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Obesogenic Environments Evidence Review

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EXECUTIVE SUMMARY

Introduction

The term 'obesogenic environment' refers to the role environmental factors may play in determining both nutrition and physical activity. Environmental factors may operate by determining the availability and consumption of different foodstuffs and the levels of physical activity undertaken by populations. This review considers the research evidence regarding the existence of obesogenic environments, placing particular emphasis on evidence from the United Kingdom.

The evidence

Environmental influences on diet may involve access to foods for home consumption from supermarkets, or access to takeaways and restaurants. Evidence from the USA suggests that the availability of high-quality and reasonably priced 'healthy' food is constrained for those who live in low-income neighbourhoods, and that this constraint may be associated with poor diet and obesity. However, similar findings are not consistently observed elsewhere, and a recent high-quality study in the UK found no effect of the introduction of a supermarket in a deprived area. These differences between the USA and elsewhere may reflect factors such as the greater degree of residential segregation based on socioeconomic and racial factors, which could influence patterns of food purchase and consumption.

Studies of the effects of the environment on levels of physical activity can be divided into those that have examined perceived or objective environmental measures. The variables considered by studies of perceived environmental attributes can be grouped into seven categories – safety, availability and access, convenience, local knowledge and satisfaction, urban form, aesthetics, and supportiveness of neighbourhoods. There is no consistent pattern of associations between the categories of environmental perceptions and overall activity. Where studies have stratified their results for gender, they have usually obtained a different association between men and women, but again with no consistent pattern.

The overall pattern of associations for the seven categories of perceived environmental variables and walking is again equivocal, although the majority of studies that have examined the relationship between convenience of local neighbourhoods and walking reported positive associations. The contribution of environmental variables in explaining variation of physical activity or walking is small and less important than sociodemographic variables. The overall quality of the studies is not high. Despite this, the findings of a recent meta-analysis support the conclusion that, in general, various perceptions of the environment have modest yet significant associations with physical activity. However, it may be that these findings are affected by reverse

causality, whereby those already engaging in higher levels of physical activity perceive their environment differently to more sedentary individuals.

Fewer studies have examined the associations of objectively measured environmental variables with physical activity. The environmental variables considered can be classified into five categories – deprivation, availability and access, urban form, aesthetics and quality, and supportiveness). Deprivation and poverty were found to be associated with low levels of leisure-time physical activity in a number of studies. The pattern of associations for most objectively measured environmental variables is equivocal. Research has focused mainly on the relationship between access to particular places and being active, such as beaches and parks, or has used composite measures to describe a supportive neighbourhood for walking. The overall pattern of associations within each category of study is inconsistent, with the exception of those looking at urban design, which have shown a relatively modest but positive association of, for example, high land-use mix and good access to services with higher levels of walking.

Although a large number of studies have examined the association between environmental characteristics and physical activity, relatively few have analysed body mass or obesity as outcomes. Most of this research has focused on measures of urban structure. The general picture from these projects is that residents of highly walkable neighbourhoods are more active and have slightly lower body weights than their counterparts in less walkable neighbourhoods, as do those living in areas with high land-use mix. The only UK study reviewed found that perceptions of social nuisances in the local neighbourhood increased the risks of obesity, while good access to leisure centres and living in a suburban environment reduced the risks. These effects remained after adjustment for self-reported participation in walking, sports and overall physical activity.

Outstanding research questions

There are a number of gaps and limitations in the evidence that arise from this review:

- A reliance on cross-sectional comparisons. Most studies have been based on cross-sectional comparisons, which make it difficult to infer causality. Well-designed studies based on interventions or those that trace a cohort of individuals over time provide stronger evidence with respect to causality and these should be encouraged.

- The problems of confounding. Many environmental and social characteristics vary together. Failure to adequately control for this can lead to residual confounding, whereby apparent associations with environmental components are, in fact, associated with being inadequately controlled for social factors.

The problems of confounding may be serious enough to explain many of the differences reported between the studies discussed in this review.

- Difficulties in defining the obesogenic environment. The majority of individuals function in multiple settings, all of which may influence decisions on food consumption and physical activity. Different types of environmental influences may operate across these multiple domains, encompassing not only physical characteristics but also those associated with social, cultural and policy environments. The research community should focus on the problems of identifying relevant environments and examining associations with alternative environmental definitions.

- Lack of evidence linking environment, physical activity and obesity. Few studies have considered measures of body mass and obesity as outcomes. Changes in activity will not necessarily lead to weight loss or gain. Directly assessing the dual outcomes of physical activity and weight is problematic, not least due to lag times that may be many years in the case of weight if an energy imbalance is small. Nevertheless, such studies would provide additional valuable evidence.

- The lack of UK evidence for environmental determinants of food availability and associated obesity. Although studies from the USA suggest social and racial determinants of food availability, there is only limited evidence of this in the UK. Differences may be due to distinctive social and racial patterns of segregation present in US neighbourhoods. However, many of the published research papers are of poor quality. There is a need to build the evidence base in the UK with high-quality studies examining the effect of interventions that modify food availability in study areas.

- Reliance on self-reported physical activity. Many of the studies reviewed have used self-reported measures of physical activity, where there is the possibility of inaccuracy and bias. There is a need for more studies using objective measurements based on the use of accelerometers and global positioning systems. This will facilitate a greater understanding of the complexity of physical activity, describing what behaviour is occurring, how much movement it produces and the location of that behaviour.

- The lack of evidence on the effects of the environment on overall physical activity levels. Most studies have examined associations between environmental characteristics and a restricted range of physical activity outcomes. These may give a poor guide to effects on overall activity levels, as some activities may displace others. There is therefore a need for more studies that examine the relationship between environmental characteristics and overall activity levels rather than targeted forms of activity.

- Poor reliability, validity and conceptual models. There is a need for improvements in the reliability and validity of environmental measures and the development of better conceptual models to link environmental components with activity and obesity. The use of standardised, reliable measures in multiple studies would help. The conceptual models and theories on which the research presented in this review draw also require refinement.

- The lack of a control group in many intervention studies. Intervention studies can be very powerful for determining causality. However, without a control group, it is impossible to determine how much of any pre/post-intervention difference is due to factors other than the intervention itself. Few studies of environmental interventions have used control groups, and this limits the strength of evidence they provide. Future intervention-based studies should include appropriate control groups.

- Lack of evidence on cost-effectiveness. At present, there is little evidence on the cost-effectiveness of potential changes to the environment that may increase levels of physical activity. Studies need to be undertaken assessing the likely costs and benefits of the most promising interventions.

- Lack of knowledge on the secondary effects of interventions. The secondary effects of environmental characteristics, and, in particular, environmental interventions, have not been well investigated. For example, the segregation of cyclists and pedestrians by the provision of paths and trails away from roads may have activity benefits but may also bring dis-benefits in terms of increased vulnerability to crime. There is a need for studies to consider the potential secondary effects of proposed changes to the environment.

Conclusion

The evidence presented in this review suggests that the environment does influence levels of physical activity and obesity. However, influences of the environment are probably small and mechanisms remain unclear.

An important question is whether the environment exerts its greatest effect among people for whom exercise is already important, who have the confidence to take part in it and who are surrounded by like-minded individuals. At present, there is scant evidence on whether the environment might have different effects on people with contrasting levels of physical activity and body weight. Will modifications to the environment lead to greater physical activity in the sedentary or will the main effects be on those who are already active?

Humans adapt readily to environments that promote sedentary behaviour and poor-quality food choices, and cultures exist where being active or eating 'healthy' foods are not high priorities and where there may be resistance to change. Changes to the environment alone are unlikely to solve the problems of increasing obesity and declining physical activity levels. A better approach is likely to involve complementary strategies addressing individual, social and environmental factors.

CONTENTS

1 INTRODUCTION

1.1 The obesity problem

The prevalence of obesity has trebled in the last 20 years. A recent report produced for the Department of Health found that 65% of males and 56% of females were overweight, and over a third of these individuals were obese.[1] It is estimated that, in 2010, around 6,659,000 men will be obese (increasing from around 4,302,000 in 2003), and 1,230,000 more women will be obese compared to 2003. Obesity is a major contributing cause of diabetes and heart disease, and also increases the likelihood of cancer developing. According to the National Audit Office, by 2010 the cost of treating obesity and related illnesses in England will be £3.5 billion.[2]

Weight gain occurs when energy intake (calories consumed) exceeds total daily energy expenditure for a prolonged period. Total energy expenditure represents the sum of three factors:

a resting energy expenditure to maintain basic body functions (approximately 60% of total daily requirements)
b processing of food (10% of daily requirements)
c non-resting energy expenditure, primarily in the form of physical activity (approximately 30% of total requirements).[3]

Obesity is frequently and mistakenly confused with inadequate levels of physical activity – a separate public health problem.[3] However, the marked rise in obesity levels among the British population is directly due to an increasing imbalance between calories consumed and those expended. So, addressing the problem requires examination of both energy intake (nutrition) and energy expenditure (physical activity).

The idea that the environment may be associated with obesity is not new, with Rimm and White arguing over 25 years ago that obesity was a product of the environment.[4] However, the concept has recently gained considerable prominence in both the research and policy communities. The term 'obesogenic environment' refers to the role environmental factors may play in determining both nutrition and physical activity, and the obesogenicity of an environment has been defined by Swinburn and Figger as 'the sum of influences that the surroundings, opportunities, or conditions of life have on promoting obesity in individuals or populations'.[5] In an earlier work, Swinburn et al. described the environment in terms of 'microenvironments' (e.g. school, workplace, home, neighbourhood), which are influenced by broader 'macroenvironments' (e.g. education and health systems, government policy, and society's attitudes and beliefs).[6] The differential ways in which these environments may influence obesity-promoting behaviour among individuals are not well understood. Nevertheless, obesogenic environments are widely accepted as a driving force behind the escalating obesity epidemic today.[7]

There is evidence that the availability of and access to certain foodstuffs may influence the nutrition of individuals, and in particular that the poor availability of high-quality reasonably priced foods may encourage weight gain due to 'unhealthy' eating practices. As there may be a social gradient in foodstuff provision, and this gradient manifests itself in a varying geography of provision, this can be considered an environmental influence on obesity. An evaluation of the research evidence on environmental determinants of food provision is provided in this review, and readers with a particular interest in this area are also referred to the Foresight short science review on *Food Access and Obesity*.[8] A key focus of the present review, however, is on the area where most research evidence exists: the role of the environment in influencing levels of physical activity and body mass.

In his report, *At Least Five a Week*, the Chief Medical Officer notes that the scientific evidence for the health benefits of physical activity are compelling.[9] The original government target was to see '70% of the population reasonably active (for example, 30 minutes of moderate exercise five times a week)' by 2020.[10] However, the Government has now admitted that this may be unachievable[11] as it requires a significant annual increase in the prevalence of physical activity at this level, estimated at 30% in the Health Survey for England 2003 conducted by the Department for Health. Physical activity can, nevertheless, play an important role in maintaining energy balance. For example, increasing physical activity levels by walking briskly for 1–1.5 miles a day (equivalent to a 15- or 20-minute walk) could offset the estimated net daily caloric imbalance of 100–150 calories.[12] Therefore relatively small changes in physical activity levels may play an important role in the reversal of obesity trends.

