Natural England Commissioned Report NECR067

Green space access, green space use, physical activity and overweight

First published 04 April 2011

www.naturalengland.org.uk

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Regular physical activity has been shown to reduce the risk of cardiovascular disease, non-insulin dependent diabetes mellitus, some forms of cancer and obesity. Physical activity is also associated with improved mental well-being. Despite the recognised benefits of regular physical activity, only 40% of men and 28% of women in England, in 2006, met the public health recommendation.

Attention has begun to focus on the extent to which the characteristics of the environment in which a person resides influences their physical activity patterns. In particular, recent research has suggested that the provision of open spaces, such as parks and other green spaces, for recreation may provide an important health resource especially in urban areas where gaining access to the open countryside can be difficult. Recent studies in England have shown that the amount of green space in an area is generally associated with better health including reduced mortality.

Much of the current green space research has focused on the proximity and accessibility of physical activity facilities and public open space. Overall, the evidence to date indicates that improving access to good quality green space in urban areas may be a promising means of increasing physical activity. However, uncertainty exists regarding the relationship between green space access, the frequency of green space use and physical activity. Furthermore, the extent to which relationships between green space and physical activity vary by population sub-group is unknown, and as the bulk of the literature is from the US or Australia there is a need for more research in the UK.

The two studies described in this report' ' perceived green space access, green space use, physical activity and overweight', and 'objectively measured green space access, green space use, physical activity and overweight', provide new evidence on the association between both perceived and objectively measured access to green space, frequency of green space use, physical activity levels, and the probability of being overweight or obese by combining information from the Bristol Quality of Life in your Neighbourhood Survey, with a comprehensive database of green space locations and characteristics within the city.

The studies examine two related but different questions. The first study examines the green space access people think they have and how this affects their use of green spaces for physical activity. The second study examines how measured distances affect peoples' use of green spaces for physical activity. As one might expect green space use declines the further people live away (measured) from green space which is supported by the findings of MENE (NECR056). Importantly through, the perceived access study shows that use also declines if people don't feel their green spaces are accessible. A range of factors such as feeling of safety, car parking, other users, can impact upon perceived accessibility.

The purpose of Natural England commissioning these studies was twofold. Firstly, to test the popular hypothesis that increasing accessible green space will lead to increased physical activity in a community resulting in beneficial health outcomes. Secondly, to examine the concept of 'accessibility' as it related to physical activity. These studies add to the evidence in both respects and Natural England will use their findings to inform and support communities in the development of green spaces where they can engage with natural environment.

This report should be cited as:

HILLSDON, M., JONES, A. & COOMBES, E. 2011. *Green space access, green space use, physical activity and overweight*. Natural England Commissioned Reports, Number 067.

Natural England Project Manager - David Stone, Evidence Team, Natural England, 3rd Floor Touthill Close, Peterborough, PE1 1XN **Dave.Stone@naturalengland.org.uk**

Contractor - Melvyn Hillsdon - Department Exercise and Health Sciences, University of Bristol and Andy Jones/Emma Coombes - School of Environmental Sciences, University of East Anglia

Keywords - green space, physical activity, equity, deprivation

Further information
This report can be downloaded from the Natural England website: **www.naturalengland.org.uk**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

ISSN 2040-5545

Summary

Perceived green space access

Just over half of men and women thought it was very easy to get a green space, although older adults, respondents who were less educated and those living in deprived neighbourhoods were less likely to say so. Approximately a third of respondents said that they used green spaces at least weekly with less frequent green space use with increasing age and worsening deprivation. The chances of reporting at least weekly green space use were increased in respondents who believed they had easy access to green space and reported green spaces and their neighbourhood as safe. Respondents who reported easy green space access and at least weekly use were also more likely to report physical activity at recommended levels.

Objectively measured green space access

When using objectively measured access to green space, 55% of people were living within 300 metres of one. When access was examined by green space type, 30% of respondents lived within 300m of Informal and Natural green spaces and less than 10% lived within 300m of Young People's and Sports green spaces. Mean distances were 2207m for Young People's, 1758m for Formal, 1082m for Sports, 570m for Natural, and 481m for Informal green space types. For all green space types, except for Young People's, visit frequency declined with increasing distance. After taking account of potential confounding, only distance to formal green spaces was associated with physical activity, with increasing distance associated with less physical activity. Distance to any type of green space was not associated with overweight or obesity when health status and other demographic factors were taken account of.

Acknowledgements

Natural England and the authors of this report would like to thank Bristol City Council for supplying their 'Quality of Life' and green space data.

Contents

Study 1 Perceived green space access, green space use, physical activity and overweight

1. Introduction

Regular physical activity has been shown to reduce the risk of cardiovascular disease[1], non-insulin dependent diabetes mellitus[2,3], some forms of cancer[4,5] and obesity. Physical activity is also associated with improved mental well-being[6]. Despite the well recognised benefits of regular physical activity, only 40% of men and 28% of women in England, in 2006, met the public health recommendation of at least 30 minutes of moderate intensity physical activity for five days per week[7].

A greater understanding of the factors that influence adults' physical activity patterns would facilitate the development of new strategies to increase activity. Traditionally, attention has focussed on individual level determinants of physical activity such as psychosocial variables[8]. However, as psychosocial variables explain a relatively small proportion of the variance in physical activity, and interventions that have attempted to increase physical activity by changing psychosocial variables have reported weak results[8,9], we need to consider alternative influences on physical activity.

Attention has recently begun to focus on the extent to which the characteristics of the environment in which a person resides influences their physical activity patterns[10,11]. Much of the work has focussed on the proximity and accessibility of physical activity facilities and public open space[12]. In particular, a number of recent policy documents have promoted the potential public health benefits of investment in parks and green spaces and their potential for increasing physical activity[13,14,15,16]. Cross-sectional studies have shown that people who live in neighbourhoods with a higher proportion of green space also report better levels of general health.[17,18] Further, people living in the greenest areas experience lower mortality rates, an effect that is particularly pronounced in lower income areas.[19] The authors suggest that their observations may be due to the beneficial effects of green space on physical activity. However, although intuitively appealing, the evidence in support of a relationship between access to green space and physical activity is sparse, especially in the UK.

A number of studies from the US have shown an association between park proximity, park use and physical activity. They have reported that people with greater access to public parks use them more and tend to be more physically active compared to people with poorer access.[20,21,22] However, one cross-sectional study of 1068 US adults found no association between having a park within 5-minutes walk from home and self reported physical activity.[23] Mixed results have also been reported in Australian studies. A cross-sectional study of 1773 adults found that good access to large, high quality public open space was associated with a higher frequency of walking[12] but another cross-sectional study from a different part of Australia found an inverse association between access to green space and physical activity.[24] To date, just one study examining green space access and physical activity has been conducted in the UK. This assessed the relationship between objectively measured access to green space and self reported physical activity in a representative sample of 4950 middle aged adults (aged 40-70 years) residing in the city of Norwich. No association was observed between reported physical activity and access to green space amongst this group.[25]

The evidence to date indicates that improving access to good quality green space in urban areas may be a promising means of increasing physical activity. However, uncertainty exists regarding the relationship between green space access, the frequency of green space use and physical activity.

Furthermore, the extent to which relationships between green space and physical activity vary by population sub-group is unknown, and as the bulk of the literature is from the US or Australia there is a need for more research in the UK.

This study proposes to examine the association between perceived access to green space, frequency of green space use, physical activity and overweight in a large sample of English adults residing in a metropolitan city.

