Activity

There were 25 studies, with 36 observations, that explored the association between green space availability and general activity. In this review general activity was defined as any physical activity that was categorised as household, walking, sport or occupational. Of the 25 studies reviewed, 24 used a self-reported measurement of general physical activity behaviour and one used an objective measurement. Self-reported physical activity tended to be captured by the use of survey data to assess whether an individual met the nationally relevant recommended physical activity guidelines, where physical activity was defined across four domains: housework, walking, sport and manual work. In the UK the guidelines are the accumulation of 150 minutes of moderate intensity physical activity, in bouts of 10 minutes or more, throughout the week[118]. The few exceptions to the use of the Government's recommended physical activity guidelines were Lackney and Kacsynski[119], who captured only neighbourhood and park based physical activity, Booth et al.[120] and King et al.[121] who estimated the energy expenditure spent participating in total physical activity and Hillsdon et al.[122] who calculated the total hours spent participating in recreational physical activity per week. Jilcott et al.[123] was the only study to measure physical activity objectively using an accelerometer.

Of the 36 observations, 24 used an objective measurement of green space availability. Seven of the observations reported a positive association, 15 reported no association and two reported a negative association; suggesting that the relationship between objective green space availability and physical activity was mixed. One explanation for these differences in results may be the variety of different methods in which studies captured the objective availability of neighbourhood green space. In general, three classifications of green space availability could be defined: distance to green space from a respondent's home, the quantity of green space available in a respondent's neighbourhood and the accessibility of a respondent's neighbourhood green space. Studies capturing the distance to green space from a respondent's home *(n=10)* and the quantity of green space available in a respondent's neighbourhood *(n=9)* found the association between green space availability and physical activity to be mixed. Seven observations reported a positive association[119, 124-128], two reported a negative association[123, 129] and ten reported no association[123, 126, 130-135]. Coombes et al.[124] reported that living closer to formal green spaces was associated with an increase in meeting the recommended physical activity guidelines, whereas, Jones et al.[131] found no association between distance to formal green space and physical activity. Likewise, Richardson et al.[128] found that having a greater quantity of neighbourhood green space was associated with higher levels of physical activity, whereas, Maas et al.[132] found no association between the quantity of green space in the neighbourhood and meeting the recommended physical activity guidelines. All studies that captured the accessibility of neighbourhood green space *(n=5)* found no significant association with physical activity[96, 122, 136-138]. Giles-Corti et al.[96] and Witten et al.[138], for example, found that access to neighbourhood green space was not associated with meeting the recommended physical activity guidelines.

Of the 36 observations, 12 used a perceived measurement of green space availability. Eight of the observations reported a positive association and four reported no association. The mixed results may again be due to the number of ways perceived availability of neighbourhood green space has been defined. Studies capturing self-reported distance to green space from a respondent's home *(n=5)* found the association between green space availability and physical activity to be mixed[119, 123, 130, 133, 139]. Six out of the seven studies capturing the perceived availability of neighbourhood green space reported a positive association with physical activity behaviour[120, 121, 123, 140-142], with only one study reporting no association[131]. Brownson[140], Humpel[141] and Huston[142] found that perceived availability of neighbourhood green space was associated with higher levels of physical activity participation.   This positive association for perceived green space accessibility is very different from the lack of association found for objective green space accessibility, suggesting that the association between green space availability and physical activity may be sensitive to the method of green space classification.

4.3.3.2 Walking

Fifteen studies, 16 observations, explored the association between green space availability and walking. Seven observations used objective measurements of green space availability and nine used perceived. The association between objective green space and walking was mixed. Of the seven studies, two reported a positive association[136, 143], one reported a negative association[132] and four reported no association[121, 137, 144, 145]. Similar to general activity, studies differed in the way in which they captured green space availability. Once again three classifications of green space availability could be defined: distance to green space from a respondent's home, the quantity of green space available in a respondent's neighbourhood and the accessibility of neighbourhood green space. Studies capturing green space distance *(n=1)* and green space quantity *(n=3)* found the association between green space availability and walking to be non-significant[121, 132, 144, 145]. King et al.[121] found that living closer to neighbourhood green space was not associated with an increase in walking behaviour[121]. Similarly, Tilt et al.[144] found no association between quantity of green space and walking behaviour. Two out of the three studies capturing the accessibility of neighbourhood green space, however, found a positive association with levels of walking[136, 143], with one reporting no association[137].

In contrast to the mixed association reported for objective green space availability, all nine studies capturing green space subjectively reported a positive association[104, 140, 141, 144, 146-150]. This positive association was found regardless of the classification of green space availability or the measurement of walking behaviour. Foster et al.[147] used a measurement of green space distance and found that living within a shorter distance to green space was associated with an increase in walking behaviour. Sugiyama et al.[104] captured the perceived greenness of the neighbourhood and reported that respondents who perceived their neighbourhood as highly green were more likely to walk for recreation. These results provide more evidence to suggest that the association between green space availability and walking may be sensitive to the method of green space classification.

One aspect of green space that has been under explored in the physical activity literature is that of quality. Only one study examined whether better quality green space was associated with increased walking behaviour[150]. In this study quality of and access to neighbourhood green space was captured using a 26 item neighbourhood open space scale. This scale was constructed by drawing upon similar instruments published within the literature. Items relating to pleasantness and lack of nuisance within neighbourhood open space were associated with an increase in participants' levels of recreational walking and items relating to good paths and facilities to neighbourhood open space were associated with walking for transport. This study indicates that it may not simply be the availability of green space in the local neighbourhood that influences walking behaviour, quality may also matter.

4.3.3.3 Cycling

Just two studies, with four observations, explored the association between green space availability and cycling. Maas et al.[132] found that in the Netherlands having a greater percentage of green space in the neighbourhood was associated with a decrease in cycling for both recreation and transportation. Zlot et al.[145], on the other hand, found no association between having a greater percentage of parkland and cycling for recreation but found a positive association for cycling for transportation. Due to the limited evidence, this mixed association in results is difficult to decipher. Each study used a different definition of green space availability and measurement of cycling behaviour. One explanation for the negative association suggested by Maas and colleagues[132] could be due to the cycling culture associated with the Netherlands. In the Netherlands there is an extensive cycling infrastructure designed to provide a wide variety of safe cycling opportunities. It could, therefore, be plausible that even if people have little green space provision within their neighbourhood of residence, there is still a vast amount of opportunity to cycle elsewhere.

4.3.4 Green Space and Restoration from Stress

Five studies, six observations, explored the association between green space availability and stress, all suggesting that greater availability of green space was associated with lower levels of stress. Only one study, two observations, was conducted using an objective measurement of green space availability[151]. This study was conducted in Scotland using salivary cortisol as a biomarker of stress, alongside a self-reported indicator of stress. The results found that a greater percentage of green space in the neighbourhood was associated with a decrease in both objective and self-reported levels of stress. The remaining studies were conducted in Denmark *(n=2)* and Sweden *(n=2)* using self-reported measurements of green space availability and levels of stress. Three out of four of the studies defined available green space as the distance from a respondent's home[97, 109, 113], with the remaining study defining it as whether they had access to green space close to their dwelling[152]. All studies reported that the greater availability of green space was associated with a decrease in self-reported levels of stress. Overall the available evidence suggests that contact with a green environment might help reduce stress at a population level. These studies to date have been conducted on a limited sample population. Four out of the five studies[97, 109, 113, 152] were conducted in Northern European countries where differences in the social, cultural or behavioural patterns of respondents may result in us being unable to generalise these study findings to that of other countries.

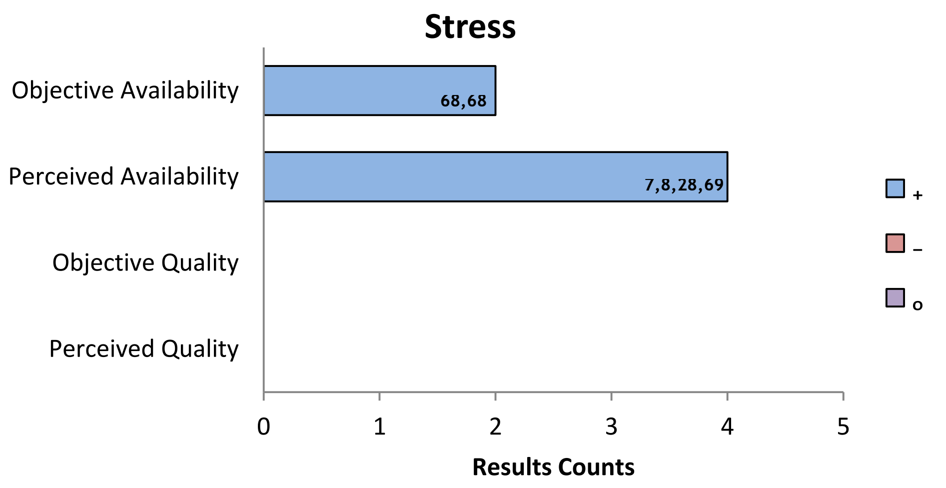


Figure 4.5 The number of articles and the evidence they provide for the association between green space and stress. A positive association is protective showing that greater availability of green space is associated with less stress. Numbers in superscript refer to the relevant article reference

4.3.5 Green Space and Social Interaction

Just five studies explored the association between green space availability and social interaction. Using an objective measurement of green space availability, Maas et al.[14] found no association between the percentage of green space in a respondent's living environment and the number of supportive interactions respondents received from their social support network. All studies using a subjective measurement of green space availability reported a positive association suggesting that perceived greenness of a neighbourhood was associated with neighbourhood social interaction[13, 104, 153, 154]. These studies, however, had a number of weaknesses. Studies by Coley et al.[153], Kuo et al.[154]

and Kweon et al.[13] were all conducted in the same highly deprived neighbourhood in Chicago where the availability of neighbourhood green space was low. Sugiyama et al.[104] had a larger study population with varying degrees of green space exposure but were still limited in its representativeness of the Australian population. Overall, these studies do provide some preliminary evidence that greater availability of green space may increase levels of social interaction.

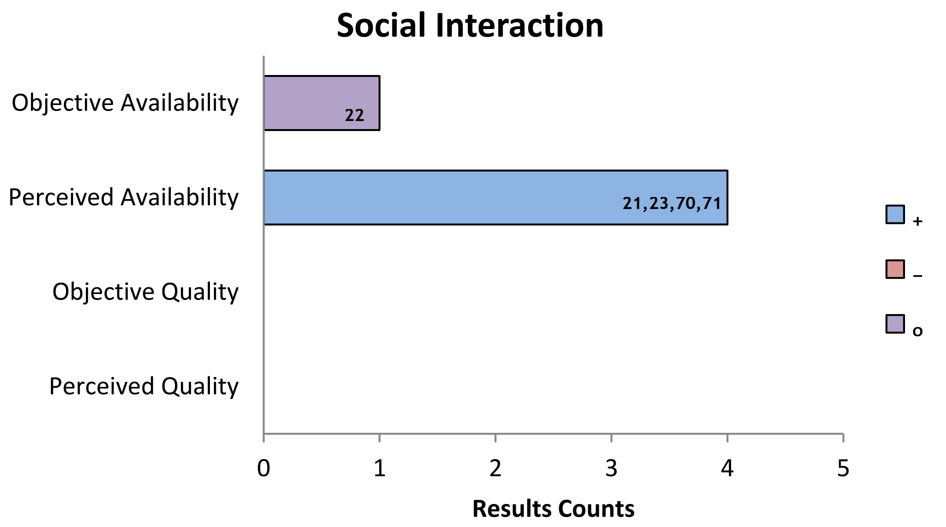


Figure 4.6 The number of articles and the evidence they provide for the association between green space and social interaction. Numbers in superscript refer to the relevant article reference

4.4 Discussion

The purpose of this chapter was to review evidence for the association between neighbourhood level, or access to green space and health and for the mechanisms proposed to explain this relationship. The results found that evidence for the relationship between green space and health was mixed. Of the 32 observations, 22 reported a positive association, one reported a negative association and nine reported no association. These results, however, differed by the health outcome under investigation. All studies exploring general health and health-related complaints reported positive associations, whereas, those capturing BMI, mortality and mental health reported a mixed association. In terms of the three mechanisms proposed to explain any salutogenic effects of green space, the results found that roughly half (28 out of the 56 observations) reported a positive association between green space and physical activity, all (seven out of seven) reported a protective association with levels of stress and four out of five reported a positive association with social interaction. Across all three mechanisms, positive associations were more likely to be found among perceived compared to objective measurements of green space availability.

Overall, there is some evidence to suggest that greater availability of green space is associated with better general health but the exact health outcomes affected and the mechanisms by which green space may impact health remains uncertain. The finding that just over half of the studies found no significant association between the availability of neighbourhood green space and levels of physical activity does question whether physical activity is the key mechanism by which green space may be salutogenic. This research, however, was limited by a number of methodological weaknesses. In this review six limitations that may account for the uncertainty in results were identified. These limitations and the contribution this thesis makes to address each limitation are illustrated in Table 4.2 and then considered below in turn.

Table 4.2 Current methodological limitations with reviewed studies and the contribution this thesis makes to address each limitation

Identified Methodological Limitation	Key Points	Thesis Contribution
Measurement of Green Space	Lack of understanding of the green space characteristics, over and above availability that may influence the association between green space and health.	Exploration of the way in which objective measurements of green space availability and self-reported measurements of green space availability and quality may be associated with both health and physical activity
Measurement of Health	Lack of understanding of the way in which green space may be associated with specific health outcomes	Exploration of the association between green space and health using specific individual level health outcomes
Measurement of Green Space Use	Lack of understanding of the type and amount of behaviour that occurs specifically in green space.	Exploration of the behaviours that occur in green space, focussing particularly on whether greater availability of green space is associated with physical activity specifically in green space
Socio-Demographic Differences in Green Space	Lack of understanding of the way in which the relationship between green space and health may differ by demographic and socio-economic characteristics	Exploration of whether socio-economic health inequalities are narrower in neighbourhoods with relatively more green space compared to those with relatively less and whether physical activity in green space is a mechanism explaining any reduction
Study Design	Lack of understanding of whether the relationship between green space and health is causal or whether it is the effects of selection	Ensure the study design makes allowance for confounding factors and controls for a number of demographic and socio-economic characteristics
Theoretical Understanding	Lack of theoretical understanding of the likely causal mechanisms by which green space may exert a salutogenic effect on health	Use of a social ecological model to refine and develop the conceptual understanding of the way in which green space may influence socio-economic health inequalities

4.4.1 Measurement of Green Space

Several characteristics of green space have been proposed to influence health and health-related behaviour. In their conceptual model of the role of public parks in public health Bedimo-Rung and Colleagues[155], identified five characteristics of the green environment: (1) access (distance and quantity); (2) features (type, size and facilities provided); (3) quality (maintenance and condition); (4) aesthetics (design and attractiveness) and (5) safety (personal and road safety). The majority of studies, to date, have focussed on green space accessibility with few studies exploring any of the remaining characteristics. In this review, for the purpose of analysis, green space availability was broken down into objective and perceived measurements of green space. The review found that there was relatively little difference in the association between green space and health by either objective or perceived measures of green space availability. The measure of availability, however, did appear to impact the mechanisms thought to explain the salutogenic effects of green space. On a whole, stronger associations were reported for perceived measurements of availability than objective measures.

One explanation for the difference in objective and perceived measurements of green space availability could be that both measures capture different aspects of green space exposure. Objective measurements of green space availability tend to capture either the quantity of green space in the neighbourhood or the distance from a respondent’s home to their nearest green space. The strength of using an objective measurement of availability is that it is not subject to any of the biases of self-report. Objective measures are, however, limited as they make the assumption that everyone has equal access to green space and that the type, facilities and quality are suitable for use. Self-reported measurements, on the other hand, are limited as they are subject to response and recall bias, but they are strengthened as they take into consideration respondents’ perceptions and perhaps real experience of their access to green space. It could, thus, be possible that self-reported measurements of availability unintentionally capture several addition characteristics of green space, for example, respondents that feel their green space is unsafe, of insufficient quality or does not provide the appropriate facilities, may not regard that green space as accessible.

This research highlights the importance that the remaining four green space characteristics may play in bettering our understanding of the relationship between green space and health. Despite this, my review identified only three studies that captured some aspect of quality[6, 117, 156] and one study that captured different green space types[124]. Research needs to develop more sophisticated measurements of green space exposure which incorporate all characteristics of green space. It is recognised that capturing these aspects is challenging but by utilising self-reported measures and developing audit tools that measure the features, quality and safety of green space we can begin to untangle the way in which green space may impact health and health-related behaviour. In the thesis I was able to begin to address this limitation by exploring both objective measures of green space exposure and self-reported aspects of green space availability and quality and seeing how each was associated with health and health-related behaviour.

4.4.2 Measurement of Health

The majority of studies exploring the relationship between green space and health have been conducted using measurements of either general or mental health. Most often this has involved the use of self-reported measures such as the single item question "in general how would you rate your health…." with response options ranging from "very good" to "very bad". Fewer studies have investigated the salutogenic effects of green space using specific health outcomes, such as cardio-vascular disease, blood pressure, diabetes and BMI. Of these, many used an ecological approach to explore the association between green space and cause-specific mortality. One advantage of using this approach is that mortality data provides a robust health outcome that documents the underlying cause of death. The disadvantage is that the underlying cause of death may be subject to some level of miss-classification which can result in information necessary for understanding specific health conditions being omitted. If the underlying cause of death, for example, is coronary heart disease much information concerning the associated risk factors such as elevated blood pressure, diabetes and obesity might be lost. Capturing this information would be advantageous in exploring the salutogenic aspects of green space because it would help increase the understanding of the mechanisms by which green space may impact health. One method in which to capture this information is through the use of individual level health data. In this review only three studies that explored the association between green space and a specific health outcome using data at an individual level were identified. These studies all explored the effects green space availability had on BMI; two capturing BMI using data derived from a self-reported questionnaire and one using data from the Heath Survey for England. In this thesis I will expand this limited number of studies and explore whether the availability of green space is associated with health using a variety of individual level specific health outcomes, including cardio-vascular conditions, diabetes, blood pressure and BMI. This will allow me to further the knowledge of the relationship between green space and health and the way in which green space is thought to exert a beneficial effect on health.

4.4.3 Measurement of Green Space Use

One of the least discussed, but perhaps most important, limitations within the literature is the assessment and understanding of the type and amount of physical activity, restoration from stress and mental fatigue and social interaction which occurs specifically in green space. Using physical activity as an example, this review identified that the majority of studies measured physical activity by assessing whether an individual met the recommended physical activity guidelines. This measurement typically captures physical activity across four domains: housework, walking, sport, and manual work, but only two (walking and sport) are likely to include physical activity undertaken in green space. If it is observed that a population residing in greener neighbourhoods are more likely to meet the recommended physical guidelines it cannot be assumed that green space is implicated. Physical activity may have occurred at work, at the gym, outwith or within their neighbourhood environment. This limitation can be demonstrated by a recent study conducted by Mytton et al.[127]. They found that neighbourhood level quantities of green space were positively associated with likelihood of meeting the recommended physical activity guidelines, resulting in a positive association being given by this review. On further exploration, the authors found no positive association between levels of neighbourhood green space and the types of physical activity plausibly associated with green space. The positive associations found were in fact due to higher levels of manual work or occupational physical activity among people who happened to reside in greener areas. Although this limitation has been illustrated using physical activity, the same can be said of the restorative and social contact literature.

This highlights the need for research to capture the actual behaviours that occur specifically in green space. The best method to achieve this is through the use of objective measurements. Within the physical activity field, for example, global positioning systems have been coupled to accelerometers and pedometers to measure physical activity[157, 158]. A recent study by Lachowycz et al[158] combined global positioning systems and accelerometers to objectively measure how different types of green space are used by children for play and physical activity. In the restorative and social contact literature, the combination of global positioning systems to objective measures of behaviour has yet to occur but possible uses could include coupling global positioning systems to blood pressure and heart rate monitors to measure restoration from stress and mental fatigue and to audits of the amount of people using green space for interaction to measure social contact. Capturing data in this way would allow the quantity of activity to be assessed, its impact and crucially, whether it occurs within green space. Due to the quantity of data produced and the practical difficulties associated with the use of objective data, implementing such methodologies would be suited to small scale studies but would create a challenging research agenda for exploring the association between green space and use at the level of the population. Population level studies need to concentrate on the utilisation of self-reported measures. One way in which to do this is to ask respondents to report both the amount of time they spend participating in physical activity, restorative activities or social interaction and to report the environments they use. By asking both the quantity and location of these behaviours, a greater understanding of the role of green space will be gained. In this thesis I will explore this limitation by investigating the behaviours that occur specifically in green space, focussing in particular on exploration of whether greater availability of neighbourhood green space is associated with physical activity participation specifically in green space.

4.4.4 Socio-Demographic differences in Green Space

Few studies have explored the way in which the relationship between green space and health may differ by demographic and socio-economic characteristics. Of the 17 studies exploring the relationship between green space and health, only 2 had a specific focus on how the relationship between green space and health may differ by gender and socio-economic position. The finding that the health benefits of green space could not be uniformly assumed across all population sub-groups suggests that this area of study warrants further investigation. Given that the key principle of public green space availability is that it is free to use, and Mitchell and Popham's[1] finding that socio-economic health inequalities are narrower in greener compared to less green areas, it may be particularly pertinent to explore whether use of green space has greater value for groups of lower socio-economic position. Mitchell and Popham[1] have suggested that the equalised opportunities for physical activity which green space could offer may be a key mechanism in explaining any socio-economic differences in the relationship between green space and health (Chapter 1, Section 1.1.1). There is no research to date that has explored whether the mechanisms postulated to explain the association between green space and health can differ by socio-economic characteristics. In this thesis I will, therefore, address this limitation and explore Mitchell and Popham's[1] hypothesis that physical activity in green space is a mechanism by which green space may reduce socio-economic health inequalities.

4.4.5 Study Design

From all the studies reviewed, only one study used a longitudinal design. The remaining studies were cross-sectional. The key limitation with cross sectional designs is that it is not possible to determine if an observed relationship between green space and health is causal. There is the possibility that selection, either direct or indirect, can occur. Direct selection occurs when peoples health influences their chances of moving to a greener environment, whereas, indirect selection occurs when people with characteristics associated with better health are more likely to move to a greener environment. There is the possibility that individual characteristics (such as demographic and socio-economic) may confound the relationship between green space and health. If house prices are higher in greener areas, for example, it could result in mainly people with higher incomes being able to reside in a greener neighbourhood. Since research has shown that higher incomes are associated with better health[20], then indirect selection based on income can be said to have occurred. One way to attempt to control for the effects of both direct and indirect selection is through the use of a longitudinal study. Longitudinal studies follow people over time, and as a result, they allow a greater understanding of a respondent's total exposure to green space and the way in which it may have differed over the life course. Given the complexity and cost of conducting longitudinal studies it is understandable that few longitudinal datasets for exploring the relationship between green space and health exist. Generally speaking studies have controlled for the effects of indirect selection by making adjustments for respondents' socio-economic characteristics. The limitation with this is that if studies do not sufficiently control for all aspects of socio-economic position then it is difficult to rule out the effects of indirect selection or other forms of confounding. Certainly, in this review, it was noted that studies varied in their measures of socio-economic position, whilst some studies failed to account for any socio-economic characteristics at all. In this thesis I will be unable to explore the association between green space and health using a longitudinal design due to there being no available dataset at the time of writing. The study design, however, will make allowance for confounding factors as far as possible through control for a number of demographic and socio-economic characteristics.

4.4.6 Theoretical Understanding

One final factor that may explain the equivocal nature of research exploring the relationship between green space and health is a lack of a theoretical underpinning which specifies the likely causal mechanisms by which green space may exert a salutogenic effect on health. It could be argued that current research exploring the relationship between green space and health has been based on loosely defined theoretical concepts resulting in specific casual pathways being poorly understood. In this thesis I have suggested the use of a social ecological model to help refine and develop the conceptual understanding of the way in which green space may influence health. In Chapter 3, I discussed the core assumption of social ecological models and the way in which they may be used to understand the role that natural environments may play in influencing health and socio-economic health inequalities. In brief, the social ecological model recognised that there is a reciprocal relationship between people and their environments, whereby, the physical and social environment influences individuals' health related behaviour and the behaviours of individuals can modify the environment. In this thesis I will use the conceptual framework described in Chapter 3 to help understand the causal pathways by which green space may impact health and the potential for them to differ by individual level socio-economic position. This will allow me to better define the specific research objectives and questions of this thesis.

4.4.7 Limitations of Review

There were several limitations associated with this review. First, the review only considered the significance and direction of each association and not the effect size, via a formal meta-analysis. This was because research exploring the relationship between green space and health has used many different measures of green space availability, and as a result, summarising them into meaningful groups to quantify effect sizes would be challenging. As a consequence no assessment has been made about the magnitude of the association. Second, the review stratified green space characteristics by objective and perceived measures, but did not stratify health outcomes or the three postulated mechanisms by their perceived or objective measures. This could have influenced the results of this review, but where any differences by outcome were observed a comment was included within the review. Third, studies used a variety of different measures of green space availability and quality. Due to the limited number of studies this review was unable to explore each definition individually. Lastly, the search was restricted to English language articles, and just three databases were searched. These databases, however, were judged to best represent relevant studies.

4.5 Research Objectives and Thesis Outline

The main aim of this thesis, set out in Chapter 1, was to determine the role of physical activity as a mechanism by which green space may promote population health and narrow socio-economic health inequalities. The broad research questions were to explore whether:

1. Greater availability of green space is associated with better health in Scotland?
2. Socio-economic health inequalities are narrower in greener areas compared to less green areas in Scotland?
3. Greater availability of green space is associated with higher levels of physical activity participation in Scotland?
4. Socio-economic inequalities in physical activity are narrower in greener areas compared to less green areas in Scotland?
5. Greater equality in access to green space contributes to narrowing socio-economic inequalities in health by encouraging use of green space for physical activity in Scotland?

This overarching aim was based on Mitchell and Popham's[1] hypothesis that physical activity in green space may be the main mechanism explaining their finding that socio-economic health inequalities were narrower in neighbourhoods with relatively more green space compared to those with relatively less. In this Chapter, I reviewed the evidence as to whether the availability of green space was associated with greater levels of physical activity. The results found that there was some evidence of a positive association between the availability of green space and physical activity but on a whole the evidence was mixed. This does begin to cast some doubt as to whether physical activity is the key mechanism explaining the salutogenic effects of green space. The current literature, however, had a number of methodological weaknesses. The most central of these for understanding Mitchell and Popham's[1] hypothesis were: the lack of understanding of the characteristics of green space that have been proposed to influence physical activity; the type and amount of physical activity that occurs specifically in green space; and the way in which the relationship between green space and physical activity may vary by different socio-economic groups (Table 4.2). If these methodological weaknesses are taken into consideration, Mitchell and Popham's[1] suggestion that physical activity in green space is key for explaining the relationship between green space and health, does remain a reasonable hypothesis to test. In order to explore this hypothesis this thesis will be conducted in two phases. Below each phase and their specific research questions will be discussed.

4.5.1 Phase One

Phase One will explore Mitchell and Popham's hypothesis that physical activity in green space is a mechanism by which the availability of green space may promote population health and narrow socio-economic health inequalities. This phase will be conducted by combining data from the Scottish Health Survey (SHS) about respondents' health and related behaviour with objective measurements of the percentage of green space in the respondent's neighbourhood of residence. Combining green space data and data from the SHS provides a variety of individual level health outcomes and measurements of physical activity in green space, allowing me to address the following five research questions:

1) Is the availability of neighbourhood green space associated with better health?
2) Is the socio-economic inequality in health narrower in the greenest compared to the least green areas?
3) Is the availability of neighbourhood green space associated with physical activity in green space?
4) Is the socio-economic inequality in physical activity narrower in the greenest compared to the least green areas?
5) Is physical activity in green space more protective of health for groups of lower socio-economic position?

4.5.2 Phase Two

Phase Two will build on Mitchell and Popham's hypothesis by exploring the role self-reported measurements of green space availability and quality may play in fostering the use of green space in Scotland. This will allow me to further the understanding of whether physical activity in green space is a mechanism by which the availability and quality of green space may be associated with better health and narrower socio-economic health inequalities. It will also allow the investigation into the competing mechanisms, restoration from stress and mental fatigue and social interaction, which have also been proposed to explain the beneficial effect of green space. Using the Green Space Scotland Omnibus Survey, the following six research questions will be addressed:

1) Is the availability and quality of neighbourhood green space associated with better health?
2) Is the socio-economic inequality in health narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
3) Is the availability and quality of neighbourhood green space associated with more frequent green space use?
4) Is the socio-economic inequality in green space use narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
5) Is the availability and quality of neighbourhood green space associated with use of green space for?
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?
6) Is the socio-economic inequality in use of green space narrower among those with available, good quality, green space compared to those with less available, poor quality green space for:
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?

4.6 Thesis Outline

The remainder of this thesis will be comprised of Six Chapters plus an Appendix. The methods will be discussed in Chapter Five and Six. Chapter Five will focus on detailing the methodology of Phase One of the research proposal, whilst

Chapter six will focus on detailing the methodology of Phase Two. The results will be explored in Chapter Seven and Eight. These chapters will again be separated by research phase, with Chapter Seven focusing on the results of the Phase One and Chapter Eight focusing on the results of Phase Two. In each of these Chapters, the descriptive statistics and the results of each research question will be discussed. The results will be discussed in Chapter Nine. This will include a synthesis of the findings from both results chapters and how they compare to the existing literature. The strengths and limitations of this study will also be discussed within this chapter. The last Chapter, Chapter Ten, will summarise the results of the thesis and discuss suggestions for future research.

Chapter 5 Methods-Phase One

This chapter describes the methods from the first phase of my research methodology, which sought to examine whether the relationship between green space and physical activity was a mechanism to reduce socio-economic inequalities in health. This research objective was addressed using five research questions (Chapter 4, Section 4.5.1). To answer each research question, data on the quantity of green space within each neighbourhood in Scotland was combined with information from the Scottish Health Survey (SHS) respondents. The SHS provided information on the socio-economic characteristics, health and physical activity across a representative sample of the Scottish Population.

The aim of this chapter is to provide an overview of both of these data sources and the way in which I selected and derived each variable for analysis. The specific objectives are to:

1. Explore the range of data sources used to capture aspects of green space exposure in Scotland. Provide a rationale for why I chose the data source used in this study.
2. Provide a summary of the SHS. Document why it was an appropriate dataset for the focus of our research study.
3. Describe the way in which the two data sources were combined.
4. Outline the way in which the outcome, explanatory and confounding variables were selected and derived.
5. Document the data analysis strategy employed.

5.1 Comparison of Green Space Indicators

Four indicators of green space are available to capture the exposure of green space throughout Scotland. These include the Coordination of Information on the Environment (CORINE), the Urban Morphological Zones (UMZs), the Estimated Exposure of Green Space and Local Authority Green Space Data. Each of these green space indicators have been derived from different data sources, using a different methodological approach. As a result, the extent to which each indicator agrees on the quantity of green space within each neighbourhood in

Scotland may vary. Selecting the most appropriate data set is, therefore, important in order to capture the best representation of the available green space and to determine the way in which this may influence population health and socio-economic health inequalities. Table 5.1 illustrates the different methodological approaches used by each green space indicator. By comparing these approaches I can weigh up the strengths and weaknesses of each data source, enabling me to select the most appropriate data set for the exploration of my Phase One research questions. The following section will explore the way in which each green space indicator was derived and provide a rationale for my chosen dataset.

Table 5.1 Summary of data source, method of collection, data type and resolution for each of the four data indicators used to capture green space exposure throughout Scotland

Green Space Indicator	Data Source	Land Cover	Data Collection	Spatial Data Type	Data Resolution
CORINE	European Environment Agency	Urban and Rural	Satellite Imagery	Polygon	1:100,000
UMZs	European Environment Agency	Urban Only	Satellite Imagery	Polygon	1:50,000
Estimated Exposure of Green Space	Richardson and Mitchell	Urban Only	Satellite Imagery	Percentage Estimate	1:1250
Local Authority Green Space Data	Various Local Authorities across Scotland	Urban Only	Open Space Audits	Polygon	Differed depending on Local Authority

5.1.1 CORINE Land Data

The Coordination of Information on the Environment (CORINE) is a land cover data set developed by the European Environment Agency[159]. It was established in 1985 to develop digital maps of the European Environmental Landscape. Using computer assisted image interpretation of remotely sensed satellite image; land cover was organised into 44 different classifications and grouped into 5 major land cover types: artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands and water bodies (Table 5.2). From these definitions a number of green space classifications could be derived. Mitchell et al.[160], for example, defined green space using all 22 CORINE land cover categories relating to the natural environment. This included urban and agricultural areas of green space but excluded wetlands and water bodies. Kabish and Haas[161], on the other hand, defined green space using only three land cover classifications. These were based on the 'green urban areas' provided in the artificial surfaces of CORINE (Table 5.2). The mapping of all land cover classifications was performed on a scale of 1:100,000. Despite this, the operational and output requirements of such a large dataset meant that the surface area of the smallest unit mapped was 25 hectare. This meant that CORINE included larger areas of green space such as parks, woodlands and cemeteries but excluded smaller areas of green space such as transport corridors (road, rail, cycle routes and walking routes).

Table 5.2 CORINE Land Use Classifications

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric**
		1.1.2. Discontinuous urban fabric**
	1.2. Industrial, commercial and transport	1.2.1. Industrial or commercial units**
		1.2.2. Road and rail networks and associated land**
		1.2.3. Port areas
		1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites
		1.3.2. Dump sites
		1.3.3. Construction sites
	1.4. Artificial, non-agricultural vegetated areas	1.4.1. Green urban areas**
		1.4.2. Sport and leisure facilities**
2. Agricultural areas	2.1. Arable land	2.1.1. Non-irrigated arable land
		2.1.2. Permanently irrigated land
		2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plantations
		2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops
		2.4.2. Complex cultivation
		2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
		2.4.4. Agro-forestry areas
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest
		3.1.3. Mixed forest
	3.2. Shrub and/or herbaceous vegetation associations	3.2.1. Natural grassland
		3.2.2. Moors and heathland
		3.2.3. Sclerophyllous vegetation
		3.2.4. Transitional woodland/shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and sand plains
		3.3.2. Bare rock
		3.3.3. Sparsely vegetated areas
		3.3.4. Burnt areas
		3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1. Inland wetlands	4.1.1. Inland marshes
		4.1.2. Peatbogs
	4.2. Coastal wetlands	4.2.1. Salt marshes
		4.2.2. Salines
		4.2.3. Intertidal flats
5. Water bodies	5.1. Inland waters	5.1.1. Water courses
		5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons
		5.2.2. Estuaries
		5.2.3. Sea and ocean

** Delineates Urban Morphological Zones

5.1.2 Urban Morphological Zones

Urban Morphological Zones (UMZs) is a dataset again prepared by the European Environment Agency[159]. It was defined to delineate urban areas, defined as a minimum of 25 hectare in area with more than 100,000 inhabitants, across 31 European Countries. It was based on a sub-section of the CORINE land cover classifications comprising of the following urban land classifications: continuous urban fabric, discontinuous urban fabric, industrial or commercial units, road and rail networks and associated land, green urban areas and sport and leisure areas (Table 5.1). This meant that it differed from CORINE land cover data as only urban areas of green space could be defined. The satellite remote sensory images were performed using a slightly higher resolution of 1:50,000. The area of the smallest unit mapped, however, remained 25 hectare. This again resulted in only large green areas, such as, parks, woodlands and cemeteries being represented.

5.1.3 Estimated Green Space Exposure Variable

The estimated exposure of green space was developed by Richardson and Mitchell[115]. It was designed to capture both large and small areas of green space by adjusting the sensitivity of CORINE land cover estimates with information from the Generalised Land Cover Database (GLUD)[162]. The GLUD classified land use at a high geographical resolution across England using digital Ordnance survey maps derived from aerial photography. The topography layer of the dataset divides the land cover into nine categories: domestic buildings, non-domestic buildings, roads, paths, railways, domestic gardens, green space, fresh water and other (mainly hard standing). From this the green space category can be used to capture the availability of neighbourhood green space. The mapping of all land cover classifications was performed on a scale of 1:1250 in all urban areas. This meant that the smallest unit mapped was precise to 10m^2 with all units of less than 5m^2 being ignored, thus, ensuring that both small and large land features were included. In terms of the availability of green space, this included paths, woodlands and agricultural areas, as well as, ambient greenery and transport verges. If this dataset was available for Scotland, it would have provided an ideal indicator of the availability of Scotland's green space. As it was only available for England, the GLUD was combined with CORINE to produce a dataset that estimated the availability of green space within all wards in Scotland[115]. The dataset was derived by Richardson and Mitchell[115] by creating a regression model in which the GLUD percentage of green space for each English Ward was predicted by a combination of CORINE's Natural land classifications (including continuous urban fabric, discontinuous urban fabric and green urban areas) and census based measures of population density. The model predicted the GLUD values very well (R^2=0.95, <0.001). This model could then be used to estimate the percentage of green space in all small areas of Scotland. One of the fundamental differences between this dataset and previous datasets is that the exposure of green space is presented as a percentage rather than as a polygon. Due to its origins of the GLUD dataset, the model estimated the percentage of green space to $10m^2$. This meant it had greater sensitivity to smaller areas of green space than the CORINE dataset.

5.1.4 Local Authority Data

Local authority data provides another method of gathering information on the availability of green space within Scotland. Until recently, local authorities captured the amount and type of green space in their area using open space audits, such as Green Space Scotland Partnership Guidance or the Scottish Planning Advice Note (PAN) 65[163]. The limitation with this method of classification was that green space data was not uniformly collected by each local authority: different local authorities captured different classifications of green space and mapped it on different scales[163]. The result of this was that green space data could not be combined across all local authorities in order to provide a representative data set of the availability of green space across Scotland. In 2007, Green Space Scotland began to overcome this limitation by commencing a program of green space mapping with all Scottish local authorities[164]. The aim of this program was to provide comprehensive information on the location, extent and type of green space across all urban areas of Scotland. The map was produced in 2011, and issued in 2012, from green space data provided by all 32 Scottish Councils. The map categorised green space into 23 types, including public parks, private gardens, play areas, allotments and amenity spaces. Where an area had more than one type of green space, primary and secondary codes were used. As this map was not available at the time of analysis I was unable to use local authority data as my measure of green space availability within Scotland.

5.2 Selection of Green Space Data

Three data sources were available to capture the quantity of green space in Scotland: CORINE, UMZs and Estimated Exposure to Green Space (Section 5.1). Before selecting the most appropriate data set for use in this study, two factors needed to be taken into consideration. The first factor was whether the sensitivity with which each indicator captured both large and small areas of green space availability may influence the relationship between green space and health. The second was the method by which each indicator could be matched to individual health and physical activity outcomes. Below each factor will be discussed in more detail.

5.2.1 Resolution of Green Space Availability

The resolution in which the availability of green space was captured differed depending on the indicator of green space (Table 5.1). The way in which this may influence the distribution of green space in a neighbourhood is shown in Figure 5.1. Using the city of Glasgow as an example, the quantity of green space detected by each indicator of green space exposure is shown. The results illustrate that each indicator detected large areas of green space exposure. The most notable example of this was Pollock Country Park (west of the M74). The indicators varied, however, in their ability to detect smaller areas of green space. Using Elder Park (east of the A739) the results showed that CORINE detected zero levels of green space, UMZs detected some levels of green space but the estimated exposure to green space detected the highest levels of green space. This difference in the sensitivity of green space availability for each green space indicator was also noted by Mitchell et al[160]. In their comparison of green space indicators across four British cities, the results found that CORINE had a tendency to report low levels of green space, where the British Ordnance Survey Master Map and the Estimated Exposure to Green Space reported higher levels. This difference became particularly evident in areas of lower socio-economic deprivation, suggesting that more deprived areas tend to have less exposure to larger areas of green space.

The difference in the resolution of green space exposure is important to take into consideration as it plausible that the association between green space availability and health may differ depending on the choice of green space indicator. Only one study, to date, has explored the extent to which the association between green space and health may depend on the measurement of green space used. Comparing CORINE, British Ordnance Survey Master Map and the Estimated Exposure to Green Space, Mitchell et al. found that, despite the differences in sensitivity, all three indicators displayed similar associations with the risk of all-cause mortality and self-reported morbidity. The results of this study would suggest that the choice of green space indicator may not influence the association between green space and health. Mitchell et al.'s study, however, was limited in the number of health outcomes investigated. It is plausible that the indicator of green space may not influence measures of 'overall' health but it may influence specific health outcomes. Larger areas of green space may facilitate physical activity and thus be associated with a reduced risk of cardio-vascular disease, whereas, smaller areas of green space may promote restoration from stress and mental fatigue and thus be associated with reduced risk of high blood pressure or poor mental health. Green space indicators that only capture large areas of green space may limit the understanding of the relationship between green space and health. As this thesis was interested in exploring the way in which green space may influence specific health outcomes, using an indicator that captured both large and small areas of green space was advantageous.