1.2 Evidence to link obesity with physical activity

The secular increase in levels of obesity observed in the UK in recent decades is associated with a similar decline in levels of physical activity. Of course, this observation is not proof of causality.[13] Nevertheless, a number of studies published since 2000 provide evidence to directly link obesity and physical activity. Many of these studies report on longitudinal associations between self-reported physical activity and body mass index (BMI) or body weight. They have generally shown that lower physical activity predicts higher subsequent weight gain.[14–16] Although few studies have examined the association between objectively measured physical activity and weight gain, Tataranni et al. reported a positive association between total energy balance at baseline and change in body weight over a four-year period in 92 adults.[17] Ekelund et al. also showed that physical-activity-related energy expenditure predicted increases in fat mass in a cohort of 739 UK adults followed for a five-year period.[18]

Given the body of evidence linking physical activity to weight gain, the question arises as to how interventions may be designed to increase activity levels. Important is the understanding that the current obesity

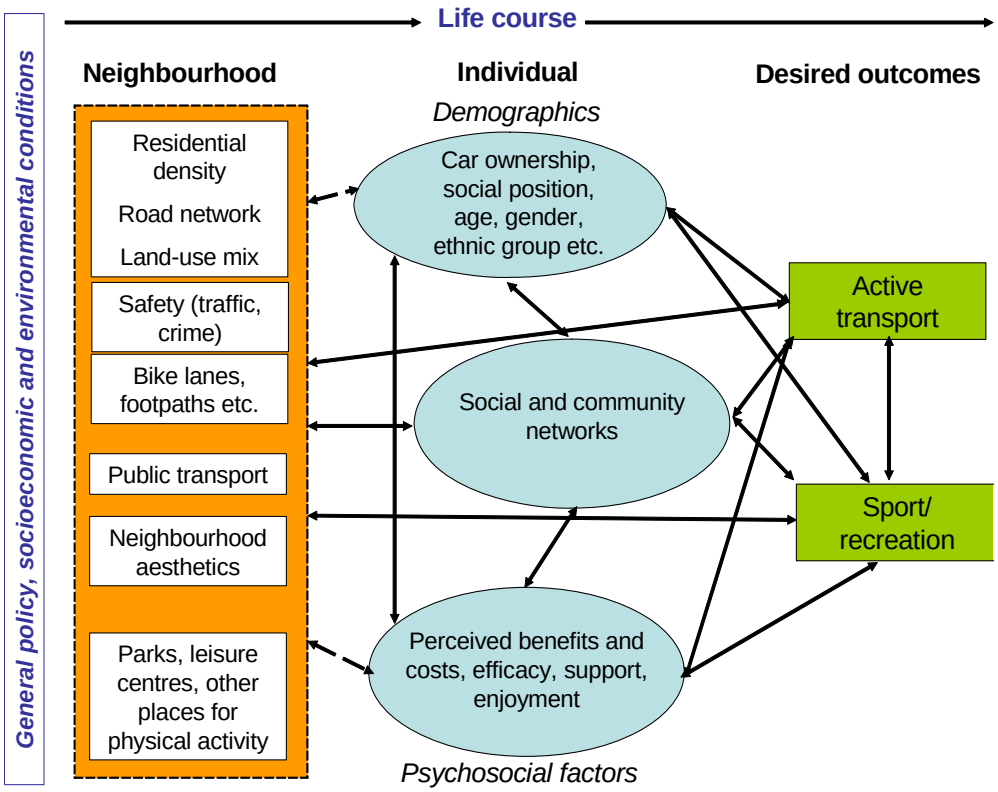
epidemic can be explained by very small, albeit increasing over time, increases in energy intake relative to expenditure. A number of trials have been undertaken with the specific aim of identifying interventions to reduce weight (usually measured by BMI) in adults[19–21] and children.[22–24] Many have involved increasing participants' levels of physical activity, either through education on the benefits of an active lifestyle or via the introduction of a structured activity programme. The results from these trials suggest that interventions may be more effective in adults than in children. However, there is still insufficient evidence on which to base conclusions about which of the approaches are most effective.[13]

Reviews of the evidence of the effects of individual-level interventions[25,26] indicate that, while positive changes in physical activity (typically moderate activity levels (generally walking) among sedentary populations) can be achieved, the effects are quite short-term (for example, <12 weeks when associated with advice from a health professional). It is suggested that larger, more sustainable changes in physical activity are more likely to be achieved by a multi-level strategy combining environmental and individual-level interventions, and in recent years the research focus has moved from individuals to the environment. This is an area in which work to produce a theoretical model has been undertaken.

1.3 A theoretical model of the environmental determinants of physical activity

It has been suggested that an unsupportive environment may play a part in the reduction of community levels of physical activity and has contributed to the rapid rise of obesity levels.[27] Supportive environments have been used, as a part of community interventions, to change and influence behaviours like smoking and sexual health. Using the environment to promote physical activity could contribute to the potential impact of a community intervention.[28] The Department of Health has reflected on the potential contribution of the environment, describing it as playing a key role in making a cultural shift to increase levels of physical activity. From the Sport England review 2005, an evidence-informed model of the potential determinants of physical activity has been proposed (Figure 1).[29]

Figure 1: Evidence-informed model of the potential determinants of sport/physical activity



Key environmental and individual determinants are proposed to interact to achieve two main domains of physical activity, namely transport activity and leisure-time activity. Key elements of neighbourhood variables include parks and other green spaces for physical activity, perceived and actual safety, land use and residential density, the provision of facilities to segregate conflicting road users, and neighbourhood attractiveness. The model proposes, for example, that increasing opportunities and access to physical activity via safe, high-quality green space will be associated with increased physical activity, although the existence of an association and how this is modified by individual variables requires detailed study.

The rest of this review details the current research evidence on the relationship between the environment, obesity and physical activity. Although not specifically excluding children, this review contains little information on the determinants of activity in infants, either in the school environment or elsewhere. Given the high priority that obesity prevention is currently being given in children and adolescents, it is unfortunate that most research in the area of environmental influences on physical activity has focused on adults.[30] In the UK, this dearth of information is in the process of being rectified, and a number of new studies are underway (e.g. CAPABLE at University College London,

SPEEDY at the MRC Epidemiology Unit Cambridge and the University of East Anglia, and Environmental Determinants of Physical Activity and Obesity in Adolescents at the University of Bristol). However, other than two methodological articles in the grey literature from CAPABLE,[31,32] these have all yet to report substantive findings. There is more evidence on the effect of food availability on children, and this is discussed in this review. Nevertheless, it is important to remember the determinants of activity and obesity among infants may be quite different from those in adults and will encompass considerations such as parenting style and school policy. These lie beyond the scope of this review.

Wherever possible, evidence has been taken from literature that is accessible and has undergone a clear process of quality review. Therefore most of the evidence presented here is drawn from peer-reviewed academic journals. Although further 'grey literature' (e.g. unpublished reports to funders, material available on websites, publications produced by non-governmental organisations) exists, it has generally not been included as it does not meet the quality review criteria. This restriction, of course, means that some evidence that has been produced has not been presented in this review.

It is important to note that this is not a systematic review. The evidence has been gathered from a wide variety of sources, including a review of online databases (Medline, CINAHL, EMBASE, AMED, PsychLit, SciSearch, GEOBASE, SIGLE and Sports Discus), the authors' own libraries, and recommendations from colleagues. The inclusion criteria were not as strict as those that may be applied for a systematic review. Nevertheless, the broad criteria used here are given in Table 1 for reference.

Table 1: Inclusion criteria

Study category	**Inclusion criteria**
Studies of food availability and body weight	1 The aim of the study was to examine the relationship between measures of body weight and food availability. 2 The outcome variable was a measure of body weight, which was compared to indicators of food availability in the analysis.
Studies of sociodemographic gradients in food availability	1 The aim of the study was to examine patterns of food availability in relation to gradients in the sociodemographic characteristics of populations.

Studies of perception measures of the environment and physical activity

1 The aim of the study was to examine the relationship between physical activity behaviour(s) and self-reported or perceived aspect(s) of the environment.
2 The physical activity behaviour(s) were examined in relation to the environmental variable(s) in the analysis.

Studies of objective measures of the environment and physical activity

1 The aim of the study was to examine the relationship between physical activity behaviour(s) and objectively measured aspect(s) of the environment.
2 The physical activity behaviour(s) were examined in relation to the environmental variable(s) in the analysis.

Interventions using the environment

1 The aim of the study was (i) to examine the effect on physical activity behaviour when changing any aspect of the environment; (ii) to use a natural or man-made element of the environment as a mechanism to increase physical activity behaviour.
2 Physical activity or physical fitness was the outcome variable.
3 The impact of the environmental change on the outcome variable was compared against a control, non-intervention group or a pre/post measure.

Measures of the environment and body weight

1 The aim of the study was to examine the relationship between measures of body weight and objectively measured or perceived aspect(s) of the environment.
2 The measures of body weight were examined in relation to the environmental variable(s) in the analysis.

The studies discussed in this review use a variety of analytical methodologies and are based on data from different sources and collected in various ways. As some techniques and datasets are more powerful than others, not all studies are of the same quality. Most of the evidence comes from cross-sectional comparisons, where the outcome (e.g. body mass) and hypothesised explanatory factors (e.g. environmental characteristics) are measured at the same time. This study design, while the most common, is relatively weak, as the coincident measurement of hypothesised cause and effect means it is not possible to determine if observed associations are causal or associated with other unmeasured factors. Intervention studies that examine the impact of an intervention to modify the environment are less common but potentially more powerful. However, they should ideally include not just an intervention group but also a control group (i.e. those who were not exposed to the intervention) and measure the

outcome (e.g. body mass) both before and after the intervention. A number of studies with these characteristics are included in this review, although many studies labelled as 'interventions' include no control group and no pre-intervention outcome measure. This makes them no more powerful than cross-sectional studies. It is helpful to keep these quality considerations in mind when interpreting the evidence in this review.

The focus of this review is on the environmental determinants of physical activity (Section 3). The relatively small number of studies that have also included body weight and obesity as an outcome measure are discussed in Section 3.5. The review also considers the literature on the environmental determinants of food availability (Section 2). Taken together these areas cover the wider definition of 'obesogenic environments'. Section 4 summarises the findings from these areas, identifies gaps in knowledge and suggests ways in which they may be filled, while brief conclusions are presented in Section 5.

2 THE ENVIRONMENTAL DETERMINANTS OF FOOD AVAILABILITY

This section discusses the evidence for environmental exposures that may encourage excessive food intake. It draws strongly on evidence presented in a recent high-quality review of research in this field.[33] The environmental influences on diet may involve access to foods for home consumption from supermarkets, or access to takeaways and restaurants, and these two components are considered separately below.