2. Methods

2.1 The survey

The data for this study were derived from a postal survey of a representative sample of adults in Bristol, UK in 2005. The Quality of Life in your Neighbourhood Survey is an annual cross sectional postal survey, undertaken by Bristol City Council since 2001, to assist monitoring of sustainability within the city. The mid-year population estimate for Bristol in 2005 was 405 600 including 323 800 adults (www.statistics.gov.uk/census, 2007). The study population was obtained by using a single-stage sampling frame. The population was stratified by the 35 electoral wards (area administrative units), representing a mix of deprived and affluent areas, the inner city, housing estates, urban areas and suburbs. Three hundred and eighty people from each ward were randomly selected from the register. Each self completed, postal questionnaire was accompanied by a letter signed by a councillor and an entry to a prize draw incentive. There was one postal reminder, which included a duplicate questionnaire. There were 6 821 respondents, a response rate of 33.9%. The sample had similar sociodemographic characteristics to the mid-year population estimates for Bristol in 2001 (www.statistics.gov.uk/census, 2007).

2.2 Dependent variables

Two measures of physical activity were used as dependent variables; self reported frequency of participation in sport and moderate physical activity (e.g. brisk walk, leisure activity, heavy gardening, heavy housework or DIY). Frequency of participation was recorded on an 8-point scale ranging from “5 times a week or more” to “never due to health reasons”. For analysis the two scales were combined and a dichotomous variable produced that was coded as ‘1’ if respondents reported a combination of moderate or sport participation at 5 times a week, or 0 if the combined frequency was less. Both height and weight were self reported and used to calculate body mass index (kg / m^2). Body mass index (BMI) was then used to categorise respondents as overweight or obese if their BMI was 25 or greater.

Respondents were asked to indicate how often they visited the city’s parks and green spaces on a 5 point scale ranging from “5 times a week or more” to “less than once a year”. For analysis, the scale was reduced to four categories: “≥once per week”, “2-3 times a month”, “1-6 times a year”, “< once a year”.

2.3 Independent variables

Perceived access

Respondents were asked: “how easy is it for you to get to the following destination using your usual form of transport?” The question included public parks and green spaces and was answered on a 1-5 point scale from “very easy” to “very difficult”.

Safety and park safety

Respondents were also asked about how safe they felt in their neighbourhood and separately how safe they felt in Bristol's parks. Respondents answered both questions on a 1-5 point scale ranging from "very safe" to "very unsafe".

Socioeconomic position

Educational level was examined by requesting the highest educational level achieved. In England, GCSE examinations are those taken at aged 16 and A-level examinations are those taken by students at aged 18. Graduate and post graduate qualifications are those which follow A-levels and usually require attendance at a university or higher educational institution. Employment status was self reported. Respondents were categorised as either in full time employment, part time employment (16-30 hours per week), retired from work or other. 'Other' included students, those looking after the home or caring for another person with an illness and the unemployed.

Respondents' postcode was used to locate them in one of 32,482 Super Output Areas (SOAs) in England, and assign an Index of Multiple Deprivation 2004 (IMD 2004) score.[26] SOAs[27] are a geographic hierarchy designed to improve the reporting of small area statistics in England. They are relatively homogeneous in size and demographic structure (minimum population 1000, mean 1500). The IMD score is a weighted area level aggregation of specific dimensions of deprivation including, income, employment, health, education, housing, environment and crime. Higher IMD scores signify more deprived areas. Quantiles of IMD score were generated (1=least deprived, 4=most deprived).

We considered that age, sex and general health might confound any association between green space access, green space use, physical activity and overweight. Self rated health was obtained from the questionnaire and was categorised as 'good', 'fairly good' or 'not good'.

2.4 Statistical analysis

Analysis was conducted in August 2008. Logistic regression was used to calculate odds ratios of visiting the city's parks and green spaces at least once a week. Logistic regression was also used to test the hypothesis that perceived access to green space, neighbourhood safety and green space use was related to reporting participation in physical activity at least 5 times a week and being overweight or obese. There were small amounts of missing data on some of the variables included in the analyses, hence slight variations in the reported N's. All analyses were conducted using Stata version 9.0 (Stata corporation, Texas 2005).

3. Results

Perceived access to green space was reported to be fairly or very easy by 88.6% of men and 86.9% of women (Table 1). Younger adults, those with higher educational attainment, not in retirement and those living in more affluent neighbourhoods were more likely to report green space access as very easy (Table 1.1).

Table 1.1. Prevalence and 95% Confidence Interval (95% CI) of perceived access to green space by selected characteristics

	Perceived access % (95% CI)				
	Very easy n=3333	**Fairly easy n=1797**	**Neither n=352**	**Difficult n=262**	**Very difficult n=115**
Variable					
Sex					
Male	56.5 (54.5,58.4)	32.1 (30.2,33.9)	6.4 (5.4,7.4)	3.7 (3.0,4.5)	1.4 (0.9,1.8)
Female	57.2 (54.5,58.4)	29.7 (28.1,31.2)	5.7 (4.9,6.5)	5.0 (4.3,5.8)	2.4 (1.9,2.9)
Age group					
17-34	59.5 (56.9,62.1)	29.0 (26.6,31.4)	5.8 (4.6,7.1)	4.4 (3.3,5.5)	1.6 (0.7,1.9)
35-54	58.3 (56.2,60.4)	29.6 (27.7,31.6)	6.8 (5.7,7.8)	3.6 (2.8,4.4)	1.7 (1.2,2.2)
55-74	57.7 (55.4,60.0)	30.7 (28.6,32.9)	4.8 (3.8,5.8)	4.7 (3.7,5.7)	2.1 (1.4,2.7)
75+	43.0 (38.9,47.2)	37.7 (33.7,41.8)	7.5 (5.3,9.7)	7.1 (5.0,9.3)	4.6 (2.8,6.3)
Education					
A level or higher	62.1 (60.1,64.0)	27.9 (26.1,29.7)	5.3 (4.4,6.2)	3.5 (2.8,4.2)	1.2 (0.8,1.7)
GCSE ‘O’ level	56.8 (54.1,60.0)	29.9 (27.4,32.4)	7.0 (5.6,8.4)	4.6 (3.4,5.7)	1.7 (1.0,2.4)
<‘O’ level	51.1 (49.0,53.2)	34.1 (32.2,36.1)	6.3 (5.2,7.3)	5.7 (4.7,6.6)	2.9 (2.2,3.6)
Employment					
Full/part time	58.4 (56.7,60.2)	29.7 (28.1,31.3)	6.3 (5.4,7.1)	4.1 (3.4,4.7)	1.5 (1.1,1.9)
Retired	50.9 (48.3,53.6)	34.6 (32.1,37.1)	6.1 (4.8,7.3)	5.3 (4.2,6.5)	3.1 (2.2,4.0)
Other	58.7 (56.2,61.3)	29.1 (26.8,31.4)	5.4 (4.2,6.6)	4.8 (3.7,5.9)	1.9 (1.2,2.6)
Neighbourhood deprivation					
1-Most affluent	63.7 (61.3,61.7)	26.7 (24.5,29.0)	5.5 (4.4,6.7)	2.4 (1.7,3.2)	1.6 (0.9,2.2)
2	59.2 (56.7,61.7)	29.9 (27.6,32.3)	5.3 (4.2,6.5)	4.0 (3.0,5.0)	1.5 (0.9,2.1)
3	57.8 (55.3,60.3)	30.5 (28.1,32.9)	5.7 (4.5,6.9)	4.1 (3.1,5.1)	1.9 (1.2,2.6)
4-Most deprived	46.0 (43.4,48.6)	35.7 (33.2,38.2)	7.6 (6.2,9.0)	7.7 (6.4,9.1)	3.0 (2.1,3.8)

Reported frequency of green space visits declined with age and deprivation and increased with education, perceived access to green space, reported green space and neighbourhood safety and self rated health (Table 1.2). There were no differences in green space visit frequency between males and females.