Differences in the sensitivity of the availability of green space may also be important when exploring the mechanism by which green space may be salutogenic. In this study I was interested in exploring the way in which physical activity may influence the relationship between green space and health. It could be argued that the ability to capture small areas of green space is not important when exploring the relationship between green space and physical activity as opportunities for physical activity may be limited in smaller areas. If larger areas of green space are not available, however, respondents may be relying on smaller areas of green space to be physically active. This may be particularly apparent among more deprived areas as it has been suggested that they have less exposure to green space[160]. Failure to capture these areas may influence the relationship between green space and physical activity. My choice of indicator, thus, had to be sensitive to large and small areas of green space.

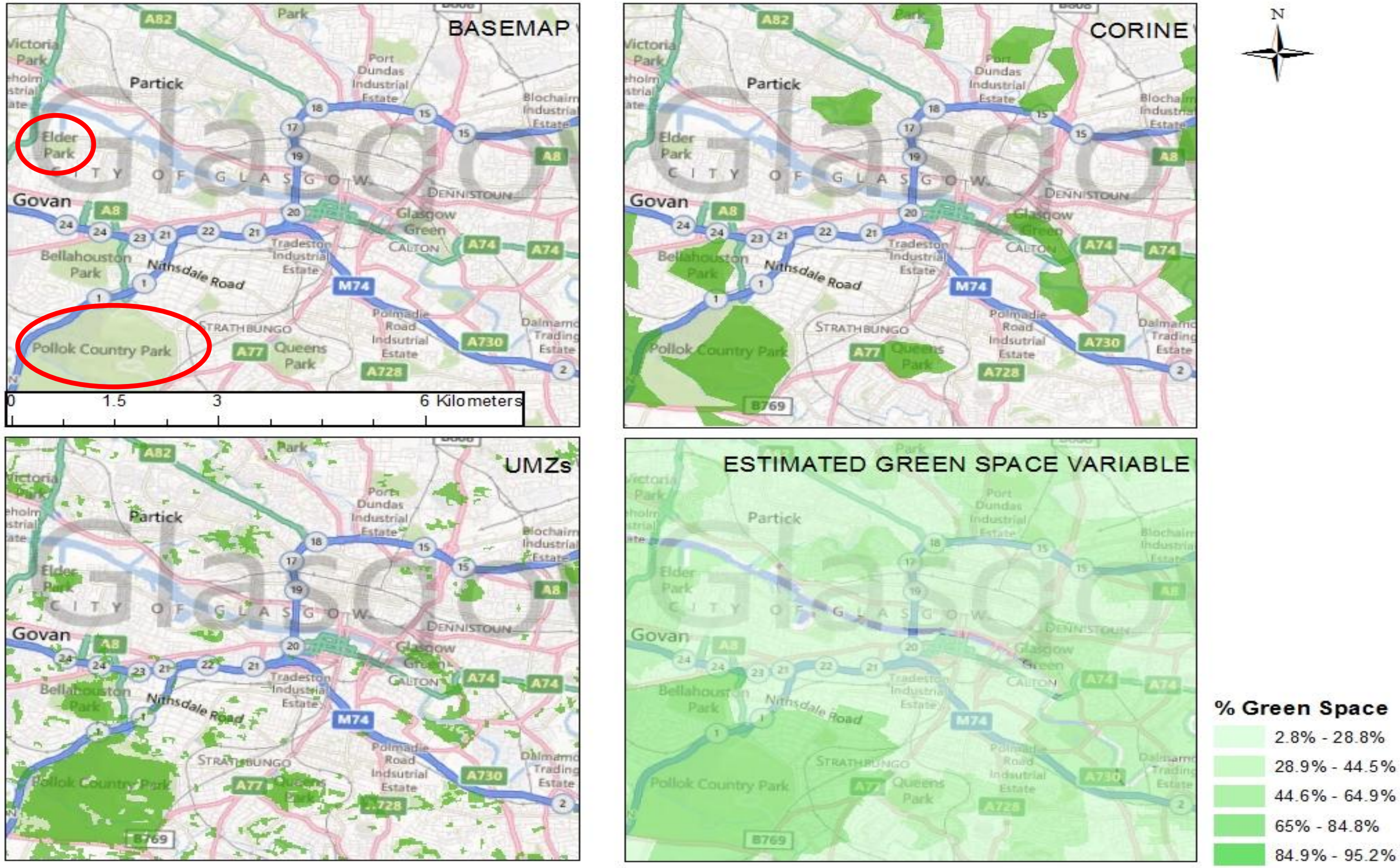


Figure 5.1 Distribution of green space in Glasgow as detected by three different green space indicators. The base map is copyright of Microsoft Bing Maps. Highlighted in red are Pollock Country Park and Elder Park

5.2.2 Matching Green Space Data to Individual Data

The second factor that needed to be taken into consideration when selecting the most appropriate green space indicator was the way in which it could be matched to individual health and physical activity outcomes. For the estimated Exposure to Green Space data set this matching process was fairly straight forward as the data were provided for every Census Area Statistic (CAS) ward in Scotland. This meant that green space data could be matched to an individual's health and physical activity outcomes via the individual's postcode, allowing the exploration of the relationship between green space and health at a ward level. Both CORINE and UMZs datasets were not provided at ward level. In order to match their data to individual survey data a green space buffer would have to be calculated. Previous studies have done this in several ways. Maas et al.[3] calculated the percentage of green space within a 1km and 3km radius of a respondent's home, whereas, Stigsdotter et al.[109, 165] calculated the distance to a respondent's home from their nearest green space. The disadvantage of this method in calculating the availability of neighbourhood green space was that I would have needed access to either the respondent's postcode or coverage of their postcode in order to calculate the green space buffers. As this data was being matched to the SHS this would have created a number of issues regarding the confidentiality and anonymity of the SHS respondents. The Estimated Exposure to Green Space Dataset, on the other hand, was already provided at ward level, resulting in there being no need to disclose the respondents' locations. This meant that the matching process could easily be done by the SHS team, thereby, ensuring the confidentiality and anonymity of the SHS respondents. Moreover, the process of matching the Estimated Green Space Exposure Variable to health data had been successfully completed in previous studies exploring the relationship between green space and health, providing a comparison for the results of my study. For these reasons and the need for sensitivity of large and small areas of green space, I selected the Estimated Exposure to Green space dataset as my measurement of green space availability.

5.3 The Scottish Health Survey

The Estimated Green Space Exposure Variable was combined with data from the 2008 SHS[165]. The 2008 SHS was the fourth of a series of surveys designed to monitor the health of the Scottish population. The first study was undertaken in 1995, with subsequent studies taking part in 1998 and 2003. The survey comprised of a set of core questions and measurements, including questions on general health, measurements of blood pressure and information on demographic and socio-economic factors. These were supplemented by a series of questions on specific health outcomes. The principal focus of the 2008 survey was on cardio-vascular disease and its related risk factors. The main components of cardio-vascular disease are coronary heart disease and stroke and the key risk factors are smoking, poor diet, lack of physical activity, obesity and alcohol misuse. The 2008 survey included detailed measures of all these factors. This provided an ideal dataset for the focus of our research study as it included detailed measurements of health and physical activity across a representative sample of the Scottish population.

The next section will briefly summarise the key design features of the 2008 survey pertinent to this research project. Full technical details of the method employed can be found elsewhere[165].

5.3.1 Sample Design, Data Collection and Response Rate

The 2008 SHS was designed to provide a nationally representative sample of the general population living in private households in Scotland. Respondents were recruited using a multi-stage stratified probability sampling design with postcodes selected at the first stage and household addresses selected at the second stage. A total of 6945 addresses were selected for the main sample in which all adults (16+) and up to two children (aged 0-15) were eligible to be selected in each household.

Data were collected at a household and individual level. The household interview obtained information such as the composition of the household, the relationship between the household members, car ownership and the household tenure. The individual interview obtained information from a wide range of topics related to health and socio-economic position. A nurse visit was conducted on a subset of respondents to collect physiological measurements (including blood pressure and waist-hip measurements) and to take blood samples.

A total of 6465 adults were interviewed. Of these, 1878 adults were eligible to take part in the stage 2 nurse visit. 1123 adults saw a nurse and 903 gave a blood sample. In terms of the response rate, 61% of eligible households from the general population sample took part in the survey, with 49% of those adults in the household taking part. A slightly higher response rate was reported for women (57%) compared to men (50%).

5.4 Matching the Two Datasets

The green space data had to be matched to the SHS respondents via their postcode. Combining data in this way can create issues surrounding individual confidentiality as matching an individual's ward of residence with the exposure of the neighbourhood green space may disclose the location of the respondent. As this study was matching green space data to individuals' levels of health and physical activity this was of particular concern. To ensure the confidentiality and anonymity of the SHS respondents the matching process was conducted in two steps. In the first step, I selected the appropriate socio-demographic, health and physical activity variables from the SHS. Any variables that may have potentially disclosed a respondent's location, such as their health board, were unavailable for selection. The selected variables alongside the green space data rounded to the nearest 5% were provided to the SHS data mangers. The reason for rounding the green space data was that it removed any unique green space values that may also have disclosed a respondent's location. The second step was then conducted by the SHS data mangers. It consisted of attaching the green space variable to the SHS respondents' relevant health and physical activity outcomes via their postcode. Getting the data matched by the SHS ensured the anonymity of the respondents as I remained blind to their CAS ward of residence. The combined data set describing the percentage of green space in each respondents ward with information on the socio-demographic characteristics, the health outcomes and levels of physical activity, was then provided to me. In the following section I will discuss the variables selected for analysis and the method employed to derive each variable.

5.5 Selection and Derivation of Variables

From the SHS, two types of outcome variables (health and physical activity) and three confounding variables (age, sex and socio-economic position) were selected and matched to the percentage of green space available in a respondent's neighbourhood (Table 5.3). The rationale for selecting each of these variables and the way in which they have been derived for analysis is shown below.

Table 5.3 Summary of the outcome, explanatory and confounding variables used within the analysis of the SHS

Outcome Variables	Explanatory Variable	Confounding Variables
Health	Green Space Availability	Age
Physical Activity		Sex
		Socio-Economic Position

5.5.1 Health Outcomes

The SHS provided a wide variety of health outcomes. These included self-reported health, blood pressure, cardio-vascular disease, body mass index (BMI), mental health, angina, heart attack, stroke, diabetes, mental well-being, longstanding illness, GP consultation and chronic obstructive pulmonary disease. For the purpose of analysis these variables were divided into two groups. The first group consisted of the health outcomes that would incorporate the main analysis and included self-reported health, blood pressure, cardio-vascular disease, BMI and mental health. The second group consisted of the health outcomes that would incorporate the sensitivity analysis and included the remaining health outcomes; angina, heart attack, stroke, diabetes, mental well-being, longstanding illness, GP consultation and chronic obstructive pulmonary disease (COPD).

The main health outcomes, self-reported health, blood pressure, cardio-vascular disease, BMI and mental health were selected as they provide a number of definitions of health and there was research to suggest that regular physical activity was associated with each health outcome [15, 166, 167]. There is convincing evidence that participating in physical activity is associated with a reduced risk of developing high blood pressure, cardio-vascular disease, obesity and depression[15, 166]. Such effects have been shown among those meeting the Government's recommended physical activity guidelines (150 minutes of moderate intensity physical activity, in bouts of 10 minutes or more, throughout the week). Manson et al.[168] found that meeting the recommended physical activity guidelines was associated with a reduction in coronary events of 30-40%. Likewise, Hamer et al.[169] found that meeting the physical activity guidelines was associated with lower odds of reporting poor mental health. This research and other studies also found that increasing physical activity levels above those recommended in the Government's guidelines was associated with even greater health benefits[15, 166]. Alongside this research, there is also evidence to suggest that contact with neighbourhood green space is associated with lower odds of reporting high blood pressure, decreased risk of mortality from cardio-vascular disease, lower likelihood of overweight and obesity and lower levels of stress and mental fatigue (Chapter 4, Section 4.3). For these reasons, blood pressure, cardio-vascular disease, BMI and mental health were included as part of my main health outcome.

There was research to suggest that participating in regular physical activity was associated with better self-reported health, but this research was mixed and less convincing. Wendel-vos et al.[167] found that moderate and high levels of physical activity were associated with better self-perceived health. Abu-Omar and Rutten[170], on the other hand, found no relation. Despite these equivocal results, research exploring the relationship between green space and health has frequently used self-reported health as an outcome variable. In the Literature Review (Chapter 4, Section 4.3.1) seven studies used a measure of self-reported health, all reporting a positive association. Self-reported health, thus, provided me with a measure in which I could easily compare my results to that of others and for this reason it was included as one of my main health outcomes.

The additional health outcomes, angina, heart attack, stroke, diabetes, mental well-being, longstanding illness, GP consultation and COPD, did not feature in the main analysis as they were either a symptom of one of the main health outcomes or the evidence in relation to physical activity or green space availability was non-existent or too inconsistent. Including them in the sensitivity analysis, however, allowed a comprehensive picture of the relationship between green space and health to be provided. The method of derivation for each main and additional health outcome will be documented below.

5.5.1.1 Self-Reported Health

The SHS team assessed self-reported health by asking respondents “How is your health in general”. The response options were “very good”, “good”, “fair”, “bad” and “very bad”. In order to make my results comparable to the green space and health literature, I dichotomised health into a binary variable. Although dichotomising health in this way raises questions as to where the most appropriate ‘cut off’ point or ‘threshold’ value should be placed, I followed the work of others and dichotomised self-reported health with ‘fair’ as the cut off point for poor health[3, 4]. Self-reported health was, therefore, recoded so that (0) stood for “very good” and “good” health and (1) stood for “fair”, “bad” and “very bad” health.

5.5.1.2 Blood Pressure

Blood Pressure was measured by the SHS team using two methods. The first method assessed high blood pressure using self-report. In this measure respondents were initially screened to enquire whether they had ever suffered from high blood pressure. Among those who mentioned they had high blood pressure, a second question was asked exploring whether they had been told they had high blood pressure from either a doctor or nurse. This allowed the SHS to derive a variable that calculated the number of respondents that currently had doctor diagnosed high blood pressure. The response labels were coded, so that a score of (0) was given for “yes” high blood pressure and a score of (1) were given for “No” high blood pressure. These variables were not re-grouped as they were suitable for analysis. The second measure calculated high blood pressure objectively during the nurse's visit. Respondent's systolic and diastolic blood pressure was taken and recorded, allowing respondents with high blood pressure to be noted. For the purpose of analysis I opted to use respondent's self-reported blood pressure measurement. This was based on several reasons. Firstly, the objective measure was conducted on a sub sample of the SHS respondents, resulting in a much smaller sample of respondents. Secondly, it is plausible that some respondents may have the condition known as white coat hypertension[171], which causes elevated blood pressure when measured by a medical professional. As blood pressure was only measured during the nurses visit there was no opportunity for these values to be re-validated and as a result elevated blood pressure may have been recorded, which may have potentially influenced my results. Lastly, blood pressure measured during the nurse's visit did not take into consideration whether a respondent has high blood pressure which is being controlled for by a drug regime. Inaccuracies could, therefore, show up in respondents' blood pressure values.

5.5.1.3 Cardio-Vascular Disease

The SHS team assessed cardio-vascular disease using a number of derived variables. I explored the use of two of these variables. The first variable explored whether a respondent had ever had a cardio-vascular condition. This included heart murmurs, diabetes, high blood pressure, angina, heart attack, irregular heart rhythm or a stroke. The response labels were coded "yes" or "no". The second variable explored whether a respondent had ever suffered from a cardio-vascular disease. Cardio-vascular disease was defined as having angina, a heart attack or a stroke. The response categories were again "yes" or "no".

I explored the association between green space availability and health on both measurements of cardio-vascular disease. The results indicated very little difference depending on which measurement was used. I, therefore, opted to use the derived variable reporting cardio-vascular condition as it gave a larger sample size. The variable did not have to be regrouped as it was suitable for analysis. I did recode it so that a score of (0) was given for "No" cardio-vascular condition and a score of (1) was given for "Yes" cardio-vascular condition.

5.5.1.4 BMI

Respondent's height and weight were taken during the nurse's visit on a sub-sample of the SHS respondents. From the information the SHS team could calculate respondents BMI (weight (kg) divided by the square of the height (m^2)). Classifications were produced to reflect the thresholds recommended by the World Health Organisation (WHO)[172] and were defined as underweight (<18.5), normal (18.5-25), overweight (25-30) and obese (30+). As this study was concerned with whether greater availability of green space was associated with a lower likelihood of overweight and obesity, I dichotomised BMI into two variables: overweight and obese. Overweight was coded so that (0) stood for BMI<25 and (1) stood for BMI>25 and obese was coded so that (0) stood for BMI<30 and (1) stood for BMI>30.

5.5.1.5 Mental Health

Mental health was assessed using the General Health Questionnaire 12 (GHQ-12). The GHQ-12 is derived from the longer established GHQ-60 and is intended as a screening tool to detect those likely to have or be at risk of developing psychiatric disorders [173]. It assesses mental health across 12 items. Six of these items are positively worded; six are negatively worded. Each item on the scale had four response options from "Better than usual" to "Much less than usual". Some examples of the items in the GHQ-12 are: (1) *Being able to concentrate on whatever you are doing,* (2) *Lost much sleep over worry and* (3) *felt constantly under strain.*

The SHS administered the GHQ-12 as part of their individual level data collection. The scores were created by summing up the responses of the items ranging from 0-12. The variable was re-grouped following the method outlines by Goldberg et al.[173]. This creates a binary variable that distinguishes between respondents with a score of 4 or more as any score exceeding the threshold of 4 indicates possible minor psychiatric morbidity. I, therefore, recoded GHQ-12 so that a score of 0-3 was regarded as having "good mental health" and a score of 4 or more was regarded as having "poor mental health".

5.5.1.6 Additional Health Outcomes

The method in which the SHS assessed each additional health outcome is detailed in Table 5.4. All variables were assessed using self-report. Angina, heart attack, stroke, diabetes and COPD were explored by asking respondents whether each symptom had been diagnosed by a doctor. Longstanding illness was captured by asking respondents whether they had ever suffered a longstanding illness and GP consultations was captured by the number of times respondents had visited their GP in the last year. The response options were all provided by the SHS and did not have to be re-grouped as they were suitable for analysis. Mental well-being was assessed using the Warwick-Edinburgh Mental Well-Being Score (WEMWBS). WEMWBS is a relatively new measure designed to capture positive mental well-being across 14 items[174]. Some examples include: (1) *I've been feeling optimistic about the future,* (2) *I've been feeling useful and* (3) *I've been feeling relaxed.* Respondents are asked to rate how often they have had these thoughts and feelings using a 5 point likert scale, ranging from "none of the time" to "all of the time". Each item is given a score 1-5 respectively, giving a minimum score of 14 and a maximum score of 70. As there are no established thresholds that indicate good or poor mental health for the WEMWBS score, the SHS team classified mental well-being into three groups: good, average and poor mental well-being. For the purpose of this study this variable was collapsed into a binary variable where (0) was good/average mental well-being and (1) was poor mental well-being.

Table 5.4 Assessment and coding of the additional health outcomes selected for sensitivity analysis

Outcome	Measurement	Code	Category
Angina	Doctor Diagnosed Angina	0	No
		1	Yes
Heart Attack	Doctor Diagnosed Heart	0	No
	Attack	1	Yes
Stroke	Doctor Diagnosed Stroke	0	No
		1	Yes
Diabetes	Doctor Diagnosed	0	No
	Diabetes	1	Yes
Mental Well-Being	Warwick-Edinburgh	0	Poor Mental Health
	Mental Well-Being Score	1	Good Mental Health
Longstanding	Whether has	0	No
Illness	Longstanding Illness	1	Yes
GP Consultation	Number of GP	0	Consultation
	Consultations per Year	1	No Consultations
COPD	Doctor Diagnosed COPD	0	No
		1	Yes

5.5.2 Physical Activity Outcomes

I defined three measures of physical activity from the SHS: overall physical activity, walking, and physical activity in green space. The first measure, overall physical activity, was explored by capturing information on the type, intensity, duration and frequency of physical activity across four domains: domestic, transport, recreational and occupational. One of the main limitations with this measurement is that you can argue that only two domains (transport and recreational) are likely to include physical activity in green space. In spite of this, previous research exploring the relationship between green space and physical activity has been conducted using measurements of overall physical activity[12]. In the literature review (Chapter 4, Section 4.3.3) 25 out of the 37 reviewed studies used a measure of overall physical activity. The second measure, walking, was explored separately as there is research to suggest that walking is the most common leisure time physical activity that predominately occurs in an outdoor environment[175]. It could, therefore, be hypothesised that levels of walking may be particularly sensitive to the availability of neighbourhood green space. In the literature review (Chapter 4, Section 4.3.3) 15 studies used a measurement of walking behaviour, with 11 reporting a positive association. Although this measure does attempt to capture one salient element of outdoor physical activity, it is still limited by its inability to conclude whether the reported walking actually occurs specifically in green space. Despite the limitations associated with both overall physical activity and walking, they were included within this study as they provided additional tests as to whether green space is associated with physical activity, and provided variables with which to compare the results of this study to that of others. The final measure, physical activity in green space, explored the amount of physical activity that occurred specifically in green space. This was included in this study as it overcame the limitations with the previous variables as it captured green physical activity. This allowed me to explore whether green space actually fosters physical activity (or not) in Scotland. Below the derivation of each physical activity variable is detailed.

5.5.2.1 Overall Physical Activity

Overall physical activity was based on the UK Government's recommendations for levels of physical activity; to accumulate 30 minutes of moderate-vigorous physical activity, in bouts of 10 minutes or more, at least 5 days a week[118]. To capture this information the SHS asked detailed questions about respondent's physical activity levels in the four weeks prior to interview. This covered the type, intensity, duration and frequency of activity, which included housework, walking, playing sport and manual work, in turn, allowing the SHS team to derive a variable which gave the number of days that respondents participated in any activity during the last week. The response options were "none", "less than once a week", "1 or 2 times per week", "3 or 4 times per week", and "5 or more times per week". From these options I was able to distinguish those who met the UK Government's physical activity recommendations, from those who did not. The variable was coded (0) if respondents did not meet the recommended physical activity guidelines and (1) if respondents did meet the recommended physical activity guidelines.

5.5.2.2 Walking

Walking, similar to overall physical activity, was again based on the UK Government's recommendations for levels of physical activity[118]. The SHS team asked respondents to report the intensity, duration and frequency of all the walking they had done during the previous four weeks, including country walks, walking to and from work and any other walking they had done. This allowed the derivation of a variable that gave the number of days walking during the last four weeks. The response options ranged from 0-28 days. To keep this consistent with the overall physical activity measure, I identified those who achieved at least 30 minutes of fast or brisk walking on at least five occasions per week, from those who did not. Over the four week period this equated to those who participated on 20 days or more walking over the past four weeks. The variable was coded (0) if respondents did not meet the recommended walking guidelines and (1) if respondents did meet the recommended walking guidelines.

5.5.2.3 Use of Green Space for Physical Activity

Use of green space for physical activity was assessed by asking a subset of respondents to report the environments they used to participate in physical activity. The options were: local pavement or streets, home/garden, open space/park, country paths, woods/forests, beach/river bank, gym/sports centre, swimming pool, outdoor sports pitch and 'somewhere else'. The SHS team did not capture the duration or intensity of physical activity that were undertaken in each environment, but respondents did report how often they used each environment for physical activity. Following Mitchell[176], I derived variables that captured the frequency with which respondents used any green environment for physical activity. This method is described in detail elsewhere[176]. It involved combining the reported uses of woods/forest, open space/park and/or non-tarmac paths in the previous four weeks, and converted this to a mean use per week. This provided me with how many times a week respondents used their green space to participate in physical activity. From this information I was able to define two different measures of use of green space for physical activity or "green physical activity" as I call it hereafter. The first measure defined green physical activity as green spaces "used once a week or more", where (0) represented those who used their green space for physical activity less than once a week and (1) represented those who used it once a week or more. The second defined green physical activity as green spaces "used three times a week or more, where (0) represented those who used their green space for physical activity less than three times a week and (1) represented those who used it three times a week or more. In general, the association between green space availability and use of green space for physical activity did not substantively differ depending on the measurement of green physical activity. I, therefore, conducted my main analysis using “use of green space at least once a week or more” as few people used their green space at least three times a week or more.

5.5.2.4 Use of a Non-Green Environment for Physical Activity

Use of a non-green environment for physical activity was not required as an outcome variable but was utilised as an additional control variable in some of the analyses described in Section 5.7. To calculate the number of respondents who used their non-green environment for physical activity I combined the reported use of pavements/streets, home/garden, gym/sports centre, swimming pool and outdoor sports field. Use of environments reported as somewhere else was rare and excluded for analysis. I captured the frequency in which respondents use their non-green environment for physical activity using the same process as above and defined ‘non-green physical activity’ as “used once a week or more” and “used three times a week or more”.

5.5.3 Green Space Availability

Selecting the percentage of green space available in a respondent’s neighbourhood provided me with an objective measurement in which to explore the association between green space and (a) health and (b) physical activity. The full rationale for why this variable was selected is available in Section 5.2. For the purpose of analysis, green space availability was categorised into equal interview groups (<25%, 25-<50%, 50-<75% and 75%+). The rationale behind this was that each group represented a ‘dose’ of green space present in a respondent’s neighbourhood. This allowed me to explore whether the association between green space availability and (a) health and (b) physical activity had a dose-response relationship, in that, with each incremental increase in the availability of neighbourhood green space there was an increase in (a) health and (b) physical activity. To be certain that this choice did not influence my results, I undertook analysis to test the sensitivity of results to different categorisations of green space and in particular to the choice of threshold for the lowest green space which would form the reference group in my analysis. Overall, I found very little impact of the method by which green space was categorised. Some differences were found when green space was categorised into 5 interval groups with the baseline category defined as <15% green space (<15%, 15-<40%, 40-<65%, 65-<85%, 85%+) but these were very slight. Where any of these differences were noted the results will be reported in the relevant sensitivity analysis.

5.5.4 Demographic Characteristics

The demographic characteristics selected were sex and age. This was based on research which suggests that both sex and age are potentially confounding variables when exploring population health[177], physical activity[83] and green space[115].

5.5.4.1 Sex

Sex was provided as a binary variable coded (0) for males and (1) for females.

5.5.4.2 Age

Age was provided on a continuous scale, ranging from 0-97 years. I excluded respondents aged 0-15 years as our study was on the adult population only. Age was then categorised into seven categories: 16-24, 25-34, 35-44, 45-54, 55-64, 65-74 and 75 plus. This allowed two categories of older age (65-74 and 75+), creating a more representative definition of the life stage. This was beneficial when exploring the relationship between green space and health as it is plausible that those aged 65-74 years may be more likely to utilise their neighbourhood green space as they have fewer health complaints and greater levels of functioning than those aged 75 years plus. Categorising age into seven categories, thus, allowed me to better capture such differences.

5.5.5 Socio-Economic Position

The SHS team provided both individual and area level measures of socio-economic position. As there is evidence to suggest that both these measures capture different aspects of socio-economic characteristics[178], I investigated whether physical activity in green space was a mechanism reducing the socio-economic gradient in health using both individual and area level measures. Two measures of individual level socio-economic position (Income and Socio-Economic Grade (SEG)) and one measure of area level socio-economic position (Scottish Index of Multiple Deprivation (SIMD)) were selected. The results exploring whether socio-economic inequalities in (a) health and (b) physical activity were narrower in greener compared to less green areas found no substantive difference depending on which measure of socio-economic position was used. I, therefore, presented my main analysis using individual level income as it is the measure that provides a direct link between a wide range of material factors and health[178, 179]; a theme central to the hypothesis of this thesis. Where any substantive differences in results were noted by measure of socio-economic position they will be reported in the relevant sensitivity analysis section. Below the derivation of each indicator is detailed.

5.5.5.1 Income

The SHS team provided equivalised income at the household level. It was coded in tertiles, where (1) was the top income tertile (>=£29900), (2) was the middle income tertile (>=£14,932<£29,900) and (3) was the bottom income tertile (<£14932), detailed in Table 5.5. None of these categories were regrouped as they were all suitable for analysis.

5.5.5.2 Socio-Economic Grade

The SHS team categorised SEG into six occupational groups, where (1) was coded professional and (6) was coded unskilled manual (Table 5.5). None of these categories were regrouped as they were all suitable for analysis.

5.5.5.3 Scottish Index of Multiple Deprivation

The SHS team categorised SIMD into quintiles. They were coded (1) for the least deprived category and (5) for the most deprived category. None of these categories were regrouped as they were all suitable for analysis.

Table 5.5 Assessment and coding of the individual (income and SEG) and area (SIMD) level indicators of socio-economic position

Measurement of Socio-Economic Position	Code	Category
Income	1	Top Tertile (>=£29900)
	2	Middle Tertile (>=£14,932<£29,900)
	3	Bottom Tertile (<£14932)
Socio-Economic Grade	1	i - Professional
	2	ii - Managerial Technical
	3	iiin - Skilled Non-Manual
	4	iiim - Skilled Manual
	5	iv - Semi-Skilled Manual
	6	v - Unskilled Manual
Scottish Index of Multiple Deprivation	1	Least Deprived
	2	
	3	
	4	
	5	Most Deprived

5.5.6 Summary

Table 5.6 provides a summary of the variables used within the main analysis of the SHS respondents and the additional variables in which sensitivity analysis was conducted.

Table 5.6 Summary of the selected variables used within the main and sensitivity analysis of the SHS respondent's

Selected Variables	Main Analysis	Sensitivity Analysis
Demographic	Age and Sex	
Socio-Economic	Income	SEG, SIMD
Health	Self-Reported Health, Blood Pressure, Cardio-Vascular Disease and Mental Health	Angina, Heart Attack, Stroke, Diabetes, Mental Well-Being, Longstanding Illness, GP Consultation and Chronic Obstructive Pulmonary Disease
Physical Activity	Overall Physical Activity, Walking Behaviour and Use of Green Space for Physical Activity	

5.6 Sample of Respondents

In this section, the sample of the respondents used to conduct the analysis of the SHS will be discussed. I will describe the data restrictions that were made, the pattern of missing data across all outcome, explanatory and confounding variables, and the sample size used for each analysis.

5.6.1 Data Restrictions

I restricted my analysis of the SHS respondents to urban areas only. There were several reasons for this. Firstly, restricting analysis to urban areas only is typical of research exploring the relationship between green space and health (Chapter 4). This allowed me to easily compare my results to that of others. Secondly, the majority of the population have been reported to live in urban settings. In the UK, for example, 90% of the current population live in urban areas[180]. Lastly, the estimated green space exposure variable used in this study poorly distinguished between variations in the availability of green space among respondents living in rural areas. This is because rural areas typically have a higher percentage of available green space, and as a result, have less green space variability.

5.6.1.1 Spatial Misalignment of Data Sets

Restricting my analysis to urban areas only, created differences in the geographical units of analysis between the measurement of green space availability and urbanity. Green space availability was calculated using CAS wards as the geographical unit of analysis, whereas, urbanity was calculated at a data zone level. Data zone is a smaller unit of analysis than a CAS ward; there are 6505 data zones but 1220 CAS wards in Scotland. This situation is known as spatial misalignment and it can cause miss-classification[181]. This miss-classification would have predominately occurred when a SHS respondent lived in the fringe of an urban or suburban area. Their data zone of residence would be classified as urban, warranting their inclusion in the sample. However, their CAS ward of residence might have extended into rural areas, resulting in the respondent being classified a high green space estimate. To ensure that this issue did not greatly impact my results I conducted a series of sensitivity analyses. The first excluded small accessible towns (population of 3000-10,000) from the analysis resulting in models being re-run on a population living in large urban areas only (population of over 125,000) and a population living in either large urban areas or other urban areas (population of 10,000 to 125,000). The second involved excluding areas with greater than 80% green space to ensure that any suburban towns being given a high green space estimate were omitted. The subsequent results remained unaltered suggesting that the issue of green space data miss-classification was not a factor influencing my results.

5.6.2 Missing Data

Table 5.7 shows the pattern of missing data across the main outcome and confounding variables. Patterns of missing data on the variables within the sensitivity analysis are given in the Appendix D.

Table 5.7 Missing data for each of the main outcome and confounding variables selected from the SHS

	Number of Missing Cases	% of Total Cases
Outcome Variables		
Health		
Self-Reported Health	1	0.02
High Blood Pressure	77	1.82
Cardio-Vascular Disease	44	1.04
BMI	295	7.11
Mental Health	411	9.73
Physical Activity		
Meeting the Physical Activity Guidelines	40	0.95
Meeting the Walking Guidelines	33	0.78
Physical Activity within Green Space	0	0.00
Confounding Variables		
Age	0	0.00
Sex	0	0.00
Income	507	12.01

Table 5.7 shows that I had low levels of missing data for the majority of outcome and confounding variables. The key exceptions to this were BMI (7.11% of total cases), mental health (9.73% of total cases) and income (12.01% of total cases). The most likely cause of this missing data was that respondents were unwilling or unable to provide any of the required information. This may represent a

possible source of bias for these outcomes as the data may not be missing at random. For example, respondents with missing mental health and income data may be those who felt they would score more poorly on the GHQ-12 questionnaire or the item related to household income. This meant that I could not simply omit all cases that had missing data (listwise deletion or complete case analysis) as the results may be biased if the remaining cases are not representative of the entire population. The missing data was, therefore, accounted for by applying Multiple Imputation (MI).

MI is the process of predicting missing data based upon existing variables from other variables available in the dataset. A full dataset is created by substituting the predicted values for the missing values. The process is performed multiple times producing a multiple imputed dataset. Each of the completed datasets is analysed by standard methods, and the results are combined to produce estimates and confidence intervals that incorporate missing data uncertainty. It must be noted that MI is not the only method for handling missing data. Statistical techniques such as Maximum Likelihood Estimation or the Expectation Maximum Algorithm also exist. These techniques have been reported to be somewhat more efficient than MI as they involve no simulation. They are, however, problem specific and often more difficult to implement. I, therefore, used MI as it was easier to use and could be conducted using Stata, Version 11.

Stata's Multiple Imputation by Chained Equations (MICE) approach was used in order to create the MI models[182]. MICE was selected as it allowed variables of different types to be imputed using different regression analysis. I created models for each research question and repeated for the main health and physical activity outcomes. Once the final estimates had been obtained I was able to run the data analysis on the imputed dataset. I could then compare whether the results differed depending on whether respondents with missing data were included. Overall, the results showed little sensitivity to the treatment of missing data. Based on these findings it was concluded that excluding respondents with missing data did not interfere with results, and as a result, the main analysis was conducted among respondents with no missing data. Results of the MI models on the main health and physical activity outcomes will be reported in the sensitivity analysis. MI models were not created for any of the additional health variables. The rationale behind this was based on the low levels of missing data within these variables and the findings that there was little sensitivity to the treatment of the missing data within our main health and physical activity outcomes and confounding variables.

5.6.3 Sample Size

Having confirmed that the results did not differ substantially after excluding respondents with missing data, I carried out separate complete case analysis for each outcome variable. Complete case analysis involves the deletion of all units with incomplete data from the analysis. Conducting this separately for each outcome variable meant that the sample size for each logistic regression model varied slightly. The sample used to explore the association between green space availability and self-reported health, for example, contained only those respondents with complete information for self-reported health and any of our control variables (age, sex and socio-economic position), and may have contained respondents who did not report information for one or more of the remaining health and physical activity outcomes. This approach was adopted as it allowed me to preserve as much of the sample as possible for each separate analysis. This was important given the number of health and physical activity outcome variables that were used within the analysis of this study.

5.6.4 Weights

All analyses were weighted to take account of any differences between the Scottish Population and the SHS sampling strategy. The weights were created by the SHS team and were designed so that the weighted age/sex profile of the sample matched the GROS 2008 mid-year population estimates for Scotland. Table 5.8 presents the difference between the un-weighted and weighted data. From the results it can be seen that the survey over-represented females and older adults. This is fairly common among survey data as females and older adults tend to be around the home more during the day. The socio-economic characteristics of the SHS respondents remained fairly consistent across weighted and un-weighted data.

Table 5.8 Differences in the un-weighted and weighted data for the demographic and socio-economic characteristics of the SHS respondents

Demographic and Socio-Economic Characteristics of the SHS respondents	Un-weighted Data (%)	Weighted Data (%)
Sex		
Male	43.49	47.52
Female	56.51	52.48
Age		
16-24	9.71	13.90
25-34	12.48	15.70
35-44	17.05	18.23
45-54	17.20	17.48
55-64	16.86	14.83
65-74	14.73	10.74
75+	11.96	9.11
Income		
Top Tertile (>=£29900)	30.46	32.41
2nd Tertile (>=£14932<£29900)	27.21	28.19
Bottom Tertile (<£14932)	30.32	27.59
Missing Data	12.01	11.81
SEG		
i - Professional	6.61	7.35
ii - Managerial Technical	27.83	28.51
iiin - Skilled Non-Manual	17.60	17.97
iiim - Skilled Manual	22.97	21.36
iv - Semi-Skilled Manual	15.42	15.40
v - Unskilled Manual	6.56	6.18
Missing Data	3.01	3.22
SIMD		
5th (Least Deprived)	21.10	21.40
4th	18.21	18.12
3rd	14.00	13.33
2nd	21.96	23.08
1st (Most Deprived)	24.73	24.07

5.7 Data Analysis

The variables selected from the SHS were used to examine the following research questions:

1) Is the availability of neighbourhood green space associated with better health?
2) Is the socio-economic inequality in health narrower in the greenest areas compared to the least green areas?
3) Is the availability of neighbourhood green space associated with physical activity in green space?

4) Is the socio-economic inequality in physical activity narrower in the greenest areas compared to the least green areas?
5) Is physical activity in green space more protective of health for groups of lower socio-economic position?

To explore each of these research questions, the analysis was conducted in three phases. Phase One consisted of descriptive statistics to explore the sample characteristics of each research question (research questions 1-5). Phase Two comprised of a series of logistic regression models designed to test for any significant associations between the availability of green space and (a) health and (b) physical activity (research questions 1 and 3). Phase Three involved the use of a number of interaction models designed to explore whether the association between socio-economic position and (a) health and (b) physical activity differed among respondents living in greener compared to less green areas (research questions 2 and 4) and whether the association between physical activity in green space and health differed among more deprived compared to less deprived populations (research question 5). Multi-level modelling was not possible in this thesis as the respondent's location or memberships of the spatial clusters used in sampling were withheld to protect confidentiality of the SHS respondents. Table 5.9 provides details of each research phase and its use in the exploration of the relevant research questions. Further details relating to the statistical techniques employed throughout the analysis are detailed below. I will begin by providing an over-view of the descriptive analysis as a whole and then I will go through the relevant statistical techniques used to explore the appropriate research questions. All statistical analyses were performed using STATA version 11 and the alpha level for statistical significance was defined as $P<0.05$.

Table 5.9 Research phases employed to explore each research question

Research Questions	Phase One	Phase Two	Phase Three
1	✓	✓	×
2	✓	×	✓
3	✓	✓	×
4	✓	×	✓
5	✓	×	✓

5.7.1 Descriptive Analysis

Descriptive statistics were used to explore the characteristics of each outcome variable (health and physical activity), explanatory variable (green space availability) and confounding variable (age, sex and socio-economic position). The aim of this descriptive work was to gain a broad overview of whether there were any socio-economic differences for each outcome and explanatory variable. The percentage difference between socio-economic position and (a) age, (b) sex, (c) health, (d) physical activity and (e) green space availability was explored. Trends in the observed value for socio-economic position were examined by conducting cross-tabulations and chi-squared tests. Chi-squared tests were used as all variables were categorical in nature. All cross-tabulations were presented using weighted data but chi-squared tests were conducted using un-weighted data as you cannot perform a weighted chi-squared test using STATA. As there was little substantive difference between the un-weighted and weighted data this should not invalidate the chi-squared value (Section 5.6.4). The results of the descriptive statistics for each of the variables used in this study are given at the beginning of the SHS results chapter (Chapter 7).