2.1 Access to foods for home consumption

The price and availability of food may mediate the relationship between the environment, diet and obesity. In particular, it could be that the local availability of a range of high-quality foods improves the quality of diets in local populations. For example, recent work by Morland et al. found that the presence of supermarkets in an area was associated with a lower prevalence of obesity.[34] However, there are strong associations between foodstuff provision and deprivation, making it difficult to determine whether any effect of accessibility is causal or due to the confounding influences of deprivation.

Studies in the USA and Canada have generally found that there are between-neighbourhood variations in the price and availability of food, with higher-quality foods being less available and more expensive in poorer communities.[35,36] Racial differences in the location of supermarkets have also been observed, with Zenk et al. reporting that supermarkets were, on average, 1.15 miles further away for residents of predominantly black compared to white neighbourhoods.[37] Another study from the USA found that supermarket provision was poorer in rural compared to urban areas.[38] There is also evidence from the USA that the provision of foodstuffs is associated with consumption. For example, Rose et al. reported a positive association between proximity to a supermarket, fruit and vegetable intake and diet quality among low-income households.[39]

In the UK, the picture regarding social and environmental equalities in foodstuff provision is less clear. Early studies undertaken in the 1980s and early 1990s suggested that similar inequalities existed to those observed in the USA, with high prices and poor availability being associated with area deprivation.[33] However, many of these works were on a small scale. More recent large and empirically robust observational studies have failed to find an independent association between neighbourhood retail food provision, individual diet, and fruit and vegetable intake,[40,41] differences in food price, availability and access to supermarkets between deprived and affluent areas,[42,43] and reasonable availability of a range of 'healthy' foods across contrasting urban areas.[44] Indeed, Pearson et al. reported that age, gender and cultural factors influenced fruit and vegetable intake rather than distance to supermarkets.[41] There are studies from Northern Ireland that have

shown that consumers using their local stores paid higher prices,[45] but there was little evidence that they had difficulty getting to a supermarket.[46]

Although much of the evidence concerning the links between diet and the retail food environment is observational, and can't therefore be used to determine the direction of causality,[33] two studies have evaluated the effects of the introduction of supermarkets on fruit and vegetable intake in deprived communities. In an uncontrolled before/after study set in Leeds, Wrigley et al. found there were some small improvements in fruit and vegetable consumption after supermarket introduction, with larger improvements being observed in individuals initially consuming two or fewer portions per day.[47] However, in a controlled before/after study in Glasgow, Cummins et al. found little evidence of any effect on fruit and vegetable intake overall, or for a 'switchers' subgroup. Fruit and vegetable consumption increased in an area with a new superstore, but notably also increased in a control group, suggesting secular changes in consumption were occurring coincidentally.[48] Unadjusted changes were similar in magnitude to those seen in Leeds, supporting the suspicion that the effects measured in Leeds, without a control group, were confounded by a secular change.

2.2 Access to fast-food outlets and restaurants

Easting out accounts for an average of 7.6% of individual energy intakes.[49] Foods purchased from fast-food outlets and restaurants are up to 65% more energy-dense than the average diet[50] and are associated with lower nutrient intake among consumers.[51] There is evidence that individuals who regularly consume these types of foods are heavier than others, even after controlling for confounding factors.[33]

From the US, Thompson et al. have shown, longitudinally, a relationship between the frequency of consumption of food from fast-food restaurants in American girls (aged 8–19 years) and the development of obesity.[52] A number of studies have found an association between area deprivation and the provision of fast-food outlets.[53–55] Provision is generally greater in more deprived areas. For example, in a recent study of the relationship between socioeconomic deprivation and the location of McDonald's fast-food restaurants in England and Scotland, Cummins et al. found that per capita outlet provision was four times higher in the most deprived census output areas compared to the least deprived census output areas.[56] A study by Maddock found that the prevalence of fast-food outlets explained approximately 6% of the variance in obesity levels recorded between residents of American states.[57] However, Simmonds et al. found no relationships between obesity and proximity to take-away outlets for adults in Victoria, Australia.[58] Similarly, no relationship was found by Burdette and Whitaker in Cincinnati USA.[59]

A recent study by Jeffery et al. examined the relationship between access to fast-food restaurants from both home *and* workplace settings

using a telephone survey of 1,033 Minnesota residents. They found eating at fast-food restaurants was positively associated with having children, a high-fat diet and high BMI. It was negatively associated with vegetable consumption and physical activity. However, proximity of fast-food restaurants to home or work was not associated with eating at fast-food restaurants or with BMI.[60]

Given that obesity, once developed, is difficult to treat, factors affecting food choices among children are of particular concern. In a recent study using spatial analysis techniques, Austin et al. found that fast-food restaurants in Chicago had a tendency to be clustered around schools, although the extent to which this is associated with population sociodemographic characteristics was not clear.[61]

Although the providers of food to be consumed outside the home have been implicated as an aspect of the obesogenic environment, they have been also identified as an important venue for initiatives to improve dietary intake, for example, to increase intakes of fruit and vegetables.[7] Here, workplaces and particularly school environments have received considerable attention. Schools are especially important environments that can shape the eating habits of young people, habits that may continue into adulthood.[62] In New Zealand, Carter and Swinburn found that 'less healthy' choices dominated school food sales and concluded that the school food environment was not generally conducive to healthy eating.[63] In the UK, the campaign by television chef Jamie Oliver was one of the driving forces behind the introduction for new nutritional standards in schools in September 2006.[64] Nevertheless, the heavy marketing of energy-dense foods, particularly to children, has been described as one probable factor behind the obesity epidemic.[65] For example, the recent analysis by Lobstein and Dibb of ecological evidence for a link between advertising to children and the risk of overweight in the USA, Australia and eight European countries, including the UK, found a significant positive correlation between the proportion of children overweight and hourly television advertisements for energy-dense micronutrient-rich foods ($r = 0.81$, $p < 0.005$) and a weaker negative correlation with advertisements encouraging healthy diets ($r = -0.56$, $p < 0.10$).[66]

2.3 Conclusion on the evidence for the environmental determinants of food availability

Although evidence from the USA suggests that the availability of high-quality and reasonably priced 'healthy' food is constrained for those who live in low-income neighbourhoods, and that there may be associations between this observation and patterns of poor diet and obesity, similar findings are not consistently observed elsewhere.[33] Indeed, a high-quality UK work by Cummins et al. found no evidence to suggest that the introduction of a supermarket in a deprived area would have an effect on diet.[67] It may be that the environmental processes that explain obesity are different in the USA compared to elsewhere. In particular, residential segregation based on socioeconomic and racial factors may

be greater, and this could influence patterns of food purchase and consumption.[33]

One problem with many of the studies in this field is that they are cross-sectional in design, and it is therefore not possible to determine the direction of causality. Rather than the provision of retail foodstuffs acting as an influence on diet, it may be that economic forces relating to supply and demand are more important, whereby healthier foods are less likely to be provided in areas where there is lower demand for them.

There is good evidence of neighbourhood and environmental influences on diet and obesity in North America, although less evidence for similar influences exists outside the USA. There is need for further high-quality studies, preferably based on interventions, to determine if the cross-sectional associations that have been observed in the USA are causal and also whether similar observations may be made elsewhere.

3 THE ENVIRONMENTAL DETERMINANTS OF PHYSICAL ACTIVITY AND OBESITY

Studies on the relationship between the environment and physical activity form part of an emerging field within the broader discipline of physical activity, sport and exercise science. This can broadly be split into three phases of research. Early studies (in the 1960s) tended to focus on the relationship between physical activity and health outcomes – notably risk of coronary heart disease. Since that time a wealth of research has confirmed the strength of the relationship between physical activity and health, resulting in landmark publications by the Surgeon General in the USA, and the Chief Medical Officer in the UK.[9,68]

The second phase of research tended to focus on assessing the effectiveness of 'interventions' to increase physical activity. Many of these interventions – such as exercise referral schemes or primary-care-based counselling – tended to operate at an individual level. While some of these interventions are effective at increasing exercise in the short term, the effects are small and there are concerns about the long-term effect and overall benefit to public health.[26]

For these reasons, many researchers have turned their attention 'upstream' to look for aspects of the built environment that may promote or discourage physical activity. This is a young field: published papers on the environment and physical activity have only been appearing in the literature in significant numbers since the mid-1990s. It is noteworthy that, in the USA, this issue has been acknowledged as being of such importance that an entire stream of research funding has been directed towards funding studies in environmental and policy correlates of physical activity (e.g. see Active Living By Design, http://www.activelivingbydesign.org).

At present, the majority of the literature in this area is concerned with investigating the relationship between aspects of the environment and participation in physical activity. In the future, it is likely that attention will turn more to intervention studies that attempt to measure the impact of changes in the environment and physical activity.

The studies that have been published to date fall into four categories, according to the methodology adopted:

1. Development of measures of the environment in relationship to physical activity
2. Cross-sectional studies examining the relationship of the perceived environment with physical activity
3. Cross-sectional studies examining the relationship of the objectively measured environment with physical activity
4. Interventions where the environment was used as a part or whole approach to promoting physical activity.

The first category (development of measures) does not encompass the consideration of outcomes (such as physical activity levels) that allow direct linkage to be made with obesogenic environments and these are therefore not considered further here.

3.1 Studies of the relationship between perceptions of the environment and physical activity

A large number of studies have examined the associations between environmental perceptions and physical activity, although few of these have been conducted in the UK. The environmental variables considered can be grouped into seven categories: safety, availability and access, convenience, local knowledge and satisfaction, urban form, aesthetics, supportiveness of neighbourhoods. The majority of studies have been conducted in the USA and Australia. They have examined the associations between an environmental variable (or variables) and either leisure-time physical activity or walking. Leisure-time physical activity is that undertaken outside the work environment and does not, for example, encompass active travel to and from work on foot or by bicycle.

The findings of the studies are discussed below under the categories of environmental variable considered by each. Also discussed are the findings from a recently published meta-analysis on perceived environmental characteristics and physical activity.

3.2.1 Safety

The majority of studies that have examined the relationship between perceived neighbourhood safety or crime and physical activity come from the USA. The large majority have found no association between perceptions of safety and leisure-time physical activity or indeed between perceptions of safety (assessed as a general item) and walking. Safety is defined differently between reports, including perceptions of living in a safe neighbourhood to the perception that there were high levels of crime in the neighbourhood. Very few papers have examined differences in perceptions of safety by gender or age.

One of the largest studies to examine the association between the self-reported safety of the neighbourhood and physical activity sampled 12,767 adults across five US states. It found significant associations between neighbourhood safety and physical inactivity in older adults – aged 65 and over – and in racial and ethnic monitories (after adjusting for race and education). The study reported odds ratios (ORs) for activity. The OR is a measure of effect size. An OR of 1 indicates that the outcome (in this case, being classified as 'active') under study is equally likely in all groups. An OR greater than 1 indicates that the outcome is more likely in the group being examined. And an OR of less than 1 indicates that the outcome is less likely. Older adults were over twice as likely to be active if they reported their neighbourhood was

extremely safe (OR 2.3, 95% CI 1.1–4.7). This was one of the few studies with a large enough sample size to examine the mediating effects of age and race on perceptions.[69] However, King and colleagues did not find any relationship between self-reported neighbourhood safety and physical activity in a sample of 2,912 women (aged 40+).[70] The study did not show any differences in proportions of self-reported crime or fear while walking or jogging between white and ethnic-minority groups using the same rating scale as the study by the Centers for Disease Control and Prevention.[69] This difference in finding might be due to using smaller samples, as the measures and data collection methods were identical for both projects.