Table 1.2. Frequency of green space visits by selected characteristics

	Green space visit frequency (%)					
	≥ weekly n=2101	2-3 /month n=1613	1-6/year n=1506	< 1/year n=1100	X^2	p-value
Variable						
Sex					1.66	0.6
Male	34.8	26.1	23.1	16.0		
Female	33.4	26.0	24.2	16.4		
Age group					557.6	<0.001
17-34	40.2	31.4	22.7	5.7		
35-54	38.4	27.9	22.8	11.0		
55-74	28.8	22.9	26.8	21.6		
75+	19.7	16.8	20.1	43.4		
Education					451.8	<0.001
A level or higher	40.6	28.7	23.8	7.0		
GCSE ‘O’ level	33.9	29.2	24.8	12.0		
<‘O’ level	26.8	21.3	23.2	28.7		
Employment					314.8	<0.001
Full/part time	34.6	28.8	25.5	11.1		
Retired	25.8	20.0	23.7	30.5		
Other	40.4	25.8	20.2	13.7		
Neighbourhood deprivation					91.3	<0.001
1- Most affluent	37.8	27.6	22.9	11.8		
2	36.1	25.6	24.2	14.1		
3	33.9	25.2	23.9	17.0		
4- Most deprived	27.4	25.5	24.2	22.9		
Access to green space					232.0	<0.001
Very easy	41.8	26.4	20.6	11.3		
Easy	27.9	27.2	28.7	16.2		
More difficult	19.8	26.1	29.1	25.0		
Neighbourhood safety					80.9	<0.001
Very safe	38.5	27.5	22.4	11.7		
Safe	32.1	25.6	25.2	17.0		
Less safe	29.8	23.7	23.3	23.3		
Green space safety					965.3	<0.001
Very safe	50.7	27.2	17.7	4.5		
Safe	35.4	28.9	25.8	9.8		
Less safe	17.4	17.8	23.7	41.2		
Self rated health					182.2	<0.001
Good	38.8	28.1	22.2	10.8		
Fairly good	30.0	24.6	25.8	19.6		
Not good	26.3	21.8	22.4	29.4		

Compared to people who reported very easy access to green space, those who reported more difficult access were 56% less likely to report visiting a green space at least weekly (Table 1.3), and those who rated the city’s green spaces as less safe compared to very safe were 60% less likely to

report a weekly visit. Surprisingly, participants were 52% more likely to report at least weekly green space visits if they rated their neighbourhood as less safe rather than safe or very safe.

Table1. 3. Odds ratios and 95% Confidence Intervals (95% CI) for at least weekly green space use by perceived access to green space, neighbourhood and green space safety, socioeconomic status and area deprivation

Variable	Odds ratio	95% CI	p-value*
Neighbourhood deprivation			0.15
1-Most affluent	Ref		
2	1.02	(0.86,1.20)	
3	0.99	(0.84,1.18)	
4- Most deprived	0.85	(0.71,1.02)	
Access to green space			<0.001
Very easy	Ref		
Easy	0.60	(0.57,0.69)	
More difficult	0.44	(0.36,0.55)	
Neighbourhood safety			<0.001
Very safe	Ref		
Safe	1.23	(1.06,1.43)	
Less safe	1.52	(1.21,1.91)	
Green space safety			<0.001
Very safe	Ref		
Safe	0.60	(0.51,0.71)	
Less safe	0.40	(0.32,0.51)	

Adjusted for age, sex, socioeconomic position and self rated health; * Values are for Wald tests of the significance of each predictor in the model

The likelihood of reporting participation in physical activity at recommended levels was 22% lower in participants who perceived access to green space as more difficult rather than very easy (Table 1. 4).

Table1. 4. Odds ratios and 95% Confidence Intervals (95% CI) for participating in at least 5 occasions per week of physical activity and being overweight/obese, by perceived access to green space and green space use

	Physical activity			Overweight/obese†		
Variable	Odds ratio	95% CI	p-value*	Odds ratio	95% CI	p-value
Access to green space			0.03			0.75
Very easy	Ref			Ref		
Easy	0.96	(0.84,1.10)		1.04	(0.91,1.19)	
More difficult	0.78	(0.65,0.94)		1.07	(0.88,1.30)	
Green space use			<0.001			0.003
≥ weekly	Ref			Ref		
2-3 times a month	0.52	(0.45,0.61)		1.34	(1.15,1.57)	
1-6 times a year	0.39	(0.33,0.46)		1.18	(1.00,1.39)	
< once per year	0.34	(0.28,0.41)		1.18	(0.98,1.44)	

Adjusted for age, sex, socioeconomic status, neighbourhood safety and self rated health; * Values are for Wald tests of the significance of each predictor in the model; † Additional adjustment for physical activity

Frequency was strongly related to participation in physical activity. Compared to weekly visitors, those who visited green spaces less than once per year were 64% less likely to report being be physically active at recommended levels. Less than weekly green space use was associated with an increased likelihood of being overweight or obese, even after adjustment for physical activity level, whereas perceived access to green space was not.

4. Discussion

In this study we have shown that perceived access to green space, green space safety, and neighbourhood safety, are all associated with the frequency that people report visiting green spaces. In addition, we have been able to show that regular green space visits are associated with increased physical activity and a lower probability of being overweight or obese, even after adjustment for potential confounders. We also show that perceived access to green space is directly associated with the probability of reporting being active at recommended levels but not overweight or obesity.

Our results relating to perceived green space access and the frequency of green space use are consistent with other similar studies. In general, those who perceive better access to green spaces, also report higher levels of their use.[28,12,29] Other studies have also found that frequent users consistently report higher levels of physical activity. [28,12,29,30,31] Yet many of the studies that examine the relationship between green space access and physical activity do not measure green space use, even though use may implicitly be hypothesised to be in the pathway. Consequently, evidence of a relationship between perceived access to green space and reported physical activity is has been equivocal.[32] Whilst, a cross-sectional study of 2000 Danish adults found a relationship between green space access and the odds of being obese that was not explained by green space use,[29] in this study we found the opposite; only reported green space use, not reported ease of access, was related to overweight/obesity in our sample. In the Danish study the authors attributed their findings to green space access being a proxy for a more pleasant neighbourhood that encourages outdoor activity. In this study, we controlled for neighbourhood deprivation so better green space access is unlikely to be a proxy for a pleasant area. It is nevertheless unusual that we found reported neighbourhood safety was inversely associated with green space use, whilst reports of green space safety went in the expected direction. It is possible that respondents who lived in less safe neighbourhoods made more trips to other neighbourhoods to enjoy the experience of more pleasant, green environments.

The main strengths of this study are the large random sample that is representative of the population of adults in the study area, along with data on a range of known confounding variables including area deprivation and self rated health. We also had information on reported ease of access and green space use amongst participants.

Weaknesses of the study include the fact that we have relied on self-report of green space access and physical activity which may lead to some misclassification bias, especially as there is some evidence that perceived access to green space may not accurately reflect objectively measured access.[33] It is also possible that the estimates of access to green space made by participants are affected by green space use; if regular users report better ease of access due to familiarity rather than other reasons, then this could lead to an exaggeration of the true affect. However, if any misclassification of green space proximity was non-differential, the observed effects would likely be underestimated. Although agreement between perceived and measured access to green space has been shown to be poor in other studies, it remains uncertain which the best predictor of physical activity or overweight. Physical activity was also self-reported and may have lead to some misclassification. Again, if this misclassification was purely random then the strength of association

with green space access and use would be attenuated, though our reported association may be biased in either direction. If there was reporting bias and participants who over reported physical activity were more proximal to green space, the observed association would be inflated. The cross sectional nature of this study leads to the possibility of reverse causality if those who live physically active lifestyles choose to live nearer to, and use green spaces more, than people who live more sedentary lifestyles. This is more likely to be true of our findings regarding green space use and overweight/obesity; the inverse association between green space use and risk of overweight remained after controlling for physical activity, suggesting that overweight adults visit green spaces less frequently than healthy weight adults, rather than green space use causing lower weight independent of an individual's level of physical activity.