5.7.2 What is the Association between Green Space Availability and (a) Health and (b) Physical Activity?

The association between green space availability and (a) health and (b) physical activity (research questions 1 and 3) were explored using logistic regression models. Logistic regression was selected as it was designed for binary outcome variables. Logistic regression analysis works by predicting the probability of an outcome occurring by fitting a log odds function to the data to estimate the log odds of the outcome given the best linear combination of a predictor (i.e.

independent) variable[183]. Maximum likelihood is used to estimate the coefficients for the log odds model with the aim of producing a fitted model which produces the highest overall probability for the observed outcomes. The exponentiated forms of the estimated coefficients are used to estimate the odds ratio for each independent variable, controlling for all other variables in the model. The goodness of fit of each model was assessed using the log-likelihood statistic. The log likelihood gives an indication of how well the model fits, where the larger the value, the poorer the fit of the model.

In this study logistic regression models were built sequentially. This approach is similar to standard regression, in that, several independent variables are used to predict an outcome variable but instead of entering them simultaneously they are entered sequentially. Entering variables sequentially can be advantageous for two reasons. Firstly, you can determine the order that the variables are entered into the logistic regression analysis. Secondly, you can examine the contribution that each independent variable makes to your initial independent variable and outcome variable. These factors made sequential logistic regression the ideal approach to analyse my research questions.

My sequential logistic regression analysis was built using four models. The sequence of these four models is illustrated in Figure 5.2. The first model explored the association between green space availability and (a) health and (b) physical activity. This allowed me to explore whether there was any independent associations before I added any of my control variables to the model. The second, third and fourth model added in each control variable (age, sex and socio-economic position) independently, allowing the exploration of whether any of the main associations differed by the addition of any control variables. Separate models were run for each health and physical activity outcome outlined in Table 5.6. For the purpose of the SHS Results Chapter (Chapter 7), I presented Model 1 independently and then grouped together models 2, 3 and 4. Where any of the main associations may differ by the addition of a particular control variable, the results will be noted in the relevant section.

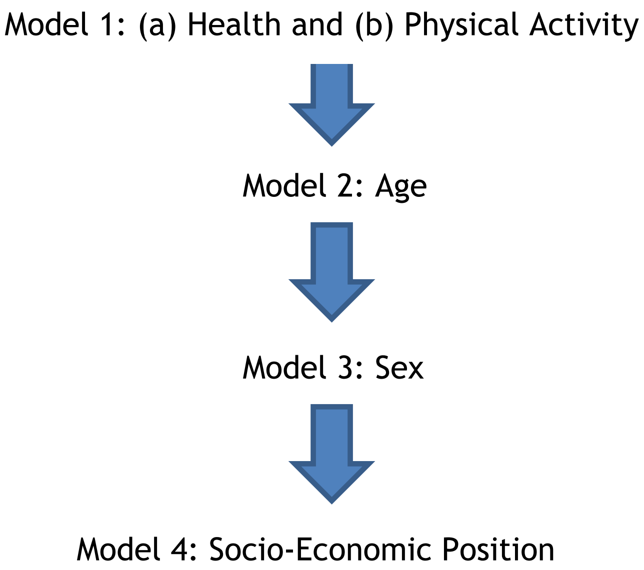


Figure 5.2 The sequential logistic regression model used to explore the association between green space availability and (a) health and (b) physical activity

5.7.3 Is the Socio-Economic Inequality in (a) Health and (b) Physical Activity Narrower among Respondents Living in Greener Compared to Less Green Areas?

Having tested for an association between green space availability and (a) health and (b) physical activity, the next step in my analysis was to explore whether this association differed by socio-economic deprivation. This was initially achieved by adding an interaction term to the model which explored whether the association between socio-economic position and (a) health and (b) physical activity varied by green space availability. As this interaction term was added to the model in conjunction with the remaining independent and confounding variables, I was able to explore whether the addition of the two-way interaction between socio-economic position and green space availability influenced the association between socio-economic position and (a) health and (b) physical activity. The first part of the model comprised of all independent and control variables that appeared in the model; the percentage of neighbourhood green space, age, sex and socio-economic position. The second part of the model added the interaction terms: [socio-economic position] x [green space availability]. The analysis was carried out in an identical fashion for each health and physical activity outcome displayed in Table 5.4.

To test whether the addition of two-way interaction term was significant, a Wald test for interaction was conducted. The Wald test is commonly used on weighted logistic regression models to assess whether the overall fit of the model is significantly improved by including, rather than excluding, the interaction term. A significant difference in the fit of the two models is indicated by a significant chi-squared value. The exact nature of any significant interactions were then further unpacked using a sequence of logistic regression models stratified by green space availability. The first model explored the association between socio-economic position and (a) health and (b) physical activity for the population that has the greatest availability of green space, the next model explored the association for respondents in the next highest group of green space availability, and so on. This method facilitated the interpretation of the interaction effects and allowed the results to be presented using odds ratios and 95% confidence intervals for each category of green space availability. The application of the interaction terms and the testing for any significant interactions is summarised in Table 5.10.

5.7.4 Is Physical Activity in Green space more Protective for Lower Socio-Economic Groups?

The final step in my analysis was to explore whether participating in physical activity within green space was more protective of health for lower socio-economic groups. This procedure followed the same format as the section above (5.7.3) and is summarised in Table 5.10. For that reason a brief outline of the interaction model is all that is required below. The association was initially explored by adding an interaction term to the model which investigated whether any association between health and participating in green physical activity varied by socio-economic position. The interaction terms used were [socio-economic position] x [green physical activity]. The resulting coefficients were tested using a Wald test for interaction to determine whether the addition of the two-way interaction term significantly improved the model fit. Any significant differences were again indicated by a significant chi-squared value. The exact nature of any significant interactions were further unpacked using a sequence of logistic regression models stratified by socio-economic position. The first model explored the association between health and physical activity participation in green space for the population classified in the least deprived socio-economic group, the second model explored the association for those in the next least deprived socio-economic group, and so on. The results were presented using odds ratios and 95% confidence intervals for each classification of socio-economic position.

Unlike previous models, this model required the additional adjustment for total physical activity and use of a non-green environment for physical activity. It was plausible, for example that a positive association between health and participating in green physical activity may not have been due to greater amounts of physical activity in green space, it could have been a result of greater overall physical activity or greater use of a non-green environment for physical activity. Adjusting for both these additional variables ruled out this explanation as much as possible, resulting in any positive association between health and participating in green physical activity being a direct consequence of physical activity specifically in green space. This procedure was carried out in an identical fashion for all health outcomes.

Table 5.10 Sequence of interaction process for research questions 2, 4 and 5

	Association between socio-economic position and (a) health and (b) physical activity by green space availability (research question 2 and 4)	Association between health and participating in green physical activity varied by socio-economic position (research question 5)
Step One: Addition of interaction terms	[socio-economic position] x [green space availability]	[socio-economic position] x [green physical activity]
Step Two: Testing of resulting coefficients	Wald Test for Interaction	Wald Test for Interaction
Step Three: Sequence of logistic regression models	Stratified by Green Space availability	Stratified by Socio-economic position

5.8 Conclusion

In this Chapter I have described the methods from the first phase of the research methodology. This included outlining the way in which the availability of neighbourhood green space was combined with information of the SHS respondents; the outcome, explanatory and confounding variables selected and derived for analysis and the data analysis strategy employed. The next Chapter will discuss the methods for the second phase of the research methodology.

Chapter 6 Methods – Phase 2

This chapter describes the methodology of the second phase of my research analysis. It used the Green Space Scotland Omnibus Survey (GSOS) to explore respondents' perceptions towards the accessibility and quality of their local green space and the impact this may have on the way in which it is used and on their self-reported health. The GSOS was selected for the second phase of my research analysis because it allowed me to build on Mitchell and Popham's hypothesis by exploring the role self-reported measurements of green space availability and quality may play in fostering use of green space in Scotland (Chapter 4, Section 4.5.2). The purpose of this chapter is to provide an overview of the GSOS and the way in which I selected and derived each variable for analysis. The specific objectives are to:

1) Provide a summary of the omnibus survey and the way in which data were collected
2) Document the method in which the outcome, explanatory and confounding variables were selected and derived for analysis
3) Describe the sample of respondents that were used to conduct the analysis of the Omnibus Survey
4) Outline the research questions and describe the data analysis that were employed to answer each research question

6.1 The Green Space Scotland Omnibus Survey

The 2009 GSOS is the third of a series of repeat cross-sectional studies designed to investigate the Scottish urban populations' use of green space and their attitudes towards the availability and quality of green space in their area[184]. It was commissioned by Green Space Scotland, an independent charitable company, whose aim is to improve the Scottish urban populations' quality of life by ensuring they have access to good quality green spaces that meet the needs of the local population.

Data were collected by a commercial contractor via telephone surveys on a sample of adults aged 18 and above. As the focus of the survey was on urban areas, respondents were initially asked a screening question to decipher whether they lived in a town/city. Data were then gathered on 1) respondents' self-reported health 2) frequency of green space use 3) use of green space 4) perceived accessibility of green space 5) individual attitudes to both green space in general and local green space and 6) perceptions of green space quality. Respondents were selected for interview across all urban areas of Scotland using a stratified random sampling technique, intended to ensure that there was a representative sample of the Scottish population. A total of 1066 interviews were completed. Despite the intention of ensuring a representative sample of the Scottish population the 1066 interviews slightly under-represented more deprived populations, so 450 boost interviews were conducted to ensure a robust dataset. The interviews were undertaken between the 12th and 27th May 2009.

6.2 Selection and Derivation of Variables

From the GSOS, three outcome variables (health, frequency of use and type of use), two explanatory variables (availability and quality of green space) and three confounding variables (age, sex and socio-economic position) were selected (Table 6.1). The rationale for selecting each of these variables and the way in which they have been derived for analysis is shown below.

Table 6.1 Summary of the outcome, explanatory and confounding variables used within the analysis of the GSOS

Outcome Variables	Explanatory Variable	Confounding Variables
Health	Green Space	Age
Frequency of Green Space use	Availability	Sex
Type of Green Space Use	Green Space Quality	Socio-Economic Position

6.2.1 Self-Reported Health

The GSOS provided information on the health of the respondents by using a variable that captured their self-reported general health. Self-reported general health is a subjective measurement that has frequently been used in epidemiological studies to monitor the health of various populations [185-187]. This is mainly because it is easy to administer [188] and has consistently been shown to be a good predictor of subsequent mortality [189-192] and morbidity [193, 194]. Although there is less convincing evidence of an association between physical activity and self-reported health (Chapter 5, Section 5.5.1.1), research on the relationship between green space and health has used self-reported health as an outcome variable suggesting that greater availability to green space is associated with better self-reported health (Chapter 4, Section 4.3.1).

Self-reported health was used as a measurement of health as it provided a variable with which I could compare my results to that of previous studies. It also provided me with a similar health outcome to that of the Scottish Health Survey. This allowed me to explore whether the association between green space and health differed by the measurement of green space availability whilst keeping a consistent measurement of health across both analyses.

The GSOS assessed self-reported health by asking respondents “how would you say your health is in general?” The response options were “very good”, “good”, “fair”, “bad” and “very bad”. In order to make my results comparable to the green space and health literature and my analysis using the SHS respondents, I dichotomised self-reported health into a binary variable. I followed the same procedure as Chapter 5, Section 5.5.1.1 and dichotomised self-reported health so that (0) stood for “very good” and “good” health and (1) stood for “fair”, “bad” and “very bad” health.

6.2.2 Frequency of Green Space Use

Frequency with which respondents use their local green space was selected as an outcome variable as I hypothesised that both availability, and quality of, green space was associated with the frequency with which green space was used. Although at the time of analysis there were few scientific studies that explored this hypothesis, there has been some recent research that suggests that the frequency of green space use declined with increasing distance [131, 195]. Furthermore there has been no study to date that has explored the association between green space quality and use. Including frequency of green space as an outcome variable provided an opportunity to increase the understanding of which green space factors influence use.

The frequency of green space use was assessed by asking respondents 'how often do you use your local green space?' The response options were "once a week or more often", "3-4 times per month", "1-2 times per month", "once every 2-3 months", "once or twice per year", "less often" and "never". As I am exploring whether physical activity is a mechanism explaining the relationship between green space and health, and it is frequent physical activity that has been shown to have health benefits [15], I recoded the frequency of green space use into a binary variable, where respondents were coded as (0) if they used their green space once a week or more often or (1) if they reported otherwise.

6.2.3 The Use of Green Space

The Omnibus Survey captured the use of green space by asking respondents "what do you use your green space for"? Respondents were asked to select one or more of the following: "to go for a walk"; "to take the children to play"; "to take the dog for a walk"; "to exercise"; "to relax and unwind"; "a place to socialise with friends"; "spending time with the family"; "to have contact with other people"; "to grow things"; "to pass through"; "other" and "unsure".

From these response options I created three variables that represented the three plausible mechanisms that have been proposed to explain the way in which green space may exert a beneficial effect on health (Chapter 4). These were (1) physical activity, (2) restoration from stress and mental fatigue and (3) social contact.

6.2.3.1 Use of Green Space for Physical Activity

To identify respondents who reported that they used their local green space to participate in physical activity I combined the reported use of "to go for a walk", "to take the dog for a walk" and "to exercise". To ensure that all other physical activity outcomes were included I also went through the 'other' category and included all other relevant responses This allowed me to create a variable classified as (0) if respondents do not use their green space to participate in physical activity and (1) if respondents do use their green space for physical activity.

To calculate the frequency with which respondents use their green space to participate in physical activity, I combined respondents' use of green space for physical activity with the frequency in which they used their green space. This produced a variable which calculated the number of respondents who reported they used their green space for physical activity "once a week or more often" ranging to those who "never" used their green space for physical activity. From these response options I calculated respondents' weekly use of physical activity within green space. This variable was coded (0) if respondents used their green space to participate in physical activity "less than once a week" and (1) if respondents used their green space to participate in physical activity "once a week or more".

6.2.3.2 Use of Green Space for Restoration from Stress and Mental Fatigue

To identify respondents using their green space to provide restoration from stress and mental fatigue, I used a similar process. I combined the number of respondents who used their green space "to relax and unwind" with any relevant responses from the "other" category. As I was interested in the frequency with which respondents used their green space for restoration, I again combined use of green space for restoration with the frequency with which respondents used their green space. This allowed me to create the variable (0) if respondents used their green space to provide restoration from stress and mental fatigue "less than once a week" and (1) if respondents used their green space to provide restoration "once a week or more".

6.2.3.3 Use of Green Space for Social Contact

To identify respondents using their green space to facilitate social contact I combined to "spend time with the family", "to socialise with friends" and to "have contact with other people" with the frequency with which respondents use their green space. This created a variable coded (0) if respondents' used their green space to facilitate social contact "less than once a week" and (1) if respondents use their green space to facilitate social contact "once a week or more".

6.2.4 Perceived Green Space Availability

The GSOS captured the availability of local green spaces by asking respondents to report 'how far away from your home (in minutes) is your local green space'. This indicator has been used within the current research literature (Chapter 4, Section 4.3). Selecting self-reported green space availability as one of my explanatory variables provided me with a previously used green space indicator, allowing direct comparison with my results to that of the literature. Moreover, it allowed me to contrast with my results from the SHS, and explore whether the association between green space and health in Scotland was sensitive to the measurement of green space availability.

The time taken from a respondent's home to their local green space was provided on a categorical scale, where response options were 'less than a 5 minute walk', 'within a 5-10 minute walk', 'within a 11-20 minute walk', 'within a 21-30 minute walk', 'more than a 30 minute walk' and 'unsure'. The response options were regrouped into a binary variable for subsequent analysis. Deciding on the typical time or distance that respondents should have to travel to have access to green space was not straight forward. Although UK planning policies now stipulate that green space provision and management should be incorporated into their urban planning documentation, currently no formal or national guidelines have been established [196]. Despite this, there have been some guidelines for the level of green space provision that might be appropriate. These include the European Environment Agency [197], which recommended that people should have access to green space within a 15 minute walking distance, and the more stringent Natural England guidelines [198], which suggested that people in urban areas should have access to green space of at least two hectares in size within 300 metres (or a five minute walk) from their home.

Taking both of these suggestions into consideration I regrouped my variable using two methods of categorisation. The first was less stringent, where (0) represented respondents who reported that their green space was less than a 10 minute walk away and (1) represented respondents who reported that green space was greater than a 10 minute walk away. The second was slightly more stringent, where (0) represented respondents who reported that their green space was less than a five minute walk away and (1) represented respondents who reported that their green space was more than a five minute walk away. There was little substantive difference in results depending on the method of categorisation. I, therefore, conducted my main analysis using the less stringent of the two variables as it provided a better representation of the overall suggested guidelines. Where there are any slight differences in results they will be reported in the section titled sensitivity analysis.

6.2.5 Perceived Green Space Quality

Quality of green space was selected as an explanatory variable as it has been suggested that it may not only be the accessibility of green space that is important for use, quality may also matter [4, 132, 150]. Few studies have explored the way in which quality of green space may impact on the use of green space (See Chapter 4, Section 4.3). Selecting a measurement of green space quality allowed me to examine whether respondent's perceptions of their green space quality were associated with both their health and their use of local green space.

The quality of respondents' local green space was assessed by asking "how satisfied are you with the quality of your green space". The response options were "very satisfied", "quite satisfied", "neither satisfied nor dissatisfied", "quite dissatisfied" or "very dissatisfied". These response options were based on a Likert scale which means that although the scale gave quantitative order to the variables, it did not indicate how much better one score is from the other. Treating this scale as continuous would automatically assume a linear trend. I, therefore, regrouped this variable into a binary variable for subsequent analysis. The variable was regrouped so that a score of (0) represented respondents who reported that the quality of their green space was 'very' or 'quite' satisfactory and a score of (1) represented respondents who reported that they were 'neither satisfied nor dissatisfied', 'quite dissatisfied' or 'very dissatisfied' with the quality of their green space. To ensure that this method of categorisation did not affect the strength of any relationships, I conducted sensitivity analysis. The variable was regrouped so that a score of (0) represented respondents who reported they were 'very' satisfied with the quality of their green space and a score of (1) represented any other response. There was no substantive difference in the results by the method of categorisation. I, therefore, conducted my main analysis where good quality green space was represented by respondents who reported they were ‘very’ or ‘quite’ satisfied with the quality of their green space. Where there was any significant difference in results by method of categorisation they will be reported in a section titled sensitivity analysis.

6.2.6 Demographic Characteristics

The demographic characteristics selected were age and sex. This was based on research which suggests that both age and sex are confounding variables when exploring population health [177].

6.2.6.1 Sex

Sex was provided as a binary variable coded (0) male and (1) female. It was not regrouped as the existing variable was suitable for analysis.

6.2.6.2 Age

Age was provided on a six point categorical scale, defined as 18-24, 25-34, 35-44, 45-54, 55-64 and 65+. It could be argued that this categorisation did not create the most representative definition of the life stage as it grouped all respondents aged 65 plus into one category. It is plausible that those at the beginning of old age (65) may have better health and levels of functioning and be able to utilise their green space more than those further into old age (those aged 85 for example). As I could not change the categorisation of age this was a potential limitation of this study.

6.2.7 Socio-Economic Characteristics

The GSOS team provided both an individual (Socio-Economic Grade (SEG)) and area (Scottish Index of Multiple Deprivation (SIMD)) level measures of socio-economic position. As there is evidence to suggest that these measures capture different aspects of socio-economic position[178], I followed the same procedure as

Chapter 5, Section 5.5.5 and explored my analysis using both measures of socio-economic position. The results found no substantive differences depending on which measure of socio-economic position was used. I, therefore, presented my main analysis using SEG, as in the absence of income; it was the measure that best represented the link between material factors and health[179]. This allowed me to maintain as much consistency as possible with the main analysis of the SHS. Where any substantive differences in results were noted by measure of socio-economic position they will be reported in the relevant sensitivity analysis section. Below the derivation of each indicator is detailed.

6.2.7.1 Socio-Economic Grade

SEG was provided on a four point scale. It was coded (1) AB, (2) C1, (3) C2 and (4) DE. Table 6.2 shows the SEG definitions. The variable was not regrouped as it was suitable for analysis.

Table 6.2 Social economic grade definitions

Social Grade	Definition
AB	Higher, and intermediate managerial/administrative/professional
C1	Supervisory, clerical, junior managerial/administrative/professional
C2	Skilled manual workers
DE	Semi-skilled and unskilled manual workers, on state benefit, unemployed or lowest skilled workers

6.2.7.2 Scottish Index of Multiple Deprivation

SIMD was provided in vigintiles where (1) represented the most deprived and (20) represented the least deprived. I regrouped this variable into quintiles to make it comparable with that of the SHS and recoded it (1) so it represented the least deprived and (5) so it represented the most deprived population.

6.3 Sample of Respondents

In this section I will describe the sample of respondents that were used to conduct the analysis of the GSOS. I will discuss the data restrictions that were made, the pattern of missing data across all outcome, explanatory and confounding variables, and the sample size that were used for each analysis.

6.3.1 Data Restrictions

The GSOS was only sampled in urban areas of Scotland. This was different to the SHS where the analysis had to be restricted to urban areas only. Only sampling urban areas in Scotland was advantageous for this study for two reasons. Firstly, it was typical of previous research exploring the relationship between green space and health [3, 6, 115, 150], and was consistent with my analysis of the SHS respondents'. Secondly, there is research to suggest the prevalent type of green space and the way in which it is used may differ by urban and rural areas [1]. In urban areas, green space will mostly be represented by parks or woodlands designed for residents recreational or leisure use. In rural areas, however, green space may be dominated by agricultural or farm land which may be less likely to be used for recreation. Restricting my analysis to urban areas was beneficial as the GSOS was interested in the use of green space for leisure purposes. Including large areas of agricultural or farmland could have resulted in the potential confounding of results.

6.3.2 Missing Data

Table 6.3 shows the pattern of missing data across all outcomes, explanatory and confounding variables. Overall, the results show that I had very low levels of missing data across all variables. The highest proportion of missing data was seen for SEG, where 5% of respondents' failed to give a response. As a value of 5% or less is seen as a relatively low level of missing data[199], I decided to adopt the typical approach, and omit all cases that had missing values (listwise deletion) from my analysis.

Table 6.3 Missing data for each of the main outcome, explanatory and confounding variables selected from the GSOS

	Number of Missing Cases	% of Total Cases
Outcome Variables		
Health	11	0.73
Frequency of Green Space Use	0	0
Use of Green Space for:		
Physical Activity	0	0
Restoration from Stress and Mental Fatigue	0	0
Social Contact	0	0
Explanatory Variable		
Availability of Green Space	18	1.19
Quality of Green Space	30	1.98
Confounding Variable		
Age	0	0
Sex	0	0
Socio-Economic Position		
SEG	76	5.01
SIMD	34	2.24

6.3.3 Sample Size

Having confirmed that I have low levels of missing data, I conducted separate complete case logistic regression analysis for each outcome variable. The advantage of carrying out complete case analysis is described in Chapter 5, Section 5.6.3. In brief, it involves deleting all cases with incomplete data from the analysis. This means that the sample size of the models will vary slightly but it will preserve as much as the sample as possible for each separate analysis. As the GSOS had low levels of missing data the variation in sample size was small.

6.3.4 Weights

All analyses were weighted to take account of any differences between the Scottish Population and the GSOS sampling strategy. Unlike the SHS, the GSOS did not create their own set of weights. I, therefore, created my own. This involved creating weights so that the weighted age/sex, SEG and SIMD profile of the GSOS matched the GROS 2009 mid-year household population estimates, SEG 2001 census data and the Scottish 2009 SIMD data, respectively. It is worthy of note that the 2001 census data were slightly out of date, but it was the best available information at the time of analysis. Table 6.4 presents the difference between the un-weighted and weighted data. From the results it can be seen that the survey slightly over-represented female and older adults. This was the same as the SHS. The SEG profile of respondents', however, over-represented lower middle class (C1) and skilled working class (C2) categories but under-represented working class (DE). SIMD was fairly consistent across quintiles. This demonstrates that the GSOS was not fully representative of the Scottish population and required the application of weights.

Table 6.4 Differences in the un-weighted and weighted data for the demographic and socio-economic characteristics of the GSOS respondents

Demographic and Socio-Economic Characteristics of the SHS respondents	Un-weighted Data (%)	Weighted Data (%)
Sex		
Male	45.98	47.73
Female	54.02	52.27
Age		
18-24	8.44	11.88
25-34	12.01	15.53
35-44	19.66	17.97
45-54	17.55	18.21
55-64	18.27	15.50
65+	24.08	20.92
SEG		
AB (Upper and Middle Class)	16.69	18.07
C1 (Lower Middle Class)	32.59	25.13
C2 (Skilled Working Class)	18.40	13.79
DE (Working Class)	27.31	38.00
Missing Data	5.01	5.01
SIMD		
5^{th} (Least Deprived)	22.76	19.72
4^{th}	16.95	23.75
3^{rd}	17.48	18.93
2^{nd}	20.65	18.73
1^{st} (Most Deprived)	19.92	16.62
Missing	2.24	2.24

6.4 Data Analysis

The variables selected from the Omnibus Survey were used to select the following six research questions.

1) Is the availability and quality of neighbourhood green space associated with better health?

2) Is the socio-economic inequality in health narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
3) Is the availability and quality of neighbourhood green space associated with more frequent green space use?
4) Is the socio-economic inequality in green space use narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
5) Is the availability and quality of neighbourhood green space associated with use of green space for?
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?
6) Is the socio-economic inequality in use of green space narrower among those with available, good quality, green space compared to those with less available, poor quality green space for:
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?

To explore each of these research questions the analysis was conducted in three phases. These phases mimic those used to examine the results of the SHS respondents. Phase One consisted of descriptive statistics to explore the sample characteristics of each research question (research questions 1-6). Phase Two comprised of a series of logistic regression models designed to test for any significant associations between the availability, and quality of, green space and (a) frequency of use, (b) purpose of use (physical activity, restoration form stress and mental fatigue and social contact) and (c) health (research questions 1, 3 and 5). Phase Three involved the use of a number of interaction models designed to explore whether there was a socio-economic related inequality in (a) frequency of use, (b) purpose of use and (c) health by green space availability and quality (research questions 2, 4 and 6). Table 6.5 provides details of each research phase and its use in the exploration of the relevant research questions. Further details relating to the statistical techniques employed throughout the analysis are detailed below. As the analysis of the

GSOS used the same statistical techniques to that of the SHS it will only be necessary to provide a brief rationale as to why each statistical technique was selected. For details of the complete rationale see Chapter 5, Section 5.7. All statistical analysis was again performed using STATA version 11 and the alpha level for statistical significance was defined as $P<0.05$. Below I will begin by providing an over-view of the descriptive analysis as a whole and then I will go through the relevant statistical techniques used to explore the appropriate research questions.

Table 6.5 Research Phases employed to explore each research question

Research Questions	Phase One	Phase Two	Phase Three
1	✓	✓	×
2	✓	×	✓
3	✓	✓	×
4	✓	×	✓
5	✓	✓	×
6	✓	×	✓

6.4.1 Descriptive Analysis

Descriptive analysis was used to explore the characteristics of each outcome variable (frequency of use, purpose of use and health), explanatory variable (availability and quality) and confounding variable (age, sex and socio-economic position). The aim of this descriptive work was to gain an overview of whether there were any socio-economic differences for each outcome and explanatory variable. Trends in the observed value for socio-economic position were explored by conducting cross tabulations and chi-squared tests. Chi-squared tests were used as all variables were categorical. All cross-tabulations were un-weighted as you cannot do a weighted chi-square test in STATA. As Section 6.3.4 demonstrates that the un-weighted data was not fully representative of the Scottish Population this does create a limitation. All cross tabulation percentages, however, were conducted using weighted data. The results of the descriptive statistics for each variable used in this study are given at the beginning of the GSOS Results Chapter (Chapter 8).

6.4.2 What is the Association between Availability, and Quality of, Green Space and (a) Frequency of Green Space Use, (b) Type of Green Space Use and (c) Health?

The association between availability, and quality of, green space and (a) frequency of green space use, (b) purpose of green space use and (c) health was explored using sequential logistic regression analysis (research questions 1, 3 and 5). Sequential logistic regression models were selected as they allow all independent and control variables to be added one step at a time. Similar to the SHS, my sequential logistic regression analysis was built up using four models. The sequence of these four models is illustrated in Figure 6.1. The first model explored the association between availability, and quality of, green space and (a) frequency of green space use, (b) purpose of green space use and (c) health. This allowed me to explore whether there were any independent associations before I added any of my control variables to the model. The second, third and fourth model added in each control variable (age, sex and socio-economic position) independently, allowing the exploration of whether any of the main associations differed by the addition of any control variables. Separate models were conducted for frequency of green space use, purpose of green space use (physical activity, restoration from stress and mental fatigue and social contact) and (c) health when green space was defined as availability, and quality of, green space. For the purpose of the GSOS results chapter (Chapter 8), I presented Model 1 independently and then grouped together Models 2, 3 and 4. Where any of the main associations may differ by the addition of a particular control variable, the results will be noted in the relevant section.

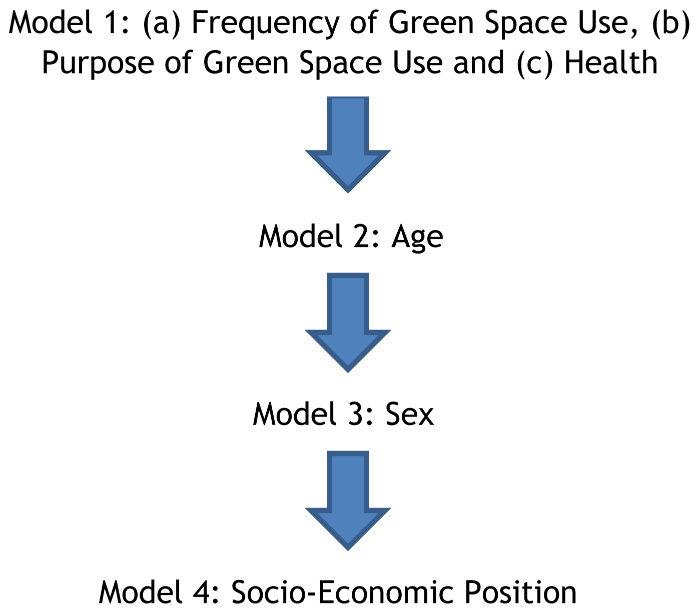


Figure 6.1 The sequential logistic regression model used to explore the association between availability, and quality of, green space and (a) frequency of green space use, (b) type of green space use and (c) health

6.4.3 Is the Socio-Economic Inequality in (a) Frequency of Use, (b) Purpose of Use and (c) Health Narrower Among Available, Good Quality Green Space

Having tested the association between availability, and quality of, green space and (a) frequency of green space use, (b) purpose of green space use and (c) health, the next step in the analysis was to explore whether the association differed by socio-economic position. This procedure is summarised in Table 6.6 and outlines below. The association was initially achieved by adding an interaction term to the model which explored whether the association between socio-economic position and (a) frequency of green space use, (b) purpose of green space use and (c) health varied by availability, and quality of, green space. This was added in conjunction with both the independent and confounding variables. The first part of the model comprised of all independent and control variables that appeared in the model. When green space was defined as availability this included availability of green space, age, sex and socio-economic position and when green space was defined as quality this included quality of green space, age, sex and socio-economic position. The second part of the model added either the interaction terms: [socio-economic position] x [green space availability] or [socio-economic position] x [green space quality].

The resulting coefficients were tested using a Wald test for interaction to determine whether the addition of the two-way interaction terms significantly improved the models fit. Any significant differences were again indicated by a significant chi-squared value. The exact nature of any significant interactions was then further unpacked using a sequence of logistic regression models stratified by availability, and quality of, green space. For green space availability the first model explored the association between socio-economic position and (a) frequency of green space use, (b) purpose of green space use and (c) health for the population that lived closest to green space, the next model explored the association for respondents in the next closest group, and so on. When green space was defined as quality, a similar model was run substituting availability of green space with quality of green space. This method facilitated the interpretation of the interaction effects and allowed the results to be presented using odds ratios and 95% confidence intervals for each category of green space whether it be availability or quality.

Table 6.6 Sequence of interaction process for research questions 2, 4 and 6

Association between socio-economic position and (a) frequency of green space use, (b) purpose of green space use and (c) health by green space (research questions 2, 4 and 6), when green space is defined as:		
	Availability of	Quality of
Step One: Addition of interaction terms	[socio-economic position] x [availability of green space]	[socio-economic position] x [quality of green space]
Step Two: Testing of resulting coefficients	Wald Test for Interaction	Wald Test for Interaction
Step Three: Sequence of logistic regression models	Stratified by Availability of Green Space	Stratified by Quality of Green Space

*Separate models were run for frequency of green space use, type of green space use and health

6.5 Conclusion

In this Chapter I have described the methods from the second phase of the research methodology. This included outlining the GSOS; the outcome, explanatory and confounding variables selected and derived for analysis and the data analysis strategy employed. The next Chapter will discuss the results for the first phase of the research methodology.

Chapter 7 Scottish Health Survey Results

This chapter presents the analysis using the green space quantity data matched with information from the Scottish Health Survey (SHS) respondents. The purpose of this analysis was to investigate whether (or not) the relationship between green space and physical activity was a mechanism reducing the socio-economic gap in health in greener areas. Descriptive statistics were used to describe the population sample and to explore the socio-economic gradient in both health and physical activity outcomes and logistic regression models were run to answer the following five research questions:

1) Is the availability of neighbourhood green space associated with better health?
2) Is the socio-economic inequality in health narrower in the greenest areas compared to the least green areas?
3) Is the availability of neighbourhood green space associated with physical activity in green space?
4) Is the socio-economic inequality in physical activity narrower in the greenest areas compared to the least green areas?
5) Is physical activity in green space more protective of health for groups of lower socio-economic position?

7.1 Descriptive Statistics

7.1.1 Demographic and Socio-Economic Characteristics

Demographic characteristics (age and sex) and socio-economic characteristics (income, SEG, SIMD) were collected for each SHS respondent (Table 7.1). The respondents were aged between 16 and 97 years, with an average age of about 50 years (mean 50.8 years, standard deviation 18.7). Of those 4189 respondents, 2199 (52.48%) were female. Income was fairly evenly distributed across each category, with missing income data accounting for 495 (11.81%) of respondents. SIMD was fairly evenly distributed among the least (21.40%) and most (24.07%) deprived category, with fewer people being classified in the third quintile (13.33%). Of the 4189 respondents who provided information on SEG, over one third (35.86%) described themselves as either professional or managerial technical.

Table 7.1 Demographic and socio-economic characteristics of SHS respondents (n (%)), including sex, age, income, SEG and SIMD (n = 4189)

Demographic and Socio-Economic Characteristics	n	Percentage
Sex		
Male	1990	47.52
Female	2199	52.48
Age		
16-24	582	13.90
25-34	658	15.70
35-44	764	18.23
45-54	732	17.48
55-64	621	14.83
65-74	450	10.74
75+	382	9.11
Income		
Top Tertile (>=£29900)	1358	32.41
2nd Tertile (>=£14932<£29900)	1181	28.19
Bottom Tertile (<£14932)	1156	27.59
Missing Data	495	11.81
SEG		
i – Professional	308	7.35
ii – Managerial Technical	1194	28.51
iiin – Skilled Non-Manual	753	17.97
iiim – Skilled Manual	895	21.36
iv – Semi-Skilled Manual	645	15.40
v – Unskilled Manual	259	6.18
Missing Data	135	3.22
SIMD		
5th (Least Deprived)	896	21.40
4th	759	18.12
3rd	558	13.33
2nd	967	23.08
1st (Most Deprived)	1008	24.07

7.1.2 Representativeness of Study Sample

A limited comparison of the SHS with the 2001 census data and population level SIMD quintiles was conducted to explore the representativeness of the study sample among urban areas of Scotland (Table 7.2). In general, the results found that the SHS was representative of the Scottish population. The age and sex of the SHS respondents was directly comparable to that of the 2001 census. The SHS SIMD quintiles were representative of the expected profile of the Scottish population at the least and most deprived level but slightly under represented respondents classified within quintile 3.

Table 7.2 Comparison of survey respondents with (a) census data and (b) population SIMD quintiles

Survey Characteristics	Scottish Health Survey 2008	Census 2001
	Urban Scotland	Urban Scotland
(a)		
Sex		
Male	48%	47%
Female	52%	53%
Age		
16-24	14%	15%
25-34	16%	18%
35-44	18%	19%
45-54	17%	16%
55-64	15%	13%
65-74	11%	11%
75+	9%	9%
(b)		
SIMD Quintiles		
1 (Least Deprived)	21%	22%
2	18%	16%
3	13%	17%
4	23%	22%
5 (Most Deprived)	24%	24%

7.1.3 Green Space Availability

Table 7.3 presents the percentage of green space available within each respondent's neighbourhood of residence. When green space availability was categorised into four equal interview groups, 22% of respondents lived in neighbourhoods with less than 25% green space and 26% lived in neighbourhoods with greater than 75% green space. When green space was categorised into five interval groups, the results found that only 3% of respondents lived in neighbourhoods with less than 15% green space.

Table 7.3 Neighbourhood green space availability of SHS respondents (N=4189)

Green Space Availability	n	Percentage
Green Space (categorised into 4 interval groups)		
<25%	936	22.35
25-<50%	1601	38.23
50-<75%	554	13.22
75%+	1097	26.20
Green Space (categorised into 5 interval groups)		
<15%	109	2.59
15-<40%	2031	48.49
40-<65%	754	17.79
65-<85%	825	19.68
85%+	479	11.44

7.1.4 Relationship between Green Space Availability and Socio-Economic Position

The association between the percentage of green space available in a respondent's neighbourhood and income is shown in Table 7.4. When green space availability was categorised into equal interview groups, the results found that less deprived populations were more likely to reside in areas with greater green space availability (28.54%) compared to those classified as more deprived (24.77%), demonstrating a socio-economic gradient in green space availability. When green space was categorised into five interval groups, the results demonstrated a socio-economic gradient in green space availability within the 65-85% category; but showed no socio-economic gradient when the availability of neighbourhood green space increased to 85% plus. No substantive difference in results was noted when socio-economic position was defined using SEG or SIMD (results not shown).

Table 7.4 The association between green space availability of the SHS respondents and income tertiles (N=4189)

	Income (%)					
	Top Tertile	2nd Tertile	Bottom Tertile	Missing	Total	x2 P Value
Green Space Availability (4 interval groups)						
<25%	21.90	20.80	22.45	27.10	22.35	
25-<50%	35.69	38.98	40.02	39.22	38.23	
50-<75%	13.87	12.63	12.76	13.92	13.22	
75%+	28.54	27.59	24.77	19.76	26.20	
Total	100.00	100.00	100.00	100.00	100.00	0.005
Green Space Availability (5 interval groups)						
<15%	2.15	1.73	1.72	7.89	2.59	
15-<40%	47.29	48.22	50.71	47.24	48.49	
40-<65%	16.25	16.91	19.22	20.79	17.79	
65-<85%	23.06	20.05	17.29	15.16	19.68	
85%+	11.25	13.10	11.06	8.92	11.44	
Total	100.00	100.00	100.00	100.00	100.00	<0.001

7.1.5 Health and Well-Being

The five indicators of health and well-being of the survey respondents are shown in Table 7.5. When asked how they felt about their life in general (75%) reported that they were either in 'very good' or 'good' health. 18% described themselves as currently having high blood pressure, 33% reported having had some type of cardio-vascular condition and 23% were classified as obese (BMI>30). Respondent's mental health score, derived from the General Health Questionnaire (GHQ), indicated that around 55% of respondents were in good mental health.

Table 7.5 Self-reported health, high blood pressure, cardio-vascular disease, BMI and GHQ of respondents (n = 4189)

Health Outcomes	n	Percentage
Self-Reported Health		
Very Good	1479	35.28
Good	1664	39.73
Fair	745	17.79
Bad	228	5.45
Very Bad	72	1.73
Missing	1	0.03
High Blood Pressure		
Yes	757	18.06
No	3391	80.95
Missing	41	0.98
Cardio-Vascular Disease		
Yes	1398	33.38
No	2781	66.39
Missing	10	0.23
BMI		
BMI<30	2629	62.75
BMI>30	953	22.76
Missing	607	14.49
General Health Questionnaire (GHQ)		
Score 0 (Good Mental Health)	2289	54.63
Score 1-3	914	21.83
Score 4+ (Poor Mental Health)	601	14.34
Missing	385	9.20

7.1.6 Relationships between Health and Socio-Economic Position

The relationship between health and household income is shown in Table 7.6. For the majority of health outcomes, the results demonstrated an income-related health inequality, such that, health got steadily worse with increasing income deprivation. Self-reported health shows that 41.45% of respondents in the top income tertile reported "very good" health compared to only 22.93% of respondents in the bottom tertile. The exception to this was Body Mass Index (BMI). Although the results showed that those in the bottom income tertile were more likely to be classified as obese (23.40%) than those in the top (21.26), the results were not dose-response; those in the middle income tertile were the most likely to be classed as obese (25.63%). No substantive differences in results were noted when socio-economic position was defined using SEG. When socio-economic position was defined using area level data, however, there was no evidence that the association between blood pressure ($x2 = 14.39$, $P = 0.072$)

and cardio-vascular disease (x2 = 10.87, P = 0.209) differed by SIMD (results not shown).