A cross-sectional study of a representative sample of 4,157 English adults found that women who reported concerns about safety during daylight were 47% less likely to report any short walks in the four weeks prior to interview compared to women who did not report safety concerns. No such relationships were observed for night-time safety or more frequent walking. Further, there were no observed relationships between men's perceptions of safety and walking.[71]

A number of studies have tried to assess the relative contribution of safety and other environmental variables in explaining variation in physical activity or walking behaviour.[72–74] All these found that safety alone and in combination with other environmental variables explained very little of the overall variance in activity, especially compared to sociodemographic variables. For example, in one of the higher-quality studies, Wilcox et al. examined the individual and environmental correlates of physical activity among 102 rural older women in South Carolina. Physical activity was assessed using the physical activity scale for the elderly (PASE) vehicle, creating a summary variable of overall physical activity. The final regression model found two environmental variables associated with overall physical activity: absence of sidewalks and perceived safety. The authors suggested that environmental variables explained 9.4% of the final variance out of 47.4% for the full model. Sociodemographic variables (age, race, education and marital status and psychological variables) contributed the rest.[73]

Brownson et al. reported that a fear of crime was only weakly associated with lower activity levels in a cross-sectional study of US adults.[75] Addy et al. examined the association between the provision of street lighting in a neighbourhood and trust of neighbours against overall physical activity and walking behaviour among a sample of 1,194 residents of southern USA counties.[76] They found that these two factors were associated with higher levels of physical activity overall, but not with higher levels of walking. Other studies found that, even if an adult reported feeling unsafe or high levels of crime in their local neighbourhood, they tended to report similar or higher levels of walking. For example, Ross examined the relationships between the self-reported safety of the local environment and walking in a sample of

2,482 urban USA adults. She found that there were paradoxical relationships between perceptions of neighbourhood safety and their walking behaviour. Residents in poorer neighbourhoods had greater perceptions of fear but walked more than residents in more affluent neighbourhoods.[77] This may be due to the geographical location of poorer neighbourhoods found nearer to central city areas. Furthermore, there was no data on car ownership. In Alberta, Canada, Garcia-Bengoecha et al. reported that women were more likely than men to perceive their neighbourhood as being unsafe for walking at night, but this was not associated with lower levels of the activity.[78] Among a sample of 577 residents aged 65 and above in Portland, Oregon Li et al. found that perceptions of safety were positively related to walking activity.[79] In a cross-sectional study of 474 adult residents of a mid-western US area, women who reported average safety levels compared to low levels were more likely to walk for exercise or walk a dog. The association was not observed in men.[80]

In one of the few studies to have been undertaken outside the USA, Shenassa et al. examined the association between perceived safety of neighbourhoods and the likelihood of exercise among residents of eight European cities, none of which were in the UK.[81] The study used data from a survey of 5,700 individuals conducted by the World Health Organisation. Among women, perception of a safe environment was associated with a 22% elevation in the odds of occasional exercise, and a 40% elevation in the odds of frequent exercise. In men, there was a 39% elevation in the odds of occasional exercise, but no association with frequent exercise after adjustment for confounding. In a second European study of 3,499 older adults – aged 75–76 years – residing in Oslo, Norway, perceptions of the safety of walking alone in the evening were associated with physical activity in women but not men. The association remained after adjusting for potential confounders.[82]

One recent study considered the association between perceptions of neighbourhood crime and physical activity in the UK. Harrison et al. examined the association between neighbourhood perceptions and self-reported physical activity among 15,461 adults living in north-west England. They found that people who felt safe in their neighbourhood were more likely to be physically active, but no associations were detected for perceptions of problems from vandalism, assaults, muggings or actual experiences of crime. The authors calculated population-attributable risks, which assume that the relationship between perceptions and activity are causal, in order to estimate that the number of physically active people in the sample would increase by 3,290 if feelings of being 'unsafe' during the day were removed, and by 11,237 if feelings of being 'unsafe' during the night were removed.[83]

A limited number of studies have reported a positive association between perceived safety and crime and levels of physical activity. No study has reported a negative association between feeling unsafe and walking. Most reports were small in sample size and did not examine

any mediating effects of gender on physical activity. One explanation for this could be that they used measures of the safety that were not specific to physical activity, and this approach might not allow adults to report the direct influence of their perceptions while walking in their local neighbourhoods. Ideally, a perception measure of the environment should refer to a specific physical activity.

3.2.2 Availability and access

Availability and access is defined here as any perception of the local built or natural environment that might encourage or support physical activity, for example, an opportunity to exercise. Examples may be perceived distance to facilities, or perceptions of the number of places to exercise in a neighbourhood. The different types of exercise facilities considered in the research literature include unspecified indoor or outdoor, indoor only, outdoor only, walking/jogging trails, streets, parks, school athletic tracks, footpaths, shopping malls, indoor gyms, treadmills and exercise equipment at home. The majority of studies have performed an analysis of the association of perceptions of availability or accessibility of different types of local exercise facilities with leisure-time physical activity. The results of these show no consistent pattern of associations between these variables and physical activity or with walking, although some have reported positive associations between single-availability/single-access items and physical activity.[84–88] Studies tend to create summary variables for perceptions of access with other categories like convenience or aesthetics.

De Bourdeaudhuij et al. reported that, for men and women, the presence of exercise equipment at home and convenience of physical activity facilities were positively correlated with vigorous physical activity. They found that sociodemographic variables like education, age and children in the home made a greater contribution to their regression models for all physical activity behaviours than environmental variables.[87] The authors did not adjust their results for these confounding variables, so it is difficult to assess the independent impact of environmental variables. Their adult sample was highly educated, with over 50% having university-education level, and this possible bias might be reflected in the types of homes and neighbourhood environments of the sample.

Huston et al. reported that adults who perceived they had access to places for physical activity were more likely to report any physical activity than adults who reported no access (OR 2.23, 95% CI 1.44–3.44). In addition, adults who perceived they had access to walking trails (OR 1.51, 95% CI 1.00–2.28) and access to places for physical activity (OR 2.15, 95% CI 1.23–3.77) were also more likely to report any physical activity compared to other adults who reported no activity in the past month. Their final regression models were adjusted for sex, age, race and education, but not for car ownership.[88]

Hoehner et al. carried out a cross-sectional study in high- and low-income study areas among census tracts in St Louis (deemed to be a 'low-walkable' city), and Savannah, Georgia (classed as 'high-walkable'). A telephone survey of 1,068 adults provided measures of the perceived environment and physical activity behaviours. Objective measures were collected through environmental audits of all street segments, including land use and recreational facilities, based on 400 m 'buffer' zones. Associations were examined between neighbourhood features and transportation and recreation-based activity. The authors reported negative relationships: those living further than 600 m from parkland were more likely to be physically active, and those who deemed the connectivity (i.e. how easy it is to walk between two points in a neighbourhood using pavements) of parkland to be 'unacceptable' were more likely to be physically active at recommended levels.[89]

A cross-sectional study of a representative sample of 4,157 English adults found no significant associations between reports of a green space or leisure centre within walking distance of home and self-reported walking in men or women.[71] However, a further cross-sectional study of 16,230 adults from each of the member states of the European Union found that, in unadjusted analysis, those reporting higher levels of physical activity were more likely to agree with a statement that the area they lived in offered many opportunities to be physically active compared to less active respondents.[90]

3.2.3 Convenience

Convenience overlaps with perceived access and availability, but it also adds a dimension of willingness to use the exercise or physical activity facility. It may measure, for example, how easily somebody may fit a visit to the park into their daily routine. The results from the published research in this field are generally similar to those for access and availability. Studies that use a summary measure of convenience have shown no consistent pattern of associations with physical activity. There has been, however, a more consistent pattern of studies reporting positive associations between perceived convenience variables and walking. A longitudinal study examined the self-reported environmental barriers (including neighbourhood convenience) and physical activity status of a random sample of 2,053 USA adults.[72,84] The aim of the work was to identify possible environmental predictors of moderate and vigorous physical activity. Those in the sample were re-surveyed at a second time point (24 months from initial survey), again measuring the same self-reports of convenience with 1,939 adults.[91] At baseline, the authors reported that low self-reported environmental barriers appeared to correlate with vigorous physical activity.[84] At follow-up, they found a positive association between perceptions of neighbourhood convenience and adoption of vigorous activity in men only,[92] and a strong predictive association between perceptions of convenience of facilities and levels of walking.[91] This study developed a summary measure of environmental convenience and found positive associations

between self-reports of convenience and moderate and vigorous physical activities. The measure of convenience of local facilities was a summary variable derived from a scale system, using 15 different items. It is difficult to separate the overall contribution of each item to this summary variable, as the individual scores for each variable were not reported.

3.2.4 Convenience, local knowledge and satisfaction

MacDougall et al. examined the association of satisfaction, assessed by scale responses to items for access, proximity and quality of local exercise, parks and recreation facilities, with low or moderate levels of physical activity among a sample of adults in Australia. The study found that high dissatisfaction scores were only associated with the lowest-activity groups, but there was no effect for convenience.[93]

3.2.5 Convenience and aesthetics

In another Australian study, Ball et al. examined the relationship between perceived environment variables and walking, and found a positive association between a summary environmental variable for convenience and aesthetics and walking for health among 3,392 adults.[94] Using a similar survey approach, a study by Carnegie et al. of 1,200 older Australian adults (aged 40–60) used confirmatory factor analysis to construct summary variables for aesthetics and practical convenience of the environment.[95] This study found that safety of walking in the day but not at night was part of a summary 'aesthetics' factor explaining walking behaviours, which included three other variables: attractiveness, friendliness, and pleasantness of the environment. Other important variables for convenience included access to shops and a local beach/park.

Among a small sample of 399 participants surveyed by mail in the USA, Humpel et al. found that men with the most positive perceptions of neighbourhood 'aesthetics' were significantly more likely (OR 7.4, $p < 0.05$) to be in the highest category of neighbourhood walking and walking for exercise (OR 3.86, $p < 0.05$), but showed no elevated levels of social walking or walking to get to places.[96] Surprisingly, no associations were observed for women, which raises the question as to whether the findings were influenced by the small sample of men (only 170).

3.2.6 Measures of urban form

Urban form is defined as particular attributes of the neighbourhood related to its structure and connectivity.[97] These characteristics include residential density, land-use mix, connectivity, and neighbourhood character. Two studies have examined the association between aspects of urban form including components of perception and physical activity.[87,97] No clear or consistent relationship emerged from either work.