Concern about the loss of public green spaces and the subsequent risk to health was first raised as early as 1833 when UK government ministers predicted that increased access to public open spaces would improve health and reduce health inequalities.[34] Nearly 200 years later, the findings of this study suggest that affording people the opportunity for recreational activity in safe and accessible public green spaces would appear to be an important element of public health initiatives designed to promote physical activity and tackle rising levels of obesity.

5. Conclusion

People who perceive easy access to safe green spaces report higher green space use, more regular physical activity and lower risk of obesity. Therefore, access to safe and convenient green space is likely to be an important environmental factor in public health efforts aimed to promote physical activity and reduce obesity.

Study 1 References

1. Lee IM, Sesso HD, Paffenberger RS. Physical activity and coronary heart disease risk in men: Does the duration of exercise episodes predict risk? Circulation 2000;102:981-986.

2. Kriska A. Can a physically active lifestyle prevent type 2 diabetes? Exerc Sport Sci Rev 2003;31(3):132-137.

3. Kriska AM, Saremi A, Hanson RL, et al. Physical activity, obesity, and the incidence of type 2 diabtes in a high risk population. Am J Epdemiol 2003;158(7):669-675.

4. Slattery ML, Edwards S, Curtin K, et al. Physical activity and colorectal cancer. Am J Epdemiol 2003;158(3):214-224.

5. Slattery ML, Edwards SL, Khe-Ni MA, Friedman GD, Potter JD. Physical activity and Colon Cancer: A public health perspective. Ann Epidemiol 1997;7:137-145.

6. Penedo FJ, Dahn JR. Exercise and well-being: a review of mental and physical health benefits associated with physical activity. Curr Opin Psychiatry 2005;18(2):189-93.

7. Craig R, Mindell J. Health Survey for England 2006. Leeds: The Information Centre, 2008.

8. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sports Exerc 2002;34(12):1996-2001.

9. Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions. How are we doing? How might we do better? Am J Prev Med 1998;15(4):266-97.

10. Craig CL, Brownson RC, Cragg SE, Dunn AL. Exploring the effect of the environment on physical activity: A study examining walking to work. American Journal of Preventative Medicine 2002;23(2S):36-43.

11. Orleans CT, Kraft MK, Marx JF, McGinnis JM. Why are some neighborhoods active and others not? Charting a new course for research on the policy and Environmental Determinants of Physical Activity. Ann Behav Med 2003;25(2):77-79.

12. Giles-Corti B, Broomhall MH, Knuiman M, et al. Increasing walking: how important is distance to, attractiveness, and size of public open space? Am J Prev Med 2005;28(2 Suppl 2):169-76.

13.CABE Space (2004) Value of Public Space

14.ODPM (2002) Green Spaces, Better Places

15. ODPM (2002) Living Places; Cleaner, Safer, Greener

16. National Heart Forum (2007).Building health: creating and enhancing places for healthy, active lives. pp14-15

17. Maas J, Verheij RA, Groenewegen PP, de Vries S, Spreeuwenberg P. Green space, urbanity, and health: how strong is the relation? J Epidemiol Community Health 2006;60:587-592.

18. Mitchell R, Popham F. Green space, urbanity and health: relationships in England. J Epidemiol Community Health 2007;61:681-683.

19. Mitchell R, Popham F. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet 2008;372:1655-1660.

20. Cohen DA, Mckenzie TL, Sehgal A et al. Contribution of public parks to physical activity. Am J Prev Med 2007;97:509-514.

21. Roemmich JN, Epstein LH, Raja S et al. Association of access to parks and recreational facilities with the physical activity of young children. Prev Med 2006;43:437-441.

22. Cohen DA, Ashwood JS, Scott MM et al. Public parks and physical activity among adolescent girls. Pediatrics 2006:118:1381-1389.

23.Hoehner CM, Brennan Ramirez LK, Elliott MB, Handy SL, Brownson RC.

Perceived and objective environmental measures and physical activity among urban adults. Am J Prev Med. 2005;28:105-16.

24. Duncan M, Mummery K. Psychosocial and environmental factors associated

with physical activity among city dwellers in regional Queensland. Prev Med. 2005;40:363-72.

25. Hillsdon M, Panter J, Foster C, Jones A. The relationship between access and quality of urban green space with population physical activity. Public Health 2006;120:1127-1132.

26. Office of Deputy Prime Minister (2004), The English Indices of Deprivation 2004, London Stationery Office.

27. http://www.statistics.gov.uk/geography/soa.asp

28. Mowen A, Orsega-Smith E, Payne L, Ainsworth B, Godbey G. The role of park proximity and social support in shaping park visitation, physical activity and perceived health among older adults. Journal of Physical Activity and Health 2007;4:167-179.

29. Nielsen TS, Hansen KB. Do green areas affect health? Results from a Danish survey on the use of green space and health indicators. Health and Place 2007;13:839-850.

30. Deshpande AD, Lovegreen SL, Baker EA, Brownson RC. Environmental correlates of physical activity among individuals with diabetes in the rural Midwest. Diabetes Care 2005;28:1012-1018.

31. Addy CL, Wilson DK, Kirtland KA, Ainsworth BE, Sharpe P, Kimsey D. Associations of perceived social and physical environmental supports with physical activity and walking behaviour. American Journal of Public Health 2004;94:440-443.

32. Kaczynski AT, Henderson KA. Environmental correlates of physical activity: a review of evidence about parks and recreation. Leisure Sciences 2007;29:315-354.

33. Macintyre S, Macdonald L, Ellaway A. Lack of agreement between measured and self-reported distance from public green parks in Glasgow, Scotland. International Journal of Behavioural Nutrition and Physical Activity 2008;5:26-XXXXX

34.UK Government. Select Committee report on public walks 1833. Shannon: Irish University Press.

Study 2 Objectively measured green space access, green space use, physical activity and overweight

1. Introduction

Despite the well recognised health benefits of regular physical activity and its role in reducing obesity, many people fail to achieve recommended activity levels. Currently, only 37% of men and 24% of women in England and Wales meet the Chief Medical Officer's guidelines of 30 minutes of moderate exercise at least five days a week (Department of Health, 2005). Furthermore, over 25% of adult men and women are currently obese or overweight in the UK, for which physical inactivity is a well established risk factor (Hu, Li, Colditz, Willett, & Manson, 2003). These figures are predicted to rise to over 50% in 2050 if current trends continue (Butland, Jebb, Kopelman, McPherson, Thomas, Mardell, et al., 2007). In order to identify appropriate interventions to promote more active lifestyles, it is important to gain a comprehensive understanding of the factors that influence activity levels.

There is increasing evidence that the environment may play a role in influencing physical activity levels (Jones, Bentham, Foster, Hillsdon, & Panter, 2007). In particular, recent research has suggested that the provision of open spaces, such as parks and other green spaces, for recreation may provide an important health resource (Macintyre, Macdonald, & Ellaway, 2008), especially in urban areas where gaining access to the open countryside can be difficult (Maas, Verheij, Spreeuwenberg, & Groenewegen, 2006). Mitchell & Popham (2008), recently highlighted lower levels of circulatory and all-cause mortality amongst English populations with the highest exposures to green space, and a number of recent policy documents have promoted their potential benefits (e.g. CABE, 2004; National Heart Forum, 2007).