Table 7.6 Associations between health outcomes and income tertiles (n = 4189)

	Income (%)					
	Top Tertile	2nd Tertile	Bottom Tertile	Missing	Total	x2 P Value
Self-Reported Health						
Very Good	48.45	34.21	22.93	30.56	32.28	
Good	39.08	44.18	35.41	40.96	39.73	
Fair	10.44	15.93	27.39	19.98	17.79	
Bad	1.59	3.96	11.25	6.04	5.45	
Very Bad	0.45	1.73	3.02	2.24	1.73	
Missing	0.00	0.00	0.00	0.22	0.03	
Total	100.00	100.00	100.00	100.00	100.00	<0.001
High Blood Pressure						
Yes	11.34	17.17	25.38	21.56	18.06	
No	87.60	82.10	73.68	76.94	80.95	
Missing	1.06	0.73	0.94	1.50	0.98	
Total	100.00	100.00	100.00	100.00	100.00	<0.001
Cardio-Vascular Disease						
Yes	26.54	31.25	43.03	34.73	33.38	
No	73.41	68.60	56.49	64.98	66.39	
Missing	0.05	0.15	0.48	0.29	0.23	
Total	100.00	100.00	100.00	100.00	100.00	<0.001
BMI						
No (BMI<30)	67.69	63.08	60.68	53.23	62.75	
Yes (BMI>30)	21.26	25.63	23.40	18.54	22.76	
Missing	11.05	11.29	15.92	28.24	14.49	
Total	100.00	100.00	100.00	100.00	100.00	<0.001
GHQ						
Score 0	59.58	59.84	44.90	51.38	54.63	
Score 1-3	23.92	19.48	23.18	18.57	21.83	
Score 4+	10.10	12.87	20.59	14.85	14.34	
Missing	6.41	7.81	11.33	15.20	9.20	
Total	100.00	100.00	100.00	100.00	100.00	<0.001

7.1.7 Physical Activity

The distributions of overall physical activity and walking of the SHS respondents are shown in Figure 7.1 and Figure 7.2. 1619 (39%) of the 4189 respondents participate in 5+ days of physical activity per week (Figure 7.1) and 784 (19%) participate in 5+ days of walking per week (Figure 7.2).

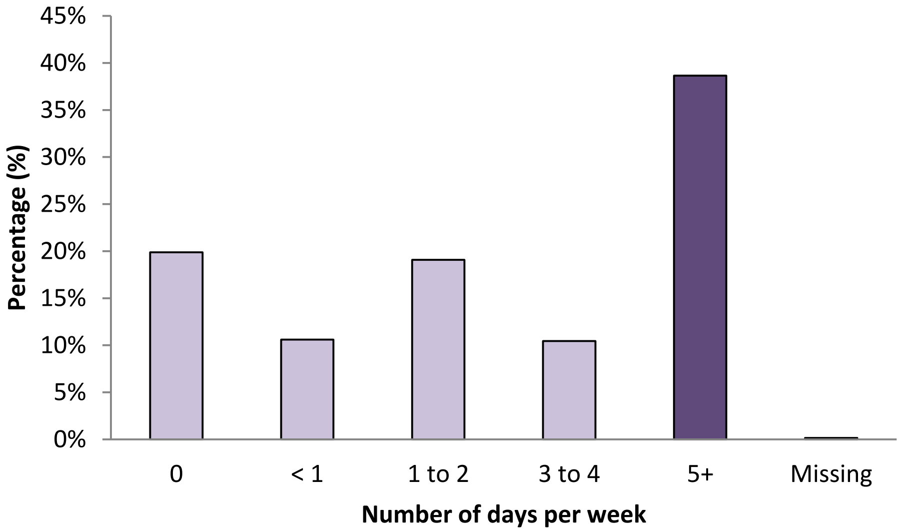


Figure 7.1 Number of days per week doing any activity (30 + mins, including 10-29 min bouts) of respondents (n = 4189). The darker bar denotes recommended physical activity guidelines.

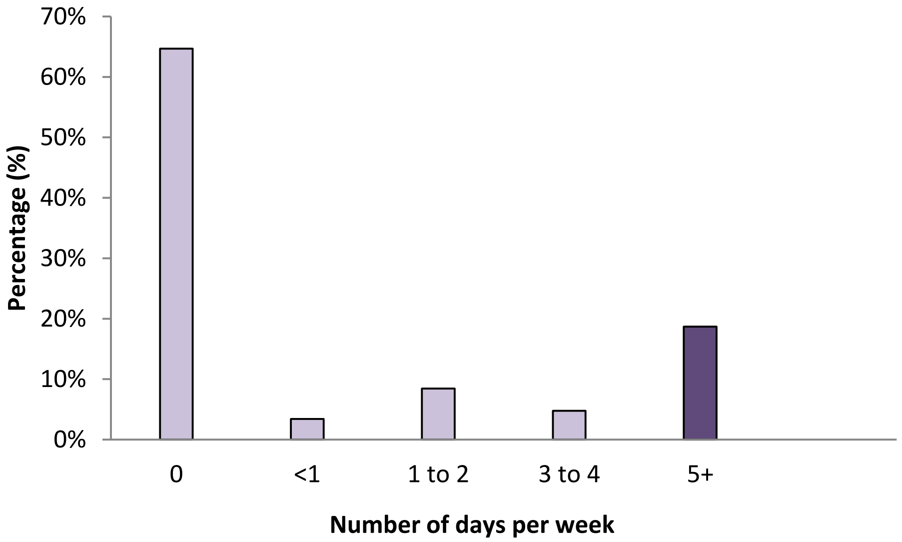


Figure 7.2 Number of days walking (30 mins +, including 10-29 min bouts) of respondents (n = 4189). The darker bar denotes recommended walking guidelines

7.1.7.1 Meeting the Recommended Physical Activity and Walking Guidelines

Overall physical activity and walking were collapsed into binary variables. These variables distinguished those who met the UK recommendations of undertaking at least thirty minutes of (a) moderate intensity physical activity and (b) fast or brisk walking on five or more occasions in a week, from those who did not. Table 7.7 presents the percentage of respondents meeting the recommended physical activity (38.64%) and walking (18.70%). These values correspond with the darker bars on Figures 7.1 and 7.2.

Table 7.7 Number (%) of respondents who meet the governments recommended physical activity and walking guidelines (n = 4189)

Physical Activity and Walking Guidelines	n	Percentage
Physical Activity[1]		
Does not meet recommended guidelines	2564	61.21
Does meet recommended guidelines	1619	38.64
Missing	6	0.15
Walking[2]		
Does not meet recommended guidelines	3406	81.30
Does meet recommended guidelines	783	18.70
Missing	0	0

[1] 30+ minutes of moderate intensity physical activity 5 days a week, [2] 30+ minutes of moderate intensity walking 5 days a week

7.1.7.2 Environments used for Physical Activity

The percentage of respondents reporting use of each environment for physical activity is shown in Figure 7.3. The results show that the most commonly reported environments for use of physical activity were local pavements of streets (64.03%) and home or garden (40.26%). The most reported use of any green environment for physical activity was open space/parks (27.68%). This was closely followed by the remaining three green environments (woods/forest (20.70%), beach/riverside (19.93%) and country paths (18.92%)).

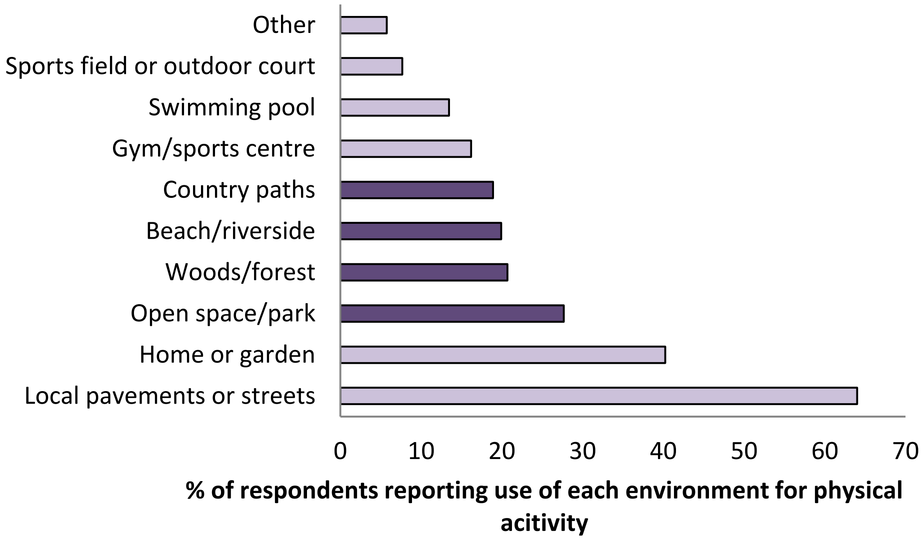


Figure 7.3 Percentage of respondents who use each environment for physical activity. The darker bar denotes environments defined as green. Use of each environment was measured for a sub-sample of the SHS respondents (n=1442)

7.1.7.3 Physical Activity in Green Space

Table 7.8 shows the number and percentage of respondents who use their green space for physical activity either once a week or more or three times a week or more. The results show that 36.33% of respondents use their green space for physical activity at least once a week or more and 18.47% use their green space for physical activity at least three times a week or more.

Table 7.8 Number (%) of respondents who used their green space for physical activity (a) at least once a week or more and (b) at least three times a week or more in the four week period preceding the interview. Measured for a sub-sample of the SHS respondents (n=1442)

	n	Percentage
Green Physical Activity (1 per week)		
Use <1 per week	918	63.67
Use >=1 per week	524	36.33
Missing	0	0
Green Physical Activity (3 per week)		
Use <3 per week	1176	81.53
Use >=3 per week	266	18.47
Missing	0	0

7.1.8 The Relationship between Physical Activity and Socio-Economic Position

The association between each physical activity outcome and income is shown in Table 7.9. The results show a socio-economic gradient with each physical activity outcome such that participation in physical activity gets steadily lower with increasing income deprivation. For example, 46.51% of respondents in the top tertile meet the recommended physical activity guidelines, compared to only 30.21% of respondents in the bottom tertile. No substantive differences in results were noted when the alternative measures of socio-economic position were used (results not shown).

Table 7.9 Associations between each physical activity outcome and income tertiles (n = 4189)

	Income (%)					
	Top Tertile	2nd Tertile	Bottom Tertile	Missing	Total	x2 P Value
Physical Activity						
Doesn't meet guidelines	53.24	60.15	69.67	65.86	61.21	
Does meet guidelines	46.51	39.79	30.21	33.97	38.64	
Missing	0.25	0.06	0.12	0.17	0.15	
Total	100.00	100.00	100.00	100.00	100.00	<0.001
Walking						
Doesn't meet guidelines	78.32	81.68	84.50	81.13	81.30	
Does meet guidelines	21.68	18.32	15.50	18.87	18.70	
Missing	0.00	0.00	0.00	0.00	0.00	
Total	100.00	100.00	100.00	100.00	100.00	0.004
Green Physical Activity*						
Use <1 per week	55.77	64.61	75.44	75.76	67.13	
Use >=1 per week	44.23	35.39	24.56	24.24	32.87	
Missing	0.00	0.00	0.00	0.00	0.00	
Total	100.00	100.00	100.00	100.00	100.00	<0.001

* n=1442

7.2 Is the Availability of Neighbourhood Green Space Associated with Better Health?

This section describes results of the analysis that explored the association between green space and health. The analytical procedure consisted of logistic regression models with sequential adjustment for demographic and socio-economic indicators (See Chapter 5, Section 5.7.2). In brief, after excluding respondents who had no income data, odd ratios and 95% confidence intervals were calculated for the association between green space and the health outcome under investigation. The baseline model (Model 1) included the measurement of green space availability. Model 2 controlled for the confounding effects of age group, sex and socio-economic position.

This chapter will present the analysis for each of the main health outcomes (self-reported health, blood pressure, cardio-vascular conditions, BMI and GHQ). Income will be used as the measurement of SES and green space will be categorised into four groups (<25%, 25-<50%, 50-<75% and 75%+). See Chapter 5 for the rationale behind the choice of health outcomes, socio-economic position and categorisation of green space. Where any of the results may differ by the additional measurements of health, socio-economic position or categorisation of green space, the results will be outlined in the section titled sensitivity analysis (Section 7.26).

7.2.1 Self-Reported Health

Results of the association between green space and the odds of reporting poor self-reported health are presented in Table 7.10. The results show no significant association between green space availability and self-reported health (Model 2). In the unadjusted and adjusted models the odds ratios were inconsistent in direction and gave no indication of a dose-response relationship, in that, the odds did not appear to fall further with each incremental increase in green space. As expected, an independent association between income and self-reported health, was observed. Compared to those in the top income tertile, respondents classified in the bottom tertile were significantly more likely to report poor self-reported health.

Table 7.10 The association between green space and poor self-reported health (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n =3597)

	Odd Ratios (95% Confidence Intervals) for Reporting Poor Self-Reported Health	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	1.10 (0.88-1.38)	1.06 (0.84-1.34)
50-<75%	1.26 (0.95-1.66)	1.22 (0.91-1.65)
75%+	1.06 (0.84-1.34)	1.03 (0.80-1.32)
Gender		
Male		1.00
Female		1.06 (0.90-1.26)
Age		
16-24		1.00
25-34		1.29 (0.80-2.07)
35-44		1.85 (1.20-2.87)**
45-54		2.85 (1.86-4.37)***
55-64		3.85 (2.52-5.88)***
65-74		4.26 (2.76-6.56)***
75+		5.27 (3.38-8.21)***
Income		
Top Tertile		1.00
2^{nd} Tertile		1.96 (1.55-2.47)***
Bottom Tertile		4.38 (3.51-5.46)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.2.2 High Blood Pressure

Table 7.11 presents the association between green space availability and the odds of reporting high blood pressure. In the unadjusted model, respondents living in greener neighbourhoods were more likely to report high blood pressure than those living in the least green areas. The results were not dose response demonstrating a threshold effect. After adjustment for age, sex and income this association was attenuated slightly and only remained weakly significant for those living in areas with 25-<50% green space (odds ratio 1.38, 95% CI 1.05-1.82). These results were contradictory to expectations as it had been hypothesised that blood pressure would be lower in areas with greater green space exposure as they provide more opportunities for physical activity.

Table 7.11 The association between green space and high blood pressure (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=3561)

	Odd Ratios (95% Confidence Intervals) for Reporting High Blood Pressure	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	1.41 (1.10-1.81)**	1.38 (1.05-1.82)*
50-<75%	1.49 (1.10-2.02)*	1.37 (0.97-1.93)
75%+	1.35 (1.04-1.75)*	1.20 (0.90-1.59)
Gender		
Male		1.00
Female		0.99 (0.82-1.20)
Age		
16-24		1.00
25-34		1.60 (0.46-5.54)
35-44		4.52 (1.46-14.0)**
45-54		12.5 (4.17-37.7)***
55-64		29.6 (9.91-88.5)***
65-74		49.9 (16.6-149.8)***
75+		63.6 (20.9-193.9)***
Income		
Top Tertile		1.00
2nd Tertile		1.48 (1.15-1.90)**
Bottom Tertile		1.67 (1.31-2.14)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.2.3 Cardio-Vascular Disease

The association between green space availability and the odds of reporting a cardio-vascular condition is shown in Table 7.12. In the unadjusted model, respondents living in greener neighbourhoods were more likely to report a cardio-vascular condition than those living in the least green areas; again the results did not suggest a dose response relationship. In the adjusted model, the associations were attenuated and all odds ratios were non-significant.

Table 7.12 The association between green space and reporting a cardio-vascular condition (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n =3588)

	Odd Ratios (95% Confidence Intervals) for Reporting Cardio-Vascular Condition	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	1.23 (1.00-1.52)*	1.20 (0.95-1.52)
50-<75%	1.38 (1.07-1.79)*	1.31 (0.98-1.74)
75%+	1.30 (1.05-1.61)*	1.20 (0.94-1.53)
Gender		
Male		1.00
Female		1.01 (0.85-1.19)
Age		
16-24		1.00
25-34		1.40 (0.85-2.32)
35-44		2.17 (1.37-3.44)**
45-54		4.42 (2.82-6.91)***
55-64		8.73 (5.61-13.6)***
65-74		16.8 (10.7-26.4)***
75+		23.0 (14.3-37.1)***
Income		
Top Tertile		1.00
2nd Tertile		1.17 (0.95-1.44)
Bottom Tertile		1.44 (1.17-1.77)**

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.2.4 BMI

No significant association was observed between green space availability and being classed as overweight ((BMI>25) (See Table 7.13)). The odds ratios were inconsistent in direction and gave no indication of a dose response relationship. No significant independent association between income and overweight was also noted. To test whether the results differed by the classification of BMI, I re-ran a similar model for those classified as obese (BMI>30). No substantive differences in results were seen (results not shown).

Table 7.13 The association between green space and being classed overweight (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n =3133)

	Odd Ratios (95% Confidence Intervals) for being classed overweight	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	1.11 (0.89-1.40)	1.07 (0.84-1.36)
50-<75%	1.40 (1.04-1.87)*	1.28 (0.95-1.74)
75%+	1.22 (0.96-1.55)	1.14 (0.89-1.45)
Gender		
Male		1.00
Female		0.73 (0.62-0.87)***
Age		
16-24		1.00
25-34		2.01 (1.42-2.85)***
35-44		3.61 (2.59-5.04)***
45-54		4.26 (3.05-5.95)***
55-64		6.63 (4.67-9.41)***
65-74		5.72 (4.00-8.18)***
75+		4.84 (3.28-7.15)***
Income		
Top Tertile		1.00
2nd Tertile		1.19 (0.96-1.47)
Bottom Tertile		0.95 (0.76-1.18)

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.2.5 GHQ

The association between green space and mental health is shown in Table 7.14. The results show no evidence of a significant association between green space availability and the odds of reporting poor mental health. An independent association between income and mental health was observed. Compared to those in the top income tertile, respondents classified in the bottom tertile were significantly more likely to report poor mental health (Odds ratio 2.90, 95% CI 2.21-3.80).

Table 7.14 The association between green space and reporting poor mental health (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 3281)

	Odd Ratios (95% Confidence Intervals) for Reporting Poor Mental Health	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	0.94 (0.71-1.24)	0.93 (0.70-1.24)
50-<75%	0.88 (0.62-1.26)	0.90 (0.63-1.29)
75%+	0.89 (0.67-1.20)	0.92 (0.69-1.25)
Gender		
Male		1.00
Female		1.46 (1.17-1.81)**
Age		
16-24		1.00
25-34		1.28 (0.80-2.03)
35-44		1.18 (0.77-1.82)
45-54		1.70 (1.11-2.60)
55-64		1.24 (0.80-1.91)
65-74		0.77 (0.48-1.23)
75+		0.62 (0.37-1.03)
Income		
Top Tertile		1.00
2nd Tertile		1.47 (1.10-1.95)**
Bottom Tertile		2.90 (2.21-3.80)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.2.6 Sensitivity Analysis

7.2.6.1 The Categorisation of Green Space

Sensitivity analysis was performed to explore whether the association between green space and each health outcome was affected by the categorisation of green space (Chapter 5, Section 5.5.3). Two categorisations of green space have been used. The first categorised green space into four groups and defined the baseline category as less than 25% green space. The second categorised green space into five groups and defined the baseline category as less than 15% green space.

For the majority of health outcomes there was little difference in results between the ways in which green space availability was categorised. The one exception to this was the association between green space and mental health.

When the baseline green space category was defined as less than 25% there was no evidence of a significant association between green space availability and the odds of reporting poor mental health (See Table 7.14). When the baseline category was defined as less than 15%, however, respondents living in areas with greater than 15% green space were significantly less likely to report poor mental health than those who lived in less in areas with less than 15% green space (See Table 7.15). The results did not suggest a dose response relationship, demonstrating a threshold effect. These findings suggest that having some green space available in the neighbourhood is sufficient for reducing levels of poor mental health but anything over and above this may have no added mental health benefit. This is consistent with studies that have shown that simply having a view of green space from a window may be sufficient to reduce levels of stress and mental fatigue.

Table 7.15 The association between green space and reporting poor mental health when green space is categorised as less than 10% (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 3281)

	Odd Ratios (95% Confidence Intervals) for Reporting Poor Mental Health	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<15%	1.00	1.00
15-<40%	0.51 (0.25-1.03)	0.44 (0.22-0.91)*
40-<65%	0.51 (0.24-1.06)	0.44 (0.21-0.93)*
65-<85%	0.47 (0.23-0.97)*	0.43 (0.21-0.91)*
85%+	0.47 (0.22-1.00)*	0.42 (0.20-0.91)*
Gender		
Male		1.00
Female		1.46 (1.17-1.81)**
Age		
16-24		1.00
25-34		1.29 (0.81-2.06)
35-44		1.20 (0.78-1.85)
45-54		1.74 (1.13-2.67)*
55-64		1.26 (0.82-1.96)
65-74		0.79 (0.49-1.26)
75+		0.63 (0.38-1.06)
Income		
Top Tertile		1.00
2^{nd} Tertile		1.47 (1.11-1.96)**
Bottom Tertile		2.92 (2.23-3.84)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.2.6.2 Other Health Outcomes

The association between green space and health was explored across a number of additional health outcomes (Chapter 5, Section 5.5.1). For each of these health outcomes, the results suggested no evidence of an association with green space availability. The finding of a lack of a significant association between green space availability and each of the main and additional health outcomes provides consistent evidence to suggest that the availability of neighbourhood green space is not associated with population health in Scotland. This lack of an association was surprising given the number of studies that had consistently reported a positive association between green space and health in other countries for a least one or two of the main health outcomes (Chapter 4, Section 4.3).

7.2.6.3 The Measurement of Socio-Economic Position

Sensitivity analysis was also performed across all health outcomes to explore whether the association between green space and health differed by the measurement of socio-economic position (Chapter 5, Section 5.5.5). When income was substituted with the alternative measurements of socio-economic position, I found that the substantive results remained unaltered. This demonstrates that the association between green space and health was not sensitive to the choice of socio-economic variable.

7.2.6.4 Missing Data

All main models excluded respondents who had no income data (Chapter 5, Section 5.6.2). To explore whether the results differed depending on whether respondents with missing income data were included, I performed two analytical procedures (Chapter 5, Section 5.6.2). In brief, the first procedure involved running logistic regression models with an additional category for those who did not report income and the second involved imputing the missing income data. The results found that the association between green space and health did not differ depending on whether respondents with income data were included or excluded. An example of the output of both additional analytical procedures, using self-reported health as the health outcome, is provided. Table 7.16

illustrates the first procedure whilst Table 7.17 illustrates the second. If both these Tables are compared to Table 7.10 it can see that there is little variation in results.

Table 7.16 The association between green space and poor self-reported health (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators when respondents with missing income data are included (n =4188)

	Odd Ratios (95% Confidence Intervals) for Reporting Poor Self-Reported Health	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	1.20 (0.98-1.47)	1.10 (0.89-1.36)
50-<75%	1.32 (1.02-1.70)*	1.21 (0.92-1.59)
75%+	1.09 (0.88-1.36)	1.00 (0.79-1.26)
Gender		
Male		1.00
Female		1.07 (0.92-1.25)
Age		
16-24		1.00
25-34		1.22 (0.80-1.87)
35-44		1.87 (1.27-2.76)**
45-54		2.84 (1.94-4.15)***
55-64		4.03 (2.77-5.85)***
65-74		4.36 (2.99-6.37)***
75+		5.59 (3.80-8.21)***
Income		
Top Tertile		1.00
2nd Tertile		1.94 (1.54-2.44)***
Bottom Tertile		4.41 (3.55-5.48)***
Missing		2.34 (1.79-3.07)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

Table 7.17 The association between green space and poor self-reported health (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators using imputed missing income data (n =4188)

	Odd Ratios (95% Confidence Intervals) for Reporting Poor Self-Reported Health	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and Income)
Green Space		
<20%	1.00	1.00
25-45%	1.20 (0.98-1.47)	1.11 (0.89-1.37)
50-70%	1.32 (1.02-1.70)*	1.21 (0.92-1.59)
75-95%	1.09 (0.88-1.36)	1.01 (0.80-1.27)
Gender		
Male		1.00
Female		1.06 (0.91-1.24)
Age		
16-24		1.00
25-34		1.23 (0.80-1.89)
35-44		1.86 (1.26-2.75)**
45-54		2.82 (1.93-4.13)***
55-64		3.98 (2.73-5.80)***
65-74		4.28 (2.93-6.27)***
75+		5.49 (3.72-8.09)***
Income		
Top Tertile		1.00
2nd Tertile		1.98 (1.56-2.52)***
Bottom Tertile		4.42 (3.49-5.60)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.2.7 Summary

In summary, the results showed no association between green space and health. These results were largely consistent across health outcome, categorisation of green space and measurement of socio-economic position. Considering the number of previous studies that have reported a positive association between green space and health, the lack of association in this project was surprising and generates a number of questions as to why the relationship between green space and health in Scotland may differ to that of other countries. These questions will be addressed in the Discussion (Chapter 9)

7.3 Is the Socio-Economic Inequality in Health Narrower Among Populations Living in Greener Areas?

This section of the results chapter presents analysis which explored whether socio-economic inequality in health varied by level of neighbourhood green space. The association was initially explored by adding an interaction term to the model which explored whether any association between socio-economic position and health varied by green space availability. The resulting coefficients were tested using the Wald test for interaction. The exact nature of any interactions was subsequently unpacked using a sequence of logistic regression models stratified by green space availability (Chapter 5, Section 5.7.3). In brief, all respondents with missing income data were excluded from analysis and odds ratios and 95% confidence intervals were calculated. Similar to the previous section, the analysis will be presented for each of the main health outcomes using income as the measurement of socio-economic position. Where any of the results may differ by health outcome, socio-economic position or categorisation of green space they will be outlined in the section titled sensitivity analysis (Section 7.3.6).

7.3.1 Self-Reported Health

The income related inequality in the association between green space availability and self-reported health is shown in Figure 7.4. The results suggest that the association between income tertiles and self-reported health did not differ significantly across groups of green space availability (Wald Test x^2 = 6.82, P=0.3380). The odds of those in the lowest income tertile reporting poor self-reported health compared to those in the highest income tertile were 3.38 (95% CI 2.26-5.05) in the least green areas and 4.95 (95% CI 3.02-8.12) in the most green areas.

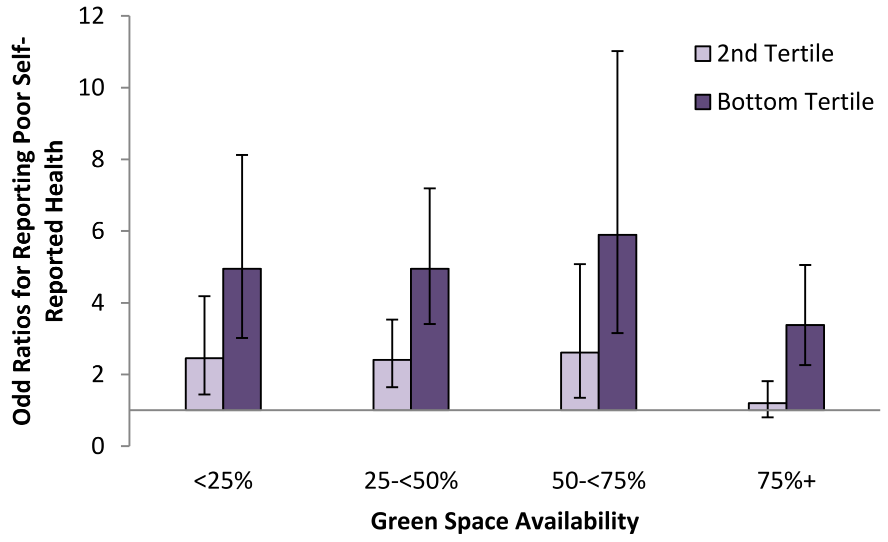


Figure 7.4 Income related inequality in reporting poor self-reported health by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3597). The interaction effect did not reach significance (x2 = 6.82, P = 0.3380) [1] **adjusted for age, sex and income**

7.3.2 High Blood Pressure

Figure 7.5 presents the income related inequality in the association between green space availability and high blood pressure. The results found that the association between income tertiles and the odds of reporting high blood pressure did not differ significantly across groups of green space availability (Wald Test x^2 = 6.95, P=0.3251). The odds ratios were inconsistent in direction and gave no indication of a dose-response relationship such that the inequality in reporting high blood pressure did not narrow with increasing green space availability.

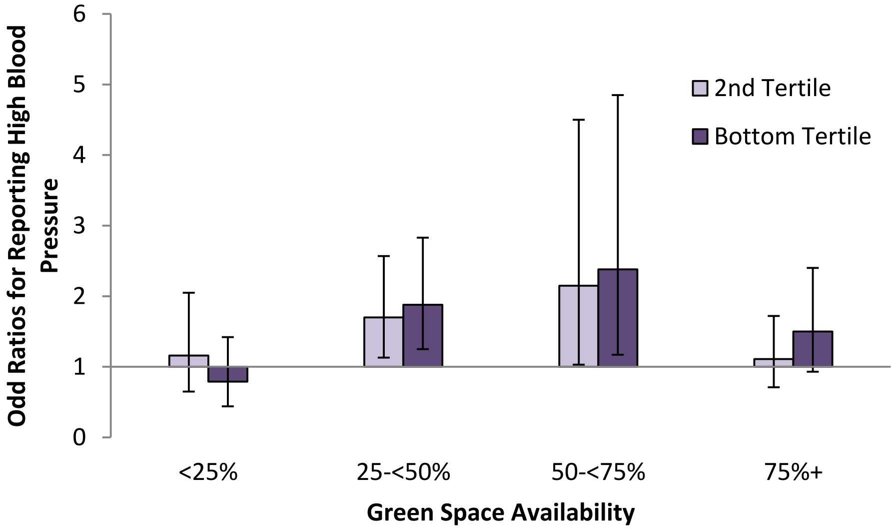


Figure 7.5 Income related inequality in reporting high blood pressure by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3561). The interaction effect did not reach significance (x2 = 6.95, P = 0.3251) [1] adjusted for age, sex and income

7.3.3 Cardio-Vascular Disease

Figure 7.6 shows that income related inequality in reporting a cardio-vascular condition widened in areas with the greatest percentage of green space, although the overall interaction effect did not reach significance (x2 = 5.09, P = 0.5328). The odds of those in the lowest income tertile reporting a cardio-vascular condition compared to those in the highest income tertile were 1.01 (95% CI 0.61-1.67) in the least green areas and 1.81 (95% CI 1.24-2.63) in the most green areas. These results did demonstrate a dose response relationship; a result which was contradictory to expectations.

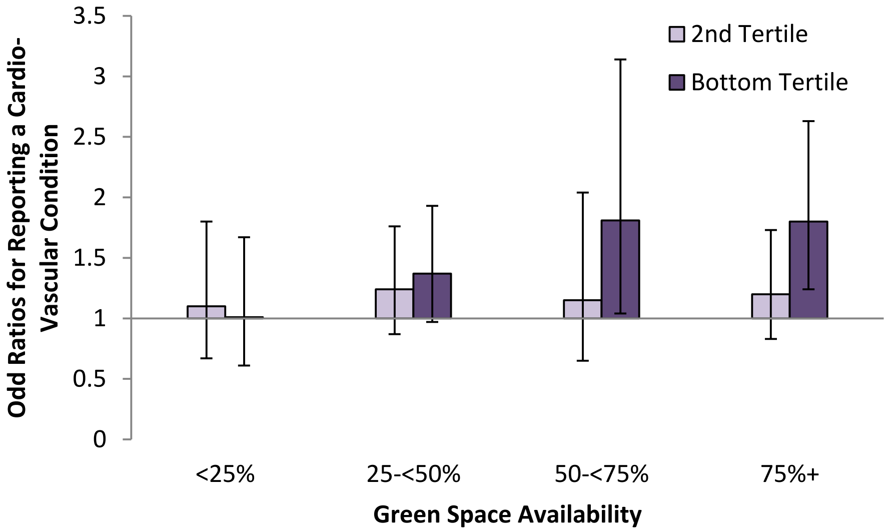


Figure 7.6 Income related inequality in reporting a cardio-vascular condition by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3588). The interaction effect did not reach significance (x2 = 5.09, P = 0.5328) [1] **adjusted for age, sex and income**

7.3.4 BMI

No significant difference in the association between income and BMI by level of green space availability was found ((x2 = 1.70, P = 0.9448) (Figure 7.7)). The odds ratios were inconsistent in direction and gave no indication of a dose-response relationship.

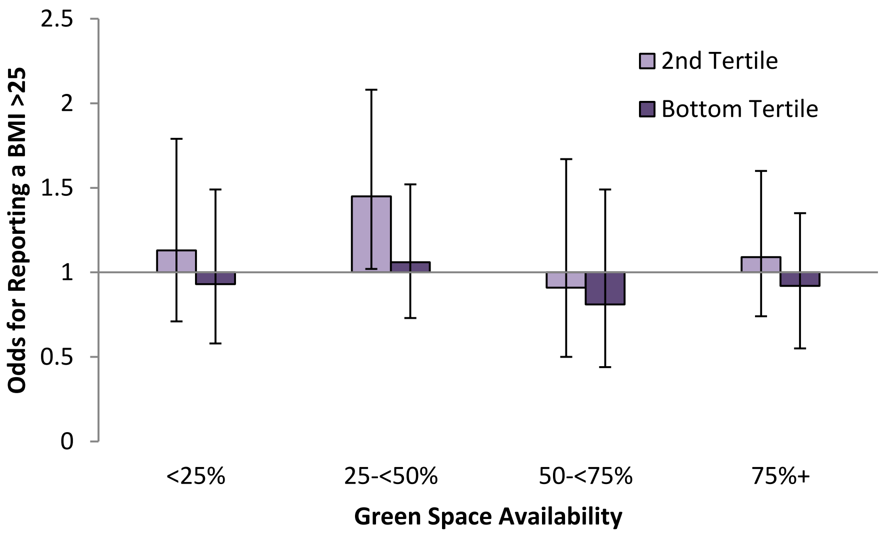


Figure 7.7 Income related inequality in reporting a BMI>25 by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3588). The interaction effect did not reach significance (x2 = 1.70, P = 0.9448) [1] **adjusted for age, sex and income**

7.3.5 GHQ

Figure 7.8 shows how income related inequality in reporting poor mental health varied by level of neighbourhood green space. The results found that the income related gap in reporting poor mental health narrowed in the greenest areas, but the overall interaction effect did not reach significance (x2 = 5.60, P = 0.4691). The odds of those in the lowest income tertile reporting a poor mental health compared to those in the highest income tertile were 3.21 (95% CI 1.84-5.59) in the least green areas and 1.71 (95% CI 1.06-2.75) in the most green areas. These results did demonstrate a dose response relationship such that the inequality got narrower as green space increased.

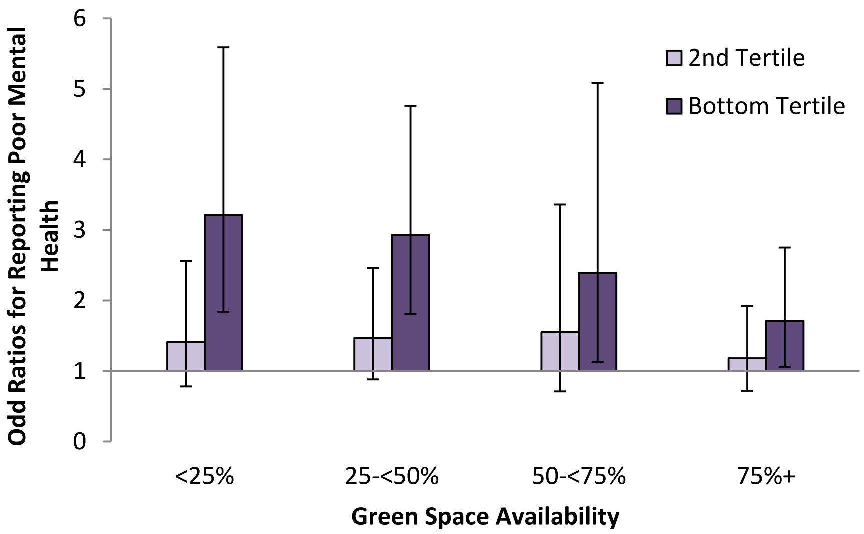


Figure 7.8 Income related inequality in reporting poor mental health by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3281). The interaction effect did not reach significance (x2 = 5.60, P = 0.4691) [1] **adjusted for age, sex and income**

7.3.6 Sensitivity Analysis

7.3.6.1 The Categorisation of Green Space

Sensitivity analysis could not be performed on the categorisation of green space as stratifying the results by green space availability left too small a sample size when the baseline category was defined as less than 15%. This was due to the small number of respondents who lived in areas with very little green space.

7.3.6.2 Other Health Outcomes

There was no evidence that the socio-economic inequality in the association between green space and health differed by the majority of additional health outcomes. The one exception to this was mental well-being where the results suggested a weakly significant interaction such that the income related gap in reporting poor mental well-being narrowed in the greenest areas ((x2 = 11.38, P = 0.0774) (Figure 7.9)). These results correspond with the finding that income related health inequalities in reporting poor mental health also narrowed in the greenest areas. The fact that neither reached significance prompts a number of questions. It could be that the weaknesses in the results simply suggest weaknesses in the true relationship. Alternatively, it could be that the socio-economic gap in health is more pronounced in Scotland resulting in the salutogenic effects of green space being insufficient to help reduce Scotland's socio-economic health gradient. These questions, along with several others, will be discussed more fully in the discussion.

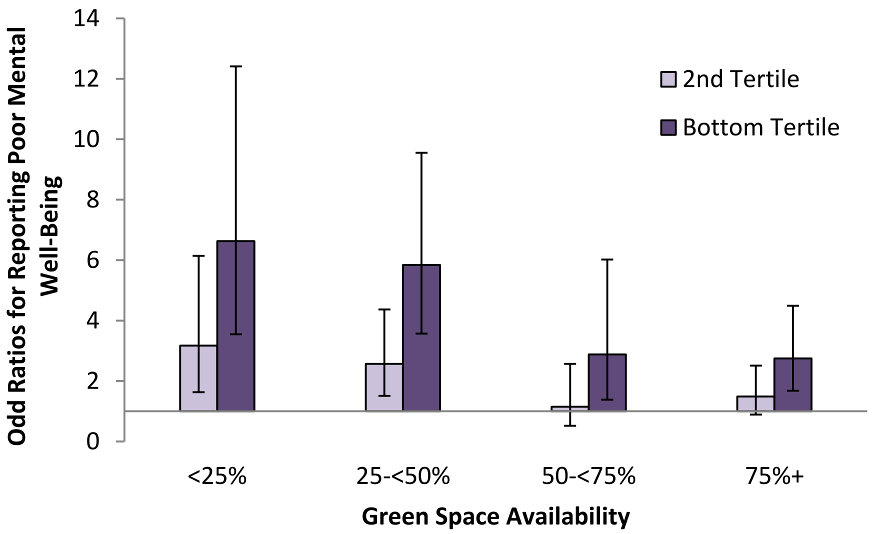


Figure 7.9 Income related inequality in reporting poor mental well-being by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3257). The interaction effect did not reach significance (x2 = 11.38, P = 0.0774)

7.3.6.3 The Measurement of Socio-Economic Position

When income was substituted with the alternative measures of socio-economic position, I found that the substantive results remained unaltered. This suggests that the socio-economic inequality in the association between green space and health was not sensitive to the measurement of socio-economic position.

7.3.6.4 Missing Data

To explore whether the results differed depending on whether I included respondents who had missing income data I performed the two analytical procedures described in the previous section. In general, imputing missing income data made very little difference to the finding that the association between socio-economic position and health did not differ significantly across groups of green space availability.

7.3.7 Summary

In summary, the results suggest that the association between socio-economic position and health did not differ by green space availability. This was consistent across health outcomes, categorisation of green space and measurements of socio-economic position. To date, only one previous study has explored the effects of green space on socio-economic health inequalities[1]. These results found that income based health inequalities in all-cause mortality and mortality from circulatory disease narrowed in populations living in the greenest areas compared to the least green areas in England. Comparing the results between this study and that of Mitchell and Popham is challenging due to the difference in the setting, sample and methodology. It is plausible that the lack of association in this study is unique to Scotland or it may question whether green space is a mechanism that will reduce the socio-economic gradient in health. I will return to these questions in the discussion.