De Bourdeaudhuij et al. found that self-reported leisure-time physical activity and vigorous physical activity were not associated with residential density or land use. They reported that land-use mix (access to shops) was positively associated with recommended levels of leisure-time physical activity and walking for exercise for women only.[87] Saelens et al. constructed a summary variable for neighbourhood walkability. They merged data on perceptions, including residential density, land use, aesthetics, walking/cycling facilities, safety and crime, and characterised neighbourhoods as having high or low walkability. They reported that highly walkable neighbourhoods were not associated with leisure-time physical activity either as leisure-time physical activity assessed by data from a movement measuring motion sensor or as walking for exercise. They found the only positive association was between moderate physical activity and one high-scoring walkable neighbourhood.[97] This paper by Saelens et al. exemplifies the merging of multiple perception variables, but this approach could mask possible relationships between individual variables and physical activity. Their study did not test for any differences in perception by gender or age. It also used a small sample of residents of San Diego (107 adults from two neighbourhoods).

3.2.7 Supportive neighbourhood

The concept of a supportive neighbourhood environment for physical activity or walking is an obvious development from examining the relationships of different categories of environmental variables. Combinations of different components of the environment could make it more attractive to physical activity (because of the effect of the sum of its parts, rather than the parts alone). This view would be supported by ecological and social cognitive psychological theories of the environment interacting with and reinforcing physical activity behaviour. However, there is no strong evidence of consistent positive associations between summary variables for a supportive neighbourhood and leisure-time physical activity.[80,85,98–100]

A limited number of studies have reported a positive association between a summary supportive neighbourhood score and walking. Giles-Corti and Donovan examined the relationship between perceived spatial access to recreation facilities and relative affluence of the local area using area socioeconomic status (SES) indices. The likelihood of perceiving that a park was within walking distance was 50% less for adults living in the lowest SES areas. Adults living in low SES areas were also less likely than adults living in high SES areas to perceive that their neighbourhood was attractive, safe and interesting for walking. They were more likely to perceive that their neighbourhood had lots of traffic and busy roads. Adults who perceived that their neighbourhoods had sidewalks and shops within walking distance were more likely to walk for transport (sidewalks: OR 1.65, 95% CI 1.12–2.41; shops: OR 3.00, 95% CI 2.04–4.40). Adults who perceived their neighbourhoods were safe, attractive and had interesting walks were more likely to walk for recreation (OR 1.49, 95% CI 1.14–1.96) and were more likely to

walk at a recommended level (OR 1.50, 95% CI 1.08–2.09). All models were adjusted for age, sex, number of children under 18 years at home, education, household income and work status, but not for access to a motor vehicle. This is important as no access to a car for personal use was associated both with walking for transport (OR 4.13, 95% CI 2.65–6.46) and walking for 150 minutes per week (OR 2.87, 95% CI 1.96–4.21).[98]

Sharpe et al. examined the association between whether or not recommended levels of moderate or vigorous physical activity were met and a range of perceived measures of neighbourhood supportiveness among 1,936 US adults. They found that unadjusted odds for meeting recommendations were significantly greater for residents reporting well-maintained sidewalks and the presence of safe areas for exercise in their neighbourhood. The relationship with sidewalk quality remained after adjustment for age, gender, race and education.[101] Suminski et al. examined the association between walking and a measure of neighbourhood functionality, computed using perceptions related to the construction/integrity of neighbourhood sidewalks and streets.[80] No associations were observed for women, and men were actually less likely to walk for transportation (OR 0.22, 95% CI 0.06–0.89) if the functional characteristics of the neighbourhood were average versus below average.

3.2.8 Consideration of the role of perceived environmental characteristics by meta-analysis

The volume of research in the field of perceived environment and physical activity is now such that it is possible to apply quantitative meta-analytical techniques to calculate summaries of associations between selected environmental characteristics and activity. A meta-analysis combines the results of several studies that address a set of related research hypotheses. In a recently published article, Duncan et al. examined correlates of activity among 16 studies that met a set of inclusion criteria. The work is noteworthy in that it is the first published meta-analysis in this field. No significant associations emerged between environmental characteristics and physical activity using crude ORs. The perceived presence of physical activity facilities (OR 1.20, 95% CI 1.06–1.34), sidewalks (OR 1.23, 95% CI 1.13–1.32), shops and services (OR 1.30, 95% CI 1.14–1.46) and perceiving traffic not to be a problem (OR 1.22, 95% CI 1.08–1.37) were positively associated with physical activity after adjustment. Variance in physical activity accounted for by significant associations was generally small, ranging from 4% (heavy traffic not a problem) to 7% (presence of shops and services).[102]

3.2.9 Summary of evidence from studies that have examined the relationship between perceptions of the environment and physical activity

There is no consistent pattern of associations between the categories of environmental perceptions and leisure-time physical activity. In cases where studies stratified their results for gender, they usually obtained a different association between men and women, but, again, with no consistent pattern of results in any one category of environment variable. The overall pattern of associations between seven categories of environmental variables and walking was again equivocal, but there were two differences to the pattern of results for leisure-time physical activity. First, there appeared to be a difference in associations by gender, and, second, two categories of environmental perceptions, safety (measured as a single item) and convenience, had more consistent patterns of positive associations. The majority of studies that examined the relationship between the convenience of the local neighbourhood and walking reported positive associations. Surprisingly, the studies reported no associations between perceptions of safety (assessed as a general item) and walking.

The studies use a mixture of analysis of single environmental variables and summary environment perception variables. The contribution of environmental variables in explaining overall variance of physical activity or walking is generally small and less important than sociodemographic variables. The overall quality of the studies is not high and they use a plethora of measures of physical activity and environmental perceptions, making it difficult to generalise the findings. Nevertheless, the findings of the meta-analysis conducted by Duncan et al.[102] support the suggestions from the other literature reviewed that, in general, various perceptions of the environment have a modest yet significant association with physical activity. However, it may be that these findings are affected by reverse causality, whereby those already engaging in higher levels of physical activity perceive their environment differently to more sedentary individuals.

3.3 Studies of the relationship between objective measures of the environment and physical activity

Compared to studies of perceptions, fewer works have examined the associations between objectively measured environmental variables and physical activity. The majority have been conducted in the USA, Australia, and Canada, with little from the UK. The reports have examined the associations between an environmental variable and either leisure-time physical activity or walking. Environmental variables are diverse and typically derived from one or a combination of three data sources: (i) audit or observations of the environment; (ii) secondary data e.g. public or written records or census data; and (iii) geographical information systems (GIS). These environmental variables can be classified into one of five categories: deprivation, availability and access, urban form, aesthetics and quality, and supportiveness.

3.3.1 Deprivation

Studies from the USA, Australia, Europe and the UK have examined the relationship between deprivation of a local area or neighbourhood and physical activity. They used widely available secondary data. Most used census data to define deprivation based on a predetermined set of variables. The studies generally assigned a deprivation score to their sample living within that particular area[103,104] and then examined the association between this score and the individuals' physical activity.

A consistent pattern of associations is generally apparent for these studies. Adults who are living in areas of high deprivation have a decreased likelihood of reporting any leisure-time physical activity. For example, a Swedish study of 9,240 adults living in 8,519 residential areas examined the relationship between area deprivation and cardiovascular risk factors, including physical activity. Residents living in the most deprived neighbourhoods were more likely to report 'almost no physical activity' compared to residents in more affluent neighbourhoods. The results remained after adjustment for personal socioeconomic position.[104] In a UK study, MacIntyre and Ellaway found that adults from a deprived ward of Glasgow were less than half as likely to report doing sport (OR 0.49) than adults who lived in more affluent wards.[103] However, this result may be limited by the potential bias of the sample (recruited opportunistically) and the crude outcome measure of physical activity (single item).

A number of studies, including MacIntyre and Ellaway,[103] have also examined the relationship between area deprivation and walking.[77,105] Both Ross and MacIntyre and Ellaway reported a positive association between deprivation and higher levels of walking.[77,103] Giles-Corti and Donovan found no association of area measure of deprivation with walking at recommended levels and walking for recreation or with walking for transport.[105]

Van Lenthe et al. investigated the association between neighbourhood socioeconomic environment and physical activity (walking/cycling to shops or work, walking/cycling and gardening in leisure time and participation in sports activities). Characteristics of the environment considered were proximity to food shops, physical design of the neighbourhoods, quality of green facilities, noise/pollution from traffic and need for law enforcement. People in the most disadvantaged neighbourhoods were more likely to walk/cycle to shops and work, less likely to walk, cycle or do gardening in their leisure time, and less likely to participate in sports activities. While walking and cycling to work/shops was not influenced by environmental characteristics, the likelihood of being physically active in leisure time was mediated by the general physical design of the different neighbourhoods and noise/pollution by traffic.[106] A study of 20 local government areas in Melbourne, Australia, found that residents living in the most deprived neighbourhoods were less likely to jog or be active at recommended levels, even after controlling for individual socioeconomic status.

Swimming and cycling rates were not associated with area socioeconomic status.[107]

3.3.2 Availability and access

Availability and access are defined as any aspect of the environment that might encourage or support physical activity (e.g. sports centres, public or private exercise facilities, public parks and beaches). There no high-quality studies from the UK and most of the data comes from Australia. Early studies examining availability and access involved environmental variables created from secondary data sets. GIS methods have allowed researchers to examine in greater detail the relationship between the environment (individual and summary variables for availability and access) and physical activity. Overall, studies that have examined the relationship of access or availability with leisure-time physical activity have consistently found no significant associations in their results, with the exception of one variable – coastal proximity. There is an inconsistent pattern of results for studies examining associations between availability and access and walking.

One early study by Sallis et al. typifies the use of secondary data to create environmental accessibility measures for different types of physical activity facilities. It examined the effect of access to built facilities on self-reported physical activity. A random sample of 2,053 San Diego adults were surveyed about their physical activity. In the survey area, the researchers classified 385 exercise places into categories of either free or pay facilities by using local directories and maps. The addresses of residents and these exercise facilities were located on a grid map and the researchers calculated the density of free or pay facilities around the residents' home addresses. The study found that vigorously active adults had a greater density of total facilities (free and pay) within 1 km bands of their home residence than the sedentary adults, after adjusting for age, education and income. This association was consistent up to 5 km (in 1 km bands) for pay facilities but not for free facilities.[108]

Bauman et al. examined whether living near to the coast was associated with different levels of physical activity. They surveyed over 16,000 Australian adults and, based on their postcodes, categorised their homes into a coastal (only if their postcode included some part of the coastline) or non-coastal location of residence. After adjusting for other demographic factors, coastal residents were less likely to be sedentary (OR 0.77, 95% CI 0.69–0.87), more likely to report being active enough for health (OR 1.27, 95% CI 1.18–1.37) and more likely to be vigorously active than those inland (OR 1.38, 95% CI 1.25–1.52).[109] One limitation of this study was the classification of residence by postcode area (which included any part of the coast). This approach used a proxy measure of closeness to the coast, rather than testing the relationship of the actual distance of adults' homes to the coast by measured distance. Another limitation was that adjustments were made for sex, age, ethnicity, education and employment, but not income. This

could be an important factor as higher-income people may be more active and more likely to live in coastal regions.