Several studies have examined the relationship between distance to green spaces and participation in physical activity. Giles-Corti, Broomhall, Knuiman, Collins, Douglas, Ng, et al. (2005) found that proximity to public open space was associated with higher levels of walking amongst residents in Perth, Australia. However, Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson (2005) found no relationship between living within a 5 minute walk from a green space and meeting physical activity guidelines in the USA, and Hillsdon, Panter, Foster, & Jones (2006) found no relationship between distance to green spaces and self reported leisure time physical activity amongst a cohort of adults in an English city. Studies that have measured the availability of green space within the neighbourhoods of participants, have drawn similarly equivocal conclusions; in the Netherlands, Maas, Verheij, Spreeuwenberg, & Groenewegen (2008) found no association between green space area and physical activity levels in adults, whilst Roemmich, Epstein, Raja, Yin, Robinson, & Winiewicz (2006) identified a strong relationship for children in the USA. Conflicting findings have also emerged from studies that have examined the correlation between green space availability and bodyweight. For example, Potwarka, Kaczynski, & Flack (2008) found no relationship between proximity to parks and overweight in Canadian children, while Nielsen & Hansen (2007) identified a significant association for Danish adults.

Overall, there is some evidence to suggest that improving access to green space in urban areas could provide public health benefits by encouraging greater participation in physical activity and reducing risks for obesity. However, there is a need to better understand the relationships between green space access and health. Many of the studies from which the current research evidence is

drawn suffer from a number of key limitations. Firstly, research findings have often been based solely on the perceived accessibility of green spaces, whilst perceptions have recently been shown not to correlate well with objective measures (Macintyre et al., 2008). Secondly, several studies have been limited by the lack of a comprehensive database on publicly accessible green space locations and hence have been unable to measure the actual opportunities for green space use amongst their participants. Thirdly, few researchers have been able to capture information on the attributes of green spaces and in particular, the types of activity that each may be particularly suitable for. Fourthly, the health related outcomes measured by many studies, for example overall moderate to vigorous physical activity, lack specificity and may only weakly be expected to be associated with green space use. Finally, very few studies have recorded the frequency with which participants actually make use of the green spaces in their area.

This study aims to provide new evidence on the association between objectively measured access to green space, frequency of green space use, physical activity levels, and the probability of being overweight or obese by combining information from the Bristol Quality of Life in your Neighbourhood Survey, undertaken amongst a large sample of adults from the city of Bristol, UK with a comprehensive database of green space locations and characteristics within the city.

2. Methods

2.1 The survey

The data for this study were derived from a large-scale postal survey of a representative sample of adults in Bristol, UK, in 2005. The Quality of Life in your Neighbourhood Survey is an annual cross sectional postal questionnaire survey, undertaken by Bristol City Council, to facilitate sustainable planning within Bristol. The survey includes information on residents' perceptions and opinions about their local community, their lifestyle, health, and also some personal details including their home postcode. The survey study population was selected from the 393,900 adults resident in Bristol (Bristol City Council, 2005) using a single-stage sampling frame. The total population was stratified by the 35 electoral wards (medium sized census tracts) in Bristol, representing a mix of urban areas and suburbs, and including affluent and more deprived areas. Three hundred and eighty people were randomly selected from the electoral register within each ward. Wards with high levels of deprivation tend to have a lower response rate and so a further 570 people were selected from the 12 most deprived areas, to provide a total sample of 20,140 individuals. Each person was sent a questionnaire to complete and return by post, and there was one postal reminder which included a duplicate questionnaire. Overall there were 6,821 respondents, equating to a response rate of 34%. The sample had similar socio-demographic characteristics to the overall population estimates from the 2001 census of Bristol (Bristol City Council, 2005).

2.2 Dependent variables

Survey respondents were requested to state their frequency of green space use and of participation in sport and moderate physical activity (e.g. brisk walking, gardening, heavy housework or DIY). They were also asked to report their and height and weight, and these were used to calculate their Body Mass Index (BMI). Three main outcomes were examined in this study: (i) the frequency with which visits were made to green space, (ii) the probability of achieving the Chief Medical Officer's guidelines for physical activity, and (iii) the likelihood of being overweight or obese (a BMI of 25 or greater).

Frequency of visits to green space was recorded on a 5-point scale, which ranged from "5 times a week or more" to "less than once a year". For outcome (i), this scale was collapsed into a

dichotomous variable where respondents were coded as “1” if they visited a green space at least once a week and “0” otherwise. For the computation of outcome (ii), self reported frequency of participation in sport and moderate activity was each recorded on an 8-point scale, which ranged from “5 times a week or more” to “never”. For analysis, the two measures were combined to produce a single variable which was coded as “1” where respondents participated in either sport or moderate physical activity at least 5 times a week and “0” otherwise.

2.3 Independent variables

Respondent characteristics

Information on age, gender, and self rated health, which was rated as ‘good’, ‘fairly good’, or ‘not good’, was obtained from the questionnaire. Respondent’s individual socioeconomic position was derived from their education level and employment status. The survey recorded highest education level attained and this was used to group respondents according to whether they had no qualifications, had completed GCSEs (aged 16), A-levels (aged 18), or a university degree. Employment status was reported as full time employment, part time employment (16 to 30 hours per week), retired, or ‘other’, which included students, those looking after the home or caring for another person with an illness, and the unemployed. These categories were combined to produce a dichotomous variable which was coded as ‘1’ for those in either full or part time employment, or ‘0’ otherwise.

Green space access measures

Respondent’s home locations were mapped using the ArcGIS 9.2 Geographical Information System (GIS) package (ESRI, California). Home locations were identified based on postcodes using the Ordnance Survey Address Point database. The measure of green space accessibility computed in the GIS was the distance along the road network from the residential location of each respondent to the nearest green space of each type considered (Table 2.1).

Table 2.1. Environmental and neighbourhood socio-demographic characteristics examined

Variable group	Variable name	Mean	Min	Max	Data source
Access to green space	Road distance to nearest green space (metres)	334.1	0.0	1682.7	Bristol Green Space Database; OS Meridian
Road density	Road density (length of roads in neighbourhood (km) divided by neighbourhood area (km^2))	11.3	2.7	20.0	OS Meridian
	A-road density (length of A-roads in neighbourhood (km) divided by neighbourhood area (km^2))	0.8	0.0	5.2	
Street connectivity	Number of junctions per km of road	5.0	0.8	7.7	OS Meridian
	Road connectivity (ratio of junctions to cul-de-sacs)	0.9	0.3	1.0	
	Effective walkable area (ratio of actual neighbourhood area (km^2) to potential neighbourhood (km^2))	0.5	0.1	0.8	
Land use	Land use diversity (HHI: measure of the number and area of land uses in each neighbourhood)	2194.6	1281.7	4794.2	OS MasterMap; OS Address Layer 2; CEH Land Cover Map of Great Britain
	Density of buildings (% area of land covered by buildings in each neighbourhood)	17.1	1.5	40.5	
	Percentage of residential buildings in neighbourhood	70.2	0.4	93.3	
	Percentage of commercial buildings in neighbourhood	17.2	0.0	78.1	
Demographic measures	Age structure (% population over 60 years)	20.0	4.5	37.1	2001 UK Census of Population, ODPM
	Ethnicity (% non-white population)	8.3	0.7	44.5	
	Levels of employment (% population unemployed)	3.2	0.7	9.7	
	Home ownership (% population who own their own home)	65.1	19.3	96.1	
	Car ownership (% population who own a car)	46.3	32.5	57.5	
	Levels of active travel (% population who walk or bike to work)	18.5	3.3	55.1	
	Limiting Long-Term Illness (% population with LLTI)	18.9	8.8	37.9	
	Neighbourhood deprivation (IMD score for neighbourhood)	29.0	4.8	65.9	