7.4 Is the Availability of Neighbourhood Green Space Associated with Physical Activity in Green Space?

This section presents the results of the analysis that explored the association between green space availability and physical activity. The analytical procedure consisted of logistic regression models with sequential adjustment for demographic and socio-economic indicators (See Chapter 5, Section 5.7.2). In brief, respondents with missing income data were excluded from the main analyses. Odd ratios and 95% confidence intervals were calculated for the association between green space and physical activity. The baseline model (Model 1) adjusted for the measurement of green space exposure whilst Model 2 additionally controlled for the confounding effects of age group, sex and socio-economic deprivation.

This section will present the analysis for each physical activity outcome: overall physical activity, walking and physical activity in green space (green physical activity). The first two measures were based on the UK government's recommendations for levels of physical activity. They were collapsed into a binary variable to distinguish those who met the UK physical activity recommendations from those who did not. The last measurement captured the frequency with which respondents used any green environment for physical activity. I defined two measures of green physical activity. Both were collapsed into binary variables, with the first being defined as "used once a week or more" and the second being defined as "used three times a week or more". This section will follow previous formats. Each physical activity outcome will be presented using income as the measurement of socio-economic position and the four group categorisation of green space. Where any of the results may differ by the additional measurement of socio-economic position or categorisation of green space the findings will be outlined in the section titled sensitivity analysis.

7.4.1 Overall Physical Activity

No association at all was observed between the availability of neighbourhood green space and meeting the recommended overall physical activity guidelines (Table 7.18). An independent association between income and meeting the recommended overall physical activity guidelines was noted. Compared to those in the top income tertile, respondents classified in the bottom income tertile were significantly less likely to meet recommended physical activity guidelines.

Table 7.18 The association between green space and meeting the recommended physical activity guidelines (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 3591)

	Odd Ratios (95% Confidence Intervals) for Meeting Recommended Physical Activity Guidelines	
	When green space is categorised as less than 20%	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	1.02 (0.83-1.25)	1.07 (0.86-1.32)
50-<75%	0.88 (0.67-1.14)	0.90 (0.68-1.18)
75%+	0.85 (0.68-1.05)	0.90 (0.72-1.12)
Gender		
Male		1.00
Female		0.61 (0.52-0.72)***
Age		
16-24		1.00
25-34		1.13 (0.82-1.56)
35-44		0.92 (0.68-1.24)
45-54		0.62 (0.46-0.84)**
55-64		0.50 (0.37-0.68)***
65-74		0.34 (0.24-0.47)***
75+		0.11 (0.07-0.18)***
Income		
Top Tertile		1.00
2nd Tertile		0.78 (0.65-0.95)*
Bottom Tertile		0.64 (0.53-0.78)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.4.2 Walking

In the unadjusted model, respondents living in the greenest neighbourhoods were less likely to meet the recommended walking guidelines (odds ratio 0.74, 95% CI 0.59-0.98) than those living in the least green areas (Model 1); a result which was contradictory to expectations. After adjustment for age, sex and income the association attenuated a little and became non-significant (Model 2). For both models the results followed a dose response relationship, in that, the odds fell further for each incremental increase in green space availability. An independent, positive association between income and meeting the recommended walking guidelines was observed.

Table 7.19 The association between green space and meeting the recommended walking guidelines (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 3597)

	Odd Ratios (95% Confidence Intervals) for Meeting Recommended Walking Guidelines	
	When green space is categorised as less than 20%	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	0.90 (0.69-1.17)	0.93 (0.71-1.21)
50-<75%	0.80 (0.57-1.12)	0.82 (0.58-1.16)
75%+	0.74 (0.56-0.98)*	0.78 (0.59-1.03)
Gender		
Male		1.00
Female		0.72 (0.59-0.87)**
Age		
16-24		1.00
25-34		0.75 (0.52-1.08)
35-44		0.64 (0.45-0.91)*
45-54		0.48 (0.34-0.69)***
55-64		0.38 (0.26-0.55)***
65-74		0.37 (0.25-0.54)***
75+		0.13 (0.07-0.23)***
Income		
Top Tertile		1.00
2nd Tertile		0.80 (0.63-1.01)
Bottom Tertile		0.77 (0.60-0.99)*

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.4.3 Participating in Green Physical Activity

No significant association was observed between green space availability and participating in green physical activity at least once a week or more (Table 7.20). The odds ratios were inconsistent in direction and gave no indication of a dose response relationship. Again, an independent association between income and participating in green physical activity was noted. No difference in results was seen when green physical activity was defined as use of green space at least three times a week or more (results not shown).

Table 7.20 The association between green space and participating in green physical activity (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 1209)

	Odd Ratios (95% Confidence Intervals) for Participating in Green Physical Activity	
	When green space is categorised as less than 20%	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	1.01 (0.73-1.40)	0.91 (0.63-1.31)
50-<75%	0.96 (0.64-1.46)	1.07 (0.67-1.69)
75%+	1.20 (0.85-1.69)	1.13 (0.78-1.65)
Gender		
Male		1.00
Female		0.98 (0.76-1.28)
Age		
16-24		1.00
25-34		1.36 (0.76-2.42)
35-44		1.37 (0.79-2.38)
45-54		1.26 (0.72-2.21)
55-64		0.98 (0.56-1.72)
65-74		1.20 (0.68-2.13)
75+		0.42 (0.21-0.85)*
Income		
Top Tertile		1.00
2nd Tertile		0.65 (0.47-0.89)**
Bottom Tertile		0.44 (0.31-0.61)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.4.4 Sensitivity Analysis

7.4.4.1 The Categorisation of Green Space

For meeting the recommended overall physical activity guidelines and participating in green physical activity there was little difference in the results between the ways in which green space was categorised. For meeting the recommended walking guidelines the results differed very slightly. When the baseline green space category was defined as less than 25% there was no significant association between green space and meeting the recommended walking guidelines, after adjustment for demographic and socio-economic characteristics (See Table 7.19). When the baseline green space category was defined as less than 15%, the unadjusted model showed that respondents living in greater than 15% green space were less likely to meet the recommended walking guidelines than those who lived in less than 15% green space (Table 7.21). After adjusting for age, sex and income the association attenuated slightly and only remained significant for those living in 65-<85% green space. The results were not dose-response but demonstrated a threshold effect. One explanation for these findings is that people living in more densely populated (and less green) areas may be more likely to walk for functional purposes, such as to go to work or to get to the shop. This may explain why my results demonstrated a threshold effect and why there was an inverse relationship between green space and meeting the recommended walking guidelines. It must be noted that car access is a potential confounder here. After running the same analysis but controlling for car availability the results indicated a lack of a significant association. This suggests that the association may not be due to a function of green space.

Table 7.21 The association between green space and meeting the recommended walking guidelines (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 3597)

	Odd Ratios (95% Confidence Intervals) for Meeting Recommended Walking Guidelines	
	When green space is categorised as less than 10%	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<15%	1.00	1.00
15-<40%	0.47 (0.25-0.90)*	0.54 (0.28-1.03)
40-<65%	0.45 (0.23-0.88)*	0.55 (0.28-1.08)
65-<85%	0.38 (0.20-0.75)**	0.43 (0.22-0.85)*
85%+	0.43 (0.22-0.86)*	0.52 (0.26-1.04)
Gender		
Male		1.00
Female		0.71 (0.59-0.87)**
Age		
16-24		1.00
25-34		0.75 (0.52-1.09)
35-44		0.65 (0.46-0.93)*
45-54		0.49 (0.34-0.70)***
55-64		0.38 (0.26-0.55)***
65-74		0.36 (0.25-0.54)***
75+		0.13 (0.07-0.23)***
Income		
Top Tertile		1.00
2nd Tertile		0.80 (0.63-1.01)
Bottom Tertile		0.77 (0.60-1.00)*

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.4.4.2 The Measurement of Socio-Economic Position

When income was substituted with the alternative measures of socio-economic position the substantive results remained unaltered. Again this suggests that the results were not sensitive to the measurement of socio-economic position.

7.4.4.3 Missing Data

There was some evidence to suggest that there was a slight variation in results when I included missing income data. When exploring the association between green space availability and (a) general physical activity and (b) walking I found the same inverse relationship, in that, with increasing green space availability the odds of meeting the recommended physical activity and walking guidelines decreased but after imputing missing income data the association just reached significance. Respondents living in the greenest neighbourhoods were less likely to meet the recommended physical activity (odds ratio 0.80, 95% CI 0.65-0.99) and walking (odds ratio 0.75, 95% CI 0.57-0.98) guidelines compared to those living in the least green areas (Table 7.22 and 7.23). No difference in results was shown for participating in green physical activity depending on whether I included those with missing income data (results not shown).

Table 7.22 The association between green space and meeting the recommended physical activity guidelines, all respondents, (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 4189)

	Odd Ratios (95% Confidence Intervals) for Meeting Recommended Physical Activity Guidelines	
	When green space is categorised as less than 20%	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	0.88 (0.73-1.06)	0.96 (0.79-1.16)
50-<75%	0.72 (0.56-0.91)**	0.77 (0.59-0.99)*
75%+	0.73 (0.60-0.89)**	0.80 (0.65-0.99)*
Gender		
Male		1.00
Female		0.60 (0.52-0.70)***
Age		
16-24		1.00
25-34		1.13 (0.84-1.51)
35-44		0.94 (0.72-1.24)
45-54		0.61 (0.46-0.80)***
55-64		0.47 (0.35-0.62)***
65-74		0.30 (0.22-0.41)***
75+		0.09 (0.06-0.13)***
Income		
Top Tertile		1.00
2nd Tertile		0.78 (0.65-0.94)*
Bottom Tertile		0.66 (0.55-0.80)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

Table 7.23 The association between green space and meeting the recommended walking guidelines, all respondents, (odd ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n = 4189)

	Odd Ratios (95% Confidence Intervals) for Meeting Recommended Walking Guidelines	
	When green space is categorised as less than 20%	
	Model 1 (Baseline)	Model 4 (+ Age, Gender and Income)
Green Space		
<25%	1.00	1.00
25-<50%	0.84 (0.66-1.08)	0.91 (0.71-1.16)
50-<75%	0.63 (0.45-0.87)**	0.67 (0.48-0.95)*
75%+	0.67 (0.52-0.87)**	0.75 (0.57-0.98)*
Gender		
Male		1.00
Female		0.69 (0.58-0.84)***
Age		
16-24		1.00
25-34		0.78 (0.56-1.09)
35-44		0.65 (0.47-0.89)**
45-54		0.47 (0.34-0.65)***
55-64		0.37 (0.26-0.52)***
65-74		0.35 (0.25-0.50)***
75+		0.10 (0.06-0.18)***
Income		
Top Tertile		1.00
2nd Tertile		0.80 (0.63-1.03)
Bottom Tertile		0.77 (0.59-0.97)*

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

7.4.5 Summary

In summary, the availability of neighbourhood green space was not associated with physical activity participation. No significant relationship was found between the quantity of neighbourhood green space and either meeting the recommended physical activity or walking guidelines; or participating in physical activity in green space. The lack of association between green space and physical activity is consistent with previous population level studies. As these studies, including this study, have all been conducted using objective measures of green space availability this may challenge the idea that the availability of neighbourhood green space is sufficient to encourage physical activity participation. Other green space characteristics, such as, quality, size or safety may also matter. It also noted that this study is the first to explore the relationship between green space and physical activity specifically in Scotland. The lack of association in my results may therefore reflect something about the social, cultural or behavioural patterns of physical activity in Scotland, the type of green space available or simply Scotland's ambient climate. This will be further discussed in Chapter 9.

7.5 Is the Socio-Economic Inequality in Physical Activity Narrower in Populations Living in the Greenest Areas?

This section of the results chapter presents analysis which explored whether socio-economic inequality in physical activity participation varied by level of neighbourhood green space. The association was initially explored by adding an interaction term to the model which explored whether any association between socio-economic position and physical activity varied by green space availability. The resulting coefficients were tested using the Wald test for interaction. The exact nature of any interactions was subsequently unpacked using a sequence of logistic regression models stratified by green space availability (See Chapter 5, Section 5.7.3). In brief, all respondents with missing income data were excluded from analysis and odds ratios and 95% confidence intervals were calculated. Similar to the previous section, the analysis will be presented for each physical activity outcome using income as the measurement of socio-economic position. Where any of the results may differ by socio-economic position or categorisation of green space they will be outlined in the section titled sensitivity analysis (Section 7.5.4).

7.5.1 Overall Physical Activity

Figure 7.10 shows how income related inequality in meeting the recommended physical activity guidelines varied by green space availability. The odds of those in the lowest income tertile meeting the recommended physical activity guidelines compared to those in the highest income tertile were 0.39 (95% CI 0.26-0.60) in the least green areas and 0.79 (95% CI 0.54-1.15) in the most green areas. There was a significant interaction effect such that the income related inequality in meeting the recommended physical activity guidelines narrowed in the greenest areas ($x2 = 17.86$, $P = 0.0066$). These results, however, did not demonstrate a dose response relationship; results for the 25-<50% and 50-<75% green neighbourhoods were very different. Due to the lack of dose-response, these results challenge the explanation that socio-economic inequality in physical activity is narrower in the greenest areas.

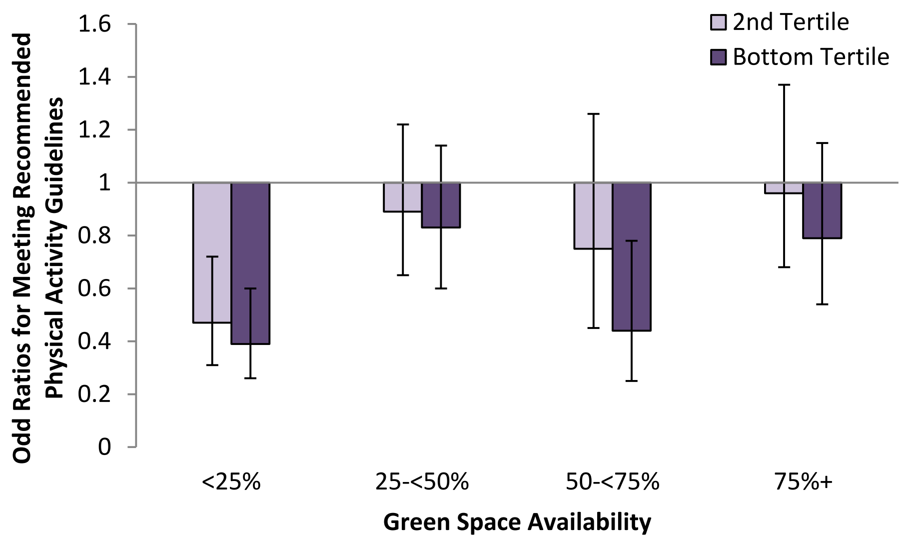


Figure 7.10 Income related inequality in meeting the recommended physical activity guidelines by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3591). The interaction reached significance (x2 = 17.86, P = 0.0066) [1] **adjusted for age, sex and income**

7.5.2 Walking

Figure 7.11 shows how income related inequality in meeting the recommended walking guidelines varied by neighbourhood green space. Again, the results showed that income related inequality in meeting the recommended walking guidelines narrowed in the greenest areas; the interaction effect was weakly significant (x2 = 12.41, P = 0.0535). The odds of those in the lowest income tertile meeting the recommended walking guidelines compared to those in the highest income tertile were 0.65 (95% CI 0.38-1.09) in the least green areas and 0.88 (95% CI 0.55-1.41) in the most green areas; neither showing a significant difference. Similar to overall physical activity, the results did not demonstrate a dose-response relationship, challenging the explanation that socio-economic inequality in walking narrows in the greenest areas.

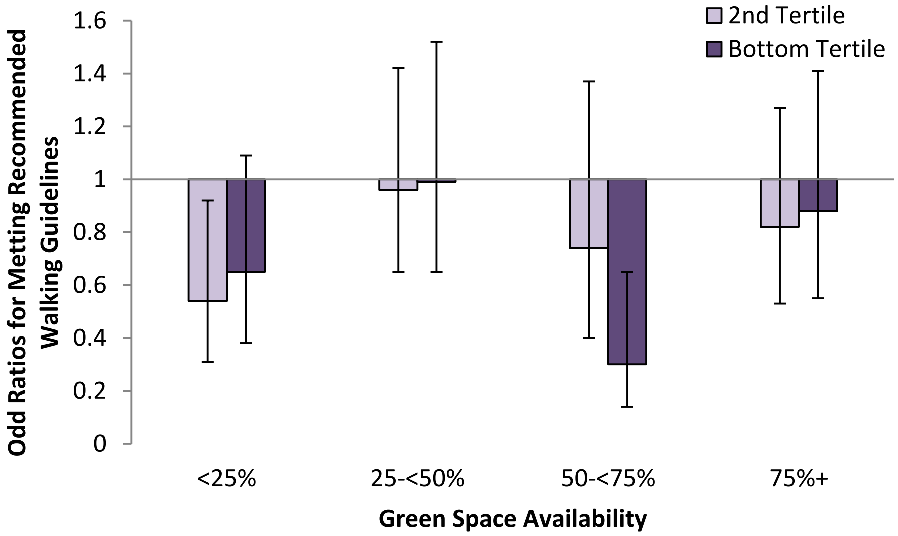


Figure 7.11 Income related inequality meeting the recommended walking guidelines by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3597). The interaction reached significance (x2 = 12.41, P = 0.0535). [1] adjusted for age, sex and income

7.5.3 Physical Activity in Green Space

No significant difference in the association between income and green physical activity by level of green space availability was found (x2 = 6.76, P = 0.3437). The odds of those in the lowest income tertile participating in green physical activity compared to those in the highest income tertile were 0.43 (95% CI 0.21-0.87) in the least green areas and 0.28 (95% CI 0.15-0.54) in the most green areas. No substantive difference in results was noted when green physical activity was defined as three times a week or more (data not shown).

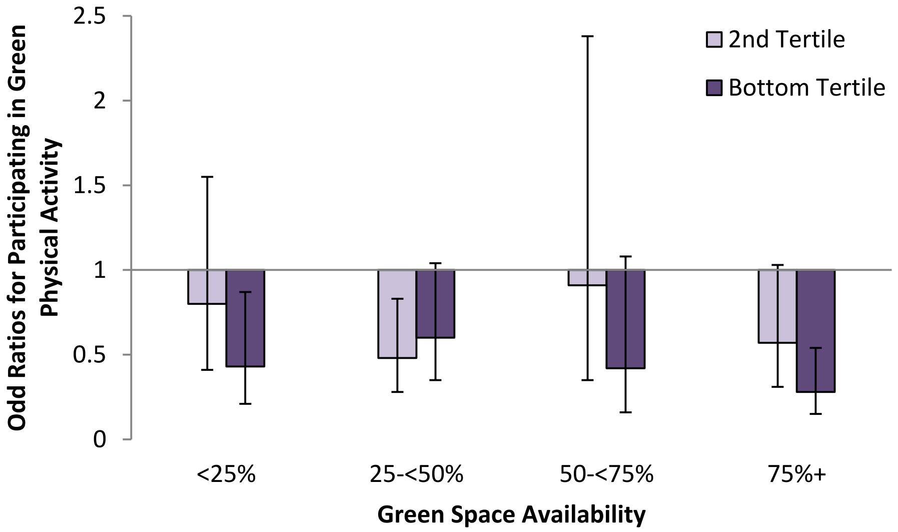


Figure 7.12 Income related inequality in participating in green physical activity by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1209). The interaction effect did not reach significance (x2 = 6.76, P = 0.3437) [1] adjusted for age, sex and income

7.5.4 Sensitivity Analysis

7.5.4.1 The Categorisation of Green Space

Similar to section 7.3, sensitivity analysis could not be performed on the categorisation of green space as stratifying the results by green space availability left too small a sample size when the baseline category was defined as less than 15%. This was due to the small number of respondents who lived in areas with very little green space.

7.5.4.2 The Measurement of Socio-Economic Position

When income was substituted with the alternative measures of socio-economic position there was a slight variation in results. Exploring the socio-economic difference in the association between green space availability and meeting the recommended physical activity and walking guidelines using income provided evidence to suggest that there was a significant interaction effect, in that, the socio-economic gap in physical activity narrowed in the greenest compared to the least green areas. The finding that the results were not dose-response questioned the causality of this relationship. When this association was explored using SEG and SIMD the interaction effect was much weaker and failed to reach any significance. See Figure 7.13 for an example of how area level deprivation in meeting the recommended walking guidelines varied by green space availability. These results provide greater evidence to support the conclusion that socio-economic inequality in physical activity did not narrow in greener areas.

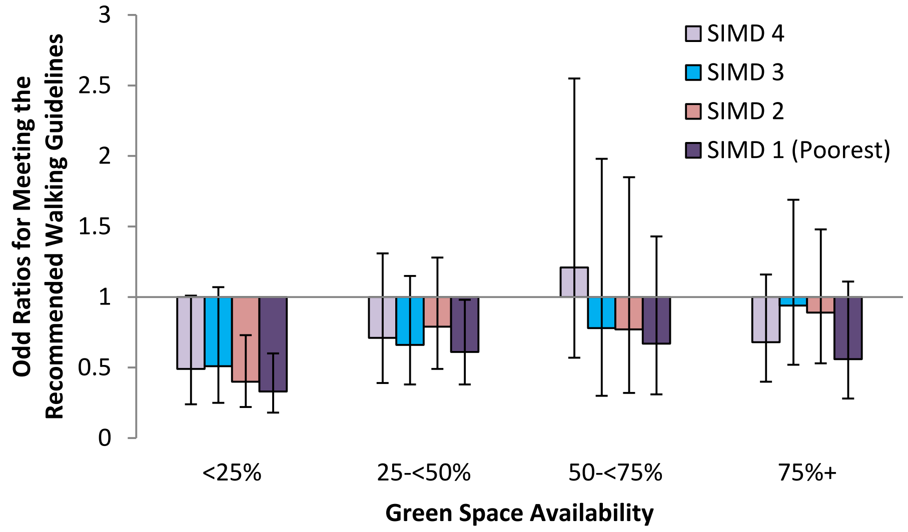


Figure 7.13 Area related inequality in meeting the recommended physical activity guidelines by green space availability. Odds ratios given relative to the reference group (Least Deprived SIMD Quintile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=3597). The interaction did not reach significance (x2 = 7.61, P = 0.8148) [1] **adjusted for age, sex and SIMD**

7.5.4.3 Missing Data

Results were similar when including, rather than excluding, respondents with missing income data (results not shown).

7.5.5 Summary

In summary, the results found no evidence that income-related inequalities in meeting the recommended physical activity and walking guidelines, or participation in green physical activity, were narrower in greener areas of urban Scotland. The absence of any evidence for narrower inequalities in greener neighbourhoods contradicted the hypothesis that the availability of green space equalises opportunities for physical activity and that this in turn produces narrower socio-economic inequalities in health. As this is the first study to explore this hypothesis, it remains unsure as to whether the lack of association is unique to Scotland or whether it adds further evidence to the finding that simply exploring the availability of neighbourhood green space may not be sufficient to understand the relationship between green space and physical activity. These questions will be addressed in Chapter 9.

7.6 Is Physical Activity in Green Space More Protective of Health for Groups of Lower Socio-Economic Position?

The final step in the analysis explored whether participating in physical activity within green space may be more protective of health for the lower socio-economic groups. The association was initially explored by adding an interaction term to the model which explored whether any association between health and participating in green physical activity varied by socio-economic position. The resulting coefficients were tested using the Wald test for interaction. The exact nature of any interaction was subsequently unpacked using a sequence of logistic regression models stratified by green space availability (See Chapter 5, Section 5.7.3). In brief, all models adjusted for age group, sex, socio-economic position, total physical activity, use of a sports environment for physical activity and use of a non-natural environment for physical activity. Adjustment for both total physical activity and specific environments was necessary because of their association with health and the fact that other environments might promote greater amounts of physical activity than others. Similar to previous sections, respondents with missing income data were excluded from analysis and odds ratios and 95% confidence intervals were calculated. The analysis will be presented for each main health outcome using income as the measurement of socio-economic position. Where any of the results may differ by the additional measurements of health or socio-economic position they will be outlined in the section titled sensitivity analysis (Section 7.6.6).

7.6.1 Self-Reported Health

No difference in the association between self-reported health and participating in green physical activity by income was found *(x2 = 0.18, P = 0.9145)*. The odds of those reporting poor self-reported health participating in green physical activity were 0.71 (95% CI 0.36-1.41) in the top income tertile and 0.50 (95% CI 0.26-0.97) in the bottom income tertile. There was no evidence of a dose-response relationship, in that, the odds of reporting poor self-reported health among those participating in green physical activity fell with increasing income deprivation. No difference in results was seen when green physical activity was defined as use of green space at least three times a week or more (results not shown).

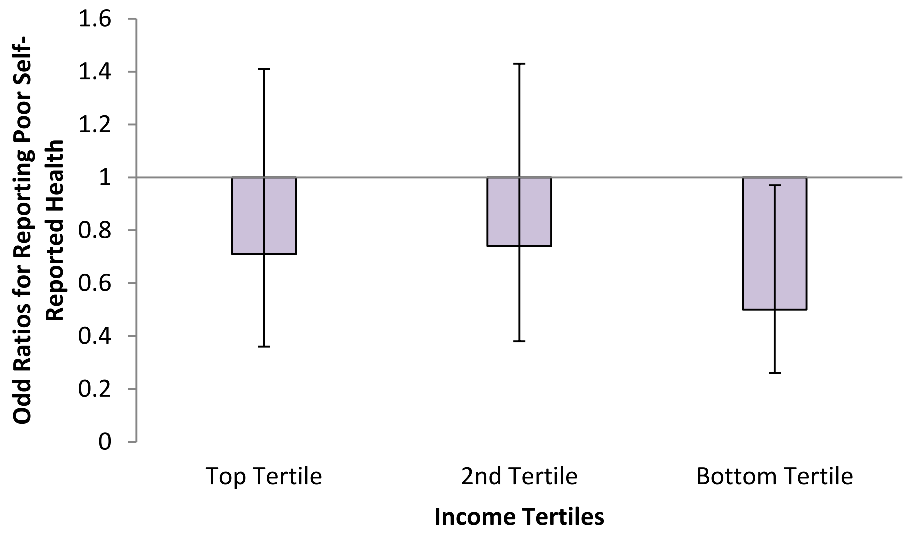


Figure 7.14 Variation in participating in physical activity in green space at least once a week or more for reporting poor self-reported health by income. Odds ratios given relative to the reference group (participating in green physical activity less than once a week or more, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1107). The interaction effect did not reach significance (x2 = 0.18, P = 0.9145) [1] adjusted for age, sex, income, total physical activity, contact with a sports environment and contact with a non-natural environment.

7.6.2 High Blood Pressure

Figure 7.15 presents the difference in participating in green physical activity in the association between high blood pressure and income. The results found that the association between participating in green physical activity and the odds of reporting high blood pressure did not differ by income tertiles *(x2 = 0.03, P = 0.9830)*. The odds ratios were fairly consistent across income tertiles. No difference in results was seen when green physical activity was defined as use of green space at least three times a week or more (results not shown).

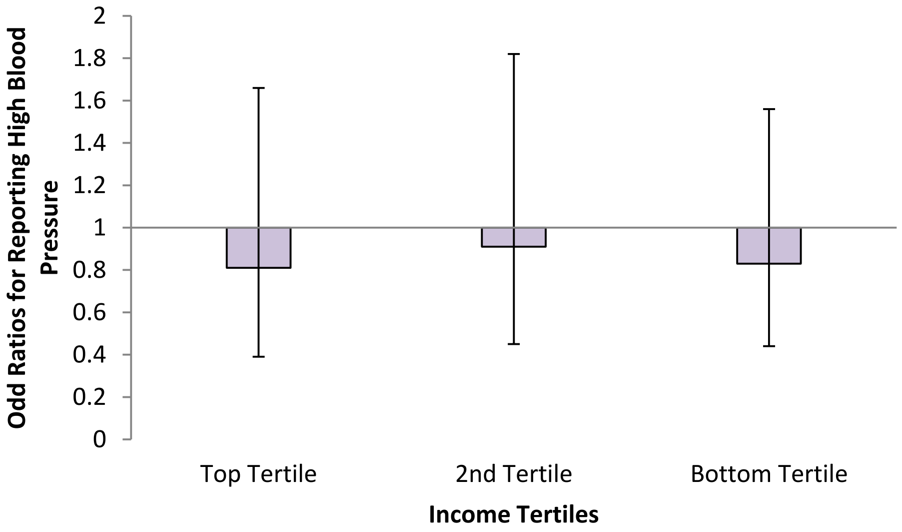


Figure 7.15 Variation in participating in physical activity in green space at least once a week or more for reporting high blood pressure by income. Odds ratios given relative to the reference group (participating in green physical activity less than once a week or more, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1100). The interaction effect did not reach significance (x2 = 0.03, P = 0.9830). **[1] adjusted for age, sex, income, total physical activity, contact with a sports environment and contact with a non-natural environment.**

7.6.3 Cardio-Vascular Disease

No difference in the association between self-reported health and participating in green physical activity by income was found (*(x2 = 0.18, P = 0.9145)* (Figure 5.16)). The odds ratios were inconsistent in direction and gave no indication of a dose-response relationship. No difference in results was seen when green physical activity was defined as use of green space at least three times a week or more (data not shown).

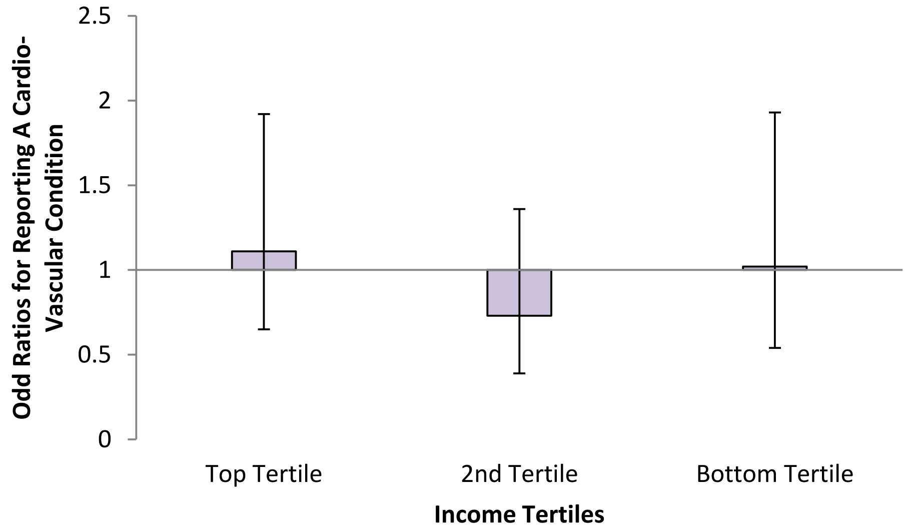


Figure 7.16 Variation in participating in physical activity in green space at least once a week or more for reporting a cardio-vascular condition by income. Odds ratios given relative to the reference group (participating in green physical activity less than once a week or more, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1105). The interaction effect did not reach significance (x2 = 1.58, P = 0.4533). [1] adjusted for age, sex, income, total physical activity, contact with a sports environment and contact with a non-natural environment.

7.6.4 BMI

Figure 7.17 presents the difference in participating in green physical activity in the association between overweight and income. The results found that the association between participating in green physical activity and the odds of being classed overweight (BMI>25) did not differ by income tertiles *(x2 = 1.71, P = 0.4244)*. No substantive difference in results was seen when green physical activity was defined as use of green space at least three times a week or more or among those respondents defined as obese (BMI>30) (results not shown).

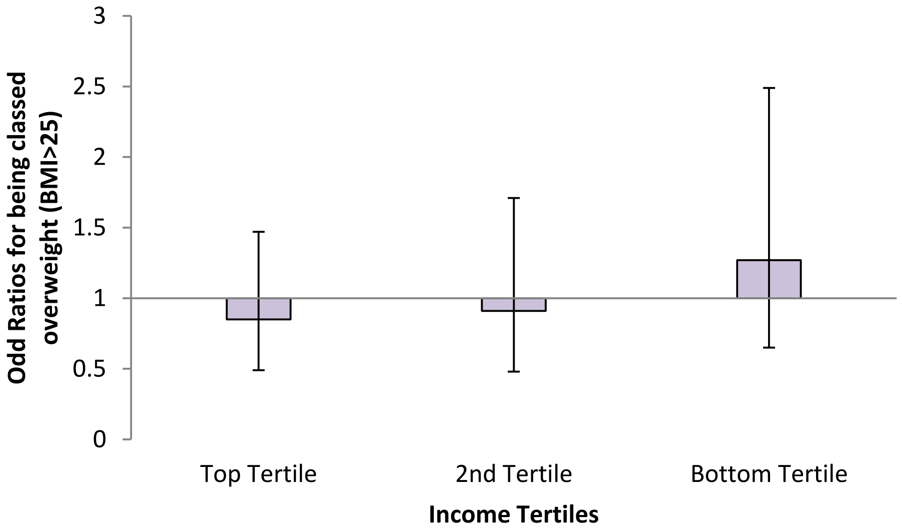


Figure 7.17 Variation in participating in physical activity in green space at least once a week or more for being classed overweight (BMI>25) by income. Odds ratios given relative to the reference group (participating in green physical activity less than once a week or more, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1105). The interaction effect did not reach significance (x2 = 1.58, P = 0.4533). **[1] adjusted for age, sex, income, total physical activity, contact with a sports environment and contact with a non-natural environment.**

7.6.5 GHQ

No difference in the association between self-reported mental health and participating in green physical activity by income was found (*(x2 = 0.18, P = 0.9145)* (Figure 7.18*))*. The odds of those reporting poor mental health participating in green physical activity were 1.11 (95% CI 0.65-1.92) in the top income tertile and 1.02 (95% CI 0.54-1.93) in the bottom income tertile. There was no evidence of a dose-response relationship. No difference in results was seen when green physical activity was defined as use of green space at least three times a week or more (results not shown).

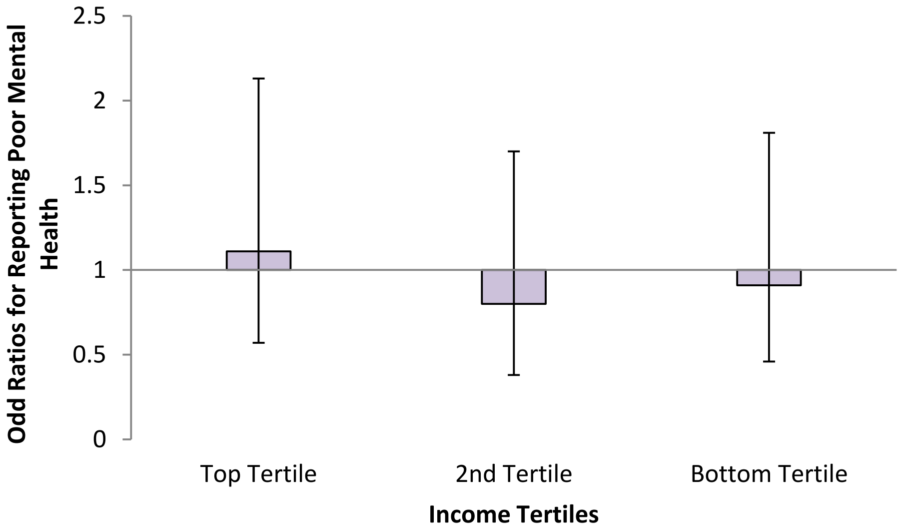


Figure 7.18 Variation in participating in physical activity in green space at least once a week or more for reporting poor mental health by income. Odds ratios given relative to the reference group (participating in green physical activity less than once a week or more, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1022). The interaction effect did not reach significance (x2 = 1.58, P = 0.4533). [1] **adjusted for age, sex, income, total physical activity, contact with a sports environment and contact with a non-natural environment.**

7.6.6 Sensitivity Analysis

7.6.6.1 Health Outcomes

No difference in the association between health and participating in green physical activity for income was found for the additional health outcomes. This suggests that participating in physical activity in green space has no added health benefit for less affluent populations.

7.6.6.2 The Measurement of Socio-Economic Position

When income was substituted with the alternative measures of socio-economic position, I found the substantive results remained unaltered. This suggests that the difference in participating in green physical activity was not sensitive to the measurement of socio-economic position.

7.6.6.3 Missing Data

No difference in results was found depending on whether we included or excluded respondents with missing income data.

7.6.7 Summary

In summary, the results found no evidence that physical activity in green space carries greater health benefits for more disadvantaged populations than for the more advantaged. This was consistent across health outcomes and measures of socio-economic position. This provides further evidence to suggest that the association between green space and socio-economic health inequalities may not be a function of physical activity specifically in green space.

7.7 Key Points

- No association was found between green space availability and health
- The association between socio-economic position and health did not differ by green space availability
- No association was found between green space availability and physical activity
- The association between socio-economic position and physical activity did not differ by green space availability
- The association between participating in green physical activity and health did not differ by socio-economic position.

Chapter 8 Green Space Omnibus Survey Results

This chapter presents the analysis of the Green Space Scotland Omnibus Survey (GSOS). Analysing the GSOS will build on Mitchell and Popham's hypothesis (Chapter 1, Section1.1.1) by exploring the role self-reported measurements of green space availability and quality may play in fostering use of green space in Scotland. This will allow me to further the understanding of whether physical activity in green space is a mechanism by which the availability and quality of green space may be associated with better health and narrower socio-economic health inequalities. Descriptive statistics were used to describe the population sample and explore the socio-economic gradient in both health and use of green space and logistic regression models were run to answer the following six research questions:

1) Is the availability and quality of neighbourhood green space associated with better health?
2) Is the socio-economic inequality in health narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
3) Is the availability and quality of neighbourhood green space associated with more frequent green space use?
4) Is the socio-economic inequality in green space use narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
5) Is the availability and quality of neighbourhood green space associated with use of green space for?
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?
6) Is the socio-economic inequality in use of green space narrower among those with available, good quality, green space compared to those with less available, poor quality green space for:
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?

8.1 Descriptive Statistics

8.1.1 Demographic and Socio-Economic Characteristics

The GSOS categorised respondents into six age groups, ranging from 18-24 years to 65+ years (Table 8.1). Of these respondents 792 (52.27%) were female. Two measurements of socio-economic position were provided, Social Economic Grade (SEG) and Scottish Index of Multiple Deprivation (SIMD). Of the 1440 (95%) respondents who gave a valid response to the question on their SEG, 274 (18.07%) were classified as upper or middle class and 576 (30.00%) as working class (Table 8.1). 76 (5.01%) provided no information on their SEG. In terms of SIMD, 299 (19.72%) were classified as least deprived and 252 (16.62%) as most deprived. 34 (2.24%) provided no information on their postcode in order to calculate their SIMD.

Table 8.1 Demographic and Socio-Economic characteristics (n(%)) including sex, age, SEG and SIMD (n=1516)

Demographic and Socio-Economic Characteristics	n	Percentage
Sex		
Male	724	47.73
Female	792	52.27
Age		
18-24	180	11.88
25-34	235	15.53
35-44	272	17.97
45-54	276	18.21
55-64	234	15.50
65+	317	20.92
SEG		
AB (Upper and Middle Class)	274	18.07
C1 (Lower Middle Class)	381	25.13
C2 (Skilled Working Class)	209	13.79
DE (Working Class)	576	30.00
Missing Data	76	5.01
SIMD		
5th (Least Deprived)	299	19.72
4th	360	23.75
3rd	287	18.93
2nd	284	18.73
1st (Most Deprived)	252	16.62
Missing Data	34	2.24

8.1.2 Representativeness of Study Sample

A comparison of the GSOS with the 2001 census data (Table 8.2a) and 2009 SIMD quintiles (Table 8.2b) were conducted to explore the representativeness of the study sample. In general, the results found that the GSOS was mostly representative of the Scottish population. The one exception to this was age, where the survey sample slightly over-represented those aged between 55-64 years.

Table 8.2 Comparison of survey respondents with (a) census 2001 data and (b) population SIMD quintiles

Survey Characteristics	Omnibus Survey 2009	Scottish Population
(a)		
Sex		
Male	48%	47%
Female	52%	53%
Age		
18-24	12%	12%
25-34	16%	18%
35-44	18%	20%
45-54	18%	17%
55-64	16%	13%
65+	21%	20%
SEG		
AB (Upper and Middle Class)	19%	19%
C1 (Lower Middle Class)	26%	26%
C2 (Skilled Working Class)	15%	15%
DE (Working Class)	40%	40%
(b)		
Quintiles		
1 (Least Deprived)	20%	21%
2	24%	21%
3	19%	20%
4	19%	20%
5 (Most Deprived)	17%	19%

8.1.3 Health

The self-reported general health of the survey respondents is shown in Figure 8.1. When asked "how would say your health is in general", 76% of respondents reported that they were either in "very good" or "good" health, 17% reported they were in fair health and 6% reported "very bad" or "bad" health.