Giles-Corti and Donovan, in their Perth study, tested Bauman's coastal hypothesis[109] with GIS-derived distance indices for each adult rather than a postcode-derived index.[98,105] They used observations of the environment (to create aesthetics data) and GIS-generated distance estimates to create a composite score of the accessibility of different types of physical activity facilities or spaces by distance. These facilities included tennis courts, swimming pools, beaches, parks, golf courses, health clubs and gyms, sports and recreation centres. The variables were combined into either natural or built facilities for physical activity. They found no significant associations between access to built or natural facilities in crude or final models (final models were adjusted for age, sex, number of children under 18 years at home, work outside of home, household income and education). They did find a positive association between a composite score for all environmental items and achieving a recommended level of exercise (OR 1.43, 95% CI 1.09–1.88).[105] They also found that access to the beach, at an individual level, was positively associated with an increased likelihood of exercising vigorously (OR 1.38, 95% CI 1.07–1.79) and with exercising vigorously at the recommended level (OR 1.58, 95% CI 1.14–2.19).[98]

Giles-Corti and Donovan also examined the association of these variables with different types of walking. Adults living in areas with high physical environment summary variable score (attractiveness and access to a beach) had an increased likelihood of walking at a recommended level (>150 minutes' walking per week) (OR 2.13, 95% CI 1.54–2.94) compared to those living in areas in the lowest quartile of access.[98] In their 2003 study, Giles-Corti and Donovan examined the associations between access to attractive open space and walking for recreation and transport, and a total measure of 'walking at recommended levels'. They reported that access to attractive open space was only associated with an increase in likelihood of walking at a recommended level (>150 minutes' walking per week) (OR 1.47, 95% CI 1.00–2.15) compared to the bottom quartile of access.[110] However, their results for both leisure-time physical activity and walking are limited for two reasons: (i) the study was conducted in one suburban Australian city environment; and (ii) the study did not report data relating to the response rate to their physical activity survey nor compare their sample to the overall population. The study may have selected a group of adults that were not representative of the rest of the population.

Troped et al. examined the associations between access barriers and the use of a local cycle path.[100,111] Their work surveyed 413 adults to investigate associations between self-reported and objectively measured physical environment variables and the use of the path in the USA. A GIS was used to map the respondents' homes and overlay other geographical data, contours and traffic density. Self-reported (OR

0.65, 95% CI 0.54–0.79) and objectively measured distance (OR 0.57, 95% CI 0.45–0.73) from home to the cycle path were both associated with a decreased likelihood of using the cycle path. An Australian study by Pikora et al. of neighbourhood environments and walking also examined aspects of the neighbourhood environment (defined as a 400 m radius from the respondent's home) using an instrument developed to capture features likely to be associated with walking and cycling. The proximity of local shops and public transport were associated with walking for transport but not recreation.[112]

Five recent studies have examined the relationship between measures of access to parks and green spaces and achievement of physical activity recommendations,[79,89,113–115] usually taken to be at least five sessions of at least 30 minutes of moderate-intensity physical activity per week. Three of these studies found no relationship between environmental variables such as access to natural facilities or open spaces, or having a park within a five-minute walk and achievement of recommended levels of exercise.[113–115] One study, which analysed a mix of objective and subjective measures of accessibility, found negative associations: those living further than 600 m from parkland were more likely to be physically active and those who reported the connectivity of parkland to be 'unacceptable' were more likely to be physically active at recommended levels.[89] In their study of walking and the built environment in 577 older adults residing in Portland, USA, Li et al. adopted a multi-level design to examine the relationship between both area and personal characteristics with self-reported walking. The authors reported significant associations between the area of green and open space in a neighbourhood and walking level, and between the number of reported recreational facilities and walking level.[79]

3.3.3 Measures of urban form

A limited number of studies have examined the association of a range of variables within the categories of urban or rural home area (assessed by home postal area and census data)[116–118] and urban sprawl,[119] with leisure-time physical activity. The patterns of associations were not consistent across studies. Some studies showed consistently positive associations between aspects of urban design (particularly property density and street connectivity) and walking.[77,79,119–122] These studies are not discussed in detail due to the heterogeneity in their research questions, methods and results and their non-generalisability to the UK. Also important is the caution from Lake and Townshend that one issue that has not clearly emerged from the existing research is whether the mere inconvenience of owning a car in higher-density neighbourhoods, associated with factors such as difficulty and safety of on-street parking, encourages more walking or cycling than urban structure.[7]

3.3.4 Aesthetics and quality

Only a limited number of studies have examined the association of objectively assessed environmental aesthetics and quality with physical activity. In Australia, Giles-Corti and Donovan made an assessment of

aesthetics based on audit data using a composite score including the presence and absence of trees in parks or roads. No association was found between appeal of the environment and physical activity. The authors reported one positive association between access to attractive public open space and walking.[105] More recently, Giles Corti et al. developed an audit tool (POST) to score the attractiveness of public open spaces. They found that residents of Perth with very good access to large, attractive open spaces were 50% more likely to achieve high levels of walking (OR 1.50, 95% CI 1.06–2.13).[114]

A cross-sectional study of 6,919 adults from eight European countries (excluding the UK) found that the level of greenery and vegetation around the home and surrounding environment was associated with the frequency of physical activity.[123] In the only study of its kind in the UK so far, Hillsdon et al. undertook a cross-sectional examination of the relationship between access to quality urban green space and level of recreational physical activity in 4,950 middle-aged (40–70 years) respondents from the European Prospective Investigation into Cancer and Nutrition (EPIC), who resided in Norwich, UK. Three measures of access to open green space were calculated based on distance only, distance and size of green space, and distance, size and quality of green space. There was no evidence of clear relationships between recreational activity and access to green spaces. Non-significant associations were apparent for all variables, and there was no evidence of a clear trend in regression coefficients across quartiles of access for either distance, size-adjusted, or quality- and size-adjusted models. Furthermore, the neighbourhood measures of access to green spaces showed only non-significant associations with recreational physical activity.[124]

3.3.5 Supportive neighbourhood

A limited number of studies have created a summary variable for a supportive neighbourhood using a combination of secondary and GIS variables.

Craig et al. constructed a 'neighbourhood supportive environment score' for walking using 18 different variables for walkability. This score was derived from observations of access to built facilities and natural facilities, parks, beach, streets, using environmental audits conducted by research staff. The study examined the walking for transport behaviour of the residents of 27 different Canadian urban neighbourhoods and their local neighbourhood score. Most of the 18 individual environmental variables were individually correlated with walking, except visual interest and aesthetics. The summary environment score was positively associated with walking to work, after controlling for education, income and area poverty.[125] This study brought together observations of the environment relevant to walking, using the same approach as Giles-Corti and Donovan.[98]

In Giles-Corti and Donovan's 2003 study, the associations between aesthetics and walking and between functional environment score and walking were both not significant. However, the authors reported a positive association between a combined composite variable called the physical environment determinant score (the highest tercile compared to the lowest) and walking at recommended levels.[110] This composite variable included access to public open space (which had an independent positive association with walking), although the combination of variables makes it difficult to identify which were making the greatest contribution. Nevertheless, using a combined variable might reflect the synergistic combination of a supportive environment, as hypothesised by theoretical ecological models of the environmental determinants of physical activity.

The study by Pikora et al., reported earlier, also constructed a combined 'walkability score' based on the presence of features in the local neighbourhood, including safety, aesthetics (cleanliness, green space etc.), function (pavement quality, street width, traffic volume etc.) and density of destinations such as local amenities and parks. Increased 'walkability' was associated with higher odds of walking for recreation and transport (OR 1.29, 95% CI 0.99–1.69; OR 1.95, 95% CI 1.49–2.55) after adjustment for potential confounders.[112]

3.3.6 Summary of evidence from studies examining the relationship between objective measures of the environment and physical activity

Deprivation and poverty were found to be associated with low levels of leisure-time physical activity in a number of studies. By contrast, coastal proximity and access to a beach is positively associated with leisure-time physical activity in two studies. The patterns of associations for other objectively measured environmental variables are equivocal. These variables include access to built facilities, parks and public open spaces and measures of urban form. Fewer studies have examined the associations between objective measures of the environment and walking than leisure-time physical activity. Studies have focused mainly on the relationship between access to particular places to be active, like beaches and parks, or have used composite measures to describe a supportive neighbourhood for walking. The overall pattern of associations within each category of study is inconsistent, with the exception of studies looking at urban design. Most have shown a relatively modest but positive association of different aspects of urban design, in particular high land-use mix and good access to services, with higher levels of walking. Unfortunately, much of this evidence comes from the USA, where urban structure is very different to that found in the UK. These findings are therefore of limited generalisability.

3.4 Studies examining environmental interventions to promote physical activity

While psychological and ecological theories and models demonstrate the possible influences of the environment on physical activity, little is known about the effectiveness of environmental interventions. Nevertheless, a number of studies have been published based around the analysis of interventions and these are discussed in this section.

3.4.1 Studies that made physical changes to the environment

These studies have used a range of different settings, including military bases, factories and local communities. Two studies examined the effectiveness of an environmental and policy-based intervention in military settings[126,127] and one study was undertaken in a workplace setting.[128] Three studies examined the impact of opening and promoting a new cycle path to promote walking and cycling in adults living near or using newly constructed cycle paths.[129–131] In the USA, these are called 'rail trails'. None of these studies were from the UK.

The studies used a combination of approaches to change the physical or policy environment. These included: (i) provision and improvement of sports and exercise facilities; (ii) change to policies to encourage adults to have greater access and time to use new facilities; and (iii) the construction of new local opportunities to walk and cycle using cycling and walking paths.

A number of studies reported a small effect of their interventions in increasing physical activity levels, either as a direct change in self-reported physical activity, cardiovascular fitness or trail usage.[126–128,130,131] Two studies demonstrated that a combination of changes to working practices, policies and the physical environment encouraged adults to maintain their vigorous physical activity and fitness.[126,127] These results were limited in generalisability because they were conducted in a military setting.

Studies that examined the effectiveness of developing of new cycle and walking paths reported some short-term changes in behaviour but the same limits to their generalisability apply. There is evidence that local promotional campaigns to market the path encouraged their use. Use of the cycle paths was mediated by proximity of users to the path (distance from home), concerns about safety and current levels of physical activity. The effect of the paths may have been greater in attracting adults who were already active rather than new exercisers. Further evaluation is needed to assess who uses these facilities, and what the contributions of their use are to overall activity levels.

3.4.2 Strengths and weaknesses of studies that made physical changes to the environment

Many of the studies in this field contain methodological limitations. The main limitations are that only two could compare their effects with a direct control or comparison group.[126,127] External events may have also

played a part in influencing the outcomes of the studies and, without the benefit of a comparison or control group, this potential bias will remain. Examples of this bias include selection bias and measurement bias. The two studies that interviewed trail users on the trails themselves reported high response rates, but using this approach only allowed the researchers to sample the exercise habits of adults who were exercising already. This could give rise to selection bias as the sample contained already-active adults.[129,130] Most studies did not present power calculations to determine sample sizes and so it is difficult to evaluate whether their responses rates were adequate to answer their study questions. They also generally presented limited information on the reliability and validity of the self-reported measures, particularly of reported physical activity related to 'using a trail'.