OS = Ordnance Survey, CEH = Centre for Ecology and Hydrology, ODPM = Office of the Deputy Prime Minister

The locations of all public green spaces within Bristol were mapped using a GIS database of their locations and attributes provided by Bristol City Council. This included details of the area and type of each green space. Green spaces were grouped into five typological categories, broadly based on those described in UK Planning Policy Guidance Note 17 (Department for Communities and Local Government, 2006a). These were: Formal (those with an organised layout and structured path network, and generally well maintained), Informal (those with an informal design and less managed feel), Natural (habitats such as heathland or woodland), Young People's (areas designed for use by children or teenagers), and Sports (areas such as playing fields and tennis courts). Where a green space fell into more than one category, the area of each was delineated separately. The GIS database was cross referenced with high resolution aerial photography of Bristol to ensure that no spaces were omitted or erroneously included. Only spaces of at least 2 hectares in size were included in the analysis, as areas smaller than this were considered unsuitable for use by adults for the purpose of being physically active. Using the Ordnance Survey Meridian database, the shortest path through the road network between each home location and an access point to a qualifying green space was identified, and the length computed. Distances were used rather than vehicle travel times as many visitors to green spaces visit on-foot.

Neighbourhood characteristics

The neighbourhood surrounding each respondent's home was delineated as the area within 800 metres along the road network from that point. This distance equates to an approximate 10 minute walk, and is comparable to that used in other recent research (e.g. Van Dyck, Deforche, Cardon, & De Bourdeaudhuij, 2008; Heinrich, Lee, Suminski, Regan, Reese-Smith, Howard, et al., 2007). A range of neighbourhood characteristics which may independently affect physical activity levels and could also moderate the effect of access to green space were calculated, and are listed in Table 1.

Road density was computed in the GIS by identifying the total length of roads in each respondent's neighbourhood and dividing this by the total neighbourhood area. To provide a measure of traffic density, the density of A-roads, which are the busiest roads in the city, was calculated. Neighbourhoods containing higher densities of A-roads were considered more heavily trafficked.

Several measures of street connectivity, representing the ease of pedestrian movement through each neighbourhood, were also generated. They included the number of junctions per kilometre of road and the ratio of junctions to cul-de-sacs (dead ends). For both of these variables, a high value is assumed to indicate a more connected road network. A measure of the effective walkable area of each neighbourhood was also calculated. This was the ratio of the area of land in the respondent's neighbourhood, delineated using 800m distances along the road network, divided by the total area of land within an 800m straight line radius of their home. Values close to unity represent a more walkable neighbourhood with smaller values representing poorer walkability.

Information on land use in Bristol was derived from Ordnance Survey MasterMap and Centre for Ecology and Hydrology (CEH) Land Cover Map of Great Britain datasets. These provided details of the spatial extent of a variety of land uses including building locations, areas of other built land, roads and pavements, private gardens, farmland, grassland, woodland, and beaches. An indicator of land use diversity was calculated using the Herfindahl-Hirschmann Index (HHI) (see Cowell, 2008). The formula used was $HHI = \Sigma(P*100)^2$, where P is the proportion of each land use in the neighbourhood. The higher the index value, the lower the levels of land use diversity. The density of buildings within neighbourhoods and the types of buildings present (percentage of residential and commercial buildings) were also estimated.

Finally, a range of measures from the 2001 UK Census of Population and the 2004 Index of Multiple Deprivation (IMD) was used to profile the socio-demographic characteristics of neighbourhoods. The IMD scores provide an indicator of material deprivation based on several components including income, employment, health, education, housing, environment, and crime (Office of the Deputy Prime Minister, 2004). High IMD scores indicate high levels of deprivation.

2.4 Statistical analysis

Binary logistic regression was used to examine the relationship between access to green space and the three outcomes studied. Age, gender, socioeconomic status, self rated health, and area deprivation were included within all regression models to account for any confounding effects of these factors. Other variables were added to the models and retained if the relationship they exhibited with the outcome was in the expected direction, and they showed a statistically significant relationship at least at the $p<0.05$ level. Tests for trend across categories were made by fitting the categorical variables as continuous measures and noting the p-value. All analyses were undertaken using the SPSS for Windows software package version 16.

3. Results

3.1 Access to green space

Overall, the majority of respondents had good access to green space, with 55% of people living within 300 metres of one. This is the target distance within which the Government agency Natural England recommends all members of the population should have access to a green space from their home. When access was examined by green space type, disparities became apparent; whilst 30% of respondents lived within 300m of Informal and Natural green spaces, less than 10% lived within 300m of Young People's and Sports green spaces. Mean distances were 2207m for Young People's, 1758m for Formal, 1082m for Sports, 570m for Natural, and 481m for Informal green space types.

Green space use, physical activity and overweight

In total, 31% of respondents reported visiting a green space at least once a week, while 18% visited less than once a year. Overall, 39% of respondents reported achieving the CMO recommended physical activity levels, while 43% were identified as being either overweight or obese.

Table 2.2 shows the odds of visiting a green space at least once a week, achieving physical activity guidelines, and being overweight or obese, by distance to green spaces. All are adjusted for respondent characteristics. The results demonstrate a statistically significant decline in the odds of visiting with increasing distance for all green space types, except for Young People's. The distance decay was particularly strong for Formal green spaces where respondents living in the furthest quartile were approximately 36% less likely to visit weekly compared to those in the nearest. Furthermore, there was a particularly strong and statistically significant decrease in odds of achieving physical activity recommendations and increase in odds of being overweight or obese associated with increasing distance to Formal green space.

Table 2.2. Odds Ratios (ORs) of visiting a green space at least once a week, achieving physical activity guidelines, and being overweight or obese by distance to green space type. All values are adjusted for age, sex, socioeconomic status, self-rated health, and area deprivation. Significance values represent the results from a test of trend across the quartiles of accessibility

Distance measure	Visiting green space at least once a week		Achieving physical activity guidelines		Being overweight or obese	
	OR	95% CI	OR	95% CI	OR	95% CI
All green spaces						
quartile 1 (nearest <100m)	1.00	-	1.00	-	1.00	-
quartile 2	0.87	(0.74-1.01)	0.95	(0.82-1.01)	0.93	(0.80-1.07)
quartile 3	0.79	(0.68-0.92)	1.01	(0.87-1.17)	0.95	(0.82-1.10)
quartile 4 (furthest >500m)	0.64**	(0.55-0.75)	0.95ns	(0.81-1.10)	0.83*	(0.72-0.96)
Formal green spaces						
quartile 1 (nearest <830m)	1.00	-	1.00	-	1.00	-
quartile 2	0.73	(0.63-0.85)	0.87	(0.76-1.01)	1.00	(0.86-1.16)
quartile 3	0.73	(0.63-0.85)	0.72	(0.62-0.84)	1.18	(1.02-1.37)
quartile 4 (furthest >2250m)	0.64**	(0.55-0.75)	0.76**	(0.65-0.88)	1.27**	(1.09-1.47)
Informal green spaces						
quartile 1 (nearest <200m)	1.00	-	1.00	-	1.00	-
quartile 2	0.80	(0.69-0.93)	0.96	(0.82-1.11)	0.95	(0.82-1.10)
quartile 3	0.70	(0.60-0.82)	0.97	(0.83-1.12)	0.96	(0.83-1.11)
quartile 4 (furthest >680m)	0.80**	(0.68-0.93)	0.98 ns	(0.84-1.15)	0.83*	(0.72-0.97)
Natural green spaces						
quartile 1 (nearest <250m)	1.00	-	1.00	-	1.00	-
quartile 2	1.03	(0.88-1.20)	1.04	(0.89-1.20)	1.05	(0.91-1.22)
quartile 3	0.85	(0.73-0.99)	1.04	(0.89-1.20)	0.94	(0.81-1.08)
quartile 4 (furthest >800m)	0.80**	(0.68-0.94)	1.05 ns	(0.91-1.22)	0.97 ns	(0.84-1.13)
Young People's green spaces						
quartile 1 (nearest <1300m)	1.00	-	1.00	-	1.00	-
quartile 2	1.07	(0.92-1.30)	1.06	(0.92-1.23)	0.90	(0.78-1.05)
quartile 3	0.98	(0.84-1.14)	0.91	(0.79-1.06)	0.98	(0.85-1.14)
quartile 4 (furthest >2800m)	0.95 ns	(0.81-1.11)	0.91 ns	(0.78-1.06)	1.06 ns	(0.92-1.23)
Sports green spaces						
quartile 1 (nearest <640m)	1.00	-	1.00	-	1.00	-
quartile 2	0.94	(0.81-1.10)	1.09	(0.94-1.26)	0.96	(0.83-1.11)
quartile 3	0.89	(0.77-1.04)	1.05	(0.91-1.22)	1.09	(0.94-1.26)
quartile 4 (furthest >1470m)	0.87*	(0.74-1.02)	1.10 ns	(0.95-1.28)	0.94 ns	(0.81-1.09)