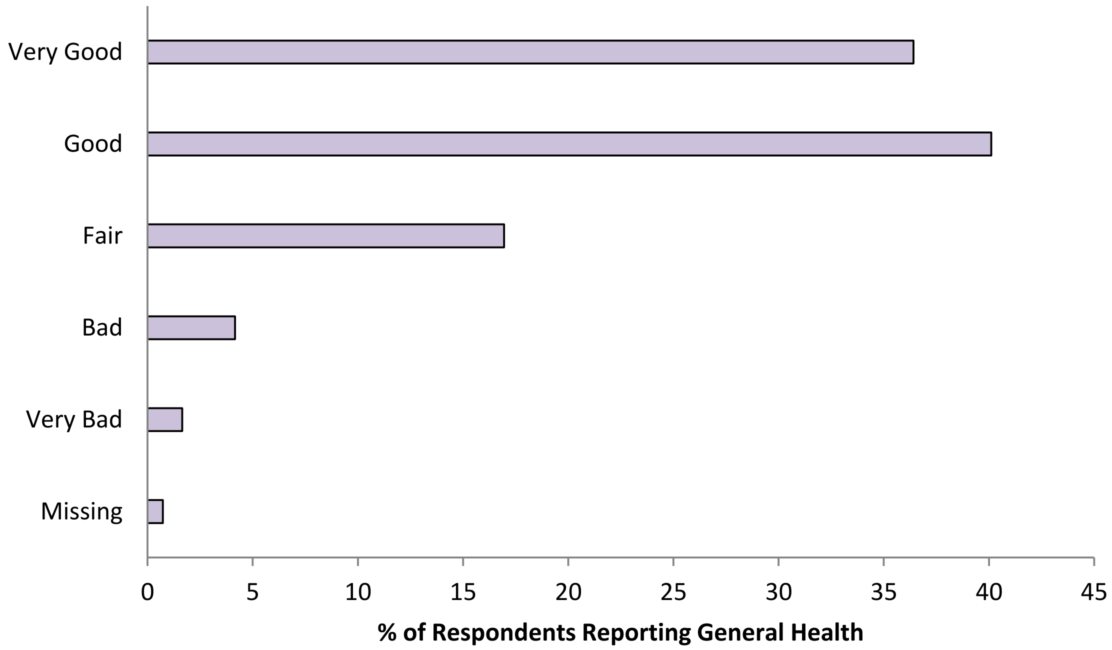


Figure 8.1 Percentage of respondents reporting their general health (n = 1516)

8.1.4 Relationship between Health and Socio-Economic Position

The association between health and SEG is shown in Table 8.4. As anticipated, the results demonstrate a clear socio-economic gradient in health, such that, health got steadily worse with increasing socio-economic deprivation. 45% of respondents classified as upper or middle class (AB) reported "very good" health compared to only 25% classified as working class (DE); a difference of 20 percentage points (Table 8.4). When socio-economic position was defined using SIMD no substantive differences in results were noted (results not shown).

Table 8.3 Associations between general health and SEG categories (n=1516)

	SEG (%)						
	AB	C1	C2	DE	Missing	Total	x^2 P Value
General Health							
Very Good	45.06	41.50	36.20	25.12	36.84	36.41	
Good	39.53	41.50	44.80	38.41	25.00	40.11	
Fair	11.86	12.75	13.98	25.36	26.32	16.95	
Bad	3.56	3.04	2.51	7.00	3.95	4.16	
Very Bad	0.00	0.81	2.15	3.62	0.00	1.65	
Missing	0.00	0.40	0.36	0.48	7.89	0.73	
Total	100.00	100.00	100.00	100.00	100.00	100.00	<0.001

8.1.5 How Often do you Use your Local Green Space?

When respondents were asked how often they use their local green space, 61% reported that they use it once a week or more often, falling to 16% who reported that they use it between 1 and 4 times per month (Figure 8.2). Only 7% of the total number of respondents reported that they never use their local green space.

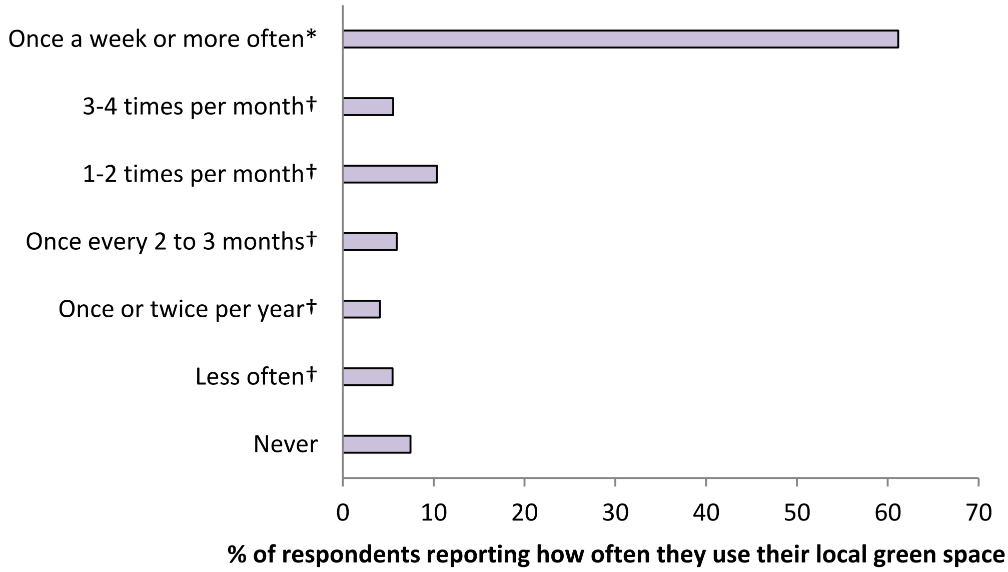


Figure 8.2 Percentage of respondents reporting how often they use their local green space (n=1516) *Category defined as use of green space at least once a week or more for subsequent analysis. †Categories combined into use green space less than once a week for subsequent analysis

8.1.6 Relationship between Use of Local Green Space and Socio-Economic Position

The results show a clear socio-economic gradient in frequency of local green space use, such that, use of green space decreased with increasing socio-economic deprivation (Table 8.4). 67% of respondents classified as upper or middle class (AB) reported that they used their green space at least once a week or more compared to 53% of respondents classified as working class (DE). This gradient became even more pronounced among respondents who report “never” using their local green space, where only 3% of those classified as upper or middle class (AB) reported to have never used their local green space compared to 15% of respondents classified as working class (DE). When socio-economic position was defined using SIMD, no substantive differences in results were seen (results not shown).

Table 8.4 Associations between how often you use your local green space and SEG categories (n=1516)

	SEG (%)						
	AB	C1	C2	DE	Missing	Total	x2 P Value
Frequency of Use							
Once a week or more often	67.19	64.17	62.72	52.90	60.53	61.15	
3-4 times per month	5.93	5.87	5.73	5.07	3.95	5.54	
1-2 times per month	12.25	9.72	11.11	10.14	6.58	10.36	
Once every 2 to 3 months	3.56	6.07	5.02	7.49	7.89	5.94	
Once or twice per year	3.95	3.44	6.09	3.86	2.63	4.09	
Less often	4.35	5.87	5.38	5.56	6.58	5.47	
Never	2.77	4.86	3.94	14.98	11.84	7.45	
Total	100.00	100.00	100.00	100.00	100.00	100.00	<0.001

8.1.7 What do you Use your Local Green Space For?

The most common use of local green space was to go for a walk, with 49% of respondents reporting that they use their local green space for this purpose. Other common uses were to take the children to play (22%), to take the dog for a walk (18%) and to relax and unwind (12%). The least common uses of green space were to pass through (3%) and to have contact with other people (0.3%). Of those reporting more than one use, the most common combination was to take the dog a walk and to go for a walk (5.80%), to relax and unwind and to go for a walk (5.15%) and to exercise and to go for a walk (4.09%). The percentage of respondents reporting their use of local green space is shown in Figure 8.3; results for combination uses are not shown.

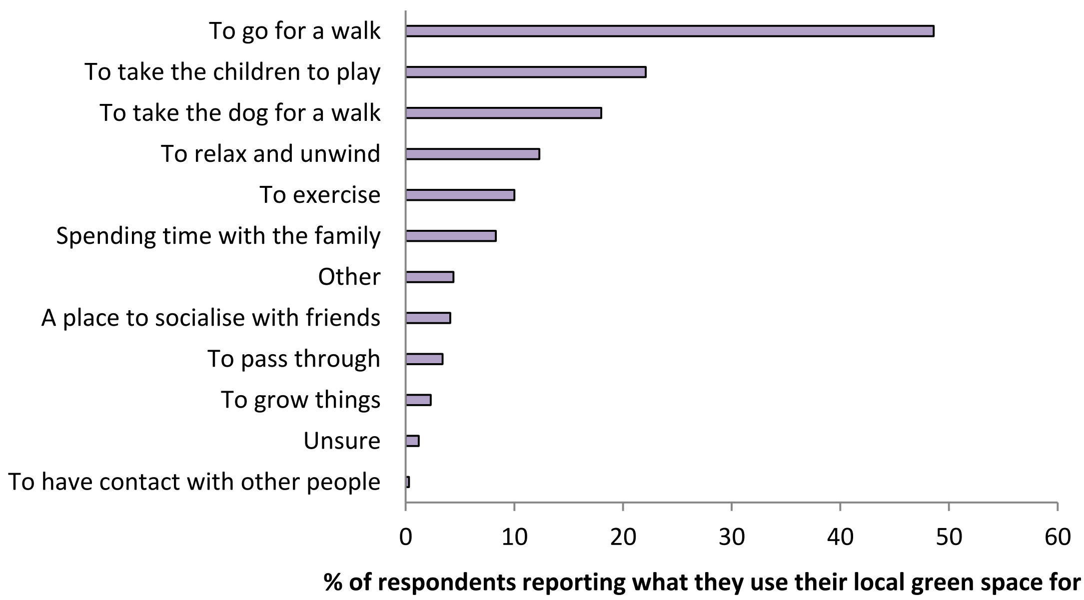


Figure 8.3 Percentage of respondents reporting what they use their local green space for (1516)

In order to conduct subsequent analysis on the mechanisms by which green space may exert a beneficial effect on health, use of green space was collapsed into three binary variables. These variables represented the three proposed methods by which green space was proposed to exert a beneficial effect on health and were defined as use of green space for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact (See Table 8.5). The footnote of Table 6.5 details the definition for each variable. The results show that the most common use of green space was physical activity. Among those who frequently use their green space (once a week or more); 76% of respondents report that they use their green space at least once a week or more to participate in physical activity. Less common was to use your green space at least once a week or more to promote restoration from stress and mental fatigue (12%) and to facilitate social contact (12%).

Table 8.5 Number (%) of respondents who reported that they use their green space once a week or more for (a) physical activity (b) restoration from stress and mental fatigue and (c) social contact (n = 927)

Use of green space for:	n	Percentage
(a) Physical Activity[1]		
Use green space once a week or more	227	24.49
Use green space once a week or more for physical activity	700	75.51
(b) Restoration from Stress and Mental Fatigue[2]		
Use green space once a week or more	815	87.92
Use green space once a week or more for restoration	112	12.08
(c) Social Contact[3]		
Use green space once a week or more	813	87.70
Use green space once a week or more for social contact	114	12.30

[1]defined as to go for a walk, to take the dog for a walk and to exercise
[2]defined as to relax and unwind
[3]defined as spending time with the family, a place to socialise with friends and to have contact with other people

8.1.8 Relationship between what you use your Local Green Space for and Socio-Economic Position

The association between SEG and use of green space for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact is shown in Table 8.6. The results show no socio-economic difference in the purpose of green space use. Among those who use their green space once a week or more, for example, 71% of respondents classified as upper or middle class (AB) compared to 77% of respondents classified as working class (DE) use their green space at least once a week or more to participate in physical activity. There was no substantive difference in results when socio-economic position was defined using SIMD (results not shown).

Table 8.6 Associations between use of green space once a week or more for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact and SEG categories (n=927)

	SEG (%)						
Use of green space for:	AB	C1	C2	DE	Missing	Total	X2 P Value
(a) Physical Activity							
Use green space once a week or more	29.41	21.77	25.71	22.83	28.26	24.49	
Use green space once a week or more for physical activity	70.59	78.23	74.29	77.17	71.74	75.51	
Total	100.00	100.00	100.00	100.00	100.00	100.00	0.364
(b) Restoration from Stress and Mental Fatigue							
Use green space once a week or more	87.65	89.59	88.57	85.84	84.78	87.92	
Use green space once a week or more for restoration	12.35	10.41	11.43	14.16	15.22	15.22	
Total	100.00	100.00	100.00	100.00	100.00	100.00	0.694
(c) Social Contact							
Use green space once a week or more	83.53	88.64	85.71	90.87	89.13	87.70	
Use green space once a week or more for social contact	16.47	11.36	14.29	9.13	10.87	12.30	
Total	100.00	100.00	100.00	100.00	100.00	100.00	0.217

8.1.9 Availability of Local Green Space

Respondents were asked to report “how far away is your local green space from your home” (Figure 8.4). The majority of respondents reported that their local green space is either less than a 5 minute walk from their home (46%) or within a 5-10 minute walk (30%). Only 6% of respondents reported that their green space is more than a 30 minute walk from their home.

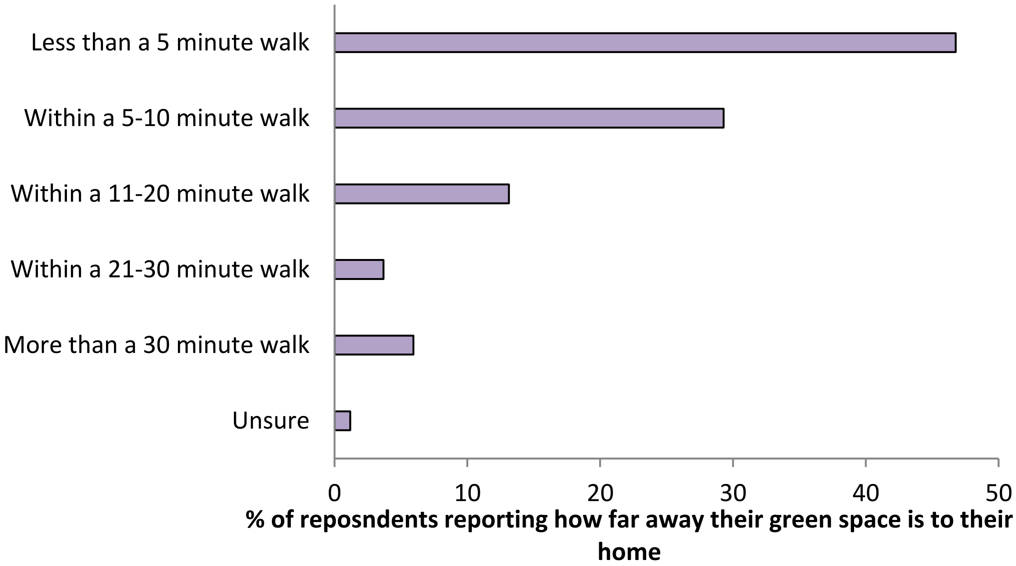


Figure 8.4 Percentage of respondents reporting how far away their green space is to their home (n=1516)

8.1.10 Relationship between Availability of Local Green Space and Socio-Economic Position

The association between perceived availability of local green space and SEG is shown in Table 8.7. A clear socio-economic gradient is shown for the percentage of respondents reporting how far away their green space is to their home. 51% of respondents classified as upper or middle class (AB) report that their green space is less than a 5 minute walk from their home compared to 43% of those classified as working class (DE) – a difference of 8 percentage points. No substantive differences in results were noted when socio-economic position was defined as SIMD.

Table 8.7 Associations between how far away your green space is to your home and socio-economic position (n=1516)

	SEG (%)						
	AB	C1	C2	DE	Missing	Total	x2 P Value
Availability of Local Green Space							
Less than a 5 minute walk	51.38	47.57	47.31	42.75	46.05	46.77	
Within a 5-10 minute walk	27.67	29.35	29.03	31.16	25.00	29.29	
Within a 11-20 minute walk	13.04	14.98	13.98	10.63	11.84	13.13	
Within a 21-30 minute walk	2.77	3.24	2.51	6.04	1.32	3.69	
More than a 30 minute walk	4.35	4.45	7.17	7.25	9.21	5.94	
Unsure	0.79	0.40	0.00	2.17	6.58	1.19	
Total	100.00	100.00	100.00	100.00	100.00	100.00	<0.001

8.1.11 Quality of Local Green Space

Respondents were asked to report “how satisfied are you with the quality of your local green space” (Figure 8.5). The majority of respondents reported that they were either very satisfied (36%) or quite satisfied (43%) with the quality of their local green space. Only 4% of respondents reported that they were very dissatisfied with the quality of their local green space.

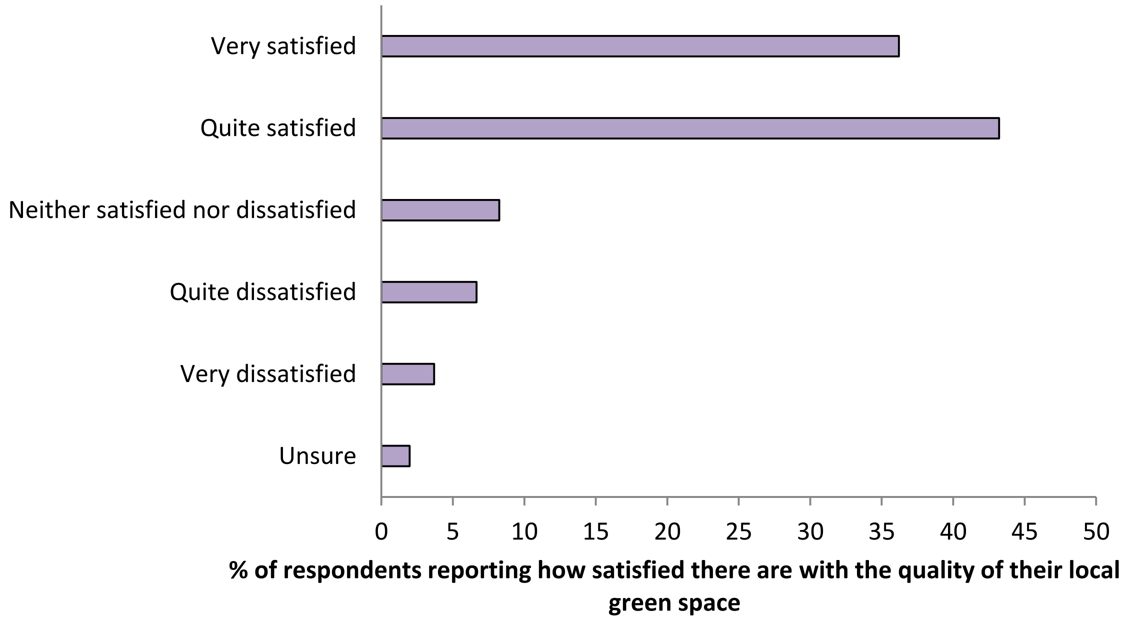


Figure 8.5 Percentage of respondents reporting how satisfied there are with the quality of their local green space (n=1516)

8.1.12 Relationship between Quality of Local Green Space and Socio-Economic Position

The association between how satisfied participants were with the quality of their local green space and SEG is shown in Table 8.8. The results suggest that the association between quality of local green space differed by SEG. 40% of respondents classified as upper or middle class reported that they were very satisfied with the quality of their local green space compared to 34% of those classified as working class. The results gave no indication of a dose response relationship, such that, perceived quality of green space decreased with increasing socio-economic deprivation. When the Chi-Square test was run excluding those with missing data, the test indicated that the association was non-significant (X^2 P Value = 0.550). When socio-economic position was defined as SIMD no substantive difference in results was found (results not shown).

Table 8.8 Associations between how satisfied you are with the quality of your local green space and socio-economic position (n=1516)

	SEG (%)						
	AB	C1	C2	DE	Missing	Total	x2 P Value
Quality of Local Green Space							
Very satisfied	39.92	25.02	39.78	33.82	31.58	36.21	
Quite satisfied	42.69	45.34	40.50	43.48	39.47	43.21	
Neither satisfied nor dissatisfied	8.70	7.89	6.81	10.14	3.95	8.25	
Quite dissatisfied	5.14	7.09	6.81	7.00	6.58	6.66	
Very dissatisfied	2.77	3.44	4.66	2.90	9.21	3.69	
Unsure	0.79	1.21	1.43	2.66	9.21	1.98	
Total	100.00	100.00	100.00	100.00	100.00	100.00	0.002

8.2 Perceived Availability of Green Space

This section describes the results of the analysis exploring the association between perceived availability of green space and each research question stated at the beginning of this results chapter. To explore the association between availability of green space and (a) frequency of use, (b) purpose of use and (c) health (research questions 1, 3 and 5), logistic regression models with sequential adjustment for demographic and socio-economic indicators were conducted. The baseline model (Model 1) adjusted for the measurement of green space availability whilst Model 2 controlled for the confounding effects of age group, sex and socio-economic position. To examine whether any of these associations differed by socio-economic position (research questions 2, 4 and 6), interaction terms were added to the model which explored whether any association between socio-economic position and (a) frequency of use, (b) purpose of use and (c) health varied by green space availability. The resulting coefficients were tested using the Wald test for interaction. The exact nature of any interactions was subsequently unpacked using a sequence of logistic regression models stratified by the availability of green space. The analytical procedure is described in detail in Chapter 6, Section 6.4. In brief, all respondents with missing data were excluded from analysis and odds ratios and 95% confidence intervals were calculated for each model. Perceived availability of green space was collapsed into a binary variable to distinguish those who perceived their green space to be less than a 10 minute walk, from those who did not. All models were presented using SEG as the measure of socio-economic position. Where any of the results may differ by the alternative measurement of socio-economic position or definitions of green space availability the findings will be outlined in the section titled sensitivity analysis (Section 8.2.7). Below the results for each research question will be presented.

8.2.1 Is the Availability of Green Space Associated with Frequency of Green Space Use?

The association between perceived availability of green space and use of green space at least once a week is shown in Table 8.9. In the unadjusted model, respondents living more than a 10 minute walk from the nearest green space were less likely to use their green space at least once a week or more (odds ratio 0.44, 95% CI 0.35-0.56) than those living less than a 10 minute walk away. After adjustment for age, sex and SEG the association remained consistent (odds ratio 0.45, 95% CI 0.35-0.58). An independent association between SEG and use of green space was also noted. Compared to those in the highest SEG (AB), respondents classified in the bottom (DE) were less likely to use their green space at least once a week or more.

Table 8.9 The association between availability of green space and use of green space at least once a week or more (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=1427)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
< 10 Minute Walk	1.00	1.00
> 10 Minute Walk	0.44 (0.35-0.56)***	0.45 (0.35-0.58)***
Gender		
Male		1.00
Female		0.91 (0.72-1.14)
Age		
18-24		1.00
25-34		2.51 (1.52-4.14)***
35-44		2.36 (1.51-3.70)***
45-54		1.89 (1.20-2.96)**
55-64		1.78 (1.13-2.79)*
65+		1.39 (0.90-2.16)
SEG		
AB		1.00
C1		0.89 (0.63-1.24)
C2		0.83 (0.57-1.20)
DE		0.61 (0.43-0.86)**

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.2.2 Is the Socio-Economic Inequality in Frequency of Green Space Use Narrower Among those with Available Green Space?

The socio-economic related inequality in the association between use of green space and green space availability is shown in Figure 8.6. The results suggest that the association between SEG and use of green space at least once a week or more did not differ significantly by availability of green space (x2 = 4.04, P = 0.2576). The odds of those in the lowest socio-economic grade (DE) compared to those in the highest SEG (AB) was 0.65 (95% CI 0.44-0.96) when green space was nearby and 0.49 (95% CI 0.24-0.99) when green space was not.

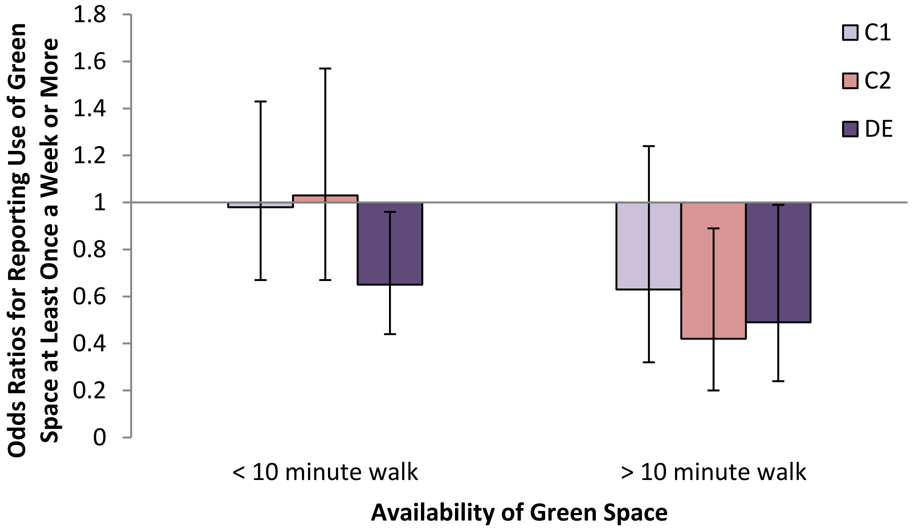


Figure 8.6 Socio-economic related inequality in reporting use of green space at least once a week or more by green space availability. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1427). There was no interaction effect (x2 = 4.04, P = 0.2576) [1] **adjusted for age, sex and seg**

8.2.3 Is Availability of Green Space Associated with Use of Green Space?

The association between availability of green space and use of green space at least once a week or more was explored for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact. These three variables were selected as they represent the three plausible mechanisms proposed to explain the way in which green space may exert a beneficial effect on health. For each logistic regression model conducted the sample was restricted to those respondents who reported frequent use of their local green space as this allowed the exploration of whether perceived availability was associated with type of use only among those who regularly use their green space.

8.2.3.1 Physical Activity

No significant association was observed between self-reported green space availability and use of green space at least once a week or more for physical activity (Table 8.10). No independent association between SEG and use of green space for physical activity was also noted. The odds ratios were inconsistent in direction and gave no indication of a dose-response relationship.

Table 8.10 The association between availability of green space and use of green space at least once a week or more for physical activity (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=879)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More for Physical Activity	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
< 10 Minute Walk	1.00	1.00
> 10 Minute Walk	0.88 (0.59-1.31)	0.85 (0.56-1.29)
Gender		
Male		1.00
Female		0.82 (0.59-1.14)
Age		
18-24		1.00
25-34		0.63 (0.32-1.24)
35-44		0.98 (0.51-1.89)
45-54		1.60 (0.80-3.20)
55-64		2.04 (1.01-4.12)*
65+		1.52 (0.77-3.00)
SEG		
AB		1.00
C1		1.63 (1.06-2.51)*
C2		1.29 (0.79-2.11)
DE		1.23 (0.76-1.98)

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.2.3.2 Restoration from Stress and Mental Fatigue

Similarly, no significant association was observed between self-reported green space availability and use of green space at least once a week or more for restoration from stress and mental fatigue (Table 8.11). Again, no independent association between SEG and use of green space for restoration was noted.

Table 8.11 The association between availability of green space and use of green space at least once a week or more for restoration from stress and mental fatigue (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=879)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More for Restoration from Stress and Mental Fatigue	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
< 10 Minute Walk	1.00	1.00
> 10 Minute Walk	1.33 (0.80-2.21)	1.26 (0.76-2.10)
Gender		
Male		1.00
Female		0.90 (0.59-1.38)
Age		
18-24		1.00
25-34		1.34 (0.40-4.45)
35-44		0.88 (0.27-2.85)
45-54		1.87 (0.61-5.77)
55-64		2.65 (0.89-7.93)
65+		3.73 (1.28-10.89)*
SEG		
AB		1.00
C1		0.90 (0.50-1.62)
C2		1.05 (0.54-2.03)
DE		0.89 (0.48-1.65)

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.2.3.3 Social Contact

The results found no significant association between green space availability and use of green space at least once a week or more for facilitating social contact (Table 8.12). An independent association, however, was noted between SEG and use of green space for social contact. Compared to those in the highest SEG (AB), respondents classified in the bottom (DE) were less likely to use their green space to facilitate social contact.

Table 8.12 The association between availability of green space and use of green space at least once a week or more for facilitating social contact (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=879)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More for Facilitating Social Contact	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
< 10 Minute Walk	1.00	1.00
> 10 Minute Walk	1.26 (0.76-2.09)	1.30 (0.77-2.17)
Gender		
Male		1.00
Female		1.01 (0.66-1.54)
Age		
18-24		1.00
25-34		0.83 (0.34-2.04)
35-44		0.82 (0.35-1.89)
45-54		1.17 (0.51-2.68)
55-64		0.71 (0.30-1.70)
65+		0.68 (0.28-1.63)
SEG		
AB		1.00
C1		0.64 (0.37-1.10)
C2		0.83 (0.46-1.50)
DE		0.51 (0.27-0.96)*

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.2.4 Is the Socio-Economic Inequality in Use of Green Space Narrower Among those with Available Green Space?

The analysis which explored whether socio-economic inequality in use of green space at least once a week or more for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact varied by availability of green space is presented below. For each model the sample was again restricted to those respondents who reported frequent use of their local green space.

8.2.4.1 Physical Activity

No significant difference in the association between socio-economic position and use of green space at least once a week or more for physical activity by green space availability was found ((x2 = 1.57, P = 0.6670) (Figure 8.7)). The odds of those in the lowest SEG (DE) was 1.3 (95% CI 0.76-2.20) when green space was reported less than a 10 minute walk away and 0.95 (95% CI 0.32-2.82) when green space was reported greater than 10 minute walk away.

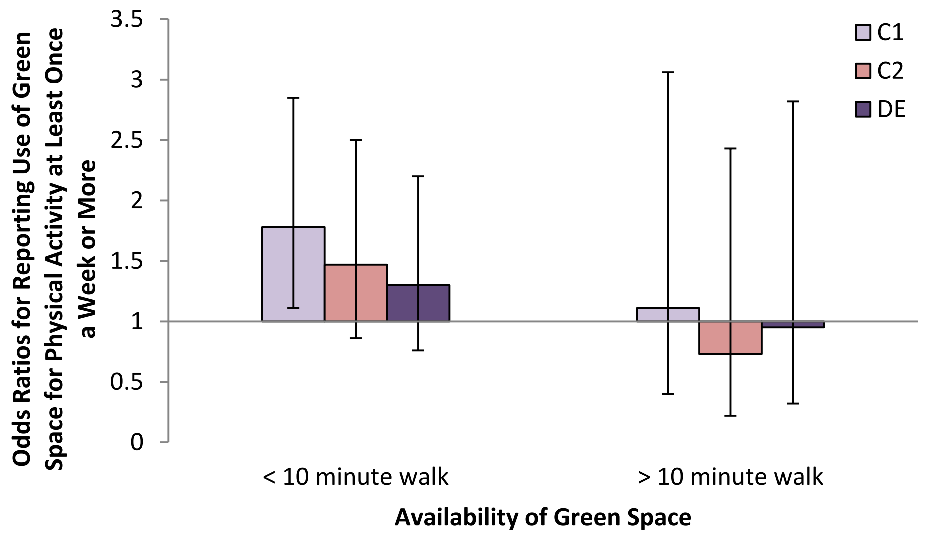


Figure 8.7 Socio-economic related inequality in reporting use of green space for physical activity at least once a week or more by green space availability. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=879). There was no interaction effect ($x2$ = 1.57, P = 0.6670) [1]
adjusted for age, sex and seg

8.2.4.2 Restoration from Stress and Mental Fatigue

Similarly, no significant difference in the association between socio-economic position and use of green space at least once a week of more for restoration from stress and mental fatigue by green space availability was found (($x2$ = 1.34, P = 0.7208) (Figure 8.8)). The odds of those in the lowest SEG (DE) was 0.87 (95% CI 0.44-1.74) when green space was reported less than a 10 minute walk away and 1.06 (95% CI 0.26-4.23) when green space was reported greater than 10 minute walk away. The wider confidence intervals, when green space is defined as greater than a 10 minute walk away, reflects the smaller sample size.

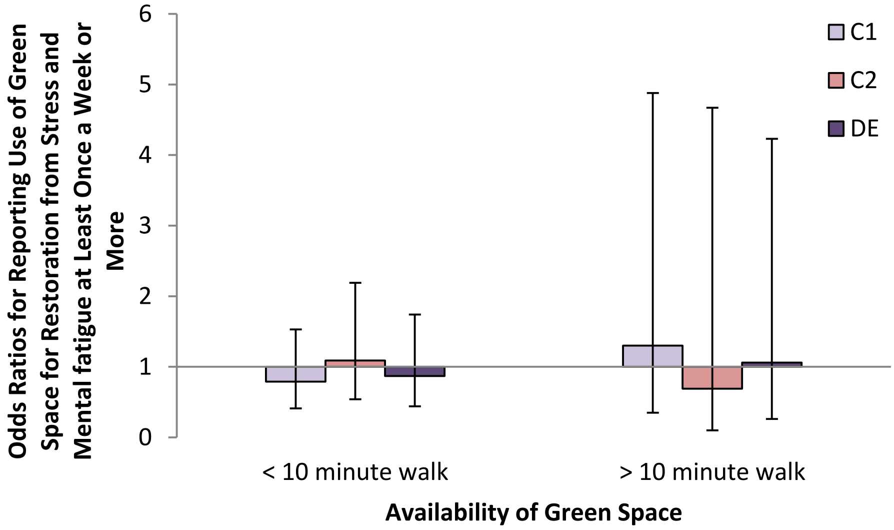


Figure 8.8 Socio-economic related inequality in reporting use of green space for restoration from stress and mental fatigue at least once a week or more by green space availability. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=879). There was no interaction effect (x2 = 1.34, P = 0.7208) [1] **adjusted for age, sex and seg**

8.2.4.3 Social Contact

Figure 8.9 shows no significant difference in the association between socio-economic position and use of green space at least once a week or more for facilitating social contact by green space availability (x2 = 1.79, P = 0.6162). The odds of those in the lowest SEG (DE) was 0.43 (95% CI 0.21-0.88) when green space was reported less than a 10 minute walk away and 0.88 (95% CI 0.23-3.27) when green space was reported greater than a 10 minute walk away. Again, the wider confidence intervals, when green space is defined as greater than a 10 minute walk away, reflects the smaller sample size.

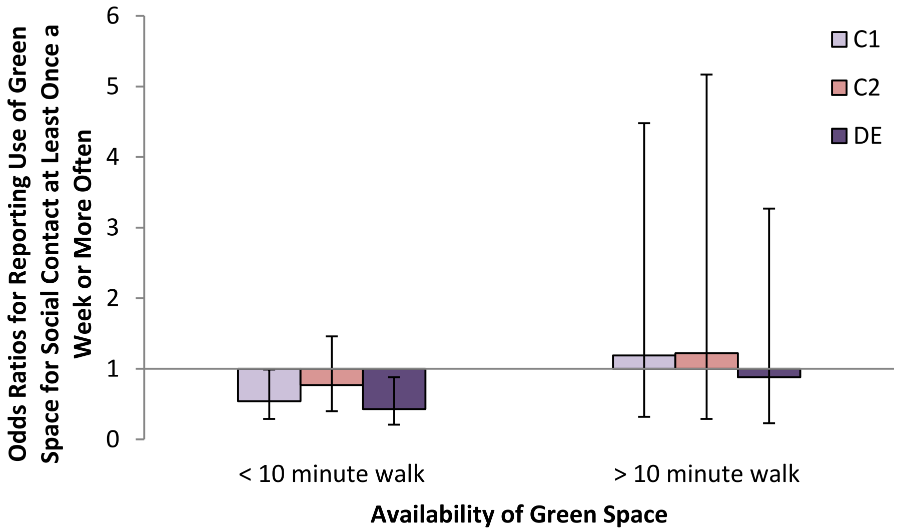


Figure 8.9 Socio-economic related inequality in reporting use of green space for social contact at least once a week or more by green space availability. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=879). There was no interaction effect (x2 = 1.79, P = 0.6162) [1]
adjusted for age, sex and seg

8.2.5 Is the Availability of Green Space associated with Health?

Results of the association between availability of green space and the odds of reporting poor self-reported health are presented in Table 8.13. In the unadjusted model, respondents reporting that their local green space was greater than a 10 minute walk away were more likely to report poor self-reported health than those reporting their green space was less than a 10 minute walk away (odds ratio1.36, 95% CI 1.03-1.80). After adjustment for age, sex and SEG the association was attenuated slightly and became non-significant (odds ratio1.25, 95% CI 0.93-1.68). An independent positive association between SEG and self-reported health was observed. Compared to those in the highest SEG (AB), respondents classified in the bottom SEG (DE) were significantly more likely to report poor self-reported health.

Table 8.13 The association between availability of green space and poor self-reported general health (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=1423)

	Odds Ratios (95% Confidence Intervals) for Reporting Poor Self-Reported General Health	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
< 10 Minute Walk	1.00	1.00
> 10 Minute Walk	1.36 (1.03-1.80)*	1.25 (0.93-1.68)
Gender		
Male		1.00
Female		1.14 (0.88-1.49)
Age		
18-24		1.00
25-34		1.05 (0.48-2.30)
35-44		1.54 (0.77-3.09)
45-54		2.27 (1.15-4.47)*
55-64		3.11 (1.60-6.03)**
65+		3.77 (1.97-7.24)***
SEG		
AB		1.00
C1		1.15 (0.76-1.75)
C2		1.30 (0.82-2.06)
DE		2.46 (1.64-3.70)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.2.6 Is the Socio-Economic Inequality in Health Narrower Among those with Available Green Space?

Figure 8.10 shows no significant difference in the association between socio-economic position and self-reported health by green space availability ($x2$ = 0.35, P = 0.9506). The odds of those in the lowest SEG (DE) were 2.50 (95% CI 1.57-3.98) when green space was reported less than a 10 minute walk away and 2.43 (95% CI 1.04-5.65) when it was reported greater than a 10 minute walk away. The wider confidence intervals, when green space is defined as greater than a 10 minute walk away, reflects the smaller sample size.

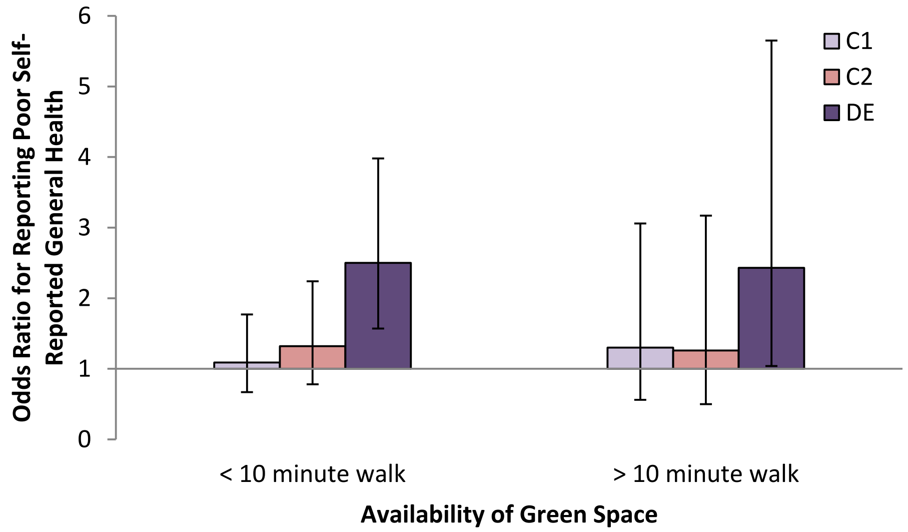


Figure 8.10 Socio-economic related inequality in reporting poor self-reported health by green space availability. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval *(n=1423). There was no interaction effect (x2 = 0.35, P = 0.9506)* [1 adjusted for age, sex and seg]

8.2.7 Sensitivity Analysis

8.2.7.1 Categorisation of Availability of Green Space

Sensitivity analysis was performed across all outcome variables to explore whether there was any variation in results by categorisation of green space availability. The first category defined availability of green space as “less than a 10 minute walk from the respondent’s home” and “greater than a 10 minute walk from the respondent’s home”, whilst, the second defined availability of green space as “less than a 5 minute walk from the respondent’s home” and “greater than a 5 minute walk from the respondent’s home”. For each outcome variable the results found no substantive differences depending on the categorisation of green space availability.