Few studies controlled for the effects of potential confounding factors such as gender or social position. Other sociodemographic and sociocultural factors may be more important in determining participation and trail usage than merely proximity. The recruitment and selection of participants to the studies also limited the generalisability of these interventions to a UK context. The study participants were generally well educated and white. None of the studies were UK-based. It is not known how well studies conducted in the US and Australia could be transferred to UK settings.

Despite the appeal of changing the environment or providing new opportunities for physical activity (e.g. cycle paths), the evidence base for these approaches in terms of promoting physical activity is small. Some evidence does exist of an effect on physical activity behaviour in the short term, but this evidence base is weakened by the poor quality of study methodology. However, it appears that proximity to different types of physical activity opportunities is a potential variable worthy of further investigation.

3.5 Studies linking environmental measures with body-weight-associated outcomes

Although a large number of studies have examined the association between environmental characteristics and physical activity, a handful have also examined body mass or obesity as an outcome. Of the studies discussed in this section, only one was undertaken in the UK.

In the earliest work to be published, Giles-Corti et al. examined the factors associated with overweight and obesity, measured according to BMI, among 1,803 adult residents of Perth, Western Australia. After adjustment for confounding factors, they found that being overweight was associated with living on a highway (OR 4.24, 95% CI 1.62–11.09), streets with no sidewalks or only one (OR 1.35, 95% CI 1.03–1.78), and perceived lack of paths within walking distance (OR 1.84, 95% CI 1.01–3.36). Poor access to four or more recreational facilities (OR 1.68, 95% CI 1.11–2.55), sidewalks (OR 1.62, 95% CI 0.98–2.68), and perceiving

no shop within walking distance (OR 1.84, 95% CI 1.01–3.36) were associated with obesity.[132]

In their study, predominately designed to test the efficacy of an instrument for measuring neighbourhood walkability, Saelens et al. evaluated the physical activity and weight status of 107 residents in 2 neighbourhoods (one with high walkability and one with low) in San Diego, California. They found that residents in the high-walkability neighbourhood engaged in an average of 52 minutes more of moderate physical activity per week than their low-walkability-neighbourhood counterparts ($p = 0.016$). The mean BMI of residents of the lower-walkability neighbourhoods was marginally higher (27.3 vs 25.4, $p = 0.051$), although the difference was attenuated by the inclusion of participant age and education level ($p = 0.097$). A much greater percentage of residents from the low-walkability neighbourhood met the criteria for being overweight (60.4% vs 35.2%, $p = 0.009$) and this difference remained after adjustment for age and education level ($p = 0.043$).[97]

In another study of urban structure and obesity (BMI >30), Frank et al. reported that a measure of land-use mix was associated with obesity among 10,878 residents of Atlanta USA, with each quartile increase in mix being associated with a 12.2% reduction in the likelihood of obesity ($p <0.001$).[133] Among a small and predominantly Hispanic sample of 452 adults, Rutt et al. also found land-use mix (less residential) was associated with higher BMI ($p = 0.03$).[134]

Using data from the USA Behavioural Risk Factor Surveillance System (BRFSS) for the period 1998–2000, Ewing et al. examined the association between an index of urban sprawl (derived from census and other secondary data), physical activity, BMI, and obesity among 206,992 adults of 448 counties. After controlling for demographic and behavioural covariates, they found that the county-level sprawl index had a small but statistically significant association with minutes walked ($p = 0.004$), obesity ($p <0.001$) and BMI ($p = 0.005$).[119] It is notable that the measure of urban sprawl was crude, and associations at the county level were not all apparent when the data was re-aggregated to metropolitan areas. In a very similar study, Lopez also used data from the BRFSS to examine associations between urban sprawl at the metropolitan level and overweight (BMI 25–30) and obesity (BMI >30). After adjustment for gender, age, race/ethnicity, income and education, the risk for being overweight increased by 0.2% (95% CI 0.06–0.3) and for being obese by 0.5% (95% CI 0.04–0.06) for each 1-point rise in their urban sprawl index (0–100 scale).[135] More recently, Doyle et al. calculated a county-level measure of walkability using data from the block sizes and road intersection counts for a sample of American counties. They compared this with the BMI of respondents to the 1988–1994 National Health and Nutrition Examination Survey. They found that individuals who lived in counties that were more walkable and had lower crime rates tended to have a lower BMI than others ($p = 0.02$).[122]

Catlin et al. measured the association of community perceptions, community infrastructure and worksite infrastructure with being overweight (BMI >25) among a cross-sectional sample of 2,821 adults interviewed by telephone as part of the US Missouri Cardiovascular Disease Survey. After adjustment for demographic and behavioural factors, environmental variables associated with being overweight included negative community perceptions (OR 1.6, 95% CI 1.1–2.3), and the absence of outdoor exercise facilities (OR 1.2, 95% CI 1.0–1.5).[136] Cohen et al. recently examined associations with an aggregated indicator of community efficacy for 807 adolescents in Los Angeles County. After controlling for neighbourhood disadvantage, they found significant relationships between collective efficacy and BMI, overweight and obesity. This was after adjustment for levels of neighbourhood disadvantage.[137] In a preliminary analysis of an ongoing study among 13,637 residents of New York City, Rundle et al. reported that, at the neighbourhood level, increased land-use mix, better access to subway stops, and increased population density were all correlated with lower BMI values.[138]

In the only study conducted in the UK, Poortinga used data from the 2003 Health Survey for England (14,836 participants) to examine the associations between perceptions of the local environment and obesity, self-related health and physical activity. He found that perceptions of social nuisances in the local neighbourhood increased the risks of obesity (BMI >30), with 'teenagers hanging around' (OR 1.25, 95% CI 1.09–1.43) and 'vandalism/damage to property' (OR 1.17, 95% CI 1.01–1.34) both being important. The study also found that good reported access to leisure centres reduced the risk of being obese by 17% (OR 0.83, 95% CI 0.75–0.92). People living in suburbs were 25% more likely to be obese compared to those living in inner urban areas (OR 1.25, 95% CI 1.08–1.44). Importantly, these effects were not attenuated after self-reported participation in walking, sports and overall physical activity were controlled for.[139] This interesting finding suggests that the association between environmental characteristics and obesity may be complex and not simply associated with differential levels of physical activity acting to influence weight.

In one of the few studies that have focused on children, Burdette and Whitaker hypothesised that overweight children would live further away from playgrounds, closer to fast-food restaurants, and in less-safe neighbourhoods compared to children of normal weight. They determined the BMI of a sample of 7,020 children in Cincinnati, Ohio. Contrary to the findings of many of the adult studies, they found no association of any of these factors, measured using a GIS, with BMI values. There was no association between BMI and neighbourhood deprivation.[59] However, in the UK, Kinra et al. used census variables to study the relationship between neighbourhood deprivation and the measured heights and weights of 20,973 children in Plymouth aged 5–14. They found that children who lived in the most deprived areas had

rates of obesity 2.5 times those of the national average ($p < 0.05$), and that there was a linear association with obesity.[140]

3.5.1 Limitations of studies that have directly linked environment, physical activity and obesity

The general picture from these projects is that residents of high-walkability neighbourhoods are more active and have slightly lower body weights than their low walkability counterparts, as do those living in areas with high land-use mix. The main limitation of these studies is that they are cross-sectional in nature and it is therefore difficult to determine if the associations they describe are causal. Furthermore, a number of the studies have relied on self-reported weight, which is problematic as people tend to under-report their weight, leading to inaccurate BMI prevalence, particularly among more socioeconomically deprived groups.[141] Although most of the studies have examined measures of urban form, the indicators are generally crude and not easily generalisable. In common with the studies using physical activity as the primary outcome, many have been based on self-report and, as Kirtland et al. point out, this is problematic because only fair to low agreement has been demonstrated between self-reports of neighbourhood and community environments and objective environmental audits[142] (see, for example, McGinn et al.[143]). Only one study has attempted to determine if associations between the environment and obesity are attenuated or explained by physical activity. That study found little evidence of attenuation, although there is, at present, no theoretical model that adequately explains this finding.[139]

4 GAPS AND LIMITATIONS IN THE EVIDENCE ON OBESOGENIC ENVIRONMENTS

There are a number of gaps and limitations in the evidence that arise from this review. These are discussed below, and suggested solutions are provided.

4.1 General issues

4.1.1 A reliance on cross-sectional comparisons

The majority of studies that have investigated the environmental determinants of physical activity have been based on cross-sectional comparisons. The evidence from these studies can be hard to interpret because it is difficult to infer causality from cross-sectional designs. This is predominantly because both outcome (in this case body weight or physical activity) and possible cause (the characteristics of the obesogenic environment) are measured at the same time. Particularly in the case of body weight, where significant changes can take many years, it is reasonable to assume that conditions at prior time points would be important. Furthermore, there may be temporal trends in selective population migration, whereby more active members of the population will seek to migrate into areas where the environmental and social conditions are more supportive for activity. Cross-sectional studies are unable to account for such possibilities. Although more time-consuming and costly to design and undertake, well-designed studies based on interventions or those that trace a cohort of individuals over time provide the strongest evidence with respect to causality and these should be encouraged.

4.1.2 The problems of confounding

It can be hard to adequately control for confounding factors in studies of obesogenic environments. One problem is that many environmental and social characteristics vary together. For example, areas with high levels of socioeconomic deprivation will also tend to have particular land-use mixes, levels of service provision, and structural characteristics. Failure to adequately control for these influences can lead to residual confounding, whereby apparent associations with the environmental components being measured are, in fact, associated with social factors that have been inadequately controlled for. Furthermore, the environment is multi-dimensional, comprising many components. The majority of the studies discussed in this review examine only a restricted number of these components, making it difficult to determine if any observed associations are causally associated with the aspects of the environment being considered or others that are not directly measured. The problems of confounding may be serious enough to explain many of the differences reported between the studies discussed.

4.1.3 Difficulties in defining the obesogenic 'environment'

Identifying specific environments that may influence nutrition and physical activity is not straightforward, an issue recently discussed by

Ball et al.[144] The majority of individuals function in multiple settings, all of which may influence decisions on food consumption and physical activity. Children live in families, yet also eat and play in schools. Adults often live and work in different geographical areas, and their homes and workplaces may be located within neighbourhoods of very different characteristics. Different types of environmental influences may also operate across these multiple domains, encompassing not only physical characteristics (those connected to built and natural environments) but also those associated with social, cultural and policy environments. Most studies to date have focused on the characteristics of the physical environment, but we may have good reason to believe that other environmental domains may also exert important influences. There is a need for the research community to focus more strongly on the problems of identifying relevant environments, and for new research to examine associations with alternative environmental definitions.

4.1.4 Lack of evidence linking environment, physical activity and obesity

The majority of studies presented in this evidence review have examined physical activity as their main outcome. Only a limited number have considered measures of body mass and obesity as outcomes. This is important as increases in activity may bring other health benefits, but will not necessarily lead to weight loss if individuals compensate by modifying their energy intake. Hence the link between physical activity and obesity is not necessarily straightforward. Directly assessing the dual outcomes of physical activity and weight is problematic, not least due to lag times, which may be many years in the case of weight if the energy imbalance is small. Nevertheless, there is rather limited evidence of the direct effects that environmental characteristics may have on obesity, and future studies should be encouraged to look at the dual outcomes of activity and weight where possible.