* p< 0.05, ** p< 0.01, ns = not statistically significant

Table 2.3 shows the direction of effect for those neighbourhood covariates where a statistically significant association with each outcome was identified. The associations for green space use, physical activity and bodyweight are generally in the direction expected with residents of more walkable and less socio-economically deprived neighbourhoods being more likely to visit green spaces, more likely to meet physical activity guidelines, and less likely to be overweight or obese. The associations with A-road density are more counter-intuitive and most likely reflect the higher walkability (e.g. more pavements, fewer cul-de-sacs) of neighbourhoods with many major roads, rather than the effects of heavier traffic flows.

Table 2.3. Direction of effect (+ positive, - negative) for neighbourhood variables exhibiting a statistically significant relationship with each outcome studied. Significance values represent the results from a test of trend across the quartiles of each variable

Independent variable	Visiting green space at least once a week	Achieving physical activity guidelines	Being overweight or obese
Road density	+**	+**	-**
A-road density	+ns	+**	-*
Number of junctions per km road	+**	+**	-**
Ratio of junctions to cul-de-sacs	+*	+**	-ns
Age structure: % population >60 yrs	-**	-**	+**
% Non-white population	+**	+**	-**
% Population who walk/bike to work	+**	+**	-**
% Population with LLTI	-**	-**	+**
Neighbourhood deprivation	-**	-**	+**

* p<0.05, ** p<0.01, ns = not statistically significant

In order to determine the robustness of observed relationships, a further set of models (Table 4) was fitted which controlled for all the neighbourhood characteristics found to be statistically significant in Table 2.3. For brevity only the model for formal green spaces is detailed in Table 2.4 as no statistically significant trends in each of the outcomes were observed for other green space types (all p>0.05). After this adjustment the associations with green space use and physical activity were somewhat attenuated but remained, whilst the trend with bodyweight was no longer apparent.

Table 2.5 shows the association between reported frequencies of green space use and the physical activity and bodyweight outcomes, both unadjusted and adjusted for age, sex, socioeconomic status, self-rated health, area deprivation, and the neighbourhood characteristics from Table 2.3. Unadjusted, there is a strong trend of a declining likelihood of achieving the physical activity recommendations and an increasing likelihood of being obese or overweight associated with less frequent use. After adjustment the trend remains for physical activity but is attenuated for bodyweight.

Table 2.4. Odds ratios for visiting a green space at least once a week, achieving physical activity recommendations, and being overweight or obese, by distance to formal green space. All values are adjusted for age, sex, socioeconomic status, self-rated health, area deprivation, and the neighbourhood variables found to exhibit an association with each outcome. Significance values represent the results from a test of trend across the quartiles of accessibility

Distance to Formal green space	**Visiting green space at least once a week**		**Achieving physical activity guidelines**		**Being overweight or obese**	
	Odds ratio	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
quartile 1 (nearest <830m)	1.00	-	1.00	-	1.00	-
quartile 2	0.73	(0.62-0.85)	0.87	(0.75-1.01)	1.00	(0.86-1.16)
quartile 3	0.81	(0.69-0.96)	0.81	(0.69-0.95)	1.01	(0.85-1.18)
quartile 4 (furthest >2250m)	0.76**	(0.62-0.93)	0.88**	(0.73-1.06)	0.98ns	(0.83-1.20)

* p<0.05, ** p<0.01, ns = not statistically significant

Table 2.5. Odds ratios for achieving physical activity recommendations and overweight or obese, by frequency of reported green space use. Values are adjusted for age, sex, socioeconomic status, self-rated health, area deprivation, and the neighbourhood variables found to exhibit an association with each outcome. Significance values represent the results from a test of trend across the quartiles of accessibility

Independent variable	Achieving physical activity guidelines		Being overweight or obese	
	Odds ratio	95% CI	Odds ratio	95% CI
Unadjusted:				
At least once a week	1.00	-	1.00	-
At least twice a month	0.59	(0.52-0.67)	1.32	(1.17-1.50)
At least once a year	0.50	(0.44-0.57)	1.39	(1.22-1.58)
Less frequently	0.39**	(0.33-0.45)	1.44**	(1.25-1.66)
Adjusted:				
At least once a week	1.00	-	1.00	-
At least twice a month	0.54	(0.47-0.62)	1.30	(1.14-1.49)
At least once a year	0.48	(0.42-0.55)	1.28	(1.12-1.48)
Less frequently	0.45**	(0.38-0.53)	1.05ns	(0.90-1.24)

* p<0.05, ** p<0.01, ns = not statistically significant

4. Discussion

Respondents who lived further from urban green spaces in this study were less likely to visit them than those nearby, and this effect was particularly strong for formal green spaces. Respondents living further from green spaces were also less likely to meet guideline physical activity levels and more likely to be overweight or obese, even after adjustment for the walkability of respondent's neighbourhoods, their socioeconomic status, and area deprivation. Importantly, when the outcomes were examined against frequency of green space use, trends were apparent whereby more frequent green space users were more physical active and less likely to be overweight or obese. The robustness of these associations was tested by controlling for a wide range of neighbourhood characteristics which were hypothesised to potentially be associated with each outcome. Subsequent associations were mostly attenuated but persistent, except for those with bodyweight which generally disappeared. This may reflect the particularly varied nature of the personal, societal, and environmental influences on weight.

The reasons for the apparent importance of formal green spaces warrant some attention. The associations with formal green space use could be artefactual if respondents were more

likely to consider this type of green space when they completed the survey, which asked them to state how often they visited a 'green space or park' but did not define these terms. However, this would not explain our observed associations with the physical activity and bodyweight outcomes. It may be therefore that the attributes of formal green spaces make them particularly suitable for physical activity. They often have a good path network, which provides a basis for a range of activities including walking, cycling and jogging (Kaczynski, Potwarka, & Saelens, 2008), and the presence of paths may also encourage active forms of travel as people may be more inclined to walk or cycle to destinations if they can incorporate a green environment into part of their journey (Giles-Corti et al., 2005). In addition, these spaces are often well maintained and are sometimes lit, and this may improve perceptions of their safety. Finally, the diverse nature of formal green spaces means they tend to offer a suitable environment for a broad range of people, whilst those provided for sport for example are often specialised, housing specific facilities, and are used by a small proportion of the population (Handy & Neimeier, 1997).