8.2.7.2 Measurement of Socio-Economic Position

Sensitivity analysis was also explored across all outcome variables to examine whether the results differed by the measurement of socio-economic position (Chapter 6, Section 6.2.7). When SEG was substituted for SIMD, I found that the substantive results remained unaltered. This suggests that the results presented throughout this section are not sensitive to the measurement of socio-economic position.

8.2.8 Summary

The results found a positive association between green space availability and use of green space at least once a week or more. This is consistent with previous research that suggests that the closer you live to your green space, the more often it is used[97, 195]. Schipperijn et al.[195] explored the association between frequency of use and distance for all types of green space. The results indicated a distance-decay relationship, where the larger the distance was associated with a lower frequency of use. The finding that this association did not differ by socio-economic position contradicted my hypothesis that more deprived populations may rely more heavily on accessible green space within their neighbourhood of residence due to reduced material resources or lack of mobility.

There was no evidence that availability of green space was associated with use of green space for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact. The finding that there was a lack of association between green space availability and use of green space for physical activity was consistent with my results from the SHS. Given the lack of association between green space availability and use, it was perhaps unsurprising to find that for each mechanism, the socio-economic inequality in frequency of green space use did not vary by green space availability. Previous research has provided evidence to suggest that these three mechanisms may interact. Participating in physical activity amongst green environments may provide greater or synergistic health benefits than participating in physical activity alone, for example. In this study the most common combination of green space use was to relax and unwind and to go for a walk. I did have the opportunity to explore whether this combination of green space use was associated with availability of green space. The sample size, however, was too small to conduct any sort of meaningful analysis.

The results found no significant association between perceived availability of green space and self-reported health. There was also no evidence that socio-economic inequalities in health were narrower when green space was reported as nearby. These findings are again consistent with those from the SHS (Chapter

7). Considering the number of previous studies that have reported a positive association between green space and health, the lack of association in this project was surprising and generates a number of questions as to why the relationship between green space and health in Scotland may differ to that of other countries. This will be discussed in Chapter 9.

8.3 Perceived Quality of Local Green Space

This section describes the results of the analysis exploring the association between perceived quality of green space and each research question stated at the beginning of this results chapter. As the analysis follows a similar format to that of Section 8.2, it is not necessary to reiterate each analytical procedure. A detailed description is provided in Chapter 6, Section 6.4. In brief, the association between quality of green space and (a) frequency of use, (b) purpose of use and (c) health (research questions 1, 3 and 5) was explored using sequential logistic regression models. To examine whether any of these associations differed by socio-economic position (research questions 2, 4 and 6), interaction terms were added to the model which explored whether any association between socio-economic position and (a) frequency of use, (b) purpose of use and (c) health varied by quality of green space. Self-reported quality of green space was collapsed into a binary variable to distinguish those who perceived the quality of their green space to be “very” or “quite” satisfactory, from those who did not. All models were presented using SEG as the measure of socio-economic position. Where any of the results may differ by the alternative measurement of socio-economic position or definitions of green space quality the findings will be outlined in the section titled sensitivity analysis (Section 8.3.7).

8.3.1 Is the Quality of Green Space Associated with Frequency of Green Space Use?

The association between perceived quality of green space and use of green space at least once a week is shown in Table 8.14. In the unadjusted model, respondents reporting that the quality of their green space was ‘very’ or ‘quite’ satisfactory were more likely to use their green space at least once a week or more (odds ratio 2.18, 95% CI 1.68-2.84) than those reporting any other response. After adjustment for age, sex and SEG the association remained consistent (odds ratio 2.34, 95% CI 1.78-3.08). An independent positive association between SEG and use of green space was also noted. Compared to those in the highest SEG (AB), respondents classified in the bottom (DE) were less likely to use their green space at least once a week or more.

Table 8.14 The association between quality of green space and use of green space at least once a week or more (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=1417)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
Any Other Response	1.00	1.00
Very or Quite Satisfied	2.18 (1.68-2.84)***	2.34 (1.78-3.08)***
Gender		
Male		1.00
Female		0.88 (0.70-1.11)
Age		
18-24		1.00
25-34		2.29 (1.38-3.79)**
35-44		2.14 (1.36-3.37)**
45-54		1.65 (1.04-2.61)*
55-64		1.47 (0.93-2.32)
65+		1.10 (0.71-1.72)
SEG		
AB		1.00
C1		0.89 (0.64-1.25)
C2		0.84 (0.58-1.22)
DE		0.64 (0.45-0.90)*

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.3.2 Is the Socio-Economic Inequality in Green Space Use Narrower Among those with Good Quality Green Space?

The socio-economic related inequality in the association between use of green space and green space quality is shown in Figure 8.11. The results suggest that the association between SEG and use of green space at least once a week or more did not differ by quality of green space ($x2 = 1.84$, $P = 0.6052$). The odds of those in the lowest socio-economic grade (DE) compared to those in the highest SEG (AB) was 0.65 (95% CI 0.30-1.42) when green space quality was satisfactory and 0.63 (95% CI 0.43-0.93) when it was not.

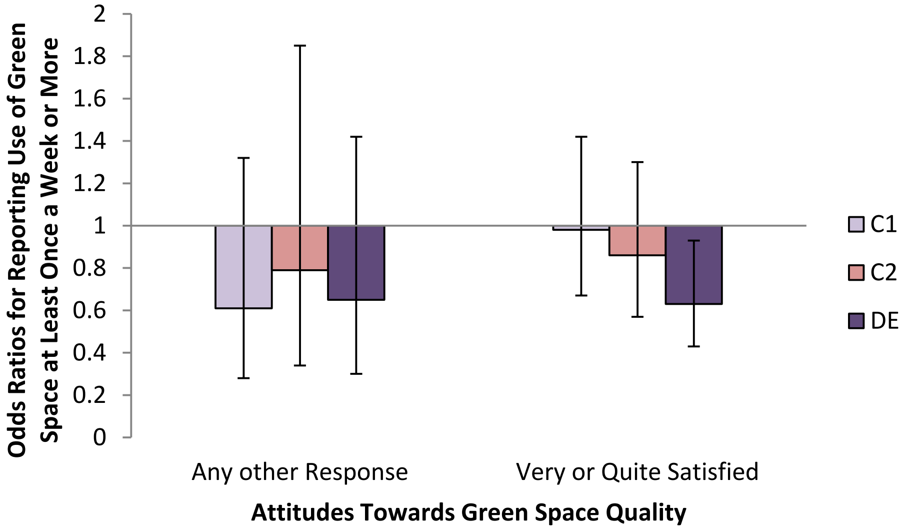


Figure 8.11 Socio-economic related inequality in reporting use of green space at least once a week or more by green space quality. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1417). There was no interaction effect (x2 = 1.84, P = 0.6052) [1] **adjusted for age, sex and seg**

8.3.3 Is the Quality of Green Space Associated with Use of Green Space?

The analysis which explored the association between quality of green space and use of green space at least once a week or more for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact is presented below. Similar to availability of green space, the analysis is restricted to those respondents who frequently use their green space.

8.3.3.1 Physical Activity

The association between quality of green space and use of green space at least once a week or more for physical activity is shown in Table 8.15. In both the un-adjusted and adjusted models the results show no significant association between green space quality and use of green space for physical activity. No independent association between SEG and use of green space for physical activity was also noted. The odds ratios gave no indication of a dose-response relationship.

Table 8.15 The association between quality of green space and use of green space at least once a week or more for physical activity (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=879)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More for Physical Activity	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
Any Other Response	1.00	1.00
Very or Quite Satisfied	1.08 (0.71-1.64)	1.05 (0.66-1.67)
Gender		
Male		1.00
Female		0.82 (0.59-1.13)
Age		
18-24		1.00
25-34		0.62 (0.32-1.23)
35-44		0.98 (0.51-1.87)
45-54		1.59 (0.80-3.17)
55-64		2.00 (0.99-4.04)
65+		1.50 (0.76-2.97)
SEG		
AB		1.00
C1		1.63 (1.06-2.51)*
C2		1.30 (0.80-2.12)
DE		1.24 (0.77-1.99)

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.3.3.2 Restoration from Stress and Mental Fatigue

Similarly, no significant association was observed between quality of green space and use of green space at least once a week or more for restoration from stress and mental fatigue (Table 8.16). Again, no independent association between SEG and use of green space for restoration was noted.

Table 8.16 The association between quality of green space and use of green space at least once a week or more for restoration from stress and mental fatigue (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=1417)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More for Restoration from Stress and Mental Fatigue	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
Any Other Response	1.00	1.00
Very or Quite Satisfied	1.19 (0.66-2.15)	0.95 (0.52-1.73)
Gender		
Male		1.00
Female		0.93 (0.61-1.43)
Age		
18-24		1.00
25-34		1.33 (0.40-4.44)
35-44		0.88 (0.27-2.86)
45-54		1.88 (0.61-5.80)
55-64		2.70 (0.90-8.14)
65+		3.89 (1.32-11.40)*
SEG		
AB		1.00
C1		0.90 (0.50-1.62)
C2		1.04 (0.54-2.02)
DE		0.92 (0.50-1.69)

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.3.3.3 Social Contact

The results found no significant association between quality of green space and use of green space at least once a week or more for facilitating social contact and no independent association between SEG and use of green space for social contact was observed (Table 8.17).

Table 8.17 The association between quality of green space and use of green space at least once a week or more for facilitating social contact (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=879)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More for Facilitating Social Contact	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
Any Other Response	1.00	1.00
Very or Quite Satisfied	1.64 (0.86-3.15)	1.74 (0.88-3.47)
Gender		
Male		1.00
Female		1.05 (0.68-1.60)
Age		
18-24		1.00
25-34		0.81 (0.33-1.99)
35-44		0.81 (0.35-1.87)
45-54		1.18 (0.52-2.70)
55-64		0.72 (0.30-1.71)
65+		0.70 (0.29-1.65)
SEG		
AB		1.00
C1		0.63 (0.37-1.09)
C2		0.83 (0.46-1.49)
DE		0.55 (0.29-1.02)

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.3.4 Is the Socio-Economic Inequality in Use of Green Space Narrower Among those with Good Quality Green Space?

The analysis which explored whether socio-economic inequality in use of green space at least once a week or more for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact varied by quality of green space is presented below. Again, the sample was restricted to those respondents who reported frequent use of their local green space.

8.3.4.1 Physical Activity

No significant difference in the association between socio-economic position and use of green space at least once a week or more for physical activity by quality of green space was found (($x2 = 3.64$, $P = 0.3031$) (Figure 8.12)). The odds of those in the lowest SEG (DE) was 1.16 (95% CI 0.36-3.75) when quality of green space was classified as 'any other response' and 1.23 (95% CI 0.72-2.09) when quality of green space was 'very' or 'quite' satisfactory. The wider confidence intervals, when green space was defined as 'any other response', reflects the smaller sample size.

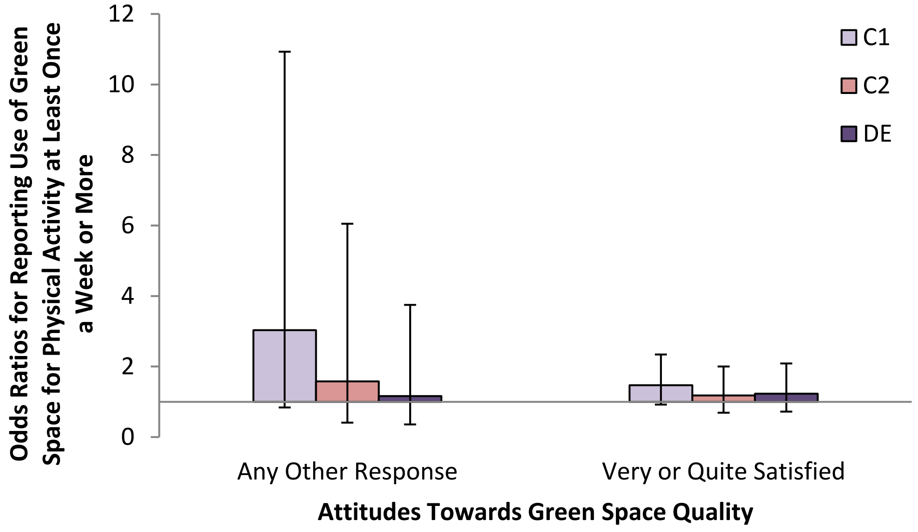


Figure 8.12 Socio-economic related inequality in reporting use of green space for physical activity at least once a week or more by green space quality. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=879). There was no interaction effect (x2 = 3.64, P = 0.3031) [1] adjusted for age, sex and seg

8.3.4.2 Restoration from Stress and Mental Fatigue

Similarly, no significant difference in the association between socio-economic position and use of green space at least once a week or more for restoration from stress and mental fatigue by quality of green space was found ((x2 = 0.72, P = 0.8687) (Figure 8.13)). The odds of those in the lowest SEG (DE) was 1.76 (95% CI 0.30-10.2) when quality of green space was classified as 'any other response' and 0.86 (95% CI 0.45-1.65) when quality of green space was 'very' or 'quite' satisfactory. Again, the wider confidence intervals, when green space was defined as 'any other response', reflects the smaller sample size.

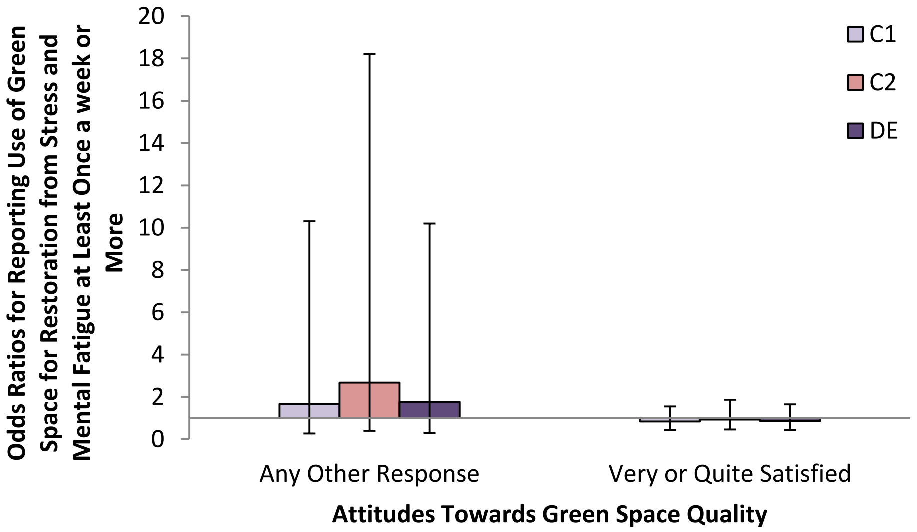


Figure 8.13 Socio-economic related inequality in reporting use of green space for restoration from stress and mental fatigue at least once a week or more by green space quality. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval) (n=879). There was no interaction effect (x2 = 0.72, P = 0.8687) [1 adjusted for age, sex and seg]

8.3.4.3 Social Contact

The socio-economic inequality in use of green space at least once a week or more for facilitating social contact by green space quality is shown in Figure 8.14. When quality of green space was collapsed into a binary variable and defined as 'very' or 'quite' satisfactory, the analysis ran into small numbers which resulted in me being unable to explore any interaction effects. For the purpose of this thesis, the number of respondents reporting 'any other response' was boosted by including those that reported that they were 'quite' satisfied with their green space quality. In this section green space quality was defined as 'very' satisfied with quality of green space.

The results suggest no significant difference in the association between socio-economic position and use of green space at least once a week of more for facilitating social contact by quality of green space (x2 = 3.80, P = 0.284). The odds of those in the lowest SEG (DE) was 0.55 (95% CI 0.26-1.18) when quality of green space was classified as 'any other response' and 0.45 (95% CI 0.15-1.35) when quality of green space was 'very' satisfactory.

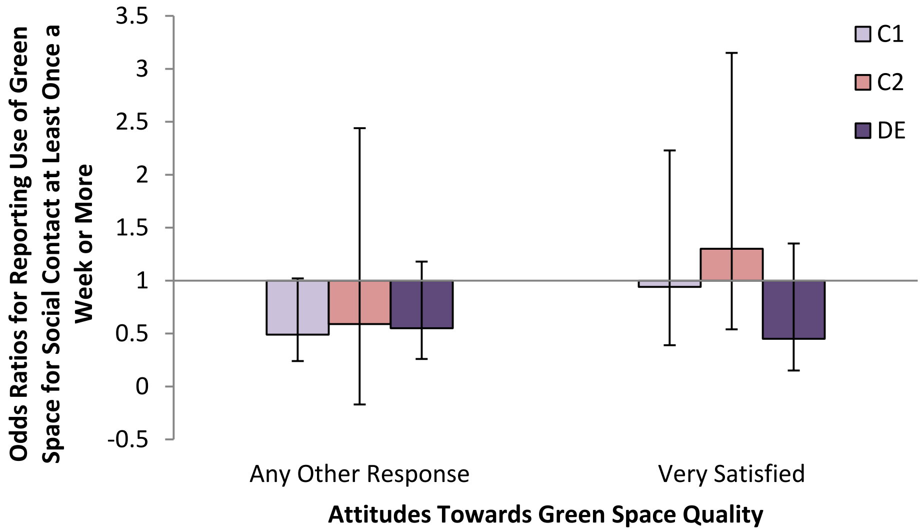


Figure 8.14 Socio-economic related inequality in reporting use of green space for social contact at least once a week or more by green space quality. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=879). There was no interaction effect (x2 = 3.80, P = 0.2844) [1] **adjusted for age, sex and seg**

8.3.5 Is the Quality of Green Space Associated with Health?

Results of the association between quality of local green space and the odds of reporting poor self-reported health are presented in Table 8.18. In the unadjusted model, respondents reporting that they are “very” or “quite” satisfied with their green space quality were significantly less likely to report poor self-reported health than those reporting ‘any other response’ (odds ratio 0.73, 95% CI 0.55-0.99). After adjustment for age, sex and SEG the results remained consistent (odds ratio 0.72, 95% CI 0.52-0.99). An independent positive association between SEG and self-reported health was observed. Compared to those in the highest SEG (AB), respondents classified in the bottom SEG (DE) were significantly more likely to report poor self-reported health.

Table 8.18 The association between quality of green space and poor self-reported general health (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=1412)

	Odds Ratios (95% Confidence Intervals) for Reporting Poor Self-Reported General Health	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
Any Other Response	1.00	1.00
Very or Quite Satisfied	0.73 (0.55-0.99)*	0.72 (0.52-0.99)*
Gender		
Male		1.00
Female		1.19 (0.91-1.55)
Age		
18-24		1.00
25-34		0.98 (0.44-2.14)
35-44		1.54 (0.77-3.07)
45-54		2.24 (1.14-4.40)*
55-64		3.08 (1.59-5.96)**
65+		3.88 (2.03-7.42)***
SEG		
AB		1.00
C1		1.20 (0.79-1.84)
C2		1.38 (0.87-2.19)
DE		2.43 (1.61-3.67)***

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.3.6 Is the Socio-Economic Inequality in Health Narrower Among those with Good Quality Green Space?

Figure 8.15 shows no significant difference in the association between socio-economic position and self-reported health by green space quality (x2 = 0.89, P = 0.8267). The odds of those in the lowest SEG (DE) were 3.38 (95% CI 1.36-8.39) when quality of green space was coded as ‘any other response’ and 2.19 (95% CI 1.38-3.48) when respondents were ‘very’ or ‘quite’ satisfied with their green space quality. The wider confidence intervals, when green space was defined as ‘any other response’, reflects the smaller sample size.

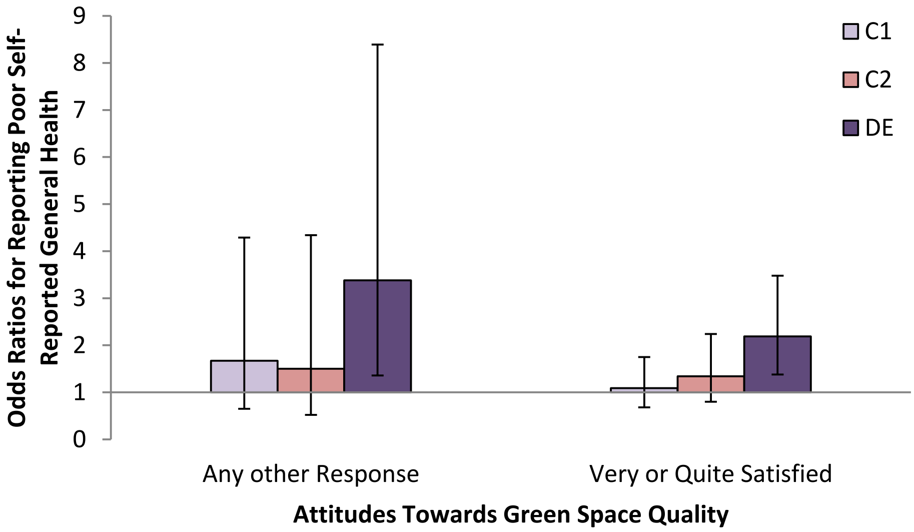


Figure 8.15 Socio-economic related inequality in reporting poor self-reported health by green space quality. Odds ratios given relative to the reference group (Socio-Economic Grade AB, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1412). There was no interaction effect (x2 = 0.89, P = 0.8267) [1 adjusted for age, sex and seg]

8.3.7 Sensitivity Analysis

8.3.7.1 Quality of Green Space Categorisation

Sensitivity analysis was performed across all outcome variables to explore whether there was any variation in results by categorisation of green space quality. The first category defined quality of green space as ‘very’ or ‘quite’ satisfactory and ‘any other response’, whilst, the second defined quality of green space as ‘very’ satisfactory and ‘any other response’. For the majority of outcome variables no substantive differences in results were found depending on the categorisation of green space quality. The one exception to this was the association between green space quality and use of green space at least once a week for restoration from stress and mental fatigue (Table 8.19). The results found that respondents reporting that their green space is ‘very’ satisfactory were significantly more likely to use their green space at least once a week or more for restoration from stress and mental fatigue than those reporting ‘any other response’ (odds ratio 1.76, 95% CI 1.17-2.65). These results suggest that perceiving green space to be ‘very’ satisfactory compared to ‘quite’ satisfactory is associated with an increase in use of green space for restoration from stress and mental fatigue.

Table 8.19 The association between quality of green space and use of green space at least once a week or more for restoration from stress and mental fatigue when quality of green space is defined "very" satisfactory (odds ratios and 95% confidence intervals), obtained from logistic regression models with sequential adjustment for demographic and socio-economic indicators (n=1417)

	Odds Ratios (95% Confidence Intervals) for Reporting Use of Green Space at Least Once a Week or More for Restoration from Stress and Mental Fatigue	
	Model 1 (Baseline)	Model 2 (+ Age, Gender and SEG)
Green Space		
Any Other Response	1.00	1.00
Very Satisfied	1.79 (1.21-2.63)**	1.76 (1.17-2.65)**
Gender		
Male		1.00
Female		0.85 (0.56-1.27)
Age		
18-24		1.00
25-34		1.86 (0.57-6.01)
35-44		1.19 (0.38-3.77)
45-54		2.24 (0.74-6.75)
55-64		3.09 (1.05-9.08)*
65+		3.62 (1.27-10.35)*
SEG		
AB		1.00
C1		0.88 (0.49-1.58)
C2		0.89 (0.47-1.69)
DE		0.76 (0.41-1.41)

* 0.01 _ p < 0.05; **0.001 _ p < 0.01; ***p < 0.001

8.3.7.2 Measurement of Socio-Economic Position

Sensitivity analysis was also explored across all outcome variables to examine whether the results differed by the measurement of socio-economic position (For more information on the measurement of socio-economic position see Chapter 6, Section 6.2.7). When SEG was substituted for SIMD, I found that the substantive results remained unaltered. This suggests that the results presented throughout this section are not sensitive to the measurement of socio-economic position.

8.3.8 Summary

Previous research exploring the association between quality of local green space and use is limited. Recent research commissioned by CABE Space is one of the few studies that have begun to fill this research gap. The study explored over 70 major data sources and assembled an inventory of more than 16,000 individual green spaces to explore the extent and condition of England's urban green spaces. Congruent with these project findings, the research suggests that the higher the quality of green space the more frequently it is used. Despite the positive association between quality and use, this study found no evidence that the association between socio-economic position and use of green space differed by green space quality; a similar pattern of results to when I explored the effects of green space availability. There are several explanations for why availability and quality of, green space did not account for the socio-economic gradient in frequency of use and these will be addressed throughout the discussion (Chapter 9).

The results found no significant association between quality of green space and use of green space for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact among respondents who regularly use their green space. This was surprising given the literature that suggests that it may not simply be the accessibility of neighbourhood green space that is important for use; aesthetic attributes of the environment also need to be taken into consideration. There was no evidence that the association between socio-economic position and use of green space for each mechanism differed by green space quality.

There was evidence of a positive association between green space quality and health. This was consistent with previous research that has found that residents living in neighbourhoods with higher quality green space were more likely to have better general and mental health than those living in areas with lower quality green space. Neither use of green space for (a) physical activity, (b) restoration from stress and mental fatigue or (c) social contact appeared to mediate the relationship, suggesting that these may not be mechanisms explaining the relationship between green space quality and health in Scotland. The results found no narrowing of the socio-economic gradient in health by green space quality. This provides further evidence to challenge whether neighbourhood green space is a mechanism that will narrow the socio-economic gradient in health in Scotland.

8.4 Key Points

- A positive association between availability, and quality, of green space was found for use of green space at least once a week or more.
- The association between socio-economic position and use of green space at least once a week or more did not appear to differ by either availability or quality of green space.
- No association between availability, and quality, of green space was shown for use of green space for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact.
- The association between socio-economic position and use of green space at least once a week or more for (a) physical activity, (b) restoration from stress and mental fatigue and (c) social contact did not appear to differ by either availability, or quality of, green space.
- No association was shown for availability of green space and self-reported health but a positive association was shown for quality of green space and self-reported health. Respondents reporting that they were satisfied with the quality of their green space were less likely to report poor self-reported health.
- The association between socio-economic position and self-reported health did not differ by either availability, or quality, of green space.

Chapter 9 Discussion

This chapter summarises and interprets the key findings of this thesis. In the first part of the chapter I will briefly review the aims and objectives of the research project, detailing the way in which the Scottish Health Survey (SHS) and the Green Space Scotland Omnibus Survey (GSOS) will be synthesised in order to pull together the results of both surveys. In the second part of the chapter, I will discuss how the results of this study compares with existing literature, highlight the strengths and limitations of this research project and propose some key implications for future research.

9.1 Research Project Summary

The overarching aim of this research project was to examine the role of physical activity as a mechanism by which green space may promote health and narrow socio-economic health inequalities. This stemmed from Mitchell and Popham's hypothesis that the equalised opportunities that physical activity in green space could offer may be a key mechanism behind the narrower socio-economic health inequalities in greener areas. To fully explore this aim, the study was conducted in two phases. Below a brief summary of each phase is provided. For a more detailed description see Chapter 4, Section 4.5.

9.1.1 Phase One

Phase One explored Mitchell and Popham's hypothesis that physical activity in green space is a mechanism by which the availability of green space may promote population health and narrow socio-economic health inequalities. This phase was conducted by combining objective data on the percentage of green space in a respondent's neighbourhood with information on the Scottish Health Survey (SHS) respondents. The following five research questions were addressed:

1) Is the availability of neighbourhood green space associated with better health?

2) Is the socio-economic inequality in health narrower in the greenest areas compared to the least green areas?
3) Is the availability of neighbourhood green space associated with physical activity in green space?
4) Is the socio-economic inequality in physical activity narrower in the greenest areas compared to the least green areas?
5) Is physical activity in green space more protective of health for groups of lower socio-economic position?

9.1.2 Phase Two

Phase Two used the Green Space Scotland Omnibus Survey (GSOS) to build on Mitchell and Popham's hypothesis by exploring the role self-reported measurements of green space availability and quality may play in fostering use of green space in Scotland. This allowed me to further the understanding of whether physical activity in green space is a mechanism by which the availability and quality of green space may be associated with better health and narrower socio-economic health inequalities. The following six research questions were addressed:

1) Is the availability and quality of neighbourhood green space associated with better health?
2) Is the socio-economic inequality in health narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
3) Is the availability and quality of neighbourhood green space associated with more frequent green space use?
4) Is the socio-economic inequality in green space use narrower among those with available, good quality, green space compared to those with less available, poor quality green space?
5) Is the availability and quality of neighbourhood green space associated with use of green space for:
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?

6) Is the socio-economic inequality in use of green space narrower among those with available, good quality, green space compared to those with less available, poor quality green space for:
    a. Physical activity?
    b. Restoration from Stress and Mental Fatigue?
    c. Social Contact?

9.2 Summary of Key Results

Tables 9.1 and 9.2 give an overview of the results from the analysis of the SHS and the GSOS data. Table 9.1 shows the association between green space and each main outcome variable, whilst Table 9.2 shows whether there was any interaction effect between green space and socio-economic deprivation for each of the main outcome variables. The results are indicated as supportive (✓) if they show a significant positive association between the measurement of green space and the outcome variable under investigation and are indicated as unsupportive (✗) if there were no significant associations. Given that there was some variation in the outcome variables between the two surveys, the cells that are not applicable to the particular measurement of green space are marked N/A in both Tables

Table 9.1 (a) The association between green space and each outcome variable and (b) the interaction effect between green space and socio-economic deprivation for each outcome variable measured by the SHS and Green Space Scotland Omnibus Survey

a	Green Space Measurement		
	Percentage[1]	Accessibility[2]	Quality[2]
Self-Reported Health	×	×	✓
Blood Pressure	×	N/A	N/A
Cardio-Vascular Disease	×	N/A	N/A
BMI	×	N/A	N/A
Mental Health	×	N/A	N/A
Frequency of Green Space Use	N/A	✓	✓
Meeting Physical Activity Guidelines	×	N/A	N/A
Meeting Walking Guidelines	×	N/A	N/A
Physical Activity in Green Space	×	×	×
Restoration from Stress and Mental Fatigue	N/A	×	×
Social Contact	N/A	×	×

b	Green Space Measurement		
	Percentage[1]	Accessibility[2]	Quality[2]
Self-Reported Health	×	×	×
Blood Pressure	×	N/A	N/A
Cardio-Vascular Disease	×	N/A	N/A
BMI	×	N/A	N/A
Mental Health	×	N/A	N/A
Frequency of Green Space Use	N/A	×	×
Meeting Physical Activity Guidelines	×	N/A	N/A
Meeting Walking Guidelines	×	N/A	N/A
Physical Activity in Green Space	×	×	×
Restoration from Stress and Mental Fatigue	N/A	×	×
Social Contact	N/A	×	×

Cells indicate whether the associations were supportive (✓) or unsupportive (×). N/A indicates that the analysis was not conducted for the designated outcome. [1] was an objective green space indicator used in the analysis of the SHS and [2] were self-reported variables measured by the Omnibus Survey.

9.2.1 Health

No association was found between green space availability and health, regardless of whether an objective or self-reported measurement of green space availability was used. Respondents who reported that they were satisfied with the quality of their green space were, however, were more likely to report better health. The results showed no narrowing in the socio-economic gap in health among respondents residing in areas with more green space compared to those residing in areas with less green space. This was consistent across all health outcomes and both objective and perceived measurements of green space characteristics.

9.2.2 Frequency of Green Space Use

Respondents who reported that they had available green space in their local area, compared to those who reported poorer green space availability, were more likely to use their green space at least once a week or more. A similar association was shown for green space quality. No significant differences in the association between socio-economic position and frequency of green space use were found for either availability, or quality of, green space.

9.2.3 Physical Activity

The amount of green space in a neighbourhood tended not to be associated with physical activity. No significant relationships were found between quantity of green space in a neighbourhood and either meeting recommended walking or physical activity guidelines, or participation in green physical activity. Similarly, there was no evidence that self-reported measurements of availability, or quality, of green space was associated with use of green space for physical activity. No significant differences in the association between socio-economic position and frequency of green space use were found for the percentage, availability, or quality of neighbourhood green space.

9.2.4 Restoration from Stress or Mental Fatigue

The results suggest that there was no association between availability of green space and use of green space once a week or more for restoration from stress and mental fatigue. A similar lack of association was shown for green space quality. The association between socio-economic position and use of green space for restoration was not found to differ by either availability, or quality, of green space.

9.2.5 Social Contact

There was no association between availability, or quality, of green space and use of green space for social contact. The results found no evidence that the association between socio-economic position and use of green space to facilitate social contact differed by either availability, or quality, of green space.

9.3 What Might Explain the Results of this Thesis?

This thesis was one of the first in Scotland to explore the association between green space and health and one of the first in the UK to explore associations between levels of green space in a neighbourhood and physical activity specifically in green space. The absence of any significant results challenged Mitchell and Popham's hypothesis that available green space provides equal opportunities for physical activity, and this in turn, provides narrower socio-economic health inequalities.

The lack of association between green space and health was contradictory with several recent studies (Chapter 4, Section 4.3). In the Netherlands, for example, the availability of neighbourhood green space was associated with better self-reported general[3] and mental health[6, 108]. Similarly, in England, a positive association was found between the percentage of green space in a respondent's neighbourhood and self-reported health[4], all-cause mortality and mortality from cardio-vascular disease[1]. Only a few studies have found consistent results to that of this thesis. In New Zealand, no association was found between the availability of neighbourhood green space and cardio-vascular disease mortality[114]. Likewise, in England, no association was found between the percentage of green space in a neighbourhood and BMI[111]. Considering the number of studies that reported a beneficial effect for green space on health, the lack of any positive association in this study was surprising.

This thesis presents several explanations for why the association between the availability of neighbourhood green space and health in Scotland may differ from that of other countries. These explanations have been grouped into two categories: substantive and methodological explanations. The following section will systematically go through each of these explanations, drawing upon evidence from this study's results and that of the existing literature.

9.4 Substantive Explanations

Six substantive explanations have been provided to explain why the association between green space and health may differ in Scotland from that of other countries. Below each of these explanations will be independently examined.

9.4.1 Differences in Green Space Quality

One possible explanation for the lack of association between green space and health in Scotland is that it may not simply be the quantity or accessibility of green space in the local neighbourhood which matters for health, quality may matter too. In the analysis of the GSOS, the results found that respondents reporting higher quality green space were more likely to report better self-reported health than respondents reporting lower quality green space but no association was shown between the availability of green space and health. The finding that quality of green space may be more important than availability of green space has also been shown in the literature. Francis et al.[117] found that respondents living in neighbourhoods with higher quality green space had higher odds of low psychological distress than respondents with low quality green space but found no association between the quantity of green space and mental health. Van Dillen et al.[6] found that both quality and quantity of green space was associated with self-reported health, acute health-related complaints and mental health but found that green space quality had added predictive value for health than quantity.

Based on these results, it could be hypothesised that the lack of association between green space availability and health in the analysis of the SHS (Chapter 7) was due to the inability to take into consideration green space quality. It is plausible that in Scotland respondents had ready access to neighbourhood green space but it was of insufficient quality to be used for physical activity. The results of the GSOS did provide preliminary evidence to suggest that this may not be the case as neither the availability or quality of green space was associated with use of green space for physical activity. Elsewhere, however, there is research to suggest that having access to attractive neighbourhood green space is more important for recreational walking than size, distance or accessibility of neighbourhood green space[150, 156]. Given that this thesis did find a positive association between green space quality and health, it could be reasonable to suggest that research exploring whether (or not) green space exerts a salutogenic effect in Scotland needs to take into consideration green space characteristics, over and above availability.

9.4.2 Differences in Socio-Economic Structure

Most of the research exploring the relationship between green space and health has been conducted in Northern European Countries. Of the 19 studies included in my literature review (Chapter 4, Section 4.3) nearly 50% were based in The Netherlands, Denmark or Sweden. It is well known that these countries differ in their health care, social welfare system and the relative distribution of income within society, compared to the UK[200]. Scandinavian countries are characterised by having a more equitable distribution of income, where the richest 20 per cent of the population are less than four times as rich as the poorest 20 per cent of the population[200]. In the UK income distribution is at least twice as big, where the richest 20 per cent have incomes about eight times greater than the poorest 20 per cent[200].

This difference in the relative distribution of income has been shown to affect many social, human and economic indicators of society[200]. There is evidence to suggest that having lower levels of socio-economic inequality can increase health, education performance and trust, whilst, decreasing violence, mental illness and teenage births, to name but a few[200]. Three plausible mechanisms have been suggested to explain the way in which this may affect population health[201, 202]. Firstly, income inequality may result in under-investment in public services, potentially limiting the life opportunities and well-being of the poor. Secondly, income inequality may decrease social capital and social cohesion, resulting in increased levels of mistrust within society. Lastly, income inequality may increase the direct psychosocial effects of social comparisons. That is the suggestion that income inequality increases negative feelings, such as worry, stress and frustration, as it places people in a hierarchy where they feel the need to compare themselves to others in society. The key understanding, from these three potential mechanisms, is that the effects of income inequality are likely to be a combination of stress, insecurity and poor social relations. The consequence of this is that the more divided a society is, the more strain is likely to be placed on the population within it. As Scotland has higher levels of income inequality compared to Northern European Countries, it could be plausible that the Scottish population experience higher levels of strain, and as a result, the health benefits that green space is thought to exert are less detectable. This difference may explain why the beneficial effects that green space is thought to exert on health may vary between Northern European Countries and that of Scotland.

The positive findings of a relationship between green space and health in England[1, 4, 203] challenges whether this offers a complete explanation for why the association between green space and health in Scotland may differ from other countries. Both England and Scotland share the same welfare state and have a similar relative distribution of income but there is evidence to suggest that greater availability of green space in England is associated with better health[4] and narrower socio-economic health inequalities[1]. An alternative explanation may be needed to explain why the relationship between green space and health is weaker in Scotland.

9.4.3 Differences in Lifestyle

The lack of association between green space and health in Scotland may be due to attitudinal or cultural differences in lifestyle. A good illustration of this difference in lifestyle is the variation in sedentary behaviour, such as television viewing and other screen based media, across countries. In Scotland, a greater amount of time is spent participating in sedentary behaviours compared to the wider UK and Europe[204]. According to the latest data the average person watches 4.5 hours of television a day in Scotland compared to an average of 4 hours across the UK and only 2.8 hours in Northern European countries such as Sweden[204]. This sedentary behaviour can also be seen in Scotland's markedly poorer levels of physical activity behaviour compared to other European countries. In Scotland 45% of men and 33% of women meet the governments recommended levels of physical activity[205], compared to 65% of men and 64% of females in Sweden[206]. Research has yet to explore the social or environmental factors that may explain this relationship, but it could be hypothesised that if the Scottish population engage in greater sedentary behaviours it may reduce their opportunities for green space use which in turn impacts the relationship between green space and health.

In this study I was able to explore this hypothesis by looking at the frequency in which respondents used their local green space. The results from the GSOS found that 61% of respondents reported that they used their local green space at least once a week or more (See Chapter 8, Section 8.1.5). If this percentage is compared to that of other countries, it can be seen that Scotland's green space use is lower than Northern European Countries, where 91.5% of residents report that they use their green space at least once a week or more[195], but is *higher* than England, where only 40.7% of residents report that they use their green space at least once a week or more[207]. I was unable to compare the types of green space use due to limited data availability. The results suggest, however, that despite the high rates of sedentary behaviour in Scotland, a majority of people are finding time to use their green space. The limitation with this current research is that although we know the frequency with which respondents use their local green space, we do not know the actual duration they spend in it. The lack of an association between green space and health in this study could be explained by the fact that respondents are using their green space but either not for long enough to gain the necessary health benefits, or in ways which are not producing a strong health impact.