4.2 Issues associated with the identification of environmental determinants of food availability

4.2.1 The lack of evidence for environmental determinants of food availability and associated obesity outside the USA

This review has highlighted a number of studies that suggest there may be social and racial determinants of food availability in the USA. However, there is little evidence to support the presence of such effects elsewhere, in particular the UK. This may be due to distinctive social and racial patterns of segregation present in US neighbourhoods, especially if food supplies are sensitive to these factors. However, many of the published research papers are of poor quality, based on cross-sectional associations. There is a need to build the evidence base in the UK with high-quality intervention-based studies that examine the effect of an intervention or interventions that modify food availability in study areas. Such work, which could be panel- or cohort-based, should ideally encompass an adequate post-intervention measurement period so that

any long-term obesogenic consequences of altered availability can be determined. It is unlikely that such studies could be based on an experimental intervention, and researchers should therefore look to make the best use of 'natural experiments', such as the opening of large supermarket facilities in areas not previously served.

4.3 Issues associated with the identification of environmental determinants of physical activity

4.3.1 Reliance on self-reported physical activity

Many of the studies discussed in this evidence review have used measures of physical activity that are based on self-report. This information is generally obtained by retrospective recall or the prospective completion of activity diaries by participants. The advantage of self-report instruments is that they are able to describe discrete physical activity behaviours such as transport and occupational, recreational and domestic behaviours. This is important, as the data reviewed tends to show different relationships between specific environmental exposures and specific physical activities. Although a number of tools used to produce measures of physical activity from such data have undergone successful validation for reliability and consistency, there are, nevertheless, known difficulties associated with reliance on self-report. The computation of objective indicators of physical activity is not a simple task. Studies that have attempted to produce such indicators have generally relied on pedometers (which measure hip movements and therefore indicate steps taken) and accelerometers (which measure activity via acceleration and deceleration). However, both technologies have their limitations. They detect movement rather than physical activity behaviours *per se* and, consequently, their output is a global index of movement that can be difficult to interpret. Further, they are poor at measuring movements occurring in water and when body weight is supported, as in bicycle use. More recently global positioning systems (GPS) technologies have advanced to the stage that lightweight, unobtrusive GPS units are available that can be worn on users' wrists. There are some difficulties in using these units in densely populated areas due to the attenuating effects of buildings on the satellite signal. Nevertheless, early results from studies that have attempted to use GPS units are promising, especially if combined with accelerometers.[145] It is hoped that progression and wider adoption of these technologies in the future will facilitate a greater understanding of the complexity of physical activity. A combination of self-report, motion sensor (perhaps combined with heart-rate monitoring) and GPS devices would allow us to better describe what behaviour is occurring, how much movement it produces and the location of that behaviour. Linked with GIS data, better explanatory models should evolve.

4.3.2 The lack of evidence for the effects of the environment on overall physical activity levels

The majority of studies that have been undertaken have examined associations between environmental characteristics and a restricted (sometimes single) range of physical activity outcomes, most commonly walking. There are problems in generalising the results of these studies to determine the effect of environmental characteristics on overall activity levels, as some activities may displace others. For example, the provision of a cycling trail in an area may be associated with a higher prevalence of cycling in nearby residents. However, these residents may be consequently less likely to undertake other types of physical activity, such as walking. Similarly, improving the quality of the trail may lead to greater usage, yet these additional users may simply alter their routes to take advantage of the facility. Indeed, it is conceivable that a strategically placed trail linking residential and employment locations could actually reduce activity levels by shortening required travel distances. There is therefore a need for more studies that examine the relationship between environmental characteristics and *overall* activity levels rather than targeted forms of activity. These studies are more difficult to undertake, as it is hard to measure overall activity. Nevertheless, modern technologies that facilitate these measurements are becoming increasingly available, as discussed in this review. Such studies will provide stronger evidence than is generally available at present for the identification of environmental modifications that may help meet current government targets for improving overall population activity.

4.3.3 Poor reliability, validity and conceptual models of the environmental determinants of activity and obesity

Authors such as Owen et al. argue that key elements of the current research agenda should include improving reliability and validity of environmental measures and the development of better conceptual models to link environmental components with activity and obesity.[146] The use of standardised, reliable self-report measures in multiple studies would help this research field to advance more rapidly, facilitating comparisons of environmental influences across a variety of locations and populations. If possible, both rated and self-reported environmental attributes should be objectively verifiable, either by independent observation or by objective indices derived from GIS databases. If strong patterns of concordance emerge between perceived and objective indices of the same environmental attributes, this would provide support for the validity of the self-reported measures of perceived environment. The conceptual models and theories on which the research presented in this review draw also require refinement and development. At present, only relatively broad models of putative environment–behaviour relationships are being used to guide research, although the recently proposed 'dual-process' view of the environmental determinants of energy-balance-related behaviours developed by Kremers et al.[147] makes progress by allowing environmental factors to influence behaviour directly, but also indirectly, by a number of hypothesised pathways.

A further requirement is that definitions of 'neighbourhood' need to be better developed. Most studies to date have relied on routine data supplied at the level of predefined administrative areas. Of course, administrative boundaries do not determine how people behave or what amenities they have access to. People living on the edge of an administrative area may be more likely to use amenities in neighbouring areas rather than the one where their home is. Some studies have used radii around people's homes to define neighbourhoods, but it is unclear what the basis is for the distances used. Also, these radii do not necessarily represent the real distance required to travel to a given amenity or facility. Further, to date, distances have generally not been weighted for quality of route. The most direct/shortest route to a destination may coincide with the largest road size, or highest volume of traffic and noise etc. It is possible that distance is mediated by the 'pleasantness' of the route.

4.4 Issues associated with the evaluation of environmental interventions

4.4.1 The lack of a control group in many intervention studies

Intervention studies can be very powerful for determining causality. However, when examining the effect of an environmental intervention on either food consumption or activity patterns, it is important, wherever possible, to also consider trends in the same outcome measure among a control group that did not receive the intervention. Without a control group, it is impossible to determine how much of any difference between the pre- and post-intervention periods is due to factors other than the intervention itself. It is well documented, for example, that there are secular trends present, whereby levels of population activity in the UK are in decline, and energy intake is increasing relative to expenditure. All other things being equal, one may expect a reduction in activity and an increase in obesity in any post-intervention period associated with these trends alone. Well-designed studies that include control groups allow for the effects of the trends to be estimated and removed. At present, relatively few studies have used control groups, and this limits the strength of evidence they provide. Future intervention-based studies should include appropriate control groups. Many 'natural' experiments are occurring all the time. New buildings, changes to infrastructure, modifications to road layouts all lend themselves to study. With the appropriate study design, such developments might provide a relatively cost-effective way of evaluating the effect of the environment on multiple outcomes.

4.4.2 Lack of evidence on cost-effectiveness

There is at present little evidence on the cost-effectiveness of potential changes to the environment that may increase levels of physical activity. For example, many potential interventions such as modifications to the design of new urban areas or the provision of new

parks and recreational facilities may have considerable cost overheads. We are not aware of studies that have attempted to quantify and compare these costs against the financial (both market and non-market) public health benefits that they may accrue. There are numerous methodological difficulties in making these comparisons. In particular, it is difficult to place a financial value on the benefits of 'good health' or costs of 'bad health', although some work has been undertaken valuing standardised measures of health such as Quality-Adjusted Life Years (QUALYs). There are, of course, considerable difficulties in directly linking physical activity levels, obesity and future health states. Nevertheless, it remains the case that money may be better spent on public health in other ways than on costly interventions that are associated with a modest health benefit. Studies need to be undertaken assessing the likely costs and benefits of the most promising interventions.

4.4.3 Lack of knowledge on the secondary effects of interventions

The majority of studies have used some measure of physical activity or obesity as their outcome measure. Given the nature of the field, this is understandable. However, the secondary effects of environmental characteristics, and in particular environmental interventions, have not been well investigated. For example, the segregation of cyclists and pedestrians by the provision of paths and trails away from roads may have activity benefits but also bring dis-benefits in terms of increased risks of crime and mugging for users of these facilities. Indeed, such dis-benefits could conceivably outweigh the benefits of the facilities. At present, there is little or no information on such considerations. There is therefore a need for studies, particularly those based around interventions, to consider the likely secondary effects of the interventions, or indeed for new studies to be undertaken that specifically focus on elucidating the range and magnitude of these secondary effects.

5 CONCLUSIONS

The evidence presented in this review suggests that the environment does influence levels of physical activity and obesity. However, it appears that any influences of the environment are small, that the mechanisms by which environmental components may operate are as yet unclear, and that the exact environmental components that affect body weight and activity are yet to be identified. Given the fact that strong associations have not generally been observed between environmental components, physical activity and body weight, it is difficult to determine how appropriate environmental modification may be for either prevention of further increases in the prevalence of obesity or a reversal of trends. Certainly, the evidence reviewed here is limited by the wide variety of study designs, general reliance on cross-sectional comparisons, low use of control populations and diversity of findings.

It is noteworthy that the evidence contained in this review suggests that perceived environmental characteristics show a stronger and more consistent association with body weight and physical activity behaviours than those that are objectively measured. This suggests that promising future avenues may seek to modify these perceptions so that the environment is seen as a positive facilitator rather than a negative barrier for healthy eating and an active lifestyle among individuals. One important yet unanswered question, for example, is whether the environment exerts its greatest effect on people for whom exercise is already important, who have confidence to take part in it and are surrounded by like-minded individuals. Or is it the case that, if the right kind of environment is built, people will start to change their beliefs and there will be a collective shift in behaviour-modifying attitudes? At present, there is no evidence as to whether or not the environment might have a differential effect on people with different levels of physical activity and body weight. Will modifications to the environment lead to the commencement of physical activity in the sedentary, increase activity in the intermittently active or help the already active sustain their behaviour? These questions have not yet been answered.

A further difficulty faced by research projects focusing on obesogenic environments, and public health interventions designed to modify them, concerns capturing the concept of the social norm and modifying that norm. Humans readily adapt to environments that promote sedentary behaviour and poor-quality food choices, and cultures exist where being active or eating 'healthy' foods are not top priorities. No matter how good the availability of high-quality food outlets and leisure facilities may be in the vicinity, certain individuals may never use them. The behaviour of these individuals may be the most difficult to modify due to both the difficulties in reaching them and overcoming their norms. Yet, from a public health point of view, reaching them may have the greatest impact. Changing behaviour at the community level and creating cultures of participation may be the best way of doing this, which raises unanswered questions as to how this might best be done. It is certainly the case that changes to the environment alone are

unlikely to solve the problems of increasing obesity and declining physical activity levels. Successfully tackling these issues will undoubtedly require a range of approaches, and complementary strategies addressing the individual, social and environmental determinants of activities may be a solution.

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