Our findings have implications for urban planning. Although UK planning policies such as Planning Policy Statement 3 (Department for Communities and Local Government, 2006b) now stipulate that green spaces should be incorporated into urban planning, there are currently no minimum requirements to ensure these guidelines are sufficiently met. Nevertheless, there have been some recommendations for the level of green space provision that might be appropriate. These suggest that people in urban areas should be able to access a green space of at least 2 hectares in size within 300m or a 5 minute walk of their home (English Nature, 1995). Our results suggest that better provision of green space may encourage greater levels of green space use, which could lead to greater participation in physical activity and help reduce levels of obesity. Our finding of particularly strong associations with access to formal parks suggests that the green spaces should be well maintained and suitable for use by a broad spectrum of the population, both key characteristics of this type of space.

Our study has a number of strengths and weaknesses. One of the strengths was the large sample size of almost 7,000 respondents. In addition, the sample purposively included a mix of respondents of different socioeconomic status, being representative of the overall population of Bristol. We had information on actual green space use amongst respondents and detailed information on the provision of green space in the city. We also had details of both the physical activity and bodyweight of respondents. A limitation of the study was that the outcome measures of green space visits, physical activity, and weight were all self reported. Notably, reported physical activity levels were somewhat high compared to overall population estimates, with 39% of our sample reporting undertaking physical activity at least 5 times a week. A further limitation is that the study is cross sectional in nature and hence it is difficult to determine if the relationships we have observed are causal. In particular, it may be that those members of the population who are more active in general choose to reside in areas with better access to green space, in which case the presence of the green spaces may not be encouraging physical activity *per se*. However, it is noteworthy that the relationships were generally apparent after adjustment for both individual and area socio-demographic factors. We also tested their robustness by controlling for a particularly wide variety of neighbourhood measures, and indeed in doing so have most likely over-attenuated the magnitude of some effects. Furthermore, although we had information on the types of green space present in Bristol we did not have detail on the specific features of each. A

valuable extension to this work would be to better understand which features might be acting to encourage physical activity, as this insight could be used to inform the design of new green spaces and the regeneration of existing ones.

5. Conclusion

This study has provided new evidence that good access to urban green spaces is associated with higher use, higher physical activity levels, and a lower likelihood of being overweight or obese. Informal physical activity is an important component of overall activity levels, and provision of facilities such as green spaces which can be used for a wide range of physical activities, has population wide benefits. It is important that supportive environments are available to facilitate active lifestyles, and our findings suggest that green spaces may provide a valuable resource in urban areas.

Study 2 References

Bristol City Council. (2005). *Indicators of the Quality of Life in Bristol*. Bristol City Council, UK, pp.84. Accessed from http://www.bristol.gov.uk/ccm/content/Council-Democracy/Statistics-Census-Information/iqol-2005-report.en (January 2009).

Butland, B., Jebb, S., Kopelman, P., McPherson, K., Thomas, S., Mardell, J., & Parry, V. (2007). *Foresight Tackling Obesities: Future Choices – Project Report*. Department of Innovation Universities and Skills, London, UK.

CABE (Commission for Architecture and the Built Environment). (2004). *Value of Public Space*. CABE, London, UK.

Cowell, F.A. (2008). *Measuring Inequality*. Accessed from http://darp.lse.ac.uk/papersdb/Cowell_measuringinequality3.pdf (January 2009).

Department for Communities and Local Government. (2006a). *Planning Policy Statement 17 (PPS17): Planning for open space, sport and recreation*. Department for Communities and Local Government, London, UK.

Department for Communities and Local Government. (2006b). *Planning Policy Statement 3 (PPS3): Housing*. Department for Communities and Local Government, London, UK.

Department of Health. (2005). *Choosing Activity: A physical activity action plan*. Department of Health, London, UK.

English Nature. (1995). *Accessible natural greenspace in towns and cities: A review of appropriate size and distance criteria*. English Nature Research Report 153. English Nature, Peterborough, UK.

Giles-Corti, B., Broomhall, M.H., Knuiman, M., Collins, C., Douglas, K., Ng, K., Lange, A., & Donovan, R.J. (2005). Increasing Walking: How Important is Distance to, Attractiveness, and Size of Public Open Space? *American Journal of Preventive Medicine*, 28 (2S2), 169-176.

Handy, S., & Neimeier, D. (1997). Measuring accessibility: an exploration of issues and alternatives. *Environmental Planning*, 29, 1175-1194.

Heinrich, K.M., Lee, R.E., Suminski, R.R., Regan, G.R., Reese-Smith, J.Y., Howard, H.H., Haddock, C.K., Carlos-Poston, W.S., & Ahluwalia, J.S. (2007). Associations between the built environment and physical activity in public housing residents. *International Journal of Behaviour Nutrition & Physical Activity*, 4, 56.

Hillsdon, M., Panter, J., Foster, C., & Jones, A. (2006). The relationship between access and quality of urban green space with population physical activity. *Public Health*, 120, 1127-1132.

Hoehner, C.M., Brennan Ramirez, L.K., Elliott, M.B., Handy, S.L., & Brownson, R.C. (2005). Perceived and objective environmental measures and physical activity among urban adults. *American Journal of Preventive Medicine*, 28 (S2), 105-116.

Hu, F.B., Li, T.Y., Colditz, G.A., Willett, W.C., & Manson, J.E. (2003). Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women. *Journal of the American Medical Association*, 289, 1785-1791.

Jones, A.P., Bentham, G., Foster, C., Hillsdon, M., & Panter, J. (2007). *Tackling Obesities: Future Choices - Obesogenic Environments – Evidence Review*. Government Office for Science, London, UK.

Kaczynski, A.T., Potwarka, L.R., & Saelens, B.E. (2008). Association of park size, distance and features with physical activity in neighbourhood parks. *American Journal of Public Health*, 98 (8), 1451-1456.

Maas, J., Verheij, R.A., Groenewegen, P.P., de Vries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: how strong is the relation? *Journal of Epidemiology & Community Health*, 60, 587-592.

Maas, J., Verheij, R.A., Spreeuwenberg, P., & Groenewegen, P.P. (2008). Physical activity as a possible mechanism behind the relationship between green space and health: A multilevel analysis. *BMC Public Health*, 8, 206.

Macintyre, S., Macdonald, L., & Ellaway, A. (2008). Lack of agreement between measured and self-reported distance from public green parks in Glasgow, Scotland. *International Journal of Behavioral Nutrition & Physical Activity*, 5, 26.

Mitchell, R., & Popham, F. (2008). Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet*, 372, 1655-1660.

National Heart Forum. (2007). *Building health: creating and enhancing places for healthy, active lives*. National Heart Forum, London, UK, pp.69.

Nielsen, T.S., & Hansen, K.B. (2007). Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. *Health & Place*, 13, 839-850.

Office of the Deputy Prime Minister. (2004). *The English Indices of Deprivation 2004: Summary (revised)*. Office of the Deputy Prime Minister, London, UK.

Potwarka, L.R., Kaczynski, A.T., & Flack, A.L. (2008). Places to Play: Association of Park Space and Facilities with Healthy Weight Status among Children. *Journal of Community Health*, 33, 344-350.

Roemmich, J.N., Epstein, L.H., Raja, S., Yin, L., Robinson, J., & Winiewicz, D. (2006). Association of access to parks and recreational facilities with the physical activity of young children. *Preventive Medicine*, 43, 437-441.

Van Dyck, D., Deforche, B., Cardon, G., & De Bourdeaudhuij, I. (2008). Neighbourhood walkability and its particular importance for adults with a preference for passive transport. *Health & Place*, 15, 496-504.