9.4.4 Differences in Health

Scotland has been labelled the 'sick man of Europe' due to high levels of poor health compared to the wider UK and the European Union[208]. The UK Governments Actuary Department suggests that life expectancy in Scotland is lower than England, Northern Ireland and Wales. For the period 2008-2010, men died 2.3 years earlier in Scotland and females died 1.7 years earlier compared to the UK[209, 210]. When compared to Sweden, the country with the highest life expectancy in the European Union, Scots die 3.6 and 3.1 years earlier, respectively[210]. This higher rate of mortality in Scotland is primarily driven by their greater than average levels of risky behaviours, such as smoking, alcohol consumption and poor diet, which have resulted in higher death rates from cardiovascular disease, stroke and cancer compared to England and Wales and the rest of Western Europe[211, 212]. In Scotland 29% of men and 28% of women[165] currently smoke compared to 27% and 24% in England[213], respectively. As the health of Scotland is so poor, it raises the question as to whether the salutogenic effects of green space may simply not be sufficient to negate the health problems of the Scottish population. This explanation has been borne out of previous studies that found a significant association between green space and health, but noted that the overall effect size of the relationship was relatively weak. In England Mitchell and Popham found that greater exposure to green space was significantly associated with a decreased risk of mortality. The incidence rate ratio, however, was 0.95 in the greenest areas, compared to 1.00 in the least green areas, suggesting that having access to green space was only associated with a decreased mortality risk of 5%. If the effect size of green space is weak in countries with higher levels of good health, then it could be plausible that green space exerts a similar beneficial effect in Scotland but due to their poor levels of health that effect goes unnoticed, explaining the lack of association between green space and health in this study

This explanation may again be key in describing why this study found no evidence of a socio-economic difference in the association between green space and health, despite Mitchell and Popham's[1] findings that income based health inequalities in all-cause mortality and mortality from circulatory disease narrowed in populations living in the greenest areas in England compared to the least green areas. It is well known that substantial inequalities in health exist between socio-economic groups and geographical areas in Scotland, compared to England (See Chapter 2, Section 2.2). In 2004-2008 life expectancy of men living in the least deprived areas of Scotland was just over 11 years higher than those in the most deprived areas, but the corresponding difference for men living in England was only 7.87 years[214]. As these health inequalities are more pronounced in Scotland than they are in England, the salutogenic effects of green space may be insufficient to help reduce Scotland's socio-economic gradient in health.

9.4.5 Differences in Weather

It is well known that weather conditions vary substantially between countries. Scotland is known for its cool weather, higher precipitation levels, and unpredictable day to day weather conditions. The wettest areas of Scotland can experience an average of 250 days of rain per year[215]. These weather conditions are similar to Northern England but differ from central and southern England, where milder and drier conditions prevail, and Northern European countries, where milder summers and colder winters are much more likely to be experienced.

Research investigating the effects of these different weather conditions on use of green space has, as far as I am aware, received little attention. Among the physical activity literature studies have shown levels of physical activity to fluctuate across seasons. Merill et al.[216] found that the percentage of respondents meeting the physical activity guidelines was highest during the summer months and lowest during the winter months. Similarly, Togo et al.[217] found that physical activity participation decreased with increasing precipitation and increased with warmer temperatures. It could, therefore, be suggested that Scotland's poorer weather conditions may discourage the amount of time respondents spend in their local green space. During a rainy day respondents may be less likely to go for a long walk in their nearby woods or countryside and instead opt for a shorter walk to their local park. This may decrease the amount of time respondents use their local green space, which in turn, may reduce the health benefits associated with use of green space. Limitations in data describing the type of green space and length of time people spent in that green space prevented the exploration of this potential explanation.

9.4.6 Differences in Power

One factor that may explain the difference in results between this study and that of others is the size of the sample study population. This study was conducted on a sample of 4222 respondents from the SHS and 1516 from the GSOS. If the sample size was compared to other National Representative Studies it can be seen that this study sample was considerably smaller. Mitchell and Popham[1] undertook a highly powered population study on the effects of green space exposure on socio-economic health inequalities in England by obtaining a total sample of 40,813,236, with records for 366,348 deaths. Similarly, Maas et al[3] study of green space and health in the Netherlands was based on a total of 250,782 respondents. The main limitation associated with having a small sample size is that you may not have sufficient power to detect any statistically significant results. This may be particularly important when exploring the relationship between green space and health as green space is only one of many factors that may influence health. The World Health Organisation identified a number of determinants of health which fell under five broad categories: policy making, social factors, health services, individual behaviour, and biology and genetics. The lack of association in my results could be due to this study not being large enough to detect the effects of green space over and above the remaining health determinants resulting in a lack of meaningful evidence of whether green space is associated with health in Scotland. There is one explanation, however, that suggests that the lack of association between green space and health in Scotland may not be due to insufficient power.

If green space exerts a beneficial effect on health you would expect the results to demonstrate a dose response relationship even if the confidence intervals are not narrow enough to give a significant result. With each incremental increase in green space availability you would expect an incremental increase in health. In my results, however, the relationship between green space and health showed no evidence of a dose-response relationship for the majority of health outcomes. The one exception to this was the socio-economic inequality in the association between green space availability and mental health where the results showed that the socio-economic gap in reporting poor mental health narrowed successively as availability to green space increased (Chapter 7, Section 7.3.5). It could be that with a larger sample size this relationship would become statistically significant but the finding that greater green space availability was not associated with the odds of reporting poor mental health (Chapter 7, Section 7.2.5) suggests that this would be highly unlikely.

9.5 Methodological Explanations

One methodological explanation has been provided to explore why the association between green space and health may differ in Scotland from that of other countries. This explanation describes the plausibility that the measure of green space availability may not capture the availability of green space in Scotland as well as it does in other countries. The reasons why are described below.

9.5.1 Measurement of Green Space Availability

In this study I explored the relationship between green space and health using two different measurements of green space availability. The first was an objective measurement which estimated the percentage of land cover within each CAS ward in Scotland that can be classified as green space (Chapter 5, Section 5.1.1) and the second was a self-reported measurement that captured how far away (in minutes) respondents local green space was from their home (Chapter 6, Section 6.2.4). Such measurements have been used previously within the green space and health literature. Richardson and Mitchell[115], using the same objectively based green space measurement as this study, conducted the first UK wide study of the relationship between green space and health. Their results suggested that mortality from cardiovascular and respiratory disease decreased with increasing green space exposure among males but no associations were shown for females. Likewise, Maas et al.[3] derived objective data from the National Land Cover Database to explore whether the percentage of green space within a 1km and 3km radius of a respondent's home was associated with subjective health among a representative study of the Dutch population. Their results found that greater green space exposure was associated with better self-reported health. Fewer studies have used self-reported availability of green space as their measurement of green space exposure. From the available evidence a positive association has been found, suggesting that living within a shorter distance to green space was associated with better health, less stress and lower likelihood of obesity[109, 113].

Due to the evidence suggesting that objective and self-reported measurements of green space availability are both positively associated with health, it appears unlikely that either measurement could be responsible for the lack of association between green space and health found in this study. No previous research, however, has explored the effects of green space availability within Scotland separately. It may be plausible that measurements of green space availability do not perform as well in Scotland. Current green space measurements may not be sensitive to the kind of green space available in urban Scotland, for example. In order to investigate this aspect further I will detail the limitations associated with use of both measurements of green space availability, and explore whether there is the possibility that limitations are more pronounced in Scotland, which may result in the lack of association between green space and health in this study.

9.5.1.1 Equalised Access

The objective measurement of green space availability calculated the percentage of green space within a respondent's ward of residence. This approach can be problematic in accurately measuring accessibility as it makes the assumptions that respondents residing in neighbourhoods that have an equal percentage of green space actually have equal access to that green space. This is the classic 'ecological fallacy' problem, inherent in all analysis using ecological measures[218]. In this study a respondent may live directly next to an area of green space, but if that green space is located in a different ward of residence it would not be classified as available green space for that respondent. Alternatively, a respondent may live in close proximity to their local green space but it may not be easily accessible due to physical barriers such as a major road or motorway. Although this is an important limitation to recognise, it may not be a factor in limiting my results, as I found a similar lack of association between green space and health when using a self-reported measurement of green space accessibility. Self-reported measurements do have a number of disadvantages, such as incomplete recall or social bias; they do not however operate on any particular geographical units of aggregation. The absence of this limitation suggests that the disadvantages associated with using the objective measurements of green space accessibility may not have influenced my results. Both measurements, nonetheless, were limited in that they failed to capture people's perceptions of their ability or willingness to actually access green space. Respondents may live in close proximity to green space, but may not perceive themselves as welcome within it or that it is suitable for their use. This has been explored in recent research from Scotland, examining the reasons why people may *not* use their local green space[219]. The results suggested that green space may not be seen as accessible if it is perceived to host anti-social behaviour or have inadequate facilities. Participants listed obstacles such as graffiti, litter, vandalism, local gangs and low quality green space. Some perceived their local green space 'not for me'. If green space is perceived as less accessible in Scotland compared to other countries this may explain the lack of association between green space and health in this study.

9.5.1.2 Type of Green Space

Both measurements of green space exposure failed to capture details of the different *types* of green space available. This meant I could not distinguish between usable (e.g. parks or woodlands) or non-usable (e.g. agricultural or commercial woodland) green space and was forced to assume that the green space in each ward, or that captured in the GSOS, was appropriate for participating in health promoting behaviours. Moreover, being unable to distinguish between these different types of green space also meant that I could not explore whether specific types of green space are more applicable for fostering health promoting behaviours than others. It could be hypothesise that having a well maintained neighbourhood park that caters for several green space requirements, such as walking, cycling and children's play areas, may encourage greater physically activity behaviours. These limitations are important in light of the recent findings by Coombes et al.[124] who explored the relationship between green space and physical activity using 5 typological categories of green space (formal, informal, natural young people's and sport). The results found that respondents living closest to formal green spaces were more likely to meet the recommended physical activity guidelines and less likely to be classified as overweight and obese compared to those living further away. No significant associations were made for the remaining types of green space. Coombes et al.[124] suggested that formal green spaces may be particularly suitable for encouraging health promoting behaviours as they are generally defined as having an organised layout and structured path network. This may facilitate a range of activities such as walking, running, cycling or active transport. They are often well maintained and some may even be lit, which may reduce some of the barriers associated with use of green space including perceptions of safety, graffiti, litter and vandalism. At the time of writing, no national dataset describing the different classifications of green space was available in Scotland. It is plausible that the type of green space prominent in urban green space is not suitable for the facilitation of physical activity explaining the lack of association between green space and health in this study.

9.5.1.3 Green Space in the Neighbourhood

Both measurements of green space accessibility used in this project captured the availability of green space at a local area level. Individuals, however, may spend a large proportion of their day outside their area of residence perhaps resulting in a level of exposure to green space which is different to those captured. Availability of green space may increase if usable green space is located close to a respondent's place of work, along the route to and from work or spatially clustered with other types of useful facilities, such as a supermarket, a family member's house or restaurant/café. Respondents may also decide to travel outwith their area of residence to visit green space that may be selected for various characteristics including size, better facilities or attractiveness. Research exploring the association between green space characteristics and the locations where use of green space may take place is scarce. Studies, to date, have begun to explore the association among children. The results suggest that children are more likely to use the green space within their neighbourhood, with gardens accounting for the greatest amount of green space use[158]. As the importance of gardens for use of green space may reflect children's restricted freedom and heightened safety concerns among parents, it is unlikely that we can compare these results to the adult population. Understanding a respondent's day to day exposure to neighbourhood green space is a limitation apparent in the majority of research exploring the association between green space availability and health. Why might this then explain the lack of association between green space and health in Scotland? One potential explanation is that respondents in Scotland may be less likely to perceive their neighbourhood green space as accessible, compared to those in other countries (Section 9.5.1.1). As a result, they may be more likely to travel outwith their neighbourhood to visit more accessible green space that is considered suitable for use. As quantifying the green space that respondents may have been exposed to throughout their day to day activities was not possible with the data available in this thesis, I cannot discount the miss-measurement of the relationship between green space availability and (a) health and (b) physical activity. This explanation may play a part in explaining the lack of association between green space and health in this study.

9.6 Strengths and Limitations

This study had a number of strengths beyond those already discussed above. It was the first study to conduct a national level exploration of the association between green space and (a) health and (b) physical activity, in many different urban areas across Scotland using a large, representative sample of the Scottish population. It matched data from the SHS with an objective measurement of green space availability providing a number of robust health outcomes capturing a respondent's general, physical and mental health, thus, creating an in depth understanding of the association between green space and health in Scotland. Alongside this the SHS provided well tested measurements of physical activity, allowing the derivation of variables which related to clinical recommendations and information on the environments in which people are physically active. This resulted in this study being the in the UK and one of the first in the world to explore the associations between levels of green space in a neighbourhood and physical activity specifically *in green space*. Lastly, this study used a strong theoretical basis to understand the individual and environmental factors that influence use of green space, which in turn helped create the aims and hypothesises documented at the beginning of this study.

This thesis also had limitations. One of these limitations, the measurement of green space availability (Section 9.5.1), has been documented throughout this chapter forming part of the discussion as to why this thesis found no association between green space and (a) health and (b) physical activity. Several other limitations, however, have to be mentioned. These include the measurement of green space quality, measurement of physical activity, measurement of health and the use of a cross-sectional design. The following section will discuss each of these limitations and the potential they may have in explaining the lack of association between green space and health in this study.

9.6.1 Measurement of Green Space Quality

The GSOS captured green space quality using a self-reported measurement. The advantage of self-report measures is that they are easy to obtain and administer. This is important when trying to explore what particular attributes of green space quality may influence health, as understanding and assessing the quality of green space objectively can be complex. This complexity can be illustrated in Green Space Scotland's guide for assessing green space quality[220]. In this guide Green Space Scotland has identified five criteria for assessing quality: accessible and well-connected; attractive and appealing; bio diverse, supporting ecological networks; active, supporting health and well-being and community supported. Identifying and capturing each of these criteria objectively would create a demanding, costly and time consuming agenda, especially at the level of the population. One of the most difficult challenges comes when trying to explore who the potential users of green space are and how their green space requirements may differ. Objective measurements may be able to identify aspects of quality that are associated with health but if the potential users do not perceive that aspect to be available or it is the wrong requirement for their use then it can limit the understanding of how quality may influence population health. It is, therefore, understandable as to why objective data is scarce and explains why the use of self-reported measurements for understanding potential users and the aspects of green space that matter most for them should not be underestimated. Despite the advantages of self-reported measurements they have a number of associated limitations. These are mostly concerned with the fact that several types of reporting bias can take place.

In the case of my measurement of green space quality, two factors may have affected its reliability. Firstly, respondents have to actually visit their green space in order to accurately report how satisfied they are with the quality. Respondents who frequently use their green space may, therefore, be more likely to perceive the quality of their green space as better than it actually is, potentially influencing the relationship between green space quality and health. Secondly, perceptions of green space quality may differ by population sub-groups, such as age, gender or socio-economic position. Older people, for example, may want well maintained, accessible paths, water features and irrigated lawns; whereas, a family with young children may be more concerned with play areas, parking facilities and toilets. My measurement of green space, however, only captured the 'general' quality of green space. The limitation with this was that I could not determine what aspects of green space quality respondents were referring to, reducing my understanding of the particular green space characteristics that may influence use of green space.

9.6.2 Self-Reported Physical Activity

Self-reported measurements of physical activity are used, in part, because they are relatively easy to administer, low cost, accessible, practical and have low interference with physical activity behaviour itself. There are, however, a number of recognised disadvantages. Of these disadvantages the main concern, for this study, are reporting bias stemming from incomplete recall and social desirability.

9.6.2.1 Incomplete Recall

Self-reported measurements of physical activity rely on respondents being able to accurately recall historical physical activity behaviour. As these measurements often ask respondents to recall physical activity over a long period of time they can be seen as a complex cognitive task, which as a result, can create several inaccuracies in the measurement of physical activity. Sallis and colleagues[221] used physical activity diaries to compare the ability of respondents to recall a range of moderate and hard intensity physical activity. Their results suggested that the recall of hard intensity physical activity was reasonably accurate but that of moderate intensity was poor. Likewise, Blair et al.[222] found that the recall of vigorous activities was more accurate than light intensity activities such as walking. Findings from other studies also suggest that the reliability and validity of recalling other activities may differ by population sub-group. Cumming and Klineberg[223] demonstrated that recall accuracy was poorer in the elderly, males and those with cognitive impairments. Similarly, Lissner and colleagues[224] observed greater systematic errors among physical activity recall in the elderly, cautioning against the use of such questionnaires among older populations

In this study, the SHS asked respondents to recall how often they were physically active and the places they used to participate in physical activity over a four week period. From the research cited above it is plausible that the respondents may not have recalled their physical activity during the past four weeks accurately, resulting in the potential for unexplained variance in the measurement of physical activity. Of particular concern could be that older adults are more likely to omit certain physical activity behaviour due to poorer memory recall. The SHS adopted a cognitive based framework, in that; for each specific physical activity listed it asked the respondent to report how many days they participated in the activity and for how long. Research has shown that including these methods into interview protocols may minimise inaccuracies associated with the recall of physical activity and, thus, may improve my measurement of physical activity participation[225].

9.6.2.2 Social Desirability

Social desirability has been referred to as the tendency for individuals to provide responses that they believe to be consistent with social norms and expectations[226]. They are often expressed in three different ways: reporting incorrect information, omitting information or altering the magnitude of the reported information. As physical activity is a well promoted health enhancing behaviour, respondents may be more likely over-report it because they either consciously or sub-consciously feel that they ‘should be active’. Research has shown some support for this limitation but evidence is far from conclusive. Warnecke et al.[227] found that social desirability predicted self-reported physical activity among a racially diverse sample of adults. Likewise, Adams and colleagues[228] found that social desirability was associated with over-reporting of physical activity when using the seven day physical activity recall questionnaire among a sample of adult women. No association was found when using the 24 hour physical activity recall questionnaire. On the other hand, Motl et al.[229] found only weak evidence to suggest that social desirability influenced self-reported physical activity among a sample of young adults. The main concern with any social desirability bias in this study was that it may have occurred differentially according to socio-economic position. If one socio-economic group over estimated their physical activity behaviour compared to another, it could have affected my measurement of inequalities in physical activity. Research exploring the effects of social desirability on self-reported physical activity by socio-economic group is limited. It is plausible that more affluent populations have a greater desire to adhere to ‘recommended behaviours’, or are at least more aware that physical activity is something that they are ‘supposed to do’ and, as a result, may be more likely to over-estimate their physical activity behaviour. However, it is also plausible that actual lower levels of physical activity among less affluent populations could result in their over-estimation of physical activity. In this study I had no way of measuring respondents’ social desirability, so the extent to which this may have influenced my results remain unknown. There is no reason to believe that these inaccuracies would be systematically associated with the availability of neighbourhood green space and, thus, bias the association between green space and physical activity.

9.6.3 Measurement of Health

In this study matching green space data to information from the SHS made a number of individual health outcomes available for analysis. These included indicators of general and mental health and a range of physical health indicators hypothesised to be plausibly associated with green space (Chapter 5, Section 5.5.1). As these variables were derived from survey data a degree of error is unavoidable. Problems associated with self-reported health outcomes include inaccuracies due to lack of comprehension, poor memory recall, social desirability bias and the interview conditions. To minimise a number of these limitations the SHS adopted a face-to-face interview technique. This reduced the cognitive requirements of respondents by allowing the interviewer to probe fully for responses, clarify any ambiguous questions and check for inconsistencies or miss-interpretations. There is research to suggest that this mode of data collection may enhance bias due to social desirability, and as a result, respondents may exaggerate their positive health status. If this threat of social desirability occurred equally among all population groups then this limitation would not have greatly affected the results of this study. There is the potential, nevertheless, that the effects of social desirability bias may have occurred differentially according to social economic position. Similar to my measurement of physical activity, it is this differential effect of social desirability bias that continues to remain a concern. It is again plausible that more affluent populations value better health than less affluent populations, which could result in over-estimation of their health status. On the other hand, health is worse among less affluent populations, which may result in over-estimation of their health status. The main threat to the validity of my study here is that health reporting bias was independently associated with neighbourhood green space. In order to reduce this limitation, all my analysis was controlled for using three separate measures of socio-economic position: income, socio-economic grade and Scottish Index of Multiple Deprivation. These three measures were used to attempt to control for all aspects of socio-economic position. I cannot, however, rule out that an aspect of socio-economic position was not adequately controlled for resulting in the potential for residual confounding.

9.6.4 Cross-Sectional Analysis

Cross-sectional analysis suffers from a number of widely known methodological limitations. One of the most recognised limitations exploring the relationship between green space and health is that it is not possible to determine if any observed relationships are causal. There is the possibility that neighbourhood factors may be subject to selection effects related to health behaviour, which may explain part of the relationship between the availability of neighbourhood green space and health. The results of selection have been discussed in Chapter 4, Section 4.4.5. Selection effects are said to occur directly or indirectly. Direct selection occurs when healthier people choose to live in greener environments, whereas, indirect selection occurs when people with certain characteristics associated with health choose to live in a greener environment. Researchers believe that these individual health associated characteristics (such as age and socio-economic position) may account for neighbourhood differences in health. It is, therefore, important to take into account and control for the possibility of selection. In this study, I discounted the effects of selection as much as possible by controlling for various demographic and socio-economic characteristics. As a cross-sectional design simply creates a 'snap shot' observation of a respondent's neighbourhood, I was unable to take into consideration the length of time that respondents were exposed to neighbourhood green space. I had no information on whether a respondent had lived in a specific neighbourhood their whole life or whether they had recently moved into that specific neighbourhood. Similarly, I was unable to decipher respondents' day to day exposure to specific neighbourhood green space. Older people may spend more time in their neighbourhood compared to younger people who may leave their neighbourhood to go to work, thus, receiving differential exposure to green space.

The limitations associated with use of a cross-sectional design may partly explain the lack of association between green space and health found in this study. Previous studies have also used a similar methodology and study design but found a positive association between green space and health. What final factor may explain the lack of association between green space and health in Scotland? It is plausible that green space and health in Scotland is not as socially clustered as other countries reducing the effect of direct and indirect selection. It has been shown that in the city of Glasgow green space availability is more equally distributed between affluent and less affluent neighbourhoods. If the association between green space and health which has been observed elsewhere was driven by the results of selection, this lack of social clustering in Scotland may reduce these effects and explain the lack of association between green space and health observed here. If this hypothesis were correct, previous studies which have found that green space exerts a beneficial effect on health may simply be a result of selection.

9.7 The Applicability of Social Ecological Models for Studying the Association between Green Space and Socio-Economic Health Inequalities

The variables selected for this study and the structure of the analysis were guided by use of a social ecological model. The core assumption of social ecological models and the way in which they may be applied to study inequalities in health was outlined in Chapter 3. In brief, social ecological models provide researchers with a theoretical framework which allow us to explore the complex interplay of factors which explain individual behaviour as they go beyond the simple consideration that either individual characteristics (e.g. socio-economic position) or independent levels (e.g. environmental factors) explain health and health-related behaviour. A social ecological model was selected for use in this study as it provided an appropriate theoretical framework in which to explore whether physical activity in green space was a mechanism with which to reduce the socio-economic gradient in health.

The strength of social ecological models is that they provide an ordered structure to explore the array of individual and environmental factors which could be hypothesised to impact individuals' health and health related behaviour. Social ecological models work across a number of levels, such as a respondent's individual, cultural, social, physical and political environment, allowing you to think through each factor independently and hypothesise the effect this may have on respondents' behaviour. In this study, this allowed the conceptualisation of the way in which green space availability and quality may influence population health and health-related behaviour. Furthermore, a social ecological model also recognises the reciprocal interaction across all variables rather than exclusively focussing on a particular one. Use of green space for physical activity in this study was determined by individual level socio-economic position as well as the availability of neighbourhood green space.

This study shows that a social ecological framework can successfully be used to study the complex array of environmental factors that may influence the socio-economic gradient of health. By laying down the foundations of this theoretical approach researchers will be able to investigate the many other potential features of the individual, social and physical environmental factors that may influence health. Being able to conceptualise the way in which different environments affect different individuals on a number of different levels will allow the use of hypothesis driven research. It is recognised that this is methodologically challenging. Data will need to be integrated at both an individual and environmental level, involving sophisticated statistical techniques, such as, multi-level modelling. Researchers will have to begin by prioritising a few of the many research questions in order to gain a greater understanding of the many different ways in which the environment may influence health. The conclusion of this thesis will explore a few of these priority research questions and the implications these may have for future research.

9.8 Summary

This thesis found no evidence to suggest that physical activity in green space was a mechanism by which green space may promote population health and narrow socio-economic health inequalities. This chapter provided several explanations, at both a substantive and methodological level, for the absence of any significant associations between green space and health in Scotland. The explanation(s) most likely to be responsible for the lack of association between green space and (a) health and (b) physical activity is difficult to decipher considering the limited number of studies that have explored the salutogenic effects of green space in Scotland. What is clear, however, is that the discussion provided in this thesis as to why green space may not be associated with health in Scotland does not contest the idea that green space is salutogenic and that participating in green space provides health benefits; rather it challenges the ideas that (i) any green space in the neighbourhood can act as venue for, and thus encourage physical activity for the residents of that neighbourhood, and (ii) this will occur equally across all population groups. In order to develop a deeper understanding of the relationship between green space and health in Scotland and the UK, a number of priority research questions need to be addressed. These research question and some potential ideas for the way in which future research can address them are discussed in the concluding chapter (Chapter 10).

Chapter 10 Conclusion

This short chapter presents a summary of key findings followed by recommendations for future research and development.

10.1 Summary of Key Findings

This thesis was one of the first to explore the role of physical activity *specifically in green space* as a mechanism by which green space may promote health or narrow socio-economic health inequalities. The results found that the amount of green space in the neighbourhood was not associated with population health or socio-economic health inequalities. The absence of both any relationship between green space availability and green physical activity, and evidence for narrower inequalities in physical activity in greener neighbourhoods, contradicted Mitchell and Popham's hypothesis that green spaces equalise opportunities for physical activity and that this in turn produces narrower socio-economic health inequalities in greener areas. Chapter 9 provided several explanations, at both a substantive and methodological level, for the absence of any significant associations between green space and health in Scotland. This raised a number of future research questions. Below each of these research questions will be discussed.

10.2 Implications for Future Research

From the results of this study, I have suggested five priority research questions. These research questions and their key implications for future research are summarised in Table 10.1. Alongside this is a discussion of why these research questions were selected and some potential ideas for the way in which future research can address each research question.

Table 10.1 Summary of priority research questions and key implications for future research

Priority Research Questions	Key Implications for Future Research
What green space characteristics are associated with health?	Evidence is needed to explain the way in which use of green space may be constrained or facilitated by green space characteristics (distance to and quality of green space, for example) and the way in which different types of green space may influence health and health related behaviour
What behaviours occur in green space and why?	Research has to investigate the behaviours that occur in green space and why; this may allow us to develop a deeper understanding of the mechanisms involved and the way in which they may interact. Participating in physical activity amongst green environments may provide greater or synergistic health benefits than participating in physical activity alone
Does an individual's exposure to green space outwith their ward of residence impact the relationship between green space and health?	Future research is needed to move beyond the exploration of neighbourhood green space and investigate peoples' exposure to green space throughout their everyday lives, examining how this differential exposure may impact the way in which they use available green space
How does the association between green space and health differ by individual characteristics?	Further understanding is needed to explore the way in which the three proposed mechanisms - physical activity, restoration and social contact - may differ by demographic, social and economic groups.
Is the relationship between green space and health causal?	Research has to move beyond cross-sectional studies and explore whether green space is causally related to health or whether it is in fact the results of selection, especially at the level of the population

10.2.1 What Green Space Characteristics are associated with Health?

There are many green space characteristics that can be hypothesised to impact health. The majority of research, to date, has focussed on measurements of green space availability. In this study the relationship between green space and health was explored using the green space exposure variable designed by Richardson and Mitchell[115]. The advantage of this variable was that it was an objective measurement of green space that was sensitive to both larger and smaller areas of green space. The disadvantages were that the data source was estimated from two other data sets and it lacked sufficient information to distinguish between different types of green space. The limitations associated with these disadvantages may have potentially impacted the relationship between green space and population health in this study (See Section 9.3.7). Greater research is needed to explore the relationship between green space and health using a more accurate and sophisticated measurement of green space. This can now be done in Scotland due to the launch of the Green Space Scotland Interactive Map[164]. The Green Space Scotland Interactive Map was compiled in 2011 from green space data provided from all 32 local councils. The local datasets were produced using aerial photo interpretation of Ordnance Survey Master Map and GIS to categorise urban green space (i.e. towns and cities with a population of over 3000) into 23 different types of open green space. These types of green space were based on the typology set out in the Planning Advice Note 65 Planning and Open Space and distinguished public parks, private gardens, play areas, allotments and amenity green spaces. The advantage of this source compared to others is that it accurately captures the amount and type of green space that is available in an area and does not have to rely on any estimates of green space availability. As this resource is only available in Scotland further work is needed to create similar datasets among other countries. Future research can use such resources to accurately measure an individual's exposure to different types of green space. This would allow exploration as to whether specific types of green space may be more beneficial to population health, in turn, creating a greater understanding of the beneficial effect that green space has been suggested to exert on health.

Alongside advancing our measurement of green space availability, further research is needed to explore what other green space characteristics may be associated with health. This study conducted some preliminary analysis and found evidence to suggest that better quality green space was associated with better health. Research, however, was based on a single item, self-reported measurement. Future research has to build upon this preliminary investigation and explore the way in which objective green space characteristics may be associated with health. Objective measurements can be captured by auditing public green space or using Geographical Information Systems (GIS). Advancing this research will help identify which particular environment attributes encourage greater use of green space. Examples may include green space size, quality or safety.

10.2.2 What Behaviours Occur in Green Space and Why?

There is a need to explore the behaviours that occur in green space and why. Future research has to build on the results of this study and explore whether physical activity specifically in green space may be a plausible mechanism exploring the relationship between green space and health among different population groups. It has to recognise that it is not sufficient to simply capture the frequency with which people visit their green space for physical activity. Information on the intensity, duration and type of activity is needed to fully understand any associated health benefits. One way to do this is the use of objective measurements of physical activity, such as, accelerometers or pedometers coupled to green space data. This will allow a much more accurate assessment of the way in which the intensity, duration and frequency of physical activity may be associated with any green space characteristics. Moreover, future research has to use the principles applied in this study and explore whether actual use of green space for (a) restoration from stress and mental fatigue and (b) social contact may be associated with population health and socio-economic health inequalities. This is particularly important as it has been suggested that these three proposed mechanisms may interact. Participating in physical activity in green space may provide more synergistic health benefits than participating in physical activity alone. Increasing our understanding of the actual behaviours that occur in green space and the reasons for why individuals' participate in them will begin to untangle the mechanisms by which green space is thought to influence health and health inequalities and will increase our understanding of whether green space may be a method in which to improve health and reduce socio-economic inequalities in health.

10.2.3 Does an Individual's Exposure to Green Space outwith their Ward of Residence Impact the Relationship between Green Space and Health?

In this study the association between green space availability and population health was explored at the neighbourhood level. The disadvantage of using the neighbourhood as a geographical unit of analysis is that individuals may spend a large proportion of their day outside their ward of residence, resulting in differential exposure to green space. This limitation may impact the relationship between green space and health. Future research has to move beyond the exploration of neighbourhood green space and investigate people's exposure to green space throughout their day to day lives. One method in which to analyse this is to combine Geographical Information Systems (GIS) with Global Positioning Systems (GPS). GIS can be used to describe the characteristics of the surroundings, such as the size or availability of green space, whilst GPS allow individuals' locations to be identified at any point in time. Combining these systems provides an objective way in which to fully explore the beneficial effect that green space has been suggested to have on health. Integrating the use of GPS into future research could also be a method with which to enhance our understanding of the behaviours that occur in green space and the way in which they may impact population health. Combining GPS with physical activity monitors such as accelerometers, for example, would allow an objective measurement of the level and location of physical activity behaviours that occurs at specific times during the day. It is recognised that the quantity of data produced by such methodologies, and the practical difficulties in running large scale studies, means that they are not well suited to capturing associations between behaviour and environment at the population level. Population level studies would have to concentrate on capturing the quantity and location of behaviour using self-report.

10.2.4 How does the Association between Green Space and Health differ by Individual Characteristics?

This was one of the first studies to explore whether the association between neighbourhood green space and physical activity specifically in green space differed by socio-economic position. Although the results of this study found no significant associations further research is needed to explore whether the association between green space and physical activity in green space may differ by demographic characteristics. It is well known that females are less likely to participate in physical activity than males, but are they less likely to use their green space to participate in physical activity? Alongside the exploration of physical activity specifically in green space, future research is needed to explore whether use of green space for (a) restoration from stress and mental fatigue and (b) social contact may differ by demographic, social or economic groups and whether these differences may partly account for any associated inequalities in health.

10.2.5 Is the Relationship between Green Space and Health Causal?

A burgeoning body of research is exploring the relationship between green space and health. Yet the majority of this research has been conducted using a cross-sectional design. The shortcoming with the use of a cross-sectional design is that it is not possible to determine if an observed relationship between green space and health is causal. Future research needs to be conducted using a longitudinal study design as this allows respondents to be followed over a long period of time, gaining an understanding of their exposure to green space. Given the complexity and cost of conducting longitudinal studies it is understandable why few longitudinal datasets for exploring the relationship between green space and health exist. One way to overcome this limitation is through the use of a natural experiment. In this context a natural experiment is referred to as the exposure of different populations to different interventions on account of the natural variation resulting from policy decisions made outwith the control of the researcher. An example of a natural experiment has recently been published in Scotland[230]. The article describes the study protocol for the evaluation of a woodland improvement programme run by the Forestry Commission Scotland. By regenerating, improving and promoting local woods as safe and accessible environments, the intervention aims to assess the impact that greater contact with woodlands have on perceived stress and mental well-being. By conducting more interventions of this nature a greater understanding of whether the relationship between green space and health is causal can be gained.

10.3 Summary

This chapter has examined the key findings of the thesis in relation to the overarching research aim and from these findings has outlined five priority research questions for future research and development.

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Appendices

Appendix A

Search Strategy

Search Terms	Medline	Number of Studies PsycINFO	Web of Knowledge
1. green space*or greenspace*	135	48	1351
2. public park*	497	48	902
3. open space*	438	352	4788
4. green environment*	10	14	168
5. natural environment*	2581	2051	18,988
6. or/1-5	3636	2054	25,834
7. health*	1,844,420	634,401	>100,000
8. physical health*	6844	8567	10,637
9. general health*	13,097	5622	18,487
10. health* behaviour*or health* behavior*	27,501	16,979	31,153
11. mental health*	82,843	304,081	>100,000
12. stress	414,768	132,830	>100,000
13. well being	27,818	33,987	>100,000
14. mental fatigue	1104	367	1488
15. restoration	68,011	3630	>100,000
16. or/7-15	2,271,793	732,317	7594
17. physical activity	34,899	11,695	75,848
18. exercise	183,027	36,881	>100,000
19. walk* or cycle*	394,576	45,542	>100,000
20. or/17-19	576,425	86,568	>100,000
21. social contact*	849	2463	3273
22. social interaction*	6764	25,058	20,043
23. social support*	45,219	33,230	60,480
24. or/21-23	52,215	59,085	82,519
25. 16 or 20 or 24	2,554,792	817,055	>100,000
26. 6 and 25	**948**	**506**	**6492**

[1]* is a truncation symbol allowing retrieval of all possible variations of a term. [2] or/ is a Boolean operator term that groups together all relevant studies into one search category

Appendix B

Key Characteristics of studies exploring the relationship between green space and health included in review, ordered by publication date

First Author	Year	Country	Design	Subjects	Health Outcome
Takano	2002	Tokyo	LT	N = 3144 Senior Citizens	Mortality
De-Vries	2003	Netherlands	CS	N = 10,197	General Health Health-related complaints Mental Health
Ellayway	2005	8 European Countries	CS	N = 6919 Adults	BMI
Maas	2006	Netherlands	CS	N = 250,782	General Health
Mitchell	2007	England	CS	32,482 LSOAs 18+ Years	General Health
Nielsen	2007	Denmark	CS	N = 1200 18-80 Years	BMI
Mitchell	2008	England	CS	N = 40,813,236 <65	Mortality
Sugiyama	2008	Australia	CS	N = 1895 20-65 Years	General Health Mental Health
Maas	2009	Netherlands	CS	N = 345, 143	Health-related complaints
Richardson	2010	UK	CS	N = 28.6 Million 16-64 Years	Mortality
Richardson	2010	New Zealand	CS	N = 1,546, 405 16-64 Years	Mortality
Stigsdotter	2010	Denmark	CS	N = 10,250 16+	General Health
Van dan Berg	2010	Netherlands	CS	N = 4529 18+	Mental Health
Van Dillen	2011	Netherlands	CS	N = 1641 16+ Years	General Health Health-related complaints Mental Health
Cummins	2012	England	CS	N = 79,136 18+ Years	BMI
Francis	2012	Australia	CS	N = 911 18+ Years	Mental Health

Appendix C

Key Characteristics of studies exploring the potential underlying green space mechanisms included in review, ordered by publication date

First Author	Year	Country	Design	Subjects	Underlying Mechanism
Coley	1997	US	CS	N = 96	Social Interaction
Kuo	1998	US	CS	N = 145 20-59 Years	Social Interaction
Kweon	1998	US	CS	N = 91 64-91 Years	Social Interaction
Booth	2000	Australia	CS	N=402 60+ Years	Physical Activity
Brownson	2000	US	CS	N = 1269 18+ Years	Walk
Brownson	2001	US	CS	N = 1818 18+ Years	Physical Activity
Troped	2001	US	CS	N = 413 18+ Years	Cycle
Giles-Corti	2002a	Australia	CS	N = 1803 18-59 Years	Physical Activity Walk
Giles-Corti	2002b	Australia	CS	N = 1803 18-59 Years	Physical Activity
Eyler	2003	US	CS	N = 181 18+ Years	Walk
Giles-Corti	2003	Australia	CS	N = 1803 18-59 Years	Walk
Grahn	2003	Sweden	CS	N = 953	Stress
Huston	2003	US	CS	N = 1796 18+ Years	Physical Activity
King	2003	US	CS	N = 49 52-62 Years	Physical Activity Walk
Troped	2003	US	CS	N = 413 18+ Years	Physical Activity
Foster	2004	England	CS	N = 4157 16-74 Years	Walk
Humpel	2004	Australia	CS	N = 800 18-69 Years	Walk
Humpel	2004b	Australia	CS	N = 800 18-71 Years	Physical Activity Walk

First Author	Year	Country	Design	Subjects	Underlying Mechanism
Deshpande	2005	US	CS	N = 278 20+ Years	Physical Activity
Duncan	2005	Australia	CS	N = 1281 18+ Years	Physical Activity
Giles-Corti	2005	Australia	CS	N = 1773 18-59 Years	Physical Activity Walk
Hoehner	2005	US	CS	N = 1053 18+ Years	Physical Activity
King	2005	US	CS	N = 158 52-62 Years	Walk
Zlot	2005	US	CS	N = 34 Countries 18+ Years	Walk Cycle
Hillsdon	2006	England	CS	N = 4950 45-74 Years	Physical Activity
Gidlof	2007	Sweden	CS	N = 500 18-75 Years	Stress
Jilcott	2007	US	CS	N = 199 40-64 Years	Physical Activity
Mowen	2007	Denmark	CS	N = 1515 50+ Years	Physical Activity
Nielson	2007	Denmark	CS	N = 1200 18-80 Years	Stress
Sugiyama	2008	Australia	CS	N = 1895 20-65 Years	Walk Socio-interaction
Sugiyama	2008b	Australia	CS	N = 268 65+ Years	Walk
Maas	2008	Netherlands	CS	N = 4899 12-65+ Years	Physical Activity Walk Cycling
Witten	2008	New Zealand	CS	N = 12,529 15+ Years	Physical Activity
Jones	2009	England	CS	N = 6821 16+ Years	Physical Activity

First Author	Year	Country	Design	Subjects	Underlying Mechanism
Kaczynski	2009	Canada	CS	N = 384 18-55 Years	Physical Activity
Lackney	2009	Canada	CS	N = 574 18-88 Years	Physical Activity
Maas	2009	Netherlands	CS	N = 10, 089 12-65+ Years	Social Interaction
Coombes	2010	England	CS	N = 6803 16+ Years	Physical Activity
Stigsdotter	2010	Denmark	CS	N = 10, 250 16+ Years	Stress
Tilt	2010	US	CS	N = 617 Adults	Walk
Toftager	2011	Denmark	CS	N = 21, 832 16+ Years	Physical Activity
Mytton	2012	England	CS	N = 31, 049 16+ Years	Physical Activity
Ward Thompson	2012	Scotland	CS	N = 25 35-55 Years	Stress
Coutts	2013	US	CS	N = 67 Countries	Physical Activity
Richardson	2013	New Zealand	CS	N = 8157 15+	Physical Activity
Schipperijn	2013	Denmark	CS	N = 1305 17-81 Years	Physical Activity

Appendix D

Missing data for each of the additional health outcomes and measures of socio-economic position

	Number of Missing Cases	% of Total Cases
Outcome Variables		
Health		
Angina	35	0.83
Heart Attack	33	0.78
Stroke	33	0.78
Diabetes	33	0.78
Mental Well-Being	481	11.39
Longstanding Illness	0	0
GP Consultation	12	0.28
Chronic Obstructive Pulmonary Disease	33	0.78
Confounding Variables		
Social Economic Grade	127	3.01
Scottish Index of Multiple Deprivation	0